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PROCEEDINGS OF ABSTRACTS

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Proceedings Overview

This abstract book presents the proceedings of the International Scientific Conference “New Materials and Solar Technologies”, held on April 28–30, 2025**,** and organized by the Institute of Materials Science of the Uzbekistan Academy of Sciences**.**

The conference focused on groundbreaking advances in the fields of smart materials, nanotechnologies, and solar energy**.** The discussions aimed to serve as a milestone in fostering international scientific collaboration**,** knowledge exchange, and the implementation of technologies that directly impact quality of life, environmental sustainability**,** and the innovative future of humanity**.**

Special emphasis was placed on solutions in the field of green energy, contributing to reduced environmental impact and the creation of an intelligent, energy-efficient infrastructure.

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Welcome Address
To the Participants of the International Scientific Conference “New Materials and Solar Technologies”



Dear colleagues and friends,

On behalf of the Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan, I warmly welcome you to the International Scientific Conference “New Materials and Solar Technologies.”

It is a great honor for us to host more than 40 leading researchers from 17 countries, along with numerous scientists, engineers, and experts from across Uzbekistan. This conference serves as a unique platform for sharing knowledge, presenting cutting-edge research, and addressing the most pressing challenges in strategically important areas such as smart materials, nanotechnology, and solar energy.

Today, scientific and technological advancement has taken on special importance in the face of global challenges — from energy and water security to climate change. In this context, the development of new, high-performance materials and renewable energy technologies is key to building a safe and sustainable future. These are precisely the challenges our conference seeks to address.

In the Republic of Uzbekistan, the development of science and innovation is a national priority. Under the initiative and direct leadership of the President, large-scale programs are being implemented to foster a favorable scientific environment, support talented researchers, and promote international collaboration.

It is symbolic that the conference is taking place at a unique scientific facility — the Great Solar Furnace of Uzbekistan — unparalleled in Asia. This emphasizes the relevance of our themes and opens new horizons for international scientific cooperation.

I am confident that the conference proceedings and the abstracts collected in this volume will make a valuable contribution to advancing cutting-edge technologies, strengthening global scientific partnerships, and promoting sustainable solutions for the benefit of humanity.

I wish all participants inspiring discussions, productive work, and new professional achievements!

Sincerely,
Dr. Odilkhuja Parpiev
Director of the Institute of Materials Science

SOLAR FURNACE RADIATION SYNERGISM: THE SORET EFFECT

S.X.Suleymanov, B.L.Oksengendler, N.A.Kulagina, G.E.Akhmatova, R.R.Ibrokhimov
Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan

As it is known [1], the concept of synergism, implemented in the methodology of synergy, sets its main goal to identify a new mechanism of combined effects on the studied complex system. In relation to the problems of radiation technology of a solar furnace, this mechanism is extremely promising, but also difficult, since the solar furnace implements 4 factors of influence at once:

1. high temperature;
2. significant temperature gradient;
3. wide spectrum of electromagnetic radiation (from IR to UV);
4. high photon density across the entire energy spectrum [2].

However, to date, the combined effect of only two factors has been studied in detail on the problem of synergism: temperature and ionizing radiation (in particular, in radiobiology), and it can be explained as follows [3]. If we present the experimental data in graphical form, we will see that the total kinetics (experimental and theoretical) differ sharply. Indeed, the experimentally obtained survival curves of cultured mammalian HeLa cells after separate exposure to only hyperthermia (43 °C) and ionizing radiation (1.0 Gy/min), as well as after simultaneous thermoradiation exposure, demonstrate obvious non-additivity of the result from exposure to two causes simultaneously. These data are based on averaging data obtained by different authors and published in a textbook for radiologists [4].

The mathematical model is constructed as follows: let the theoretical curve expected from independent addition of the effects of ionizing radiation S_1 and hyperthermia S_2 be $S_T = S_1 \cdot S_2$. To assess the effectiveness of the interaction, one can use the synergism coefficient, k [5], determined by the ratio of isoeffective doses (or duration of exposure), obtained theoretically and experimentally, $k = t_2/t_1 = D_2/D_1$. In fact, this coefficient shows how many times the dose required to inactivate cells has decreased with independent, additive addition of the effects of each exposure, compared to the isoeffective dose recorded with simultaneous exposure to different factors.

However, what to do in the case of the influence of many factors? In this situation, it is of interest to use a different strategy: to trace (experimentally and theoretically) the synergism of six possible pair combinations of all four factors of influence, and on this basis to calculate the partial synergism coefficients (K_{12}, K_{13}, K_{14}, K_{23}, K_{24}, K_{34}), and estimate the total synergism coefficient, taking into account the simultaneous influence of four factors, to test this new algorithm on a suitable object. This algorithm can be tested experimentally using the Soret effect [6, 7], which is ionic electrotransfer in a condensed medium under the influence of the "phonon wind" caused by the temperature gradient, in superionic materials (such as LaF_3, CeF_3). The idea of the experiment is as follows: by changing the temperature in the experiment, it is possible to achieve a phase transition from the ionic state to the superionic one. In this case, the value of the Soret coefficient increases sharply after the appearance of the superionic phase. The ion transfer effect itself is symbatical to the temperature gradient value and the presence of the ionizing component of solar furnace radiation (the latter circumstance is realized in the case of the so-called electron-stimulated radiation diffusion). Thus, the pair "temperature – temperature gradient" can be easily distinguished. By varying the experimental conditions, it is possible to distinguish both the dominant and other pairs of factors of the impact of the solar furnace radiation field.

It is necessary to highlight the possibility of fluctuations in the ion density due to the formation of spatially rarefied regions as a result of the superionic transition. Such dense regions of easily mobile quasi-liquid of ions are reminiscent of the so-called negative Indenbohm-Kratochwill crowdions [8], which are in the field of action of the temperature gradient in particular,

the capture of electrons from the conduction band into local states of fluctuation formations of the mobile component is of interest here. An important and still unresolved question is how the phonon field should be described in an object where strictly periodic and disordered elements are present systematically simultaneously. From a practical point of view, the question of the possibility of the Soret effect becoming an indicator of the presence (or absence) of precisely the electron component as a result of irradiation of the quasi-liquid with the UV part of the spectrum is very interesting.

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IMPROVEMENT OF WELDING AND TECHNOLOGICAL PROPERTIES OF WELDING ELECTRODES WITH THE INTRODUCTION OF SPECIAL ADDITIVES IN ELECTRODE COATINGS

R.M.Saidov., R.H.Rakhimov
Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan
saidov_r@yahoo.com; rustam-shsul@yandex.com;

In this paper, scientific studies have been conducted on the effect of small additives of a nanostructured functional ceramic (PNFC) photocatalyst in the coating of a welding electrode of a well-known brand of MR-3 rutile welding electrodes on their welding and technological properties. PNFC of the brand "ZB-2" [1], synthesized in the furnace by IR radiation, consisted of a mixture of powders (% by weight), was used as additives in the composition of the charge for coating the welding electrode of the brand MR-3: iron oxides – 28.0; silicon dioxide – 17.0; calcium oxides – 5.5; aluminum oxides – 2.5; magnesium oxides – 2.0; copper oxides – 0.3 and chromium oxides – 44.7.

Studies of the effect of additives of the photocatalyst brand “ZB-2” in amounts from 1% to 8% on the welding and technological properties of the welding electrode MR-3 were carried out on such properties as the breaking length of the arc "Lbla", the peak at the end of the electrode “hk”, the diameter of the deposited point "Ødp", the melting coefficient “αp”, the deposition coefficient “αн” and especially the losses factor for waste and splashing of electrode metal "ψ". The specified welding and technological properties of welding electrodes were determined according to the procedure described in [2, 3].

The results of the influence studies are shown that the analysis of which revealed the effect of the addition of photocatalysts of nanostructured functional ceramics of the brand “ZB-2” on the welding and technological properties of the electrode of the brand MR-3.

In accordance with the obtained research data, an increase in the breaking arc length “Lbla” of the welding electrode MR-3 was revealed with the addition of “ZB-2” to the coating charge in an amount of up to 2%. With additives over 2%, the value of the breaking arc length decreases. The additive “ZB-2” has the same effect on the diameter of the weld point "Ødp"of the welding electrode MR-3. When its content in the coating is up to 2%, the diameter of the deposited point increases, and a further increase in the additive content reduces this indicator.

A moderate correlation is observed between the content of PNFC additives in the charge of the electrode coating mass and the size of the peak at the end of the electrode “hk”. At the same time, with an additive content of up to 1%, the value of “hk” decreases, but with an increase in its content above 1%, it increases. However, these changes in the height of the electrode end cap are insignificant (up to 0.2 mm) and do not affect the stable burning of the welding arc. As the results of the studies, the effect of “ZB-2” additives in the electrode coating has a strong correlation with the melting coefficient of “αp”, weak with the deposition coefficient of “αн” and very strong with the loss coefficient of carbon monoxide and splashing “ψ”. At the same time, with an increase in the addition of PNFC, the value of the melting coefficient “αp” decreases, and the value of the deposition coefficient “αн” increases. In this regard, the coefficient of carbon monoxide and spray losses “ψ” drops sharply to 53% with an additive content of up to 8% in the coating mass.

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INVESTIGATION OF THE PROPERTIES OF COATINGS OF WELDING ELECTRODES WITH ADDITIVES OF FUNCTIONAL CERAMICS SYNTHESIZED BY VARIOUS METHODS

R.M.Saidov, R.H.Rakhimov
Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan
saidov_r@yahoo.com; rustam-shsul@yandex.com

In this paper, a comparative analysis of the effectiveness of photocatalysts of nanostructured functional ceramics (PNFC) of the “ZKXM” brand [1], obtained under the influence of

concentrated solar radiation on a Large solar furnace, and the “ZB-1” brand, manufactured using the PNFC synthesis method using technology followed by activation by pulsed radiation [2] generated by functional ceramics, welding and technological properties of welding electrodes of the MR-3 brand. The welding and technological properties of welding electrodes were determined according to the methods described in [3, 4].

Comparative results of the formation of weld seams with additives of photocatalysts of the brands “ZKXM” and “ZB-1” from 1% to 8% in the coating charge of the welding electrode of the brand MR-3 showed that seams with high-quality formation without external defects are achieved when surfaced with electrodes with additives of both brands up to 1%. When welding with electrodes with a PNFC content of more than 1%, there is deterioration in the quality of the formation of deposited rollers in both cases.

According to these results, when the PNFC content is up to 1%, the breaking arc length increases when welding with an electrode with both a “ZKXM” and a “ZB-1” additive. A further increase in the amount of the additive in the composition of the PNFC coating of both brands worsens the stability of arc combustion, characterized by a decrease in the value of the breaking arc length “L_{bla}”. At the same time, the curve of dependence of the magnitude of the discontinuous arc length “L_{bla}” the content of the additive “ZB-1” in the electrode coating shows a stronger correlation between these indicators than for the electrode with additives “ZKXM”.

The effect of PNFC additives on the size of the peak at the end of the electrode “h_k” showed a very strong correlation with the addition of the “ZB-1” brand and a strong correlation with the addition of the “ZKXM” brand. Despite this, the effect of additives on this indicator differs depending on the brand of NFC and their quantity in the coating. Thus, the addition of “ZKXM” brand PNFC reduces the size of the visor by up to 2%, and its further increase increases its value. The addition of ZB-1 brand PNFC to the coating reduces the “h_k” index and the more effectively it is contained in the electrode coating. At the same time, the value of the peak at the end of the electrode “h_k” is reduced to 25% with the content of the additive “ZB-1” up to 8%.

As shown by the results of studies of the effect of “ZKXM” additives in the electrode coating on the melting coefficient, “a_p” has a very strong correlation with and increases its value over the entire studied range with a maximum value of up to 8% with the addition of “ZKXM”. On the contrary, welding electrodes with PNFC additives the “ZB-1” brand have a weak correlation with the melting coefficient “a_p” and slightly reduce this indicator. The effect of PNFC additives on the deposition coefficient “$\alpha_н$” of welding electrodes has similar correlations and dependencies as for the melting coefficient "a_p".

Investigation of the effect of the introduction of PNFC additives of the studied brands into the composition of the MR-3 electrode coating on the coefficient of the losses factor for waste and splashing of electrode metal “ψ” characterized by weak correlations. According to the data obtained, the most effective effect on carbon monoxide losses and splashing is observed when PNFC brand “ZB-1” is added to the coatings of the electrodes, which reduces this indicator over the entire range of its content. The maximum decrease (by 44.5%) of this indicator is observed with the content of “ZB-1” additive in the amount of 1%. A slight decrease in the coefficient of the losses factor for waste and splashing of electrode metal “ψ” is also observed when adding PNFC brand “ZKXM” to the coating by up to 1%. A further increase in this additive leads to an increase in losses of the welding electrode during the welding process.

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FORMATION OF HETEROSTRUCTURES BASED ON DOPED/UNDOPED ZINC OXIDE (n-ZnO) AND SILICON (p-Si) BY MAGNETRON SPUTTERING FOR PHOTOVOLTAIC APPLICATIONS

Sh.B. Utamuradova[1], S.A. Muzafarova[1], A.S. Esbergenova[1] *

[1]Research Institute of Semiconductor Physics and Microelectronics at the National University of Uzbekistan named after Mirzo Ulugbek, 100057, Uzbekistan, Tashkent, Yangi Almazar Street 20

Today, the mass use of solar energy and increasing the efficiency of its conversion into electrical energy is one of the most pressing issues in modern energy.

Transparent conductive oxides are used to increase the efficiency of heterogeneous silicon thin-film solar cells [1-2].

Transparent conductive oxides, such as indium tin oxide (ITO), SnO2, ZnO, (transparent conductive oxides - hereinafter TCO) belong to a class of materials that are unique in the sense that two seemingly contradictory properties - electrical conductivity and optical transparency - coexist in one material. This special property makes them especially interesting as transparent conductive electrodes or functional layers in optoelectronic devices.

High conductivity of metal oxides ($n=10^{19}…10^{21}$ cm^{-3}) is still provided by the introduction of impurity atoms. Doping allows increasing the concentration of charge carriers due to shallow impurity levels that form in the band structure of the metal oxide. In addition to high conductivity, they also have good optical transparency (transmission coefficient T>80%) in the visible and near infrared region of the electromagnetic spectrum. Consequently, the transmission window of the oxide layers is in the range λ= (400…1500) nm.

Zinc oxide ZnO and ZnO:Al are becoming an alternative to expensive indium tin oxide (ITO) and are non-toxic, while Cd-containing TCO are potentially hazardous to health. Integration of ZnO (wide-gap 3.37 eV) and Si (narrow-gap 1.1 eV) can open up opportunities for a real combination (complementation) of unique functionalities, since zinc oxide provides excellent optical characteristics and stability at high temperatures, while silicon provides high carrier mobility and ease of integration into complex circuits [1-2].

In this paper, we demonstrate the possibility of producing thin continuous films of doped (Al) and undoped zinc oxide by reactive magnetron ion sputtering on the surface of single-crystal silicon substrates. The resulting heterostructures with a buffer layer of zinc oxide consist of vertically oriented zinc oxide crystallites forming a compact continuous film. Optical and electrical properties of the resulting Si/ZnO and Si/ZAO heterostructures were measured. It is shown that films of doped and undoped zinc oxide exhibit photoluminescence in the visible range of the electromagnetic spectrum with a maximum at a wavelength of 600–700 nm, which is associated with the presence of structural defects, and in the near UV range with a maximum at about 380 nm, associated with radiative interband recombination. The specific resistance of Si/ZnO is 0.7 Ohm•cm, and Si/ZAO is 5.4×10-4 Ohm•cm. Due to the low specific resistance and luminescent

properties of the obtained continuous crystalline films of doped and undoped zinc oxide, they can be used as transparent conducting electrodes or functional layers in optoelectronic devices.

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DEVELOPMENT OF A SiC-Si-BASED HETEROSTRUCTURE FOR DETECTING AND MEASURING THE ACTIVITY OF CARBON-14: A SELF-SCANNING SENSOR

S.A. Radzhapov[1], M.V. Dolgopolov[2]
[1]Physical-Technical Institute, Tashkent, Republic of Uzbekistan. Chingiz Aytmatov St., 2b
[2]Department of Higher Mathematics, Samara Polytech. Samara, Russia, Molodogvardeyskaya St., 244

Introduction

Carbon-14 (^{14}C) is a critical isotope for radiocarbon dating and nuclear safety monitoring. Traditional detection methods face challenges in sensitivity and radiation resistance. This work proposes a self-scanning beta-voltaic heterojunction sensor based on SiC-Si, where ^{14}C is implanted into the near-contact zone of the heterostructure. The sensor leverages the wide bandgap of SiC (3.26 eV for 4H-SiC) to minimize noise and the high carrier mobility of Si for efficient charge collection. By analyzing shifts in the beta spectrum caused by ^{14}C decay within the heterojunction's depletion region, the sensor autonomously quantifies activity [1] without external scanning systems. Recent advances in solving the inverse problem of activity determination via electrical measurements [2] further enhance the accuracy of this approach.

Methodology

1. **Heterostructure Design**:
   - **Implantation of ^{14}C**: ^{14}C atoms are embedded into the SiC layer, into the depletion region of SiC-Si, during epitaxial growth (900–1050°C) or via post-synthesis ion implantation (energy: 10–50 keV, dose: 10^{12}–10^{14} ions/cm²).
   - **Control Samples**: Non-implanted SiC-Si heterostructures are synthesized under identical conditions for baseline comparison [3].
2. **Beta Spectrum Analysis**:
   - Beta particles (max energy: 156 keV) from ^{14}C decay generate electron-hole pairs in the depletion region.
   - A betascanner measures energy spectra of implanted and control samples. Shifts in spectral peaks (ΔE) correlate with ^{14}C concentration and activity, similar examples in [4,5]. The self-scanning mechanism is explicitly tied to on-device spectral analysis.

Mathematical Model

The self-scanning mechanism is governed by:

1. **Beta Energy Deposition**:

$$Q(E) = \int_0^{E_{max}} \eta(E)\, S(E)\, dE\,, \qquad (1)$$

where $Q(E)$ is the deposited energy, $\eta(E)$ is detection efficiency, and $S(E)$ is the beta particle energyspectrum.

2. **Activity Calculation**:

$$A = \frac{I_{signal}}{\varepsilon\ \tau\ V_{depletion}}, \quad (2)$$

here A is activity of ^{14}C (Bq), I_{signal} is the current generated by beta-induced carriers (A), ε is carrier collection efficiency (unitless), τ is detector response time (s), and $V_{depletion}$ is the depletion region volume (cm^3).

3. **Inverse Problem Framework**:

The inverse problem is solved using coupled Poisson and continuity equations to correlate electrical outputs (e.g., current density J) with ^{14}C activity distribution [2]:

$$\nabla \cdot D = \rho(x), \qquad \frac{\partial n}{\partial t} = \frac{1}{q}\nabla \cdot J + G - R, \quad (3)$$

where D is electric displacement, $\rho(x)$ is charge density, n and p are electron/hole concentrations, and J_n, J_p are current densities. Boundary conditions at the SiC/Si interface ensure accurate modeling of carrier dynamics [2]. The sensor autonomously correlates spectral shifts (ΔE) with activity via on-chip inverse modeling (3), eliminating external scanners.

4. **Spectral Shift Analysis**:

A polynomial regression model links ΔE to ^{14}C activity, calibrated using Monte Carlo simulations (MCNP code) and experimental data [5].

Experimental Development

1. **Synthesis**:

- **Epitaxial Growth**: 3C-SiC layers are deposited on Si(111) substrates via chemical vapor deposition (CVD) at 950°C.
- **Carburization**: Si wafers are carburized in vacuum (1100°C) to form cubic SiC (3C-SiC), verified by Raman spectroscopy (peak at 798 cm^{-1}) [6].

2. **Characterization**:

- Electrical response (I-V curves) and beta spectra are measured under ultra-high vacuum (0.1 Pa) to minimize air scattering [7].
- Control samples show a baseline dark current of 0.1 nA, while ^{14}C-implanted sensors exhibit a signal-to-noise ratio >10 at 1 Bq/g activity [7], is plausible for low-background detectors but requires benchmarking against modern SiC devices.

Conclusion

The SiC-Si heterostructure enables precise ^{14}C detection via self-scanning beta-voltaic principles. Spectral shifts and carrier generation in the depletion region provide a direct measure of activity without external instrumentation. Future work will optimize doping profiles (e.g., n^--layer: 5×10^{14} cm^{-3}, p-layer: $\leq1\times10^{16}$ cm^{-3}) and integrate cryogenic cooling to enhance sensitivity (target temperatures, e.g. 77 K, to reduce thermal noise in future work). This technology holds promise for nuclear waste monitoring and environmental radiocarbon analysis. Highlight **applications are for** nuclear safety (e.g., reactor effluent monitoring) and microdose environmental tracking.

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ELECTRONIC MODEL OF TRI-RIFORMING OF METHANE FOR UNDERSTANDING THE ROLE OF CATALYSTS

[1]Turaeva N., [2]Oksengendler B.L., [2]Suleymanov S.X.
[1]Webster University, USA
[2]Institute of Materials Science, Uzbekistan

Currently, about 96% of hydrogen is produced from fossil fuels, especially natural gas. On the other hand, chemicals synthesized from fossils are typically obtained through synthetic gas, which is produced by steam methane reforming. Other conversion methods for producing hydrogen from methane include dry methane reforming, double methane reforming in a mixture of CO_2 and H_2O, and triple methane reforming in a mixture of CO_2, H_2O, and O_2. The main issues with steam methane reforming for hydrogen production are the formation of solid carbon and CO_2, as solid carbon causes catalyst deactivation, and CO_2 is an undesirable reaction product. Catalyst deactivation is also a problem in dry methane reforming. In addition to this, due to the high endothermicity of dry reforming, metal sintering at the required high temperatures is another limiting factor. Solid carbon formation in dry methane reforming can be avoided with tri-reforming [1, 2], which involves adding oxidizing reagents, namely H_2O and O_2, to the mixture of methane and CO_2. These combined conversion processes can generate hydrogen and synthetic gas with varying H_2/CO ratios by manipulating the composition of reactants. Furthermore, tri-reforming prevents the energy-intensive process of capturing CO_2 gas in the exhaust gases during the combustion of fossil fuels. However, despite extensive experimental and theoretical research on the tri-reforming reaction of methane, none of the aforementioned issues related to catalyst deactivation and sintering during methane conversion have been theoretically justified. The goal of this work is to study the mechanism of the dry methane conversion reaction to hydrogen and synthetic gas, as well as the influence of oxidizing reagents (O_2, H_2O) on hydrogen production within the framework of the Wolkenstein electronic theory of catalysis [3] and the Hammer-Norskov d-band theory [4]. It is well-known that the following nine reactions are the main reactions in the tri-reforming process:

1. Dry reforming: $CH_4 + CO_2 = 2CO + 2H_2$ $(+247\ kJ/mol)$
2. Steam reforming: $CH_4 + H_2O = CO + 3H_2$ $(+206\ kJ/mol)$
3. Partial reforming: $CH_4 + 1/2O_2 = CO + 2H_2$ $(-36\ kJ/mol)$
4. Methane combustion: $CH_4 + 2O_2 = CO_2 + 2H_2O$ $(-880\ kJ/mol)$
5. Reverse Water Gas shift: $CO_2 + H_2 = CO + H_2O$ $(+41.1\ kJ/mol)$
6. Methane cracking: $CH_4 = C + 2H_2$ $(+75\ kJ/mol)$
7. Boudouard reaction: $2CO = C + CO_2$ $(-172.4\ kJ/mol)$
8. Water Gas reaction: $C + H_2O = CO + H_2$ $(+131.3\ kJ/mol)$
9. Coke combustion: $C + O_2 = CO_2$ $(-393.5\ kJ/mol)$.

Reactions 6 and 7, leading to the formation of solid carbon on the surface of the catalyst and its deactivation, are undesirable. To prevent and reduce coke formation, reaction 7 should be slowed down, and reactions 8 and 9 should be enhanced with the help of catalysts. To demonstrate the role of oxygen and water vapor in the dry reforming reaction, we can consider a simplified mechanism for hydrogen formation, ignoring reactions 2, 3, 4, and 5. Then, by considering the strong and weak chemical adsorption of intermediates on the catalyst surface, a rate expression for the tri-reforming reaction can be derived as a function of the catalyst's Fermi level. Based on the proposed model, it is possible to qualitatively analyze at which values of the Fermi level the hydrogen yield is maximum and coke formation on the catalyst surface is minimized. The proposed model will have practical significance for finding the optimal catalyst and effectively implementing tri-reforming of the methane gas.

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SYNTHESIS AND SPECTROSCOPIC CHARACTERISTICS OF OXYFLUORIDE GLASS-CERAMICS WITH YTTERBIUM, ERBIUM, AND THULIUM IONS

E. E. Trusova[1], A.S. Yasukevich[2], V. E. Kisel[2], S.E. Kichanov[3]
[1]Belarusian State Technological University, Belarus
[2]Belarusian National Technical University, Belarus
[3]Frank Laboratory of Neutron Physics Joint Institute for Nuclear Research, Russia

Transparent oxyfluoride glass and glass-ceramics are of practical interest as they are up-conversional luminescent materials applicable in various branches of industry. Such materials combine desirable spectroscopic properties of low-phonon fluorocarbon materials and simplicity of production, high chemical resistance, mechanical strength and the optical quality of the oxide materials. The low phonon energy of the matrix leads to the reduced probability of the non-radiative relaxation from excited state, which leads to high luminescence efficiency, comprising up-conversion. This research presents glass-ceramics based on $PbO–PbF_2–CdF_2–GeO_2–SiO_2$ glass-forming system with erbium, ytterbium and thulium ions.

Glass was synthesized according to traditional method by melting of the batch prepared from chemically pure reagents in the electrical furnaces. Glass temperature is 900±50 ºC, with exposure at the maximum temperature for 30 minutes till complete melting and degassing. Primary annealing of glass samples was performed at 300 ºC. The synthetized glass had high transparency, homogeneity and stability of vitreous state. Glass density is 6075 kg/m^3. Thermal linear expansion coefficient of the glass is 90 10^{-7} K^{-1}.

Absorption spectra of glasses exhibit characteristic lines attributed to Yb^{3+}, Er^{3+} and Tm^{3+} ions. Up-conversion luminescence was excited by the radiation of a laser diode into the absorption line of Yb^{3+} ions (≈970 nm). In the up-conversion spectra of glasses, lines are observed that are characteristic of transitions from excited energy levels of Er^{3+} and Tm^{3+} to the lower laying levels of these ions. Glass after primary annealing has the CIE color coordinates x = 0.23 and y = 0.25, which corresponds to a light blue hue.

It is well known that the effectiveness of luminescence correlates with the structural characteristics of glass-ceramics, and the growth of the crystal phase depends on the conditions of glass secondary thermal treatment. Using differential scanning calorimetry method, these conditions were determined to be 390–405 C for 5 hours.

The X-ray diffraction patterns were collected with the PANalytical Empyrean Advance X-ray diffractometer in Bragg–Brentano geometry with a Cu-K_α radiation source and the PIXcel 3D detector. X-ray diffraction patterns of glassy samples reveal a typical pattern for scattering from amorphous glass materials. However, in X-ray spectra of the samples after the secondary heat treatment the presence of multiple diffraction peaks was observed, which indicate formation of the crystalline phase. The position of these peaks corresponds to a cubic structure with Fm3m symmetry group, corresponding to the PbF_2 crystalline phase. Interestingly, this crystalline phase formation is only observed when several rare earth oxides are present simultaneously in the glass as prepared. Doping of nanocrystals with RE ions promotes efficient up-conversion luminescence and leads to a change in the color range of up-conversion luminescence.

The CIE color coordinates of the up-conversion luminescence for different secondary heat treatment conditions are as follows: x = 0.17, y = 0.19 (390 °C°/5 h); x = 0.15, y = 0.15 (395 °C /5 h); x = 0.18, y = 0.19 (390 °C°/5 h). Visually, the color is perceived as bright blue.

Variation of the RE ions content and the secondary heat treatment regime of the oxyfluoride glass-ceramics allows for targeted changes in the spectral composition of up-conversion luminescence. Such materials are of considerable interest for use as secondary radiation sources in lighting devices and information display systems.

BETAVOLTAICS: ADVANCES IN EFFICIENCY, HYBRID SYSTEMS, AND MANUFACTURING CONTROL

M.V. Dolgopolov[1], R.Kh. Rakhimov[2]
[1]Department of Higher Mathematics, SAMARA POLYTECH. Samara, Russia, Molodogvardeyskaya St., 244
[2]Institute of Materials Science, Academy of Sciences Republic of Uzbekistan, Tashkent, Republic of Uzbekistan. Chingiz Aitmatov St., 2b

Betavoltaic technology, which converts beta radiation into electricity, has evolved into a cornerstone for long-term micro-energy solutions, driven by breakthroughs in heterojunction design, isotope integration, and manufacturing precision [1–3]. Recent studies highlight record efficiencies (>24%) and novel hybrid systems, positioning betavoltaics for applications in aerospace, medicine, and IoT. Innovations in materials and scalable manufacturing processes ensure reliability and commercialization potential.

Key Developments include:

1. High-Efficiency SiC/Si Heterojunctions:

o C-14 Integration: Optimized {3C,4H}-SiC/Si structures with embedded C-14 achieved 21.31% efficiency (~300 nW/cm²) via HT CVD synthesis, minimizing self-shielding [2,4].

o Stability: Validated for satellite power systems with >50-year operational lifespan [4].

2. Perovskite Innovations:

o $FAPbI_3$ with Cs^+/QD Additives: A novel dual-additive strategy stabilized the α-phase, enabling 28% efficiency under β/photo dual irradiation (90% retention over 5,000 hours) [5].

o $CsPbBr_3$/Ni-63: Protective Al_2O_3 coatings reduced degradation to <5% over 10,000 hours (24.8% efficiency, 920 nW/cm²) [3].

3. Graphene-Enhanced Systems:

o Parallel 63NiO/GaP heterojunctions with graphene interlayers achieved 5.2 μW/cm² initial power (18.5% efficiency) [6].

4. Isotope Optimization: Ni-63 and C-14 dominate, but Pm-147 from nuclear waste shows potential (800 nW/cm²) [7].

Hybrid Energy Systems [8-11]

• Betavoltaic Zn-Ion Integration:

o 3D MoS_2/Conductive Polymer: Jiang et al. demonstrated a hybrid cathode combining MoS_2's high capacity (200 mAh/g) with PEDOT's conductivity, achieving 95% capacity retention after 500 cycles [8].

o Self-Recharging Betavoltaic Zn-Ion Batteries: Ding et al. integrated a Ni-63 betavoltaic layers with a Zn-ion intercalation hosts, enabling self-recharging (0.5 μW/cm² charging rate) and 150 mAh/g capacity [9,10].

• Supercapacitor Coupling: Naseem et al. reported hybrid systems pairing betavoltaics with graphene supercapacitors, achieving 85% round-trip efficiency for IoT applications [11].

Manufacturing Breakthroughs

• Process Optimization: Zhang et al. introduced in-situ X-ray monitoring during SiC/Si heterojunction fabrication, reducing defects by 20% and improving yield by 15% [12].

• Nanostructured Composites: A (graphene)/SiC composite ([13] ChinaXiv, 2025) enhanced beta absorption by 30% via interface nanoporous engineering, achieving 18.2% efficiency with Ni-63 or C-14 [2,13].

Challenges

• Self-shielding: Addressed by 3D porous SiC (40% loss reduction), 3D nanoporous SiC structures mitigate this by increasing beta absorption [4].

• Material Degradation:

o Perovskites: Unprotected $CsPbBr_3$ degrades by 15% in 2,000 hours. Al_2O_3 coatings and Ce^{3+} doping extended perovskite lifespan [3,5].

o Process Sensitivity: Zhang et al. showed that defects introduced during SiC/Si deposition reduce efficiency by 20%. In-situ X-ray monitoring during CVD improved layer uniformity, boosting yield by 15% [12].

• Isotope Availability: Pm-147 recycling from nuclear waste offers a sustainable alternative path for high-power applications (800 nW/cm²) [7].

Case 1 Study: Optimized C-14/SiC Design/Efficiency: 21.31% [2,4,14]. Mechanism:

o Isotope integration via CVD into the depletion region.

o Optimal doping ($N_d=10^{17}\div10^{19}$ cm^{-3}) and 0.4 μm SiC thickness.

Case 2 Study: PIN Junction with Gradient I-Layer/Structure: 63Ni-SiC PIN heterojunction [13]. Results:

o 2.82% efficiency (14.69 nW/cm²), 1.44 V open-circuit voltage.

o Significant improvement in conversion efficiency vs. prior work.

Case 3 Study: Hybrid C-14/SiC-Zn-Ion Integration

• Design: Combines C-14/SiC betavoltaic layers with Zn-ion intercalation cathodes [2,9,10,14].

• Calculations:

o Energy Deposition: 85% of C-14 β-energy (max 156 keV) absorbed in SiC layer.

o Self-Recharging: $P_{charge}=A\cdot E_\beta\cdot\eta/t=0.1$ mCi·0.156 MeV·0.21/3600 $s=0.5$ $\mu W/cm^2$, where A = activity, E_β = beta energy, η = efficiency.

Future Directions

1. Material Innovations: Lead-free perovskites (Sn/Ge-based) and 2D chalcogenides (MoS_2) [3,5,8].

2. Space Applications: Radiation-hardened graphene/perovskite arrays for deep-space probes [6,9].

3. Medical Implants: Ultra-thin SiC{C-14}/Si devices (~0.1 mm) for pacemakers (10÷50 μW) [2,14].

4. Green Standards: Protocols for Pm-147 recycling aligned with UN SDGs [7].

Conclusion. Betavoltaics is transitioning to mainstream adoption, driven by material innovations (SiC, perovskites), hybrid systems (Zn-ion, supercapacitors), and advanced manufacturing. The integration of gradient PIN junctions and in-situ process control underscores the field's dynamic evolution, supported by interdisciplinary collaboration and sustainable isotope management.

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PLASMA-ENHANCED PHOTOCATALYSIS FOR ENVIRONMENTAL APPLICATIONS

Sh.Tojiyev[1], A.Kodirov [1,2], N.Mukhammadali[1] and J.Razzokov[1,2].

[1]Institute of Material Sciences, Academy of Sciences, Chingiz Aytmatov 2b, 100084 Tashkent, Uzbekistan;
[2] Institute of Fundamental and Applied Research, National Research University TIIAME, Kori Niyoziy 39, 100000 Tashkent, Uzbekistan tshaxzod984@gmail.com

Introduction

Environmental catalysis, particularly photocatalysis, plays a crucial role in promoting sustainable chemical processes and addressing environmental challenges. These catalytic techniques effectively degrade organic pollutants in water, synthesize fine chemicals, and facilitate essential reactions, such as the oxygen reduction reaction (ORR), oxygen evolution reaction (OER), hydrogen evolution reaction (HER) and nitrogen reduction reaction (NRR). The development of high-performance catalysts is essential for improving efficiency, selectivity, and stability in these processes [1]. Recently, non-thermal plasma (NTP) has gained increasing recognition for its potential in the design and modification of catalysts across various fields. By combining plasma treatment with photocatalysis, researchers have observed synergistic effects that enhance the overall efficiency of catalytic processes.

Non-Thermal Plasma and Catalyst Modification

NTP is a powerful tool for catalyst modification. NTP can treat catalysts at low temperatures, using gases like Nitrogen (N_2), argon (Ar), and oxygen (O_2) to enhance catalytic activity and stability [2]. This treatment process modifies catalysts by doping, etching, or exfoliating, thereby adjusting their surface properties and electronic structures to expose more active sites. Over the past two decades, the broad application of atmospheric NTP has expanded into sectors such as environmental engineering, aerospace, biomedicine, and the textile industry, making it an increasingly valuable technology [3]. In NTP, the electric field transfers energy to gas electrons, which subsequently collide with neutral species, generating highly reactive, short-lived species such as oxygen radicals ($O^{\cdot}$), ozone (O_3), nitrogen radicals ($N^{\cdot}$), excited nitrogen radicals (N^{*}), nitrogen ions (N^{2+}), and hydroxyl radicals ($\cdot OH$). These reactive species drive the desired chemical reactions by interacting with the catalyst [4].

Mechanisms of Plasma-Enhanced Catalysis

Plasma treatment enhances catalyst performance through several key mechanisms. Firstly, it increases the dispersion of active sites on the catalyst surface by restructuring metal particles and redistributing active phases, which boosts overall catalytic activity [5]. Secondly, plasma treatment alters the electronic properties of catalysts by changing oxidation states or introducing new

electronic states, thereby improving both reaction efficiency and selectivity. Moreover, plasma treatment can induce significant morphological changes, such as creating nanostructures or increasing surface roughness, which further enhances catalytic performance. Recent studies have demonstrated the effectiveness of plasma treatment in various catalytic processes. For instance, plasma treatment has been shown to improve catalysts used in oxidation and reduction reactions by modifying surface chemistry and active site distribution. Plasma doping introduces new elements into the catalyst structure, optimizing its performance for specific reactions by altering its electronic and chemical properties [6].

Challenges and Future Directions

While plasma treatment offers numerous benefits, it also faces certain challenges. One key issue is process optimization, as precise control over parameters such as gas composition, power, and treatment duration is essential for achieving the desired catalyst modifications and ensuring consistency. Additionally, material compatibility remains a challenge since not all catalysts respond well to plasma treatment. As such, future research should focus on identifying suitable materials and optimizing plasma parameters. To overcome these challenges, researchers should aim to combine plasma treatment with other advanced techniques, employ in situ characterization methods to monitor modifications, and explore new catalyst materials. These efforts will likely lead to further advancements in plasma-enhanced photocatalysis, expanding its application in environmental and industrial processes.

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MEASUREMENTS OF THE COUPLING COEFFICIENT BETWEEN THE STRAIGHT AND RING WAVEGUIDES.

Sattarov S., Zakhidov A., Usanov R., Khudaykulov B.
Samarkand Quantum Center, Uzbekistan, jizpi_sattarov@list.ru

Introduction. Ring micro-resonators (RMR) are widely used in integrated optics as devices for optical signal processing, filtering [1,2] and speed modulator [3] and gas sensors [4, 5]. Their operation is based on the high sensitivity of the quality factor of ring resonators to environmental conditions. When a sufficient number of particles appear near the waveguide, strong energy scattering on these particles is detected. The quality factor of the resonator decreases sharply and thus it is possible to estimate the concentration of particles with known optical properties. The basic structure of a RMR is the design of a straight waveguide connected to a ring waveguide. An important characteristic of this resonant structure is the coupling coefficient. It depends on the distance between the ring and the straight waveguide. The absorbed power in a RMR can be regulated by the level of this coupling. Due to the importance of this parameter, in this work,

experimental measurements of the spectra of RMR with different coupling levels were carried out. The purpose of the study is to find the optimal mode of resonant absorption of various modes, all other things being equal.

Measurements. The measurement of the spectrum of natural frequencies of the integrated resonator at different coupling levels was measured using a setup partially described in the paper [6]. The tunable Toptica CTL-1550 laser was used as a radiation source, to the input of which a triangular signal was fed from the pulse generator for frequency tuning. The optical scheme had two equivalent arms, the signals from which were fed to an oscilloscope for visual control. The array of experimental data represents the dependence of the transmitted power on time. The signal of the transmitted power has the form of a smoothly changing curve with characteristic narrow dips corresponding to the modes of the RMR. The measurements were carried out on one integrated microcircuit with 4 blocks of resonators with different dx. The simulation was performed using © COMSOL MultiPhysics 6.1 software. The following calculation scheme was performed: - the power flow of the field entering the turn of the ring resonator was investigated from the distance between the waveguides dx.The refractive index tables for SiO_2 and Si_3N_4 as a function of wavelength were taken from the integrated chip manufacturer's datasheet.

Conclusions. Thus, the results of experimental measurements of the spectrum of the RMR's eigenmodes with a successive decrease in coupling (increase in the gap between the waveguides) confirm a decrease in the intensity of the total field, including reflectance, transmitance and loss [7]. Experimentally, it was not possible to find the optimal conditions for maximum energy transfer at the resonant frequency due to the limited size of the gap.

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PHASE FORMATION AND OXIDATION RESISTANCE IN Ti-Si-B_4C AND Ti-Al-B_4C COMPOSITES AFTER HIGH-TEMPERATURE ABLATION

Dawid Kozień1, , Wojciech Banaś1, David Salamon2, Daniel Valasek2, Peter Tatarko3, Michal Hičák3, O ndrej Hanzel3, Paweł Nieroda4, Katarzyna Pasiut1, Leszek Chlubny1, Zbigniew Pędzich1

1 Department of Ceramics and Refractory Materials, AGH University of Krakow
2 Central European Institute of Technology, Brno University of Technology
3 Department of Ceramics, Institute of Inorganic Chemistry, Slovak Academy of Sciences
4 Department of Inorganic Chemistry, AGH University of Krakow

The experiment was designed to investigate phase formation and structural transformations in composite materials based on Ti-Si-B_4C and Ti-Al-B_4C systems. Composites were synthesised using nanopowders of boron carbide and intermetallic compounds through Spark Plasma Sintering (SPS) and Self-propagating High-temperature Synthesis (SHS). Six polycrystalline samples were

produced and subjected to thermal ablation at temperatures ranging from 1800 to 2000 °C, simulating extreme conditions, to assess the phase stability and oxidation resistance.

X-ray Absorption Spectroscopy (XAS) techniques in the soft X-ray range (100–2000 eV) were employed at the PIRX beamline using Partial Fluorescence Yield (PFY) and Total Electron Yield (TEY) detection modes. These methods facilitated the investigation of chemical bonding and elemental distributions, particularly at the carbon K-edge and titanium $L_{2,3}$ edges. The study identified the formation of new phases, such as TiB_2, SiC, and AlB_2, and evaluated the thermal stability of the materials.

The primary achievements of the experiment included the identification of the phase transformations and oxidation behaviours after ablation. The Ti-Al-B_4C composites demonstrated excellent oxidation resistance and maintained structural integrity, attributed to the formation of protective Al_2O_3 and TiB_2 phases. Ti-Si-B_4C composites developed a passivating oxide layer rich in TiO_2 and B_2O_3, which partially enhanced their high-temperature stability but exhibited localized surface degradation. Elemental mapping provided insights into the elemental migration phenomena during ablation, and the phase transformations and oxidation behaviours post-ablation provided crucial insights into the performance of Ti-Al-B_4C and Ti-Si-B_4C composites under extreme conditions. The Ti-Al-B_4C composites showcased remarkable oxidation resistance and structural integrity, primarily due to the formation of protective Al_2O_3 and TiB_2 phases. These phases act as barriers against further oxidation, effectively shielding the underlying material from degradation. The presence of aluminum in the composite played a pivotal role in forming the stable Al_2O_3 layer, whereas boron carbide contributed to the formation of the robust TiB_2 phase.

In contrast, the Ti-Si-B_4C composites exhibited a different behaviour, developing a passivating oxide layer predominantly composed of TiO_2 and B_2O_3. This layer contributes to enhancing the high-temperature stability of the material to some extent. However, the protection was not as comprehensive as in the Ti-Al-B_4C system, as evidenced by localized surface degradation. Elemental mapping conducted during the experiment provided valuable information on the migration of elements during the ablation process, offering insights into the dynamic changes occurring within the material structure. These findings have significant implications for the design and optimisation of high-temperature materials for applications in extreme environments such as aerospace and thermal protection systems.

Several challenges have been encountered, such as post-ablation sample heterogeneity, variations in oxidation effects, and low-intensity signal detection at specific absorption edges. Despite these challenges, the experiment was successfully conducted through meticulous planning and optimisation of measurement strategies.

In conclusion, a comparative analysis revealed that Ti-Al-B_4C composites outperformed Ti-Si-B_4C composites in terms of oxidation resistance and thermal stability. The formation of compact protective layers in Ti-Al-B_4C samples reduced elemental diffusion and improved surface integrity under extreme thermal conditions. In contrast, Ti-Si-B_4C composites, despite forming an oxide barrier, exhibited greater vulnerability to surface degradation.The superior performance of Ti-Al-B_4C composites in oxidation resistance and thermal stability can be attributed to the formation of a dense, adherent protective layer on the surface. This layer, likely composed of complex aluminum and titanium oxides, acts as an effective barrier against further oxidation and elemental diffusion. The compact nature of this protective layer ensures minimal oxygen penetration into the bulk material, preserving the structural integrity of the composite even under extreme thermal conditions. Additionally, the presence of aluminum in the composite may contribute to the formation of a stable alumina (Al_2O_3) layer, known for its excellent oxidation resistance properties.

In contrast, Ti-Si-B_4C composites, while capable of forming an oxide barrier, demonstrated less effective protection against oxidation and thermal degradation. The oxide layer formed on these composites may be less compact or more prone to cracking under thermal stress, allowing for increased oxygen diffusion and subsequent material degradation. The silicon in the composite

might form silica (SiO_2) or titanium silicides, which, although protective to some extent, may not provide the same level of oxidation resistance as the aluminum-containing counterparts. This difference in protective layer quality and stability explains the greater vulnerability of Ti-Si-B_4C composites to surface degradation under similar thermal conditions, highlighting the importance of alloying element selection in designing high-temperature resistant materials.

These findings support the development of ultrahigh-temperature ceramics (UHTCs) with enhanced durability for aerospace and energy applications. Further studies enabled by additional beamtime will allow comprehensive mapping of compositional gradients and verification of bonding states, leading to the optimisation of synthesis routes and material properties.

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CVD GROWTH OF DISCRETE MULTILAYER GRAPHENE DOMAINS: MORPHOLOGICAL AND STRUCTURAL ANALYSIS

O.M.Tursunkulov[1], G.B.Khojieva[1,2], M.A.Sobitov[2], B.B.Gulamov[1], Sh.G.Khojiev[1].
[1]Center for Advanced Technologies.
[2]National University of Uzbekistan.

In the past decade, carbon-based nanostructured materials and their derivative systems have emerged as one of the most dynamic and transformative research frontiers in materials science. Among these, graphene stands out as a revolutionary material, offering unparalleled mechanical, electrical, and thermal properties that make it highly attractive for next-generation nanotechnology applications. Its exceptional characteristics—including ultrahigh carrier mobility, atomic-scale thickness, and remarkable strength—have spurred intense research efforts worldwide, drawing attention from academia, industry, and government research institutions [1–4]. A critical evaluation of existing literature reveals that contemporary studies on layered carbon nanomaterials pursue two complementary objectives: (1) the development of novel, scalable, and cost-effective synthesis techniques to produce high-quality graphene films and (2) the strategic modification of graphene's intrinsic properties through chemical functionalization, doping, or hybrid nanostructure integration to tailor its performance for specific applications [5]. Following the landmark experimental demonstrations of multilayer graphene fabrication, the scientific community has witnessed an exponential increase in publications investigating its synthesis-structure-property relationships, with particular emphasis on optimizing growth parameters, defect engineering, and large-area deposition methods [6]. One of the most promising methods for producing graphene is chemical vapor deposition (CVD). Unlike other technologies, graphene obtained by CVD stands out due to the uniformity of the films produced across the substrate surface. This is because, during graphene growth, the decomposition of a carbon-containing gas (such as methane) occurs at high temperatures across the entire surface of the metal catalytic substrate. The objective of this work is to develop a technology for producing discrete graphene domains on a copper substrate using CVD, followed by an analysis of the surface morphology and structure of the obtained samples. Subsequently, the transfer of graphene onto a silicon substrate using an organic adhesive film was performed. Graphene synthesis was carried out using CVD on a copper substrate. A copper foil (99.99% Cu) with a thickness of 100 μm and dimensions of 2×3 cm was used as the substrate. Before loading into the reactor, the substrate was sequentially washed in acetone, isopropyl alcohol, and distilled water, followed by drying at 50°C for 60 minutes. The cleaned copper substrate was then placed horizontally in the center of the reaction chamber, and a preliminary evacuation was

performed using a vacuum pump. Once a pressure of 1–4 Torr and the required heating temperature were reached, graphene synthesis was initiated. In the first case, the reactor was heated to 300°C under preliminary vacuum, followed by the introduction of hydrogen gas. The temperature was then raised to 1000°C, where stabilization of temperature and pressure occurred, after which the copper substrate was annealed at 1000°C. During annealing, the surface oxide layer was removed, and the grain size of the substrate increased. After thermal annealing in a hydrogen flow, methane gas was introduced into the reactor as a precursor gas for 30 minutes at a pressure of 1–4 Torr. At this stage, graphene films formed on the copper substrate grains. In the final step, the methane flow was turned off, and an argon flow was introduced. Simultaneously, the reactor's metal casing was raised to enable rapid cooling. Exponential cooling to 200°C was achieved within 7–15 minutes. Optical and scanning electron microscopy (SEM) images of the copper substrate after CVD treatment revealed discrete, darkened rectangular regions of varying orientations, identified as multilayer graphene domains. Further SEM magnification (10 μm and 1 μm scales) confirmed continuous domains of multilayer graphene with non-uniform growth directions. The morphology of the sample showed that most domains had a rectangular shape with varying orientations, and their sizes ranged from 10 to 100 μm. The degree of non-uniform domain clustering was found to depend on the orientation of the copper crystals. Raman spectra of the copper substrate with CVD-grown graphene domains were studied. Typically, graphene exhibits three main bands in Raman spectra: the G-band, D-band, and 2D-band. The initial baseline curvature in the spectra was attributed to oxidation of the copper substrate. Additionally, the presence of a weak and broad D-peak (1350 cm^{-1}) indicated defects in the graphene films, resulting from structural disorder in the domains formed after high-temperature thermal treatment in a methane environment. The most prominent G-band (1582 cm^{-1}) suggested a high degree of crystallization in certain regions. The observed 2D-band (2700 cm^{-1}) was broader and asymmetric, indicating the formation of multilayer graphene. The intensity ratio of the D and G bands (ID/IG) was approximately 1, further confirming the non-uniform structure with disordered graphene domains. To study the functional properties of the synthesized graphene, it was transferred to an isolated SiO_2/Si substrate using an adhesive layer and substrate etching. A polymethyl methacrylate (PMMA) polymer film was used to capture individual multilayer graphene domains after etching the copper substrate. The PMMA coating was applied via spin-coating at up to 2500 rpm, followed by drying in an oven. Once the sample surface was uniformly coated with a ~0.5 mm PMMA film, the original substrate was etched in a nickel etchant solution. The copper etching process took 30 minutes, leaving a free-floating PMMA film with graphene on the etchant surface. The separated PMMA/graphene film was washed in distilled water and transferred onto an SiO_2/Si substrate. The structure (SiO_2/Si–graphene–PMMA) was then dried in an oven at 50°C for 1 hour. This method allowed complete transfer of the synthesized graphene onto an isolated insulating substrate. Subsequently, the PMMA was removed in a dichlorobenzene (Sigma-Aldrich) solution, followed by drying at 150°C for 30 minutes in air. The morphology of the graphene film on the SiO_2/Si substrate was then examined. Optical and SEM images before and after PMMA dissolution in dichlorobenzene revealed non-uniform wrinkles, surface irregularities, and some blistering after drying. Residual PMMA islands and deposits were observed in areas with wrinkles and roughness, contaminating the graphene surface and degrading its functional properties, which is critical for nano- and microelectronics applications. To avoid these issues, methods for direct graphene transfer without polymer coatings should be explored. Therefore, in CVD graphene synthesis, the use of polymer coatings should be minimized, and direct transfer to an insulating substrate should be pursued. This study was carried out as a joint project funded by KOICA, in collaboration with the Korea Research Institute of Chemical Technology (KRICT) and the Advanced Technology Center (ITC).

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WAVE PACKET DYNAMICS IN GRAPHENE WITH PHOTONIC CRYSTAL-INSPIRED CIRCULAR POTENTIALS

M. Suleimanov[1,*], H. Yusupov[2], Sh. Nurmatov[1], Kh. Rakhimov[1], A. Chaves[3], M. Yusupov[4]

[1] Institute of Materials Science, Academy of Sciences of Uzbekistan, Tashkent, Uzbekistan
[2] Kimyo International University in Tashkent, Tashkent, Uzbekistan
[3] Departamento de Física, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil
[4] Institute of Fundamental and Applied Research, NRU TIIAME, Tashkent, Uzbekistan
* e-mail: m.sulaymonov@imssolar.uz

Charge carrier dynamics in graphene have been widely studied in disordered potential landscapes, such as randomly distributed scatterers [1,2], defects or dopants (see review paper [3,4] and references therein), revealing reduced transmission and longer interaction times due to enhanced scattering. Complementary studies [5] have explored wave packet propagation in periodic potentials, uncovering non-monotonic dependencies of transmission on barrier height and the effects of geometric arrangement. For example, staggered or asymmetric periodic configurations suppress transmission more effectively than symmetric ones [6]. These findings emphasize the importance of periodicity and geometry in tuning graphene's electronic properties. While wave packet dynamics have been examined in pristine [7], doped [8], and magnetically biased graphene [9,10], theoretical studies involving structured potential barriers remain limited.

In this work, we investigate wave packet dynamics in graphene influenced by periodically arranged circular potential steps, inspired by photonic crystal geometries. These alternating positive and negative potentials resemble electron- and hole-rich puddles arising from intrinsic disorder and offer new ways to control charge carrier behavior in graphene-based nanodevices. Using the Dirac continuum model and numerical simulations, we analyze how barrier height, radius, and spacing affect transmission and scattering.

The novelty of our study lies in applying photonic crystal-inspired potential patterns to graphene, emulating refractive index modulation and enabling band gap formation and wave localization. By drawing analogies with photonic crystal physics, we demonstrate how such

patterns can manipulate charge carriers in graphene. Extending our previous work [5], we show that this approach bridges fundamental physics with applications in electronic material design.

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COMPARATIVE ANALYSIS OF DIFFERENT METHODS TO CALCULATE THE POSITION OF THE SUN

A.Gafurov* and Sh.Nurmatov

Institute of Materials Science, Uzbekistan Academy of Sciences, Tashkent, Uzbekistan

e-mail: a.gafurov@imssolar.uz

The Earth axial tilt is named obliquity (e). It is the angle between the Earth rotation axis and a perpendicular to the Earth's orbital plane (ecliptic). According to Connaissance des temps (an official yearly publication of astronomical ephemerides provided by IMCCE and being considered as a reference in the field of astronomy), on 1st of January 2000 its value was about 23°26'21"= 23.44° [1] and as it varies very slowly over the time, in 2019 it is still about 23.44°. The diagrams of track represent the trajectory of the Sun for a terrestrial observer. Due to the obliquity, there is an angle which varies every instant between the celestial equator and the direction of the centre of the Sun. This angle is named the declination. At both solstices, declination reaches a peak (maximum for the summer solstice for which the declination equals the obliquity and a minimum for the winter solstice. The declination is zero at the equinoxes: the Sun is at the intersection between the ecliptic and the celestial equator on the celestial sphere. One of these two point is the vernal point reaches at the spring equinox. This angle is necessary to determine the Sun position (i.e. determining the azimuth and the elevation angle or height).

This method uses accurate and complete astronomical data [2]. Consequently, it is very accurate and it involves to solve the Kepler equation. Within the context of an elliptic orbit, three anomalies can be defined: the true anomaly (ν), the mean anomaly (M) and the eccentric anomaly. The true anomaly v is the angle formed by the major axis and the vector from the Earth (focus) to the Sun. According to Kepler's second law, this vector sweeps out equal areas in equal times.

The mean anomaly M is the angle formed by the major axis and the vector from the (Earth) focus to a satellite making its revolution with a uniform motion. More specifically, M is the angle travelled during the same interval of time (as v) by a satellite on a circular orbit having the same period as the elliptic orbit. Given that on circular orbits the motion is uniform, this definition allows to have a clock who's the duration to make a full rotation is the period of the elliptic orbit.

The eccentric anomaly E is the angle formed by the major axis and the vector from the centre of the ellipse to the point belonging to the circumscribed circle of the ellipse and having the same abscissa than the Sun. Solving Kepler equation, is finding $E(e,M)$, i.e., finding E knowing e and M. The eccentricity e and the mean anomaly M are astronomical data given in the reference [1].

As it does not exist direct solution of this equation, it is necessary to solve it numerically. To reach the solution, a fixed-point iteration algorithm will be used with Python: First, initialization of E_0=M. When, above a specific rank n, *En+1 - En* is less than the tolerance, the while loop is finished and E is formatted to be in **[0**; **2**π]. In our investigation we are used Python to solve Kepler equation.

All of these values are given as a function of d which is the number of days counting from the 1st of January 2000. Indeed, even if variations of the eccentricity, the obliquity and the longitude of perihelion are small over the time, it is better to take them into account to improve the accuracy of the declination, especially if it is calculated for a very remote date in the future. The longitude of perihelion w is the angle from the direction of the vernal point to the perihelion and measured in the direction of the motion.

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METHODS OF PRODUCING GREEN HYDROGEN USING SOLAR PANELS

M.U. Nosirov, Kh. Rakhimov, Sh. Nurmatov

Institute of Materials Science, Academy of Sciences of the Republic of Uzbekistan

Hydrogen is an environmentally friendly fuel, but it does not exist in a free state on Earth. One of the most common sources of hydrogen is water, which covers 71% of our planet. Hydrogen can be extracted from water using various methods, such as thermolysis and electrolysis. Typically, these processes rely on non-renewable energy sources like coal, oil, gas, nuclear energy, and fusion energy. However, "green" hydrogen can be produced using renewable energy sources, including solar, wind, tidal energy, waste, biomass, and others. In Uzbekistan, among renewable energy sources, solar energy has the greatest potential compared to other renewable options. The current state of hydrogen energy, as well as methods and technologies for hydrogen production, have been explored in the Refs. [1-3].

Conversion Method. Currently, one of the most widespread methods for producing hydrogen is the thermochemical method, specifically steam methane reforming, which involves the dissociation of methane molecules using superheated steam [1]. The conversion method entails the oxidation of methane with water vapor, as described by the following formula: $CH_4 + H_2O \rightarrow CO + 3H_2$

Complete methane conversion is practically achieved at temperatures above 1200°C. However, this method releases significant amounts of CO_2 into the atmosphere. Moreover, the technological process relies on non-renewable energy sources (coal, oil, gas).

Methods of Hydrogen Production Using Solar Energy. Although hydrogen is an environmentally clean fuel, its production process often pollutes the atmosphere, depending on the energy source used. By employing renewable energy sources, it is possible to produce "green" (environmentally friendly) hydrogen. In Uzbekistan, solar energy stands out as the renewable source with the greatest potential. Therefore, it is reasonable to explore methods of hydrogen production using solar energy [4]. These methods can include thermolysis or electrolysis of water. In the Ref. [5], based on an analysis of existing hydrogen production methods and considering the technical capabilities of the Big Solar Furnace at the Institute of Materials Science of the Academy of Sciences of Uzbekistan, the potential for producing hydrogen via water thermolysis in the focal zone of a solar concentrator was demonstrated. Additionally, the Ref. [6] presented photocatalytic methods for hydrogen production using concentrated solar radiation.

Using Solar Energy for Hydrogen Production via Water Electrolysis. We have developed a water-alkaline electrolyzer with varying capacities (from 1 to 10 kW). Steel plates were used for the electrodes and the device housing, while aqueous NaOH solutions served as the electrolyte. The electrolyzer is powered by electricity generated from a 10 kW solar photovoltaic station.

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COMPUTATIONAL MODELING OF COLD PLASMA-INDUCED DESTABILIZATION OF E-CADHERIN–B-CATENIN PROTEIN COMPLEX IN INFLAMMATORY BREAST CANCER

Akramova Rukhsora[1*], Jamoliddin Razzokov[1], Yusupov Maksudbek[1]

[1]Institute of Fundamental and Applied Research, National Research University TIIAME, 100000, Tashkent, Uzbekistan

[*Contact email: rukhsora.akramova@ifar.uz]

Abstract. This study investigates the hypothesis that cold atmospheric plasma (CAP) may destabilize the E-cadherin–β-catenin protein complex in inflammatory breast cancer [1], thereby weakening cell-cell adhesion within metastatic emboli [2]. To explore this, a non-reactive molecular dynamics simulation protocol was implemented using the GROMACS package to compare the structural stability of the native E-cadherin–β-catenin interface and its oxidatively modified counterpart. Protein oxidation was introduced by selectively targeting plasma-sensitive amino acid residues to mimic the biological effects of reactive oxygen and nitrogen species generated by CAP.

Preliminary simulation results suggest a reduction in binding affinity and loss of key interfacial contacts in the oxidized complex without concominant activation of the Wnt/β-catenin signaling pathway, assuming intact proteasomal degradation machinery in inflammatory breast cancer cells.

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SOL-GEL SYNTHESIS OF Mg^{2+} MODIFIED Li-Mn BASED SPINEL STRUCTURED OXIDES

Sh.A.Begimkulova[1*], A.M.Nasimov[1], A.I.Ivanets[2], O.N.Ruzimuradov[3]
[1]Uzbekistan, Samarkand, Samarkand State University
[2]Institute of General and Inorganic Chemistry, National Academy of Sciences of Belarus, Minsk, 220072 Belarus
[3]Turin Polytechnic University in Tashkent, Tashkent, 100095 Uzbekistan
*e-mail: bshahnoza0206@gmail.com

The growing dependence on fossil fuels is causing significant damage to the environment, so the demand for alternative energy is growing rapidly. The use of alternative energy systems such as wind, hydroelectric and solar power mainly requires batteries to store energy. Nowadays, batteries have become integral to everyday life and are essential in nearly all aspects of human activity, particularly regarding electronic devices. While the main characteristic of primary (non-rechargeable) batteries is their ease of use, secondary (rechargeable) batteries are increasingly being used. Secondary batteries have a reverse electrode reaction and the ability to recharge cells [1].

Lithium-ion batteries are a particularly attractive type of secondary battery [2]. One of the main reasons for the practical use of lithium-ion batteries is that lithium is the lightest of the metals and has good electrical properties, providing high energy capacity. In synthesized lithium-ion batteries, it is preferable to use Li-Mn-O oxide compounds with a spinel structure as cathode elements. The advantages of Li-Mn systems include high specific capacity, acceptable electrical conductivity, and no toxic effects on the environment and humans. Moreover, $LiMn_2O_4$ spinel has a high potential. The sol-gel method is a convenient method for synthesizing $LiMn_2O_4$ spinel. Optimal conditions for synthesis by the sol-gel method include the importance of controlling the Li/Mn ratio, concentration of metal salts, pH control, precursors, hydrogel transitions, etc. [3-5].

The work aims to identify the main factors affecting the phase composition of Li–Mn adsorbents modified with Mg^{2+} ions and to study their adsorption properties.

The sol-gel method was used to synthesize spinel-structured $LiMn_2O_4$ and $LiMg_xMn_{(2-x)}O_4$ samples. In the synthesis process, aqueous solutions of $LiNO_3$, $Mg(NO_3)_2 \cdot 6H_2O$ and $Mn(NO_3)_2 \cdot 4H_2O$ were used as initial reagents, which were mixed in certain stoichiometric ratios. As a result, $LiMg_xMn_{2-x}O_4$ ($0 \leq x \leq 0.7$) oxides were formed.

Stoichiometric amounts of manganese (II) nitrate tetrahydrate salt ($Mn(NO_3)_2 \cdot 4H_2O$) and magnesium nitrate hexahydrate salt ($Mg(NO_3)_2 \cdot 6H_2O$) were dissolved in distilled water to prepare various mixed solutions. The molar ratio of Mg/Mn was changed from 0 to 0.7. Then, lithium nitrate ($LiNO_3$) solution was added dropwise to the resulting mixtures and stirred continuously for 1 hour at room temperature. Li/(Mg+Mn) salts were mixed in a molar ratio of 1:2. Citric acid was used as an activating reagent during the synthesis process, with an equal molar ratio (citric acid)/(Li+Mg+Mn salts). Subsequently, the resulting mixtures were kept at 80 °C for 8 hours to ensure gel formation and heated at 120 °C to eliminate residual water. The dried mixtures were subject to calcination at 700 °C for 7 hours to obtain the ultimate spinel phase.

To carry out the adsorption processes of Li^+ ions, all the synthesized Li-Mn spinel-structured samples were converted to the H-form. For this, 0.3 g of the adsorbent sample was added to 50 ml of 0.1 M hydrochloric acid solution at a temperature of 25 °C and the process was continued for 24 h with constant stirring (400 rpm). Then the samples were filtered, washed several times with distilled water until the pH was neutral and dried at 60 °C.

The adsorption of Li^+ onto the H-form samples was studied in a batch system. 0.10, 0.20, 0.30 and 0.40 M solutions of Li^+ were prepared by dissolving $LiNO_3$ in double-distilled water. A

0.300 g sample of the adsorbent was placed in a 50.00 mL solution of $LiNO_3$ at 25 °C for 24 hours. To determine the adsorbent dosage of the spinel samples, the adsorbent concentration was varied from 0.05 to 0.3 g/l. Then, the adsorbent mixture was centrifuged at 3500 rpm for 5 min and the solution was filtered using PTFE 32 mm 450 nm syringe filters to determine the Li^+ concentration. The adsorption parameters of the samples, temperature (25 °C), adsorbent concentration (0.3 g/L), contact time (24 h), and initial Li^+ concentration (0.1–0.4 M) were chosen to be the same for each pH value. The adsorption activity is calculated using the following equation:

$$q = \frac{(C_0 - C_e) \times V}{\mathrm{m}}$$

where is the adsorption capacity (q), mmol/g; the initial and equilibrium concentrations of lithium ions in the solution are (C_0 and C_e), mmol/l; aliquot volume (V), l; and the mass of the adsorbent (m), g. Lithium and manganese concentrations were analyzed using a light absorption spectrophotometer Shimadzu UV-2600i (Japan).

Initial studies showed that the adsorbent with the composition of $LiMg_{0.7}Mn_{1.3}O_4$ had the highest adsorption capacity. The adsorption isotherms of the best sample ($LiMg_{0.3}Mn_{1.7}O_4$) were investigated at prepared solution temperatures of 25, 35, and 45 °C.

Studies have shown that the adsorption capacity of Li^+ ions increases with increasing temperature, which confirms the endothermic nature of the lithium-ion adsorption process. This phenomenon is probably due to the activation of the interaction forces between ions and the adsorbent surface under the influence of temperature, an increase in the diffusion rate, and an acceleration of the ion exchange kinetics.

At the same time, a significant increase in the size of agglomerates from 0.1 μm to 3 μm was observed. Also, the maximum adsorption capacity for a monomolecular layer of $LiMg_{0.3}Mn_{1.7}O_4$ adsorbent reached 65 mg/g in a sample solution at 45 °C. Further studies on the adsorption kinetics and multi-cycle adsorption processes of the obtained adsorbents are planned. In addition, their effectiveness will be evaluated through large-scale tests to confirm the practical application of these materials.

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SYNTHESIS OF NANOCOMPOSITE BASED ON METAL OXIDES IMMOBILIZED WITH ORGANIC DYES.

Sh.E.Mirzaev[a], A.A.Samiev, A.M.Nasimov
[1]Uzbekistan, Samarkand, Samarkand State University
a) mirzayevsherzodbek877@gmail.com

In recent years, semiconducting metal oxide nanomaterials have attracted great interest among researchers thanks to their unique important properties such as optical transparency, electrical conductivity, and ferromagnetism [1]. The unique physicochemical properties of metal oxide nanomaterials are associated with the high density of edges and corners on their surfaces and their limited size. The potential technological applications of metal oxide nanoparticles are being investigated in several fields, including materials chemistry, medicine, agriculture, IT, biomedicine, optics, electronics, catalysis, environment, energy, and sensors. The properties of the ensuing systems can be modified and governed by various methods used to synthesize semiconducting metal oxide nanomaterials [2].

It is known that SiO_2/ZnO nanocomposite has been widely studied for various researches such as gas sensors, and photocatalysis. There are many chemical methods for the formation of nanoparticles in the SiO_2 matrix. Due to different synthesis methods, the same material has different physicochemical properties. Their properties are greatly influenced by the synthesis conditions. Since new technologies for the formation of metal oxide nanomaterials with controlled size, shape, and composition are constantly emerging, the created methodology should have some convenient and useful practical indicators. In addition, when choosing a new synthesis method, it is important to pay attention to indicators such as mass production, rapid production, uniform morphology, cost-effectiveness, low temperature, and diversity of the created nanomaterials [3-4].

The sol-gel route is a cheap and simple chemical synthesis method for the preparation of metal oxide films. The advantage of this process depends on several parameters such as precursors, solvents, substrate, solution mixing and gelation time, preheating, annealing, and coating methods [5].

Here ZnO-SiO_2 nanomaterials were synthesized utilizing the sol-gel route. ZnO-SiO_2 thin layers were obtained by spin coating and their physicochemical properties were studied.

Zinc acetate ($Zn(CH_3COO)_2*2H_2O$), Bromcresol Purple (BCP) (chemically pure grade, Khimreagent, Uzbekistan) and Tetraethyl orthosilicate (TEOS), cetyltrimethyl ammonium bromide (CTAB) (chemically pure grade, Merck, Germany) were used to obtain nanocomposite material. All the chemicals were used without any further purification.

The optimal molar ratio of the components was chosen as TEOS : H_2O : C_2H_5OH : HCl ~ 1 : 4 : 4 : 0.25. The resulting solution was aged for one day and the pH of the solution was found to be acidic.

To synthesize ZnO nanoparticles, 0.324 g of zinc acetate dihydrate ($Zn(CH_3COO)_2*2H_2O$) was dissolved in a mixture of 30 ml of isopropyl alcohol, 10 ml of double distilled water and 1 ml of hydrochloric acid. The resulting solution was stirred at high speed for 60 minutes at 70°C and then aged in a vacuum oven at 300°C for 2 hours. The basic reaction process can be represented by the following two equations:

To form the ZnO-SiO_2 layer, a mixture of 2 ml of ZnO solution, which had been aged for 2 hours, was added dropwise to the previously prepared 10 ml of SiO_2 solution. During the mixing process, 0.5 ml of 0.5 M STAB solution was added and stirred at high speed for 30 minutes. To ensure the immobilization of the organic dye in the ZnO-SiO_2 sol-gel layer, 0.5 ml of 0.1 M BCP indicator solution was added dropwise to the resulting mixture and the process was intensively stirred at 80 ° C for 1 hour. The resulting mixture was left at room temperature for several days for the aging process.

To form a thin layer, the prepared BCP@ZnO-SiO_2 mixture was deposited on 15x20 mm microscope slides by spin coating method for 30 seconds at 3000 RPM. Before forming the layer, the above technical and chemical treatment was performed to clean the glass substrates. The prepared solution for forming the thin layer was dripped onto the glass substrate using an automatic pipette. The coated substrates were first dried at 70 °C for 30 minutes and then at room temperature for several days. The formed thin layer was washed thoroughly with water to eliminate excess and unbound dye species.

The XRD analysis results show that the ZnO-SiO_2 composite materials have undergone a slight transition from an amorphous (glass) structure to a crystalline structure. The crystallization of the ZnO-SiO_2 sample was found to be 17%.

The wide-angle X-ray diffraction pattern showed that 2θ values of the diffraction peaks for zinc oxide were ¼ 31.69, 34.54, 36.211, 47.57, 56.54, 47, 56.54 corresponding to the orientation planes (100), (002), (101), (102), (110), (103), (112) and (201), respectively. This conforms to the wurtzite structure diffraction standard card No. 36-1451.41,42. The wurtzite phase can be identified when compared to the SiO_2 sample, which means that ZnO-SiO_2 contains ZnO particles.

SEM images show that the amount of ZnO in the thin film formation had a notable effect on the surface morphology. Increasing the zinc oxide content from 5 to 15% did not improve the quality of the coating. It can be seen that the surface of the sample with 5% ZnO content is not homogeneous, and various peaks appear on the surface. The SEM images reveal of the sample with 10% ZnO content that a homogeneous layer has formed on the surface. However, very few cracks occur. In the samples with an increased ZnO content of 15%, the layer is almost not formed, and a large number of fractures occur .

The morphological properties of the thin film consisting of BCP@ZnO-SiO_2 immobilized with an organic dye have improved. The film has formed a smooth surface similar to glass.

We have prepared thin films of nanostructured composite materials based on metal oxides immobilized with organic dyes utilizing the sol-gel method. The spin coating technique has once again been proven to be a suitable method for preparing thin films. It was found that the addition of ZnO to the amorphous SiO_2 layer resulted in a crystallization of 17%. The best surface morphology was observed to be the layer formed from a mixture of ZnO-SiO_2 10:90%. The BCP indicator was homogeneously immobilized on this layer. These highly efficient nanocomposite materials may serve as promising candidates for adsorbents aimed at eliminating persistent organic pollutants from water.

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HIGHER ENTROPY CrMnFeCoNi/NF ALLOY NANOPARTICLES FOR ENHANCED HYDROGEN PRODUCTION

M. D. Pecherskaya[a,*], F. Hoshimov[a], Sh. I. Mamatkulov[a]

[a]*Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov 2B st., Tashkent, 100084, Uzbekistan*
*e-mail: mariya.pecherskaya@yahoo.com

The development of high-performance and durable electrocatalysts for the hydrogen evolution reaction (HER) is crucial for efficient and sustainable hydrogen production, especially in alkaline media. Among various materials, high-entropy alloys have attracted significant attention due to their unique synergistic effects and enhanced catalytic properties [1-3].

In this study, a CrMnFeCoNi/NF electrocatalyst is synthesized through a hydrothermal method and evaluated for its HER performance in alkaline conditions. The precursor solution was prepared by dissolving equimolar amounts (1 mmol each) of Cr, Mn, Fe, Co, and Ni nitrates, along with 3 mmol of urea and 3 mmol of NH_4F, in deionized water. A pre-cleaned piece of nickel foam (NF) was immersed in this solution and sealed in a Teflon-lined stainless-steel autoclave at 160°C for 12 hours. The resulting sample was thoroughly washed and dried at 60°C.

Electrochemical performance was evaluated in 1.0 M KOH electrolyte using a standard three-electrode system. The HER activity was assessed by analyzing the overpotential and Tafel slope. The CrMnFeCoNi/NF catalyst exhibited a low overpotential of 96 mV at a current density of 10 mA cm^{-2}, indicating efficient catalytic activity and favorable kinetics. The Tafel slope was calculated to be 122.54 mV dec^{-1}, further confirming the enhanced charge transfer characteristics and superior electrocatalytic efficiency.

Moreover, chronoamperometric measurements performed at a constant potential for 24 hours revealed a minimal current density decay of only 0.6%, demonstrating excellent long-term operational stability. The superior performance of the CrMnFeCoNi/NF catalyst is attributed to the synergistic effects of the multiple transition metal elements and the highly conductive nickel foam substrate, which together enhance electron transport and active site exposure. These findings highlight CrMnFeCoNi/NF as a promising, scalable, and cost-effective electrocatalyst for efficient alkaline water splitting and sustainable hydrogen production.

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DEVELOPMENT OF TRANSITION METAL DICHALCOGENIDES FOR OPTOELECTRONIC DEVICES AND SELECTIVE AMPLIFICATION ENHANCEMENT.

K.Saidov[1, 2], Kh.Sattarov[1], Kh.Foziljonov[1], O.Ruzimuradov[2, 3]

[1]Department of Electronics and Radio Engineering, Tashkent University of Information Technologies, Tashkent 100200, Uzbekistan
[2]Material Sciences Institute, Academy of Sciences of the Republic of Uzbekistan, Tashkent 100084, Uzbekistan
[3]Department of Natural and Mathematic Sciences, Turin Polytechnic University in Tashkent, Tashkent 100095, Uzbekistan

Low-dimensional materials have exhibited remarkable physical properties, with TMDs such as MoS_2, $MoSe_2$, $MoTe_2$, WS_2, WSe_2, WTe_2, and $PdSe_2$ attracting significant attention as potential candidates for the post-silicon era. Single layers of these 2D TMD nanomaterials have demonstrated high efficiency in light absorption, resulting in enhanced photodetector responsivity. TMDs possess a characteristic MX_2 structure, where M represents a hexagonally arranged sheet of atoms, sandwiched between two layers of X atoms. These crystals are held together by weak van der Waals forces, enabling their exfoliation into single 2D flakes from bulk crystals. The absence of covalent bonds between adjacent layers minimizes dangling bonds, contributing to their chemical stability and reduced carrier scattering. These features, along with high anisotropy in their electrical properties, make semiconducting TMDs excellent candidates for next-generation electronic and optoelectronic devices, such as FETs, light-emitting diodes, and Van der Waals heterostructure devices. Additionally, the 2H phase of $MoTe_2$ has been extensively researched for applications in spin transport electronics and solar cells. $MoTe_2$ FETs, in particular, display both unipolar and ambipolar charge transport characteristics, with their polarity easily tunable via the contact electrode [1, 2].

The adjustable band structure of TMDs enables control over key material properties, making them suitable for applications in electronics, photonics, and energy. Their current-voltage characteristics were also analyzed. Opto-electrical tests on 15-layer $MoTe_2$ revealed a trap density of $\sim 6\times10^{12}$ cm^{-2}. The device showed enhanced AC photocurrent and on/off ratio, suggesting improved photoresponse without gate modulation. The study highlights the integration of $MoTe_2$ with h-BN in heterostructures, focusing on synthesis, precise dry transfer, and structural analysis using Raman, XRD, and AFM. Improved mobility and performance were observed, particularly at 80 K, influenced by phase transitions and interface quality. BMIM-BF_4 ionic liquid encapsulation was used to boost $MoTe_2$ FET performance, achieving stable unipolar p-type behavior with strong transconductance, high on/off ratio, and enhanced durability, making it ideal for advanced 2D device applications [3].

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SYNTHESIS OF GRAPHENE OXIDE

M.Jumayeva, R.Khasanov, Sh.Mamatkulov, Kh.Butanov
Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan, Chingiz Aytmatov St. 2B, 100078, Tashkent, Uzbekistan
e-mail: m.jumayeva1988@gmail.com

Graphene oxide (GO) is a layered carbon structure with oxygen-containing functional groups (=-O, -OH, -O-, -COOH) attached to the surfaces and edges of the layers [1]. GO, like other two-dimensional carbon materials, can be monolayer or multilayered. The monolayer structure is called graphene oxide, while the bilayer GO is referred to as bilayer graphene oxide. Graphene oxide (GO) is synthesized by oxidizing graphite into graphite oxide and then converting this graphite oxide into GO. The properties of the material depend on the synthesis method, as well as the amount and type of oxygen groups present in the resulting GO. Unlike graphene, GO is hydrophilic, making it easier to prepare suspensions based on water or organic solvents. Highly oxidized forms of GO have a band gap of about 2.2 eV and are used as electrical insulators. Furthermore, reduced graphene can be obtained through thermal or chemical reduction of GO. These processes alter the properties of GO and provide the opportunity to obtain new materials [2].

There are several methods for producing graphene oxide. The Hummers method is the most widely used and classical method for obtaining graphene oxide. In this work, GO was synthesized by modifying materials and conditions based on the Hummers and Tour methods. The process is as follows:

Graphite + $NaNO_3$ + Sulfuric acid (H_2SO_4) + Potassium permanganate ($KMnO_4$)

The process was initially conducted in an ice bath, followed by an oil bath. Excess potassium permanganate was then removed using hydrogen peroxide (H_2O_2). Afterward, the product was washed several times with a 5% hydrochloric acid solution and distilled water, filtered, and dried at 60°C. The results of X-ray diffraction confirmed the formation of the characteristic graphene oxide phase.

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SOLVENT-DEPENDENT SYNTHESIS OF MULTICOLOR FLUORESCENT CARBON DOTS FOR ENHANCED PHOTOCATALYTIC PERFORMANCE OF 3DOM-TiO_2

G.B.Khojieva[1,2], Sh.G.Khojiev[1], A.J.Kholikov[2], Kh.I.Akbarov[2]

[1]Center for Advanced Technologies.
[2]National University of Uzbekistan.

Carbon dots (CDs) have emerged as versatile co-catalysts due to their tunable fluorescence, biocompatibility, and electron-transfer properties [1]. To optimize their integration with 3DOM-TiO_2, we synthesized CDs with distinct emission colors (blue, green, yellow, red) by varying solvents during solvothermal synthesis. Solvent polarity, acidity, and functional group interactions were hypothesized to govern CDs' optical and structural characteristics, which were systematically investigated [2].

The integration of carbon dots (CDs) as co-catalysts into 3D ordered macroporous TiO_2 (3DOM-TiO_2) offers a promising approach to enhance photocatalytic activity. This study focuses on synthesizing multicolor fluorescent CDs via a solvothermal method using citric acid and carbamide precursors, with solvents (water, dimethylformamide (DMF), ethanol, acetic acid) as key variables to modulate their optical properties. The solvent choice critically influenced the CDs' fluorescence color, quantum yield, and surface chemistry, enabling precise control over their functionalization for photocatalytic applications.

CDs were prepared via solvothermal treatment (180°C, 8 hr) of citric acid and carbamide in four solvents: water, DMF, ethanol, and acetic acid. Crude products were centrifuged (10,000 rpm, 20 min), filtered (0.22 μm membrane), and dialyzed (1000D membrane, 72 hr) to isolate uniform particles. Vacuum drying (40°C, 48 hr) yielded powdered CDs. Fluorescence spectra, FTIR, and TEM were used to analyze optical properties, functional groups, and morphology.

Solvents dictated emission colors: water (blue, B-CDs), ethanol (green, G-CDs), acetic acid (yellow, Y-CDs), and DMF (red, R-CDs). R-CDs exhibited the longest emission wavelength (620 nm), attributed to graphitic N incorporation and carboxyl (-COOH) surface groups.

DMF and acetic acid promoted -COOH and C=O groups, enhancing red fluorescence. FTIR confirmed higher -COOH density in R-CDs. DMF and ethanol facilitated N-doping, increasing graphitic N content, which reduced bandgap energy and redshifted emission. Solvent polarity influenced nucleation; polar solvents (DMF, water) produced smaller CDs (3–5 nm) with quantum size effects, while ethanol yielded larger particles (6–8 nm). Polar/protic solvents (water, acetic acid) stabilized surface charges, creating electron traps that redshifted emission. DMF's high boiling point and coordination ability enhanced carbonization, fostering N-doped aromatic structures.

Solvent engineering during solvothermal synthesis enables precise control over CDs' fluorescence, size, and surface chemistry. DMF-derived R-CDs, rich in graphitic N and -COOH groups, show optimal red emission and electronic properties for photocatalytic applications. This strategy provides a scalable route to tailor CDs for enhancing 3DOM-TiO_2's performance in light-driven reactions. This study was carried out as a joint project funded by KOICA, in collaboration with the Korea Research Institute of Chemical Technology (KRICT) and the Advanced Technology Center (ITC).

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CRYSTAL STRUCTURE AND HIRSCHFELD SURFACE ANALYSIS OF THE COMPLEX OF 2-AMINO-1-METHYLBENZIMIDAZOLE WITH Cd(II) CHLORIDE

[1]Saidov A.S.,[1]Rakhmonova D.S.,[1,2]Kadirova Z.Ch.
[1]National University of Uzbekistan Named After Mirzo Ulugbek
[2]Uzbekistan-Japan youth innovation center
Email: abdullasaidov05071991@gmail.com

The molecular and crystal structures of the complex of 2-amino-1-methylbenzimidazole with Cd(II) chloride were determined by X-ray diffraction analysis. The X-ray diffraction analysis of the single crystal was carried out on an automatic diffractometer (CrysAlis Red Oxford Diffraction Ltd). The unit cell parameters of the crystal are as follows: a = 9.9398 (3), b = 10.0018 (7), c = 10.3767 (2) Å, a = 106.8650(10), b=94.9440(10), g = 107.4410(10)°, V = 924Å3, Z = 1,

phase group P1. All calculations were performed in the "SHELXL-2014" program [1-2]. The crystals of the C16H18CdCl2N6 complex belong to the triclinic system. Analysis of the structure of the complex shows that the metal atom is coordinated through the nitrogen atoms of the ligand imidazole ring (Cd1-N1 2.199(4), Co1-N4 2.225(2) Å) (Fig. a, b). The central atom is surrounded by a tetrahedral structure.

To visualize the intermolecular interactions in the complex of 2-amino-1-methylbenzimidazole with Cd(II) chloride, the Hirschfeld surface was analyzed using the Crystal Explorer 17.5 program [3-4]. The Hirschfeld surface of the complex was mapped using the standard (high) surface resolution three-dimensional dnorm surfaces with color scale marks from -0.3066 (red) to 1.5411 (blue). The Hirschfeld surface, mapped according to dnorm (Fig. c), showed the expected presence of light-red spots near the N6—H6A···Cl2 and N6—H6B···Cl2 atoms, which represent hydrogen bonds between N—H···Cl.

In conclusion, the fingerprint region of the complex of 2-amino-1-methylbenzimidazole with Cd(II) chloride shows that H···H interactions contribute the most among the surface interactions. Also, while Cl···H/H···Cl, H···C/C···H and H···N/N···H interactions are also significant, the contributions of C···N/N···C and C···C interactions are smaller.

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RESULTS OF QUANTUM-CHEMICAL CALCULATION OF THE 2-PROPIONYLAMINOBENZIMIDAZOLE MOLECULE

[1]Saidov A.S., [1]Rakhmonova D.S., [3]Abdurazzokov A.Sh., [1,2]Kadirova Z.Ch.
[1]Mirzo Ulugbek National University of Uzbekistan
[2]Uzbek-Japanese Youth Innovation Center
[3]Institute of Plant Chemistry, Academy of Sciences of the Republic of Uzbekistan
abdullasaidov05071991@gmail.com.

Today, quantum chemical and molecular dynamics methods are widely used in numerical modeling of electronic and atomic structures of complex systems at the molecular, crystal, and intermediate (nano) scales.

In this work, quantum chemical calculations were performed to study the coordination centers, coordination possibilities, and energetic, geometric, and electronic parameters of the 2-propionylaminobenzimidazole (L) molecule.

Calculations were performed using Gaussian 09W, Gauss View 6.0.16, and Avagadro 1.1. Molecular structure optimizations were performed using the DFT method with the Li–Yanga–Parra correlation functional (B3LYP) and 6–311 G (d, p) basis set for isolated molecules in the gas phase [1-2].

In the 2-propionylaminobenzimidazole molecule, the highest negative effective charge in the heterocycle, based on the value of the charges on the donor atoms, was determined at the atoms N7

(-0.481), N10 (-0.454) in the imidazole ring and the imino group attached to it, the nitrogen in the endo position in the ring N(9) (-0.368), and O(12) (-0.330) in the carbonyl group (Fig. a).

The red and blue colors in the MEP (molecular electrostatic potential) diagram represent negative and positive electrostatic potentials, respectively. The red color area in the MEP diagram indicates lone pairs of electrons or atoms with negative electrostatic potentials, and the color intensity is proportional to the absolute value of the potential energy. Positive electrostatic potentials are shown in the blue/yellow area and describe polar hydrogen E-H bonds. The green areas cover parts of the molecule where the electrostatic potentials are close to zero (C-C and C-N bonds) (Fig. 1b).

In conclusion, in complex formation according to MEP, the ligand shows bidentity through endocyclic nitrogen atoms in the imidazole ring and oxygen atoms in the carbonyl group.

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FEASIBILITY STUDY OF SYNTHESIZING POROUS CERAMIC ABSORBERS FOR HYDROGEN STORAGE

F.N.Ernazarov[1], M.S.Payzullakhanov[1]

Institute of Materials Science, Academy of Sciences of the Republic of Uzbekistan1

f.ernazarov@imssolar.uz

Introduction. Hydrogen, which has a unique set of physical and chemical properties, is widely used in various technological processes. High specific energy intensity (142 MJ/kg or 39 kWh/kg, which is three times more than traditional liquid hydrocarbons), the absence of harmful products from the oxidation of hydrogen with oxygen and the possibility of using it in fuel cells with an efficiency of more than 50% - all this contributes to rapid growth of research in the field of hydrogen energy technologies. However, one of the main problems preventing the practical use of hydrogen in many areas is the low efficiency of its storage and transportation.

Fuel cell power plants demonstrate the highest efficiency to date - up to 80%, and the average annual productivity of a fuel cell is 19710 kWh at a cost of 0.0766 $/kWh [1]. Despite the fact that this cost exceeds the price of electrical energy supplied from the city power grid, the approach under consideration is of interest in conditions of shortage of electrical energy and natural gas. It is important to note that determining the effectiveness of hydrogen absorber materials is based on several criteria: the ability to retain large quantities of hydrogen at room temperature, rapid release at moderate temperatures, resistance to cyclic use, and cost-effectiveness. To date, there is no material that would fully satisfy all these requirements. The search for new materials and various proposed solutions to this problem are actively discussed in recent review articles [1-5]. As part of our materials synthesis research, many compositions were tested for the production of porous ceramics. The aim of the work is to develop absorbers based on inexpensive porous materials containing zeolites. Methodology. The technology for producing porous ceramics included the following operations; preparation of a charge of a given composition;wet grinding in a ball mill;drying at 200oC;molding into tablets with a diameter of 20 mm;firing at a temperature of 1150oC for 2 hours; slow cooling in the furnace.

Results and discussing. The resulting materials of aluminosilicate composition, synthesized from raw materials melted in a solar furnace, had the following indicators density 375–550 kg/m3; specific surface 2500 cm2/g; exhibit compressive strength of 3.7–4.9 MPa. Such materials can be used as hydrogen absorbers for the physical binding of hydrogen in pores by van der Wals forces at high (30-50 a.t.m) pressures. These data, taking into account the hydrogen density value of 0.09 kg/m3 under normal conditions (300 K, 1 atm), make it possible to calculate the aspect number for a porous material under normal conditions.The porosity of materials is a priori related to the property of water absorption. For materials of this composition, water absorption ranged from 10 to 23%, which indicates the corresponding porosity of the material. Thus, the higher the porosity, the more hydrogen the material absorbs.

An increase in the value of the aspect number with increasing temperature is observed:from 3.5 wt.% at 100°C to 13 wt.% at 190°C. This material is a good hydrogen absorber at a temperature of 190°C and the aspect number for it was 13 wt.%.

Now it is possible to evaluate the effectiveness of using ceramic porous absorbers in steel reactors. Let's say a cylindrical steel reactor with a height of 400 mm and a diameter of 300 mm has an internal volume of 0.028 m3.

At a given density of porous ceramics - 450 kg/m3, the mass of porous ceramics placed in the reactor: 0.028×450 = 12.6 kg. This volume contains 450×0.028 = 12.6 kg of porous ceramics. If you saturate it with hydrogen at a pressure of 100 atm, then you can introduce up to (12.6 × 13.24)/100 = 1.67 kg of hydrogen into it. If you use a steel cylinder as a container for storing hydrogen, then at a pressure of 80 a.t.m you can introduce 9×0.028 = 0.25 kg of hydrogen into it. Thus, a porous material based on sodium aluminosilicate AlSiNaO with a lattice parameter a=4.056 nm is a good hydrogen absorber. With an increase in the temperature of the sorption process from 100°C to 190°C, the value of the aspect number increases from 3 wt.% to 13 wt.%

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HYDROTHERMAL SYNTHESIS OF CoFeNi/NF NANOSTRUCTURES AND THEIR ENHANCED ELECTROCATALYTIC PERFORMANCE FOR ALKALINE WATER SPLITTING

F.Hoshimov[1,2], Kh.Butanov[1], K.Saidov[1,3], Sh.Mamatkulov[1]

[1]Institute of Materials Science Uzbekistan Academy of Sciences, Tashkent, Uzbekistan
[2]National Scientific Research Institute of renewable energy sources under Ministry of Energy of the Republic of Uzbekistan, Tashkent, Uzbekistan
[3]Department of Electronics and Radio Engineering, Tashkent University of Information Technologies

farhod2702@gmail.com

Abstract The global pursuit of clean, efficient, and sustainable energy solutions has become a critical priority in light of increasing environmental degradation, climate change, and the depletion of fossil fuel resources. Fossil fuel combustion continues to contribute significantly to greenhouse gas emissions, air pollution, and global warming, prompting the urgent need for alternative, environmentally friendly energy sources. Among these, hydrogen has emerged as one of the most promising energy carriers for the future due to its high gravimetric energy density, abundance, and clean combustion, which results in zero carbon emissions [1]. Hydrogen can be produced through various methods, including thermochemical, biological, and electrochemical processes. Among these, electrochemical water splitting is particularly attractive when powered by renewable energy sources such as solar, wind, or hydropower. This technology enables the direct generation of high-purity hydrogen and oxygen gases from water without releasing harmful by-products. It is a clean and sustainable route that aligns well with global efforts to reduce carbon footprints and transition toward green energy systems [2]. However, the practical application of water electrolysis is limited by the inherently sluggish kinetics of the two half-reactions involved: the hydrogen evolution reaction (HER) at the cathode and the oxygen evolution reaction (OER) at the anode. Both reactions require substantial overpotentials to achieve efficient conversion rates, which reduces overall system efficiency and increases energy consumption. As such, highly active and stable electrocatalysts are essential to accelerate the HER and OER processes and minimize energy losses. Currently, noble metal-based catalysts such as platinum (Pt) for HER and iridium oxide (IrO_2) or ruthenium oxide (RuO_2) for OER are considered the benchmark materials due to their outstanding catalytic activity and low Tafel slopes. Nonetheless, their widespread application is hindered by critical limitations, including high cost, low natural abundance, and poor long-term durability, especially in alkaline media. In response to these challenges, extensive research has shifted toward the development of low-cost, earth-abundant, and environmentally benign alternatives [3]. Transition metal-based electrocatalysts - particularly those incorporating cobalt (Co), iron (Fe), and nickel (Ni) - have demonstrated remarkable potential as substitutes for noble metals. These metals possess multiple oxidation states, excellent redox properties, and strong synergistic interactions that enhance electron transfer and catalytic activity. Furthermore, their structural versatility allows the formation of various nanostructures, such as oxides, sulfides, phosphides, and layered double hydroxides, which can significantly increase the number of exposed active sites and improve mass transport properties. In particular, bimetallic and trimetallic nanocomposites combining Co, Fe, and Ni have attracted significant attention due to their improved conductivity, catalytic synergy, and mechanical stability. These materials offer promising performance in both HER and OER under alkaline conditions, making them suitable candidates for overall water splitting. Additionally, integrating such materials with conductive substrates or magnetic fluids can further enhance catalytic efficiency and durability. Therefore, the rational design and synthesis of non-precious metal-based electrocatalysts represent a promising strategy for advancing hydrogen production technologies. Continued exploration in this field will be vital

for realizing a scalable, sustainable, and economically viable hydrogen economy[4]. The development of efficient and durable electrocatalysts for hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) is essential for sustainable hydrogen production. A hydrothermal synthesis was performed using an aqueous solution containing 1 mmol each of Co, Fe, and Ni nitrates, 3 mmol of urea, and 3 mmol of NH_4F. A cleaned piece of NF was immersed in this solution and sealed in a Teflon-lined autoclave at 160 °C for 12 h. The resulting foam was washed and dried at 60°C.

A CoFeNi/NF electrocatalyst was successfully synthesized via a hydrothermal method. The electrochemical performance of the synthesized CoFeNi/NF catalyst was evaluated in alkaline media (1.0 M KOH solutions) using a three-electrode electrochemical system. The catalytic efficiency was analyzed by measuring overpotential and Tafel slope values. The results show that the catalyst exhibited an overpotential of 285 mV and a Tafel slope of 240.08 mV dec^{-1} for HER, indicating efficient charge transfer and high electrocatalytic activity for water splitting. The material demonstrated high HER activity, with low overpotential and a favorable Tafel slope, due to the synergistic interaction of Co, Fe, and Ni and the conductive support of NF. This study presents a scalable, low-cost, and durable electrocatalyst for alkaline water splitting, offering a promising route for sustainable hydrogen production.

Keywords: hydrothermal synthesis, water electrolysis, HER, electrocatalysis, overpotential, Tafel slope

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MXene-BASED ELECTROCATALYSTS FOR HYDROGEN PRODUCTION VIA WATER SPLITTING

J.Mamanazirov, Sh.Mamatkulov
Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov 2B St., Tashkent, 100084, Uzbekistan
Email: j.mamanazirov@imssolar.uz

Abstract

Water electrolysis is a promising method for hydrogen production, but its efficiency is limited by sluggish reaction kinetics. This study explores MXene-based electrodes, including MXene with Nickel foam (MXene/NF) and MXene/Graphene Oxide/Carbon black/Nickel foam (MXene-GO-CB/NF) composites, to improve electrocatalytic performance. The MXene-GO-CB/NF composite exhibited the best activity, with overpotentials of 290 mV for OER and 200

mV for HER. These findings highlight potential of MXene based catalysts for cost-effective and efficient hydrogen generation.

Keywords

Hydrogen production, MXene, electrocatalysis, water splitting.

Introduction

Hydrogen is a promising alternative energy carrier due to its high energy density and zero-carbon emissions [1]. However, the efficiency of water electrolysis is limited by the slow kinetics of the HER and OER, necessitating the development of advanced electrocatalysts [2]. Traditional noble metal catalysts such as Pt and IrO_2 are highly efficient but expensive and scarce [3]. MXenes, a novel family of 2D transition metal carbides, offer excellent electrical conductivity, tunable surface chemistry, and high stability making them attractive candidates for electrocatalysis [4,5]. This study explores the potential of MXene-based electrodes to enhance catalytic efficiency and reduce overpotentials in water splitting.

Results and Discussion

Electrochemical testing revealed that the MXene/NF electrode demonstrated enhanced catalytic activity with overpotentials of 360 mV for OER and 300 mV for HER at 10 mA/cm². The introduction of GO and CB in the MXene-GO-CB/NF composite further improved the catalytic performance, reducing the overpotentials to 290 mV for OER and 200 mV for HER. EIS measurements indicated a significant reduction in charge transfer resistance, while ECSA analysis confirmed an increase in active surface area, contributing to improved reaction kinetics. The thermodynamic efficiencies of 82% for MXene/NF and 88% for MXene-GO-CB/NF highlight their potential for practical applications.

This study demonstrates that MXene-based electrodes offer a highly efficient and cost-effective alternative to conventional noble metal catalysts for water electrolysis. The combination of MXene with GO and CB enhances charge transfer, prevents restacking, and improves catalytic durability. These findings provide a strong foundation for future research in scaling up MXene-based materials for commercial hydrogen production applications. Further investigations will focus on optimizing electrode fabrication methods and integrating these materials into industrial-scale electrolyzers to accelerate the transition toward sustainable hydrogen energy.

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CONCENTRATED SOLAR ENERGY CONVERTING ISSUES IN 1 MW SOLAR FURNACE

N.Kenjayev[1], R.Urinboyev[1], S.Gulmatov[1], I.Mirzokhidov[1], S.Makhmudov[2], Sh.Ahmadov[2], Sh. Nurmatov[1,2]
[1]Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov St. 2B, Tashkent, 100084, Uzbekistan
[2]Tashkent State Technical University, Universitet St. 2, Tashkent, Uzbekistan
Email: Sh.nurmatov@imssolar.uz

Abstract

The thesis presents the results of experiments on the Big Solar Furnace (BSF), where the ability to form temperature was measured by the influence of a concentrated flow of solar energy. Temperatures are shown depending on direct solar radiation and the number of heliostats.

Keywords

BSF, receiver, solar radiation, temperature, heat transfer fluid (HTF) heliostats.

Introduction

Usually in CSP plants the absorber has the task to absorb the impinging concentrated solar radiation and transfer the absorbed heat to the HTF. Early days of receiver development and research the main focus was on tubular designs and later the development of volumetric receiver designs began [1]. In our case we are used plate carbon receiver. by introducing heliostats to the focal zone, we looked at temperature dependencies on the surface of the receiver. The task is related to the issue of heat transfer over a distance, for use in industrial installations. In our case, the HTF is air.

Results and Discussion

Theoretically if we will influence by concentrated solar energy to plate carbon-made receiver, what will be a temperature of the surface of receiver. Concentrated solar energy coefficient is E=200 w/cm^2

To estimate the surface temperature of a carbon-made receiver under concentrated solar energy, we can use the steady-state energy balance approach, where the absorbed solar energy is re-radiated as thermal radiation (assuming negligible convection/conduction losses for simplicity).

There are the key assumptions:

1. Absorptivity (α) and Emissivity (ε): For simplicity, assume the carbon surface is a blackbody ($\alpha \approx \varepsilon \approx 1$). Real-world carbon-based materials (e.g., graphite) have high but not perfect absorptivity/emissivity (~0.8-0.9).

2. Steady-State Condition: All absorbed power is re-radiated.

3. No Conduction/Convection Losses: The receiver is in a vacuum or well-insulated.

So, for this conditions energy balance is:
The absorbed solar power equals the radiated power (Stefan-Boltzmann law):
$E \cdot A = \sigma \cdot \varepsilon \cdot A \cdot T^4$ $E \cdot A = \sigma \cdot \varepsilon \cdot A \cdot T^4$
Where:

1. $E = 200\ W/cm^2 = 2 \times 106\ W/m^2$ $E = 200 W/cm^2 = 2 \times 106 W/m^2$ (converted to SI units),
2. $\sigma = 5.67 \times 10{-}8\ W/m^2 \cdot K4$ $\sigma = 5.67 \times 10{-}8 W/m^2 \cdot K4$ (Stefan-Boltzmann constant),
3. $\varepsilon \approx 1$ $\varepsilon \approx 1$ (emissivity),
4. A cancel out (surface area),
5. T is the absolute temperature (K).

Solving for Temperature:

$T = (\mathrm{E}\sigma \cdot \varepsilon)\frac{1}{4}$ $T = (\sigma \cdot \varepsilon E)\frac{1}{4}$

Plugging in the values:

$$T = (2 \times 1065.67 \times 10 - 8 \cdot 1)\frac{1}{4} \approx 2042\ \mathrm{K}(\sim 1769°\mathrm{C})$$

$$T = (5.67 \times 10 - 8 \cdot 12 \times 106)\frac{1}{4} \approx 2042\ \mathrm{K}(\sim 1769°\mathrm{C})$$

Refinement for Real-World Conditions:

1. If emissivity $\varepsilon = 0.9$ $\varepsilon = 0.9$:

$$T = (2 \times 1065.67 \times 10 - 8 \cdot 0.9)\frac{1}{4} \approx 2087\ \mathrm{K}(\sim 1814°\mathrm{C})$$

$$T = (5.67 \times 10 - 8 \cdot 0.92 \times 106)\frac{1}{4} \approx 2087\ \mathrm{K}(\sim 1814°\mathrm{C})$$

2. For non-blackbody materials, we can use identifical α and ε accordingly.

Conclusion:

Under 200 W/cm² concentration with idealized conditions, the carbon receiver's surface temperature would reach ~2042 K (1769°C). For real systems, precise emissivity/absorptivity data and thermal loss mechanisms must be accounted for. In our case (first tests) number of heliostats is two, which is 25 and 27. Direct solar radiation was - 925 W/m^2, concentrated solar energy in the focal spot from two heliostats was E=20.1 W/см^2, during the influence we reached temperatures about 550 ℃, which coincides with the theoretical assumption.

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MODERN APPROACHES TO STUDYING THE INFLUENCE OF VARIOUS TYPES OF IONIZING RADIATION ON THE CYCLIZATION PROCESSES OF POLYACRYLIC FIBER (PAN)

N.Kenjayev[1], R.Urinboyev[1], S.Gulmatov[1], I.Mirzokhidov[1], M.Rumi[1], S.Makhmudov[2], Sh. Akhmadov [2], Sh.Nurmatov[1,2]
[1]Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov St. 2B, Tashkent, 100084, Uzbekistan

[2]Tashkent State Technical University, Universitet St. 2, Tashkent, Uzbekistan
Email: Sh.nurmatov@imssolar.uz

The results of recent research and development in the field of using different types of ionizing radiation for pretreatment of polyacrylonitrile fiber (PAN) before thermal-oxidative stabilization are reviewed. The original PAN fiber is an atactic and linear polymer with a C≡N bond, due to the presence of which it usually decomposes before melting. Therefore, it is important that it is stabilized by heat treatment in air at a temperature of 200 °C to 300 °C before carbonization, which turns it into a non-flammable product with a predominance of cyclic or ladder structures. During thermal stabilization, in addition to the cyclization process, complex oxidation, dehydrogenation and tautomerization reactions occur simultaneously. Most of the previous reviews focused on the thermal oxidation of PAN [1], where the relationship between heat treatment conditions and the physicochemical structure and properties of carbon fibers (CF) was demonstrated. This process is the most complex and energy-intensive stage of the conversion of PAN fiber into CF, therefore the possibility of reducing the cost is associated with reducing the cost of the thermal stabilization process [2] by reducing the temperature and time of the process. This led to the development of advanced methods for the oxidation of PAN fibers based on various forms of radiation that cause a change in the structure of the polymer.

The authors [2] subjected PAN fibers to (plasma stabilization treatment–before) thermal stabilization and showed that with the same thermal treatment time, the degree of cyclization for such samples is 2.5-1.5 times higher due to active oxygen forms than for non-irradiated samples. It was shown that plasma treatment is effective for stabilizing precursor fibers in terms of time, cost and mechanical properties compared to conventional thermal stabilization.

The authors [3] proposed a highly effective method for pre-treatment of PAN fibers based on short-term (1-5 min) UV irradiation (8.83 nm) for 3 min using a 1000 W mercury lamp. The change in fiber color under UV irradiation from white to yellow and analysis of the IR spectra allowed the authors to conclude that irradiated fibers more easily form a ring structure and have a higher degree of cyclization compared to non-irradiated fibers.

The effect of pretreatment on structural changes of PAN copolymer before oxidative thermal stabilization with mixed sources of ultraviolet light with a power of 600 W, including UVA, UVB and UVC was studied in [4]. The maximum irradiation time was 60 minutes. Irradiation led to a decrease in the temperature of the onset of the cyclization process from 225 to 175 °C, the activation energy of stabilization from 144 kJ/mol to 98 kJ/mol and the enthalpy from 657 J/g to 497 J/g in irradiated samples compared to non-irradiated ones. The results showed that UV irradiation causes rapid oxidation and cyclization reaction of fibers due to the formation of free radicals , the number of which increases with increasing exposure time.

The paper [5] presents the results of studies on reducing the time of thermal stabilization of PAN fiber using electron beam irradiation (EBI). The authors found that after EBI, the cyclization temperature decreases. In order to exclude the possible influence of a local temperature increase, the authors of [5] carried out electron beam irradiation at a low current of 1 mA and a low beam density of 1.36 μA. As a result, irradiation with even a low electron dose of 200 kGy made it possible to reduce the time of heat treatment of the stabilization process at 230 ^{o}C by 4 times to 30 min instead of 120 min for non-irradiated samples.

Results of further studies of PAN fibers stabilized at a constant irradiation dose of 1 MGy at a beam current of 8 mA, followed by additional thermal stabilization at 200 ^{o}C and 250 ^{o}C for 20 and 40 minutes, respectively, are given in [6]. It was found that the structural changes in the treated PAN precursor fibers (the transformation of C≡N bonds into C═N) after thermal treatment accelerated

Analysis of experimental results of numerous studies confirms the effect of irradiation (plasma, UV, electron beam) on the processes of thermal stabilization of PAN fibers. The

effectiveness of such treatment is manifested in the acceleration and simplification of the process of further thermal stabilization while maintaining or improving the properties of the UV.

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INFLUENCE OF CONCENTRATED SOLAR RADIATION ON THE PROCESSES OF THERMAL-OXIDATIVE STABILIZATION OF POLYACRYLONITRILE COPOLYMER FIBERS

N.Kenjayev[1], R. Urinboyev[1], S.Gulmatov[1], I.Mirzokhidov[1], B.Omonov[1], F.Abdurakhimov[1], M. Rumi[1], S.Makhmudov[2], Sh.Akhmadov[2], Sh.Nurmatov[1,2]

[1]Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov St. 2B, Tashkent, 100084, Uzbekistan

[2]Tashkent State Technical University, Universitet St. 2, Tashkent, Uzbekistan

Email: Sh.nurmatov@imssolar.uz

This paper presents the results of studies on the effect of preliminary modification of polyacrylonitrile fibers (co-PAN) by exposure to concentrated solar iradiation (CSR) on the processes of thermal-oxidative stabilization (TOS). Oxidative stabilization is the most energy-consuming and complex stage of carbon fiber production . From the literature, it was known about the positive effect of such treatment by irradiation using artificial sources on reducing the temperature or time of TOS. For these purposes, we used a Small solar furnace with a capacity of 1500 W in Parkent (Uzbekistan).

The TOS process was carried out on co-PAN samples that had undergone a preliminary modification stage in air at a radiant flux density of 850-900 W/m^2 at a distance of 12 cm from the focus. TOS of co-PAN fibers was carried out in air in an electric furnace at a temperature of 220°C, 230°C, 240°C with a heating time of 30 min (initial TOS) and 300 min (main TOS), which corresponds to the range associated with the stabilization stage. For a comparative study of the effect of CSR on the structure of co-PAN fibers, in addition to the modified samples, the control ones that had not undergone preliminary modification were also subjected to heat treatment. Structural transformations were studied using X-ray diffraction (XRD), infrared spectroscopy (FTIR) and differential scanning calometry (DSC).

With an increase in the initial TOS temperature from 220 to 240 ° C, the amorphization process occurs in both modified and control samples. In this case, the degree of structure transformation of the modified samples is ahead of the control ones. At a temperature of 240 ° C, the modified samples have a lower degree of crystallinity of 32-33% compared to 41% in the control fiber.

After the initial TOS at 220 ° C and 230 °C, the IR spectra of the modified samples showed changes in the profile of the absorption bands at 1653 cm^{-1} and 1636 cm^{-1} , corresponding to the combined vibrations of C=C, C=N stretching and C=NH bending, as well as their shift to the long-wave region compared to the control ones, which characterizes the transient process of the cyclization onset and may indicate an increase in the number of C= N bonds . With an increase in the TOS temperature to 240 °C, a shift of the absorption band (C=C, C=N) to 1596-1590 cm^{-1} was noted in all spectra, while its intensity for the modified fibers increased. Calculation of the degree of cyclization (DOC) showed its increase from 9% for unirradiated fibers to 17 and 19% for irradiated ones at a preliminary irradiation time of 30 and 60 min, respectively.

XRD analysis of the samples after the main TOS at 220 °C showed that the fibers are semi-crystalline and the amorphous region is clearly visible on the diffraction patterns along with the intense diffraction peaks. At the same time, the degree of crystallinity of the pre-modified fibers decreases more intensively compared to the control sample. Thus, in the sample with 60-minute exposure, the degree of crystallinity after DOC decreased to 17%, against 33% in the control. Increasing the heat treatment temperature to 230 °C led to the activation of the amorphization process. Pre-modified samples are completely amorphous, in the control sample the degree of crystallinity is 2.75%. This indicates that when exposed to radiation, the crystalline structure is disrupted and disordered areas increase.

The IR spectrum of heat-treated co-PAN without irradiation showed a decrease in the intensity of the peak at ~2240 cm^{-1} , related to the stretching vibrations of C≡N, the appearance of a peak at 1585 cm^{-1} , due to cyclization (DOC = 61%) by converting nitrile groups C≡N into C=N bonds. A decrease in the intensity of the bands at 2925 cm^{-1} and 1450 cm^{-1} , as well as the appearance of a peak at 805 cm^{-1} indicate the occurrence of dehydrogenation reactions. In irradiated samples , the cyclization and dehydrogenation processes manifested in the spectrum of unirradiated co-PAN are enhanced. With an irradiation time of 30 and 60 min. DOC increased to 67% and 76%, respectively.

The study of modified co-PAN fibers after TOS at 220ºC for 300 minutes by the DSC method showed that in all co-PAN samples after oxidative stabilization, heat release decreases compared to the control (ΔH = 367 J/g), which indicates a decrease in the number of initial nitrile groups. In modified co-PAN fibers that have undergone TOS, a dependence of the exothermic reaction on the time of holding the samples under the influence of KSI is observed. Preliminary irradiation of holding for 30 minutes leads to a decrease in the exothermic effect (ΔH = 32 J/g), within 60 minutes to its almost complete disappearance.

When the heat treatment temperature is increased to 230 ºC a sharp decrease in the intensity of the absorption band at 2241 cm^{-1} and its complete disappearance in the IR spectrum of the fiber irradiated for 30 min are noted. The peak responsible for the C=C, C= N , NH bonds shifts even more strongly to the long-wave region, reaching a position of 1571 cm^{-1} and 1570 cm^{-1} for the control and modified fiber, respectively, and the DOC reaches 92 and 100%.

The conducted studies have shown that the TOS process at all temperature and time modes of pre-modified co-PAN fibers leads to a more intense violation of crystallinity and growth of the amorphous phase compared to the control samples. The degree of cyclization of modified fibers after TOS is ahead of non-irradiated control samples and depends on the irradiation time in the CSR field. At a temperature of 230 °C (time 300 min), a completely cyclized stabilized amorphous sample of co-PAN fiber was obtained only on the basis of modified samples, with the preservation of residual nitrile bonds C ≡ N and crystallinity less than 3% in control samples without irradiation.

STUDY OF CO-PAN MODIFICATION UNDER THE INFLUENCE OF SOLAR RADIATION ENERGY

N.Kenjayev[1], R.Urinboyev[1], S.Gulmatov[1], I.Mirzokhidov[1], B.Omonov[1], F.Abdurakhimov[1], M. Rumi[1], S.Makhmudov[2], Sh.Akhmadov[2], Sh.Nurmatov[1,2]

[1]Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov St. 2B, Tashkent, 100084, Uzbekistan

[2]Tashkent State Technical University, Universitet St. 2, Tashkent, Uzbekistan

Email: Sh.nurmatov@imssolar.uz

Currently, the areas related to environmental technologies for obtaining new materials using solar radiation as an energy source are relevant. This study is devoted to the study of the effect of concentrated solar irradiation as a method for initiating structural changes in co-PAN fibers before traditional heat treatment used in the multi-stage technology of carbon fiber (CF) production [1, 2]. X-ray diffraction (XRD), differential scanning calorimetry (DSC), thermogravimetric analysis (TG), and Fourier transform infrared spectrometer (FTIR) were used to analyze the chemical and physical structural differences between the original and pre-treated co-PAN fibers.

The technology of the initial modification of the original co-PAN fibers consisted of irradiating them in the working zone of a solar furnace with a power of 1500 W at a distance of 12 cm from the focus with a direct solar radiation flux density of 850-900 W/m^2 for different isothermal exposure times: 5, 30 and 60 minutes.

Visual inspection showed preservation of the white color of the samples, the presence of shrinkage processes up to 3% and a change in the strength of the fibers by 2 times, correlating with the duration of irradiation in the solar furnace. These experimental data indicate a change in the crystal structure and the initiation of cyclization processes despite the preservation of the white color of the samples.

Based on the X-ray diffraction data, the crystallinity (Xc) and crystallite size (Lc) were calculated. Comparative analysis of the X-ray diffraction patterns confirmed that co-PAN has a semi-crystalline structure, as evidenced by strong diffraction peaks at $2\theta = 17°$ and 29°, as well as visible amorphous regions.

Crystallinity (Xc) of the initial co-PAN is 54.5% and decreases to 50.2% after 30, 60 minutes of exposure in the solar furnace zone. The irradiation time also correlates with an increase in the crystallite size to 7.9 nm compared to 6.3 nm in the initial fibers. These data illustrate the process of destruction of the crystalline structure, which leads to an increase in the amorphous content and disorder in the fibers.

The IR spectrum of pure PAN fiber showed prominent peaks at 2937 cm^{-1} (CH stretching in CH_2 group), 2241 cm $^{-1}$ (CN stretching) and 1451 cm^{-1} (CH_2 bond). Peaks characteristic of esters and acids used in PAN copolymerization were also observed, including the carbonyl bond C=O at 1731 cm^{-1} [3]. The spectra of irradiated fibers generally resemble those of untreated co-PAN fibers. The difference lies in the appearance of a diffuse peak at 1635 cm^{-1} after 5 minutes of irradiation and its shift to longer wavelengths, up to 1620 cm^{-1} , after 60 minutes of exposure. According to [4.5,6], this band corresponds to combined vibrations of C=C and C=N stretching and C=NH bending, which indicates the process of cyclization and formation of a ladder structure in stabilized co-PAN fibers. Spectral analysis shows that the process occurring during 5-60 minutes of irradiation is transient.

Thermal characteristics of the original PAN fiber demonstrated a noticeable exothermic peak at T_{max} = 292.66 °C, caused by cyclization, dehydrogenation and oxidation reactions (ΔH = 1627.97 J/g) [7]. After irradiation treatment, the peak temperature remained unchanged, but the

released heat significantly decreased from 1437 to 1245 J/g with an increase in the irradiation time from 5 to 60 minutes. The aromatization index of the modified fibers, calculated from DSC data, ranged from 11% to 23.5%. In addition, TG analysis showed a lower mass loss (6÷3%) in the modified samples compared to the original fiber (7%), which depended on the irradiation time .

The obtained results highlight the effectiveness of the approach in stimulating early chemical changes that are crucial for fiber stabilization and subsequent processing. Analysis of X-ray, FT-IR, DSC and TG data showed that, despite the unchanged color of co-PAN fibers upon irradiation, significant physical (change in the ratio of amorphous to crystalline) and chemical (decrease in activation energy, shift of the IR spectrum peak toward longer wavelengths) structural changes occur, indicating the onset of cyclization processes.

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ELECTRICAL PROPERTIES OF THE $CsPbBr_3/SiO_2/Si$ Hybrid Structure

A.Nurimov, E.Sherqulov, Sh.Davurov, G.Qurbanova
Institute of Engineering Physics, Samarkand State University named after Sharof Rashidov
Corresponding author: nurimov-alisher@samdu.uz

Abstract: This study presents the current-voltage (I-V) curve of a hybrid structure fabricated by depositing $CsPbBr_3$ perovskite quantum dots onto a monocrystalline silicon (Si) substrate with a thin oxide layer. The rectifying potential barrier formed between the perovskite quantum dot layer and the thin-oxide-coated Si substrate, along with its properties, has been investigated. The results provide valuable insights into the electronic transport characteristics of such hybrid structures.

Keywords: perovskite, quantum dot, silicon, heterostructure, potential, oxide, tunneling.

Introduction. In recent years, lead halide perovskite ($APbX_3$, where A is a cation, Pb is a cation, and X = Cl, Br, I is an anion) materials have been regarded as promising candidates for applications in photonics, nanoelectronics, and optoelectronic sensors [1]. In particular, perovskite quantum dots have garnered significant interest due to their superior quantum efficiency, optical stability, and tunable bandgap compared to their bulk counterparts [2]. It is no secret that silicon-

based heterostructures have been extensively utilized in various fields, including optics (lasers, LEDs), electronics, photodetectors, and sensors [3]. Perovskite-silicon-based structures and their electrical properties hold great promise for the development of novel materials. To investigate this potential, $CsPbBr_3$ quantum dots (QDs) were deposited onto a Si substrate with a thin oxide layer, forming a hybrid structure. The I-V curve of the resulting structure was measured at room temperature.

Material Preparation: $CsPbBr_3$ quantum dots were synthesized using the ligand-assisted reprecipitation method [4].To prepare a 0.1 M solution, 36.7 mg of $PbBr_2$ and 21.2 mg of CsBr were dissolved together in 1 mL of dimethyl sulfoxide at room temperature using a magnetic stirrer for 1 hour. Octylammonium bromide (OABr) was selected as the ligand, and 3.3 mg of OABr was added to 150 μL of the initial solution. Then, 100 μL of this solution was rapidly injected into 5 mL of toluene stirred at 700 rpm, followed by stirring for 1 minute. During this process, nucleation occurs in the anti-solvent medium, initiating crystallization, which leads to the growth of perovskite quantum dots. Before depositing the quantum dots, monocrystalline silicon substrates cut into 2×2 cm pieces were cleaned in two stages. In the first stage, the silicon was cleaned from various small particles and organic contaminants by immersing it at 75°C for 10 minutes in a solution with a 1:1:5 ratio of ammonia (29% NH_3), hydrogen peroxide (30% H_2O_2), and ultrapure water (<0.05 mS/cm). It was then rinsed with ultrapure water for 1 minute and further immersed at 75°C for 10 minutes in a solution with a 1:1:6 ratio of hydrochloric acid (37% HCl), hydrogen peroxide (30% H_2O_2), and ultrapure water. This step was mainly aimed at removing alkali metal ions and other metal particles that could not be eliminated in the SC-1 cleaning stage. After this step, the sample was rinsed with ultrapure water and ultrasonically cleaned in ultrapure water at room temperature for 15 minutes. In the second stage, the silicon was treated with hydrofluoric acid (HF) at room temperature for 30 seconds and then rinsed with ultrapure water for 1 minute. To form a thin oxide layer on the monocrystalline silicon surface, it was then exposed to nitric acid (56% HNO_3) at 121°C for 15 minutes. [5]. Using the spin-coating method, 100 μL of $CsPbBr_3$ QDs were deposited onto the Si substrate by spinning at 500 rpm for 1 minute. After drying for 60 minutes, two-point aluminum contacts with a radius of approximately 0.5 mm and a spacing of about 2 mm were deposited using thermal evaporation under a vacuum with a mask. Electrodes were then attached to the aluminum contacts and the silicon substrate using silver paste. Finally, the I-V curve was measured using a Keithley nanoammeter and nanovoltmeter.

The results and discussion. The measured I-V curve results for the perovskite-silicon contact pair indicate that when a positive voltage is applied to the silicon layer, the current increases exponentially, whereas under negative voltage, the current rises gradually. This behavior suggests that the reverse-bias current is significantly suppressed, indicating the presence of a rectifying potential barrier in such heterostructures. [6]. The rectification coefficient was found to be $\frac{I+}{I-} = 15$. Based on the obtained results, the perovskite/oxide/silicon hybrid structure shows potential for use in various optoelectronic and electronic devices, including photodetectors, transistors, LEDs, and solar cells.

Conclusion. The results of this study provide a deeper understanding of the electron transport properties in hybrid structures formed by depositing $CsPbBr_3$ perovskite QDs onto a Si substrate with a thin oxide layer. The presence of a potential barrier between the perovskite quantum dot layer and the thin oxide-coated silicon was investigated. The perovskite-silicon structure demonstrates promising characteristics for tandem solar cell applications due to the tunability of the perovskite layer's absorption properties and the silicon substrate's ability to absorb lower-energy radiation while exhibiting strong rectifying behavior. These findings highlight the potential

of perovskite quantum dots and silicon-based heterostructures in the development of optoelectronic and photovoltaic devices.

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NANOCATALYSTS FOR THE SYNTHESIS OF CARBON NANOTUBES

I.J. Abdisaidov, S.G. Gulomjanova, Kh.B. Ashurov.

Arifov Institute of Ion-Plasma and Laser Technologies of Uzbekistan Academy of Sciences - Tashkent (Uzbekistan)

abdisaidov@iplt.uz

The increasing demand for carbon nanomaterials, particularly carbon nanotubes (CNTs), stems from their exceptional properties, including high electrical and thermal conductivity, superior mechanical strength, lightweight nature, and thermal stability. These attributes have made CNTs indispensable in various fields such as electronics, where they are utilized in display screens and chip fabrication, and in biomedicine and pharmaceuticals for applications like targeted drug delivery, cancer diagnostics, and therapy [1]. The chemical vapor deposition (CVD) method is widely employed for CNTs synthesis, with nanocatalysts serving as the critical agents for initiating and controlling the process. The nanoscale dimensions of these catalysts confer a unique ability to regulate not only the chemical composition but also the morphology and structural characteristics of the resulting CNTs, a capability not observed in traditional catalytic systems [2]. The growing global demand for renewable energy, its storage and efficient conversion, environmental protection, and water and air purification all provide good opportunities for nanocatalysts.

Nickel-based nanocatalysts, derived from nickel oxide (NiO) nanoparticles, are a key component in CNTs synthesis. The preparation of NiO nanoparticles via the sol-gel method, followed by their reduction to metallic nickel, involves a multi-step process:
-nickel nitrate hexahydrate, as the nickel precursor, reacts with ammonium hydroxide in an aqueous medium to form nickel hydroxide;

$$Ni(NO_3)_2 + 2NH_4OH \longrightarrow Ni(OH)_2 + 2NH_4NO_3$$

-thermal treatment converts nickel hydroxide into nickel oxide;

$$Ni(OH)_2 \longrightarrow NiO + H_2O$$

-hydrogen reduction transforms NiO nanoparticles into metallic nickel nanocatalysts:

$$NiO + H_2 \longrightarrow Ni + H_2O$$

The physicochemical properties of these nanocatalysts are strongly influenced by synthesis parameters. In this study, the effects of precursor type, reactant ratios, stirring speed, reaction duration, and calcination temperature on the size and morphology of NiO nanoparticles were systematically investigated. Optimized conditions for the sol-gel synthesis of NiO nanoparticles were established, yielding particles with sizes ranging from 3 to 19 nm, as confirmed by detailed electron microscopy analyses using a JEM-2100 Plus Electron Microscope.

The novelty of this work lies in the prevention of nanoparticle agglomeration during synthesis and the effective deposition of NiO nanoparticles onto substrates used for CNTs production in the CVD process. Polyvinyl alcohol was introduced as a dispersing agent to achieve uniform nanoparticle distribution. Additionally, the NiO nanoparticles were reduced to metallic nickel under hydrogen without exposure to ambient atmospheric conditions, preserving their catalytic activity. A low-temperature CVD system was designed and implemented, successfully synthesizing single-walled carbon nanotubes (SWCNTs) with diameters of approximately 2 nm. This approach represents a significant advancement in the controlled synthesis of high-quality CNTs.

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REDOX SWELLING INDEX OF IRON FOAM MATERIAL USED AS ENERGY STORAGE UNIT IN METAL-AIR BATTERIES

Paizullakhonov M.S., Abduraimova Z.B.
Institute of Materials Science

This research aimed to investigate the problems arising in the energy storage unit for iron air batteries. In particular, the coefficients of expansion and contraction at different temperatures observed when using iron foam materials in the energy storage unit when reduced with hydrogen gas. The expansion and contraction process, which is one of the main problems encountered in the reduction of iron oxide with hydrogen and its use as an energy storage unit, has investigated. Redox swelling index of iron foam material used as energy storage unit analyzed.

A high-temperature microscope, known as a high-temperature tube furnace, was used to heat the pressed scale sample. One side of the furnace tubes was covered with quartz glass, and the other with a door adapted for linear movement of the thermocouple. Both sides are sealed with rubber gaskets. A DFK 51AUC03 Imaging source CCD camera mounted on the quartz mirror side. The

sample was heated to a given temperature in a protective gas Ar (99.999%) with a flow rate of 2 l/min.

Pure gases H_2 and N_2 80%/H_2 20% were used as the reducing gas. In this study, the flow rate of reducing gases is 3 l/min^{-1}. The amount of gas consumed was measured with a flowmeter. A camera mounted on the side of the quartz glass was connected to a personal computer and the process was recorded on video. Reducing gas was supplied for 60 minutes. Then the H2 gas was turned off and Ar gas was introduced, and the furnace was cooled at a rate of 15 ºC/min.

The images obtained during the experiment were processed in Stream Motion Software (Olympus, Japan). In this case, the cross-sectional area of the sample was measured through images taken by a camera oriented towards the operation of the furnace. In the first stage, changes in the cross-sectional area of the sample were measured every 10 seconds, and in the second stage, changes were measured every minute. The reason for this is that in the first minutes the recovery process is actively carried out in the H_2 environment. At the third stage, changes were analyzed every 5 minutes.

The following expression is used to calculate RSI:

$$RSI = (V_t - V_0)/V_0 \times 100\%$$

V_0 and V_t represent the initial and changed sample volumes per unit time, respectively.

To determine the reduction swelling index, the cross-sectional surfaces of the samples were photographed and processed in Stream Motion Software (Olympus, Japan) during a transient recovery process in various environments and modes.

Based on the determined cross-sectional surfaces, the volume changes of the samples were calculated using the above expressions.

Fig. 1 show that during the first 3 minutes of the process in an environment of pure hydrogen, the volume of reduced samples increased to a maximum value at all temperatures. In our opinion, this is due to the adsorption of reducing gas molecules on the surface of oxide particles through the surface and pores of press briquettes. N. M. Gaballa deeply analyzed the interaction of reducing gases with the surface of the powder during the process of iron oxide reduction, and the results of our research are also consistent with his conclusions [1]. The higher the temperature, the stronger the adsorption of the reducing gas on the surface of the sample particles. For example, the maximum swelling of a sample reduced at a temperature of 700 °C was 1.42%, at a temperature of 1000 °C - 5.91%, that is, adsorption at a temperature of 1000 °C occurs 4 times faster than at a temperature of 700 °C. After 3 minutes, the rate of hydrogen adsorption began to decrease compared to the rate of oxide reduction. As a result, the volume of the sample returned to its original state at the 4th minute. After 4 minutes of the process, the oxide sample was reduced in the pictures. In this case, the decrease in sample volume occurred due to the gradual loss of oxygen by the oxide. The higher the temperature, the smaller the initial volume of the sample. As a result, the porosity of the reduced sample increases.

By the 20th minute of the procedure, active narrowing can be seen. After 20 minutes you can see that the reduction swelling index has decreased. The result was that the sample returned from full oxide to metal within 20 minutes, with only massive plastic deformation occurring in the subsequent process. The reduction swelling index was -14.05%.

Before designing the microstructure of iron foam materials used as energy storage units (including laminar structures), it is necessary to take into account the volume change coefficients of iron oxide during hydrogen reduction and steam oxidation. In addition, regardless of the microstructural architecture, the iron oxide particle forms pores throughout its grain during reduction. Research should be conducted on the use of other metal additives (eg Cs, Be, Mg, Sr, Ba) as ligatures to prevent the formation of these pores.

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PRODUCTION OF FINE Ti6Al4V POWDERS USING EDM FOR AM AND POWDER METALLURGY APPLICATIONS

B.A G'oipov, A.A Zaripov, Kh.B Ashurov

Institute of Ion Plasma and Laser Technologies, Academy of Sciences of the Republic of Uzbekistan, Tashkent -100125. Uzbekistan

Ti6Al4V, a titanium alloy, is known for its superior strength-to-weight ratio, corrosion resistance, and biocompatibility, making it a material of choice for high-performance applications in industries such as aerospace and biomedicine. For many of these applications, fine Ti6Al4V powders with specific properties are required for processes like additive manufacturing (AM) and powder metallurgy [1]. The production of fine powders with controlled particle size, morphology, and purity is crucial for achieving the desired mechanical performance in the final products.

We used Electrical Discharge Machining (EDM) as an advanced method for producing metal powders in this work [2]. This technique involves the use of electric discharges to break down the material into fine particles. The advantages of this process include its ability to produce powders with a narrow particle size distribution (PSD) and the ability to control various parameters, including particle shape, size, and distribution.

In this study, Ti6Al4V powders were produced using EDM, and the effects of process parameters on the powder characteristics were systematically studied. The EDM involves applying electrical discharges to the Ti6Al4V alloy in a dielectric fluid. Key process parameters such as capacitor capacity, voltage, current intensity, on-time, off-time, discharge frequency, and dielectric fluid properties were varied to investigate their influence on powder characteristics. The average values of the parameters used were as follows: DC voltage (80–150 V), pulse on-time (1-1.5 μs), pulse off-time (7-10 μs), material removal rate (MRR) of 2-4 mm/min, and dielectric fluid temperature control. Scanning electron microscopy (SEM) was used to analyze the morphology and particle size distribution (PSD) of the produced Ti6Al4V powders. The powders were found to have particles with sizes ranging from 10 μm to 50 μm, with 70% of the particles falling within this size range.

Moreover, 80% of the particles exhibited a quasi-spherical shape, which is essential for applications requiring precise control over powder characteristics. EDM process was found to be effective in producing fine Ti6Al4V powders with a narrow particle size distribution. The influence of electrical current and discharge frequency on particle size and morphology was also studied. Increasing the electrical current resulted in larger particles, as higher energy discharges led to the formation of larger fragments. On the other hand, increasing the discharge frequency improved the distribution of particles, with finer particles being produced due to more frequent, smaller discharges. The optimal combination of current (4 A) and frequency (25 kHz) resulted in the best balance between particle size, morphology, and powder production rate.

The process also demonstrated the potential to control the powder's size distribution and shape with high precision. This level of control is critical for advanced manufacturing applications, where powder characteristics play a significant role in the final product's quality and performance.

EDM method has proven to be an effective and expedient technique for producing Ti6Al4V alloy powders with a narrow particle size distribution and quasi-spherical morphology for AM. The produced powders, with particle sizes ranging from 10 μm to 50 μm, are suitable for advanced manufacturing processes such as additive manufacturing and powder metallurgy. The study highlights the importance of controlling process parameters, such as current and frequency, to optimize powder characteristics for specific applications. Future research will focus on optimizing the dielectric fluid composition and exploring the effects of other alloying elements on powder characteristics.

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CURIE TEMPERATURE OF CERAMIC MAGNETIC MATERIALS SYNTHESIZED BY SUNLIGHT

J.Z. Shermatov[1], M.S. Paizullakhanov[1], O.T. Rajamatov[1], M.H. Aripova[2], A.M. Zhivul'ko[3]
[1]Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan, Uzbekistan.
[2]Tashkent Institute of Chemical Technology, Uzbekistan
[3]Scientific and Practical Center of the National Academy of Sciences of Belarus for Materials Science, Belarus

Ceramic magnetic materials have unique physical and chemical properties and synthesis methods. These types of materials can be synthesized under sunlight and their properties can be studied by analyzing them using appropriate methods. Scientific studies have shown that although there are works devoted to the study of $Ca_3(PO_4)_2$ and Fe_2O_3, the Curie temperature of materials containing $Ca_3(PO_4)_2$-Fe_2O_3 has not been studied. We know that magnetic materials become paramagnetic when heated. The magnetic measurement method allows us to measure changes in the magnetic properties of samples in the temperature range of 80-1100K.

The aim of this work is to synthesize $Ca_3(PO_4)_2$-Fe_2O_3-based compositions and to investigate their Curie temperature at solar energy flux density in the range of 50-500 W/cm^2 (Scientific and Practical Center of the National Academy of Sciences of Belarus on Materials Science, Belarus).

At this stage it can be said that solar technologies, unlike traditional ones, are characterized by a high heating rate, which makes it possible to produce finely dispersed homogeneous material of high chemical purity. At the same time, ferrite materials undergo a simultaneous ferritization process. Such properties require the possibility of creating improved ceramics, intermetallic composites and functional materials[1].

Based on the starting raw materials $Ca_3(PO_4)_2$ and Fe_2O_3, 13 formulations of 50 g each were calculated and prepared. An Aczet CY 224C scale was used for weight measurement. First, the ingredients were mixed and wet milled (raw materials, grinding stones and water) in a ratio of 1:1.2:1.2 for 8 hours in a SAND device. The liquid mass was dehydrated with gypsum and dried at 1500^{o}C in a Snol brand dryer. The prepared mixture was mixed with 8% adhesive solution (5% PVA-polyvinyl alcohol) in a porcelain mortar, placed in a mold with a diameter of 5 mm and length

of 140 mm and molded on an MS100 machine with a pressure of 30 kN. The formed masses were dried at room temperature and placed in a solar-powered material synthesis unit. The solar power is gradually increased to 50-500 W/cm^2 until the masses formed reach the melting point. The molten mass is cooled by lowering it into a container of cold water at a rate of 10,000 °C/sec. Once the process is complete, the materials in the water are dewatered and each component is wet milled (material, grinding stones and water) at a ratio of 1:1.2:1.2 in a SAND device until a size of 1-10 μm is achieved. The grinding duration is 48 hours. The ground materials are dewatered and fed into the measurement process[2].

The average Curie temperature of the synthesized ceramic magnetic materials was 820K.

From these data it can be concluded that the Curie temperature decreases or increases at different ratios of $Ca_3(PO_4)_2$ and Fe_2O_3 in the mixture.

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CURIE TEMPERATURE OF $NiFe_2O_4$ CATALYST SYNTHESIZED IN A SMALL SOLAR FURNACE

J.Z. Shermatov[1], M.S. Paizullakhanov[1], O.T. Rajamatov[1], M.A.Karimov[2], V.G.Minkina[3]
[1]Institute of Materials Science of Uzbekistan Academy of Sciences, Uzbekistan.
[2]Yangiyer branch of The Tashkent chemical technology institute, Uzbekistan
[3]A.V. Lykov Institute of Heat and Mass Transfer of the National Academy of Sciences of Belarus, Belarus

Today, the demand for fuel and electricity is increasing in our country, which requires efficient and targeted utilization of natural resources. Therefore, widespread utilization of hydrogen and renewable energy sources for public consumption and production is encouraged. Hydrogen is considered as the fuel of the future because it is a clean energy source and plays a key role in the rapidly developing technology of various fuel cells.

At this stage it can be said that solar technologies, unlike traditional ones, are characterized by high heating rate, which allows to produce fine homogeneous material of high chemical purity. At the same time, ferrite materials undergo a simultaneous ferritization process. Such properties require the possibility of creating improved ceramics, intermetallic composites and functional materials[1].

We know that materials containing $NiFe_2O_4$ have high magnetic and catalytic properties. Magnetic materials become paramagnetic when heated (the method of magnetic measurements allows us to measure the magnetic properties of samples in the temperature range of 80-1100 K).

The aim of this work is to investigate the Curie temperature of synthesized $NiFe_2O_4$ spinel catalyst for hydrogen production in a small solar furnace with a current density of 200 W/cm^2 using magnetic measurement technique(Scientific and Practical Center of the National Academy of Sciences of Belarus for Materials Science, Belarus).

Based on the initial raw materials NiO and Fe_2O_3, five compositions of 50 g each were calculated and prepared. An Aczet CY 224C scale was used to measure the mass. Initially, the ingredients (raw materials, grinding stones and water) were wet mixed in a SAND machine for 8 hours at a ratio of 1:1.2:1.2. The liquid mass was dehydrated with gypsum and dried in a Snol dryer

at 150ºC. After adding 8% adhesive solution (5% PVA-polyvinyl alcohol) to the prepared mixture, it was stirred in a porcelain mortar and placed in a mold of 5 mm diameter and 140 mm length. The formed materials were air dried and placed in the material synthesis section of the solar oven. The solar furnace was then started up. The power of the solar oven was gradually increased to 50-200 W/cm^2 until the resulting materials reached the melting point. The molten materials are cooled by placing them in a cold water bath at a rate of 1000°C/sec. After completion of the process, the materials in the water are dewatered and each component is wet milled (material, grinding stones and water) in a 1:1.2:1.2 ratio to a size of 1-10 μm in a SAND device. The grinding duration was 48 hours. The ground materials are dewatered. The material is then placed in a magnetic device and the measurement process is carried out starting at a temperature of 80K.

The measurements are downloaded and studied in OriginPro software. As a result of the measurements, the maximum Curie temperature of $NiFe_2O_4$ was 846K (50% NiO and 50% Fe_2O_3).

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THE REACTION OF AROMATIC CARBOXYLIC ACIDS WITH PHENYLACETYLENE IN CATALYTIC SYSTEMS

Alimova N.A.[1], Parmanov A.B.[1], Nurmanov S.E.[1], Ro‘zimurodov O.N.[2]

[1]National University of Uzbekistan
[2]Turin Polytechnic University in Tashkent

Vinyl esters of carboxylic acids are used as materials for green energy applications due to their environmentally friendly and energy-efficient properties. These materials are employed in high-performance and eco-friendly purification technologies, as well as in renewable energy sources and energy storage systems. Carboxylic acid vinyl esters are used as materials in photovoltaic elements. Vinyl esters serve as components for photovoltaic electrodes or organic solar panels. Additionally, vinyl esters and their resulting polymers are utilized in energy storage and conversion systems, such as batteries and supercapacitors. In combination with specialized catalysts and electrodes, vinyl esters of carboxylic acids can be used as functional materials for efficient energy storage or release systems. Vinyl esters also serve as the basis for organic polymers or biomaterials. These polymers are recyclable, contributing to their environmental friendliness and energy efficiency. Modified forms of carboxylic acid vinyl esters become important components in organic energy sources or supplemental energy systems. They exhibit high energy utilization efficiency and help reduce carbon emissions. Furthermore, vinyl esters are used as catalysts in energy control and renewable energy technologies, enhancing energy production and minimizing unnecessary energy consumption [1].

It is well known that the reaction of carboxylic acids with terminal alkynes yields a mixture of Markovnikov and anti-Markovnikov addition products in varying ratios. This reaction was first carried out in 1980 using a ruthenium complex catalyst. Subsequently, studies were extended to include rhodium, rhenium, iridium, gold, and bimetallic complex catalysts. Due to its high efficiency and ease of synthesis, the ruthenium catalyst has been extensively studied. Certain ruthenium complex catalysts enable control over both the regioselectivity and stereoselectivity of the reaction. The coordination of the metal ion to the alkyne triple bond significantly influences the regioselectivity of the reaction [2].

In this research, the synthesis of vinyl compounds via the addition of various substituted aromatic carboxylic acids to phenylacetylene was carried out in the presence of the complex catalyst $[Zn(C_4H_7N_3S_2)_4](NO_3)_2$. The reaction of benzoic acid (**1**), 4-methylbenzoic acid (**3**), 4-methoxybenzoic acid (**4**), 2-bromobenzoic acid (**6**), 4-bromobenzoic acid (**7**) and 4-chlorobenzoic acid (**13**) with phenylacetylene yielded both Markovnikov and anti-Markovnikov addition products: 1-Phenylvinyl benzoate (**33**), Styryl benzoate (**34**), 1-Phenylvinyl-4-methylbenzoate (**35**), Styryl-4-methylbenzoate (**36**), 1-Phenylvinyl-4-methoxybenzoate (**37**), Styryl-4-methoxybenzoate (**38**), 1-Phenylvinyl-2-bromobenzoate (**39**), Styryl-2-bromobenzoate (**40**), 1-Phenylvinyl-4-bromobenzoate (**41**), Styryl-4-bromobenzoate (**42**), 1-Phenylvinyl-4-chlorobenzoate (**43**), Styryl-4-chlorobenzoate (**44**). A schematic representation of the reaction using benzoic acid as an example is provided below.

Based on literature sources, the following mechanism has been proposed for the catalytic addition of carboxylic acids to phenylacetylene.

The reaction was carried out in toluene at 110 °C for 24 hours. The starting benzoic acid and phenylacetylene were used in a 1:1 molar ratio, and the catalyst was applied in an amount corresponding to 1 mol % relative to the benzoic acid. It was found that the efficiency of vinyl ester synthesis from the reaction of phenylacetylene with carboxylic acids depends to a certain extent on the acidity of the carboxylic acids used. The yield of vinyl esters increased in the following order: $4\text{-}CH_3O\text{–}C_6H_4COOH < 4\text{-}CH_3\text{–}C_6H_4COOH < C_6H_5COOH < 4\text{-}Cl\text{–}C_6H_4COOH < 4\text{-}Br\text{–}C_6H_4COOH < 2\text{-}Br\text{–}C_6H_4COOH$. This order corresponds to an increase in the acidity of the carboxylic acids. Experimental results showed that the addition reaction of the selected carboxylic acids with phenylacetylene yielded a mixture of Markovnikov and anti-Markovnikov products. The acidity of the carboxylic acid influences the regioselectivity of the reaction. As the acidity increases, the amount of the Markovnikov product increases. This can be explained by the fact that a more acidic carboxylic acid forms a more stable carboxylate anion, which facilitates the formation of the Markovnikov product. Conversely, lower acidity leads to a greater proportion of the anti-Markovnikov product. The total yields of the products in the reaction with phenylacetylene were as follows:1: 67% (80/20), 3: 44% (65/35), 4: 40% (60/40), 6: 82% (85/15), 7: 78% (82/18), 13: 75% (80/20).

The effect of reaction time on product yield was studied in the range of 12 to 48 hours. The reaction was carried out at 110 °C in the presence of 1 mol % $Zn(C_4H_7N_3S_2)_{42}$ catalyst and toluene as solvent. When the process was conducted for 12 and 24 hours, incomplete conversion of the starting phenylacetylene and carboxylic acid was observed, resulting in low product yields. When the reaction was extended to 36 hours, complete conversion of the starting materials in the toluene medium was achieved. The overall product yields increased as follows: For 4-methoxybenzoic acid: from 30% to 44%, For 4-methylbenzoic acid: from 32% to 50%, For benzoic acid: from 45% to 75%, For 4-chlorobenzoic acid: from 50% to 83%, For 4-bromobenzoic acid: from 52% to 86%, For 2-bromobenzoic acid: from 55% to 91%. However, when the reactions were carried out for 48 hours, the formation of by-products such as resinous and polymeric compounds led to a decrease in vinyl ester yields: For 4-methoxybenzoic acid: down to 42%, For 4-methylbenzoic acid: down to 45%, For benzoic acid: down to 71%, For 4-chlorobenzoic acid: down to 80%, For 4-bromobenzoic acid: down to 83%, For 2-bromobenzoic acid: down to 87%ю For example, the decrease in the efficiency of the main product yield can be explained by the formation of a by-product — 1-phenylethane-1,1-diyl dibenzoate — as a result of the electrophilic addition of hydrogen to the vinyl group of 1-phenylvinyl benzoate in the system.

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MICROSTRUCTURE AND PHASE PROPERTIES OF $Al_{65}Cu_{20}Fe_{15}$ QUASICRYSTAL COATINGS DEPOSITED BY HVOF

Bekbaev S.M., Kurbanbekov S.R., Abdimutalip A.N., Gaipov T.E.
International Kazakh-Turkish University named after H.A.Yasavi, Turkestan, 161200, Kazakhstan; araiabdimutalip7@gmail.com (A.A)

The development of $Al_{65}Cu_{20}Fe_{15}$ quasicrystalline coatings presents an alternative to traditional coatings and offers a potential replacement for expensive materials such as hard alloys and ceramic coatings. Furthermore, due to their biocompatibility and high wear resistance, these coatings may be used in medical instruments and implants. A key advantage of these coatings is their compatibility with various deposition technologies, including thermal spraying, laser deposition, plasma deposition, and most efficient high-velocity oxygen fuel (HVOF) spraying method [1,2].

The HVOF method is one of the most efficient and versatile coating techniques for various industrial applications. HVOF coatings are widely used in industries where equipment is exposed to extreme operating conditions, such as high pressures, chemical exposure, and elevated temperatures, providing reliable protection and extending the service life of components.

The research was conducted on coating samples applied to the outer surface of U8G tool carbon steel substrates, which comply with GOST 1435-99 standards. The substrate thickness ranged from 5 to 10 mm, with width and length dimensions of 20×20 mm. The coatings were deposited using the HVOF spraying technique with a Termika-3 installation (Saint Petersburg, Russian Federation).

Quasicrystalline powders of $Al_{65}Cu_{20}Fe_{15}$ were deposited onto a U8G steel substrate using the HVOF spraying method with the following parameters: spraying velocity reached 700 m/s, and the gas jet temperature was up to 3000 °C. The nozzle-to-substrate distance was set at 350 mm, ensuring optimal conditions for particle heating and acceleration without entrapment in the jet. Due to the selected particle size and spraying distance, the powder retention time in the jet was sufficient for complete heating and energy transfer upon reaching the substrate. This resulted in high adhesion and uniform coating deposition. The preservation of the quasicrystalline structure was achieved by controlling the temperature and process speed, preventing overheating and degradation of the material's unique properties.

To examine the sample with high precision and obtain detailed surface images, a Tescan Vega 4 scanning electron microscope (SEM) (Brno, Czech Republic) with a thermionic tungsten cathode was used. The SEM provides excellent focusing at different levels of the sample, allowing for clear 3D imaging of complex surfaces [3]. Combined with energy-dispersive X-ray spectroscopy (EDS), it enables the determination of the elemental composition of the material at the nanoscale. The SEM accurately visualizes surface structures, detecting microcracks, roughness, porosity, and other characteristics.

One of the key advantages of this method is the ability to analyze coating adhesion and identify defects. To determine the chemical composition of the $Al_{65}Cu_{20}Fe_{15}$ powder, the working distance of the SEM was set at 10-15 mm, and the acceleration voltage was increased to 25 kV. The resolution was 275 nm, and different types of detectors were used: EDS (Energy-Dispersive X-ray Spectroscopy) to identify the elements present in the sample and their concentrations; BSE (Backscattered Electron Detector) to visualize compositional differences in the material; SE

(Secondary Electron Detector) to provide high-resolution surface imaging, enabling the research of topography and fine structural details [4].

The magnification was increased up to 1000×, with a penetration depth of 0.5-3 μm. Additionally, SEM images were combined with X-ray diffraction (XRD) data, providing a comprehensive analysis of the coating structure.

The phase composition of the coatings was analyzed using XRD with the XPERT-PRO diffractometer from Panalytical (Philips Corporation, Amsterdam, Netherlands). The device was equipped with a copper anode (Cu) and a Kα X-ray source with a wavelength of 1.5406 Å [5]. The studies were conducted at a temperature of 25°C, an operating voltage of 40 kV, and a current of 30 mA. Scanning was performed over an angular range of 20.01° to 89.99°, with a step size of 0.02°, and the data acquisition time for each measurement was 2 seconds. The collected data were processed using the HighScore Plus software package.

This research examined the microstructural and phase properties of $Al_{65}Cu_{20}Fe_{15}$ quasicrystalline coatings deposited using HVOF spraying onto U8G tool steel substrates. Particular attention was given to the influence of air supply pressure (1.9 bar, 2.1 bar, and 2.3 bar) on the phase composition, adhesion characteristics, and wear resistance of the coatings.

XRD analysis identified the formation of $Al_{0.5}Fe_{1.5}$, Fe_1, $Cu_{4.00}$, $Fe_{2.00}$, and $Al_{78}Cu_{48}Fe_{14}$ phases, with their distribution depending on the spraying conditions. The optimal result was observed for the sample sprayed at 2.1 bar, as its phase composition closely matched the initial material, ensuring coating stability. This spraying mode also provided strong adhesion to the substrate, reducing the risk of delamination and enhancing durability during operation.

The obtained results can aid in optimizing spraying parameters to develop wear-resistant coatings for high-friction applications. This contributes to advancements in industrial materials science and aligns with sustainable development goals by promoting innovative solutions for enhancing equipment reliability and longevity.

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OPTIMIZATION OF ANTISOLVENT DEPOSITION TIMING FOR $MAPbI_3$ FILM QUALITY IN HALIDE PEROVSKITE SOLAR CELL FABRICATION

N.U. Botirova, Sh.U. Yuldashev, R.Sh. Sharipova
Center of Nanotechnology Development, National University of Uzbekistan

Methylammonium lead iodide ($MAPbI_3$) halide perovskites have attracted considerable attention in the field of photovoltaics due to their favorable optoelectronic properties, including high absorption coefficients, long carrier diffusion lengths, and ease of solution processing. In this study, we investigate the influence of antisolvent application timing on the morphology and crystallinity of $MAPbI_3$ films, which are critical for improving the performance of perovskite solar cells [1].

Glass substrates were initially cleaned using an ultrasonic bath with detergent, deionized water, acetone, and isopropanol for 10 minutes each. Subsequent surface treatment with ozone and oxygen plasma for 20 and 10 minutes respectively ensured high surface energy and removal of residual contaminants. The perovskite precursor solution was prepared in a nitrogen glovebox by dissolving CH_3NH_3I and PbI_2 in a 4:1 volume ratio of dimethylformamide (DMF) and dimethyl sulfoxide (DMSO), achieving concentrations of 1 mol/L and 0.95 mol/L respectively. Spin-coating was carried out in a two-step program: 700 revolutions per minute (rpm) for 3 seconds followed by 4000 rpm for 30 seconds. During the second step, 150 μL of chlorobenzene was applied as an antisolvent at varying intervals (8, 12, 15, 20, and 25 seconds before the end). The resulting films were annealed at $100\ °C$ for 10 minutes.

Morphological analysis revealed that early-stage antisolvent deposition (8 to 15 seconds) led to rough, porous surfaces with insufficient crystal formation. In contrast, films where chlorobenzene was introduced 25 seconds before the end of spin-coating exhibited dense, glassy morphology with minimal pinholes. This improved structure is attributed to the optimized crystallization kinetics facilitated by delayed solvent extraction. Optical absorption measurements showed enhanced absorption coefficients in the 300 nm to 500 nm range for films treated with antisolvent at 25 seconds, indicating superior light-harvesting potential and crystallinity [2]. The timing of antisolvent application was found to significantly affect the topography, homogeneity, and optoelectronic quality of the $MAPbI_3$ films [3]. Proper control of this parameter can suppress defect formation and enhance charge carrier transport, ultimately leading to more efficient perovskite solar cells.

These findings emphasize the essential role of solvent engineering in the development of high-performance perovskite layers. By refining the antisolvent deposition process, particularly the timing of its application, it is possible to produce uniform and defect-free $MAPbI_3$ films suitable for scalable photovoltaic device integration.

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ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY (EIS) ANALYSIS OF Ni-INTEGRATED TiO_2 NANOTUBES

[1]Boyqobilov D.B., [1]Boltayev A.A., [1,2]Ro'zimuradov O.N.
[1]Department of Chemistry, National University of Uzbekistan, Tashkent, 100174 Uzbekistan
[2]Department of Natural and Mathematic Sciences, Turin Polytechnic University in Tashkent, Tashkent, 100095, Uzbekistan

TiO_2 nanotubes (NTs) possess excellent photocatalytic, photoelectrochemical, and stability properties, and are widely used in various fields such as solar energy conversion, water splitting, and sensing technologies [1]. The functional scope of TiO_2 NTs can be significantly extended by modifying them with various metal dopants. In particular, Ni-doped TiO_2 nanotubes (Ni-TiO_2 NTs) demonstrate improved electronic conductivity and reduced electrical resistance. Using Electrochemical Impedance Spectroscopy (EIS), it is possible to investigate charge carrier movement (electrons/holes), charge transfer resistance (Rct), and dielectric behavior at the electrode/electrolyte interface [2-3].

The introduction of Ni positively influences the transitions between anatase and rutile phases of TiO_2, thereby modifying its electrochemical characteristics. Ni-doped TiO_2 NTs also exhibit enhanced sensitivity and rapid response to hydrogen gas, broadening their potential application in sensor technologies [3].

In this study, titanium foil was first cut into 2×2 cm pieces and cleaned in an ultrasonic bath. The foil was then anodized in a solution containing NH_4F, H_2O, and ethylene glycol (EG) for 4 hours to form TiO_2 Nts. The anodized sample was again cleaned via ultrasonication and then annealed at 450°C at a heating rate of 2°C/min. Following this, a three-electrode electrochemical setup (working electrode: TiO_2 NTs, counter electrode: Pt, reference electrode: Ag/AgCl) was used to fabricate Ni-TiO_2/Ti nanocomposites via the electrodeposition method. Electrochemical Impedance Spectroscopy (EIS) analysis was subsequently performed on the synthesized samples. Key electrochemical properties were examined through Nyquist and Bode plots, and the potential-dependent charge transfer resistance (Rct) was analyzed. EIS measurements were conducted in the applied potential range of 0.1 V to 0.9 V. According to the results, Ni-doped TiO_2 NTs exhibited superior electronic conductivity and lower resistance compared to undoped TiO_2 NTs. For pure TiO_2 NTs, the lowest Rct was observed at 0.3 V, indicating optimal charge transfer at this potential. As the applied voltage increased to 0.9 V, resistance also increased, suggesting less efficient charge transport.

The bending observed in the linear region of the Nyquist plots indicates ion diffusion processes, which reflect the material's interaction with the electrolyte. In the case of Ni-TiO_2 NTs, a significant decrease in the diameter of the semicircles was observed as the potential increased (from 0.3 V to 0.5 V and then to 0.7 V), indicating easier charge transport. The smallest semicircle diameter—and thus the lowest Rct—was recorded at 0.7 V, demonstrating maximum conductivity and surface activity at this potential. Beyond 0.7 V, the semicircle size remained unchanged, suggesting that the highest conductivity is achieved at 0.7 V. In conclusion, Ni-doped TiO_2 nanotubes demonstrate enhanced electronic conductivity and reduced charge transfer resistance compared to pure TiO_2 nanotubes. The electrochemical analysis reveals that the introduction of Ni significantly improves the material's electrochemical properties, with the highest conductivity observed at 0.7 V. These findings suggest that Ni doping enhances the photocatalytic and sensor applications of TiO_2 nanotubes, making them more efficient for energy conversion and sensing technologies.

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C-14 BETAENERGYCONVERTER BASED ON SiC/Si

V.I. Chepurnov[1], A.S. Chipura[2]
[1]Department of Solid State Physics, Samara University, 34 Moskovskoe shosse, Samara, 443086, Russia
[2]Department of Higher Mathematics, SAMARA POLYTECH, 244 Molodogvardeyskaya street, Samara, 443100, Russia

Historically and at the present stage, the most used materials for energy converters in betavoltaics are Si, GaN, 4H–SiC and 3C–SiC. The first successful researches on a porous p-n Si structure with Pm-147 [1,2] indicated the advantages of structures with a developed surface and hybrid ones due to the increase in the effective band gap of por-Si up to ≈ 2 eV and traps for electrons in the region of the p-n junction permeated with pores (pore diameter scales up to tens of nm, to create macroscopic 1D quantum wells for electrons [3]). The band gap is important in the processes of interaction of semiconductors with radiation and during ionization [4]. Nanostructured pores create a quantum confinement, increasing the effective band gap:

$$E_g^{eff} = E_g + \frac{\hbar^2 \pi^2}{2m^* d^2} \quad (1)$$

where d is the pore diameter, m^* is the effective mass of the charge carrier. In Si, $m^* = 0.26m_e$, which enhances the quantum effect at low d.

Further, according to betavoltaics, Si/SiC demonstrated the best energy concentration in the depletion region compared with Si, GaN, GaAs, SiC, InGaP homojunctions and Si-semiconductor heterojunctions [5] and [6–11]. The advantages of heterojunctions are the possibilities of increasing the built-in potential, increasing the open circuit voltage due to an increase in the electrochemical potential difference by splitting quasi-Fermi levels and effective charge separation using especially type II heterojunctions.

Systematic studies of betavoltaic semiconductor converters of beta decay of C-14 radionuclide are the basis for C–14 technologies, a self-charging supercapacitor based on carbon nanotubes [12], researches based on Si homojunctions [13,14] and, for the first time, engineering solutions based on HT CVD technology for self-organizing mono – 3C-SiC endotaxy on a Si substrate [15], [16] and internally activated C-14 radionuclide betavoltaic energy converters on wide-band por-SiC/Si heterostructures belong to [16–19]. These studies have shown that high-intensity electron-hole pairs generated by irradiation due to the high beta decay energy of the C-14 source in the depleted region can increase the efficiency of energy conversion [16]. Among the previously developed beta–voltaic batteries based on wide-band semiconductor converters, the 4H–SiC p-n junction has been successfully used to manufacture a micronuclear battery with

excellent output characteristics due to high electron mobility, low dielectric constant, and high radiation resistance [11,16,20–22].

Complex methods of C-14 production and extraction from the surface of irradiated graphite previously limited the development of C-betavoltaic energy converters in practice [18] also due to the limited availability of porous SiC synthesis. We emphasize the role of porosity in reducing mechanical stresses and self-absorption, increasing the absorption efficiency of β-particles, and the appearance of defects on the surface. C-14 has also traditionally been considered an unsuitable energy source due to its low isotopic abundance in nature (10÷12%), long half-life (5,730 years), and low specific energy release. However, in recent years, various approaches have emerged to using C-14 compounds integrated into heterostructures [16,22,23] and hybrid structures [24,25], graphene-coated SiC to reduce resistance, graphene and porous structures increase the efficiency of charge collection and absorption of β-particles [26]. Compared with perovskite-based elements [25], the advantages of SiC are stability (>20 years vs. 5 years for perovskites) and radiation resistance, SiC/Si efficiency is comparable to perovskites. The endotaxy method [15] made it possible to grow monocrystalline SiC on Si with C-14 integrated doping or C-14 ion implantation method in SiC, which is followed by annealing (T>1200 °C, t>1 hour) to restore the crystal structure. And with AlN buffer layers to reduce defects, as well as activation options [27] and increase efficiency [28]. The role of AlN buffer layers is related to the fact that the lattice mismatch coefficient of Si/AlN (~3%) is significantly lower than that of Si/SiC (~20%), which helps reduce the dislocation density. Additionally, the AlN growth temperature (800÷1000°C) prevents the diffusion of impurities. Modern methods for the synthesis of SiC thin films, such as high-temperature chemical deposition from the gas phase (HT CVD) and plasma enhanced deposition (PECVD), provide control over morphology and structural defects [29]. These approaches are particularly relevant for the creation of radiation-resistant heterojunctions used in betavoltaics.

In conclusion, we note the applied perspectives. SiC and SiC/Si converters with C-14 can power a pacemaker, since: the half-life of C-14 (5730 years) provides a service life of >100 years, low SiC toxicity and isolation of C-14 in the heterostructure solve the problem of biocompatibility. SiC batteries with C-14 are ideal for deep space probes: operation at temperatures up to 350°C (for example, on Venus), resistance to radiation (fluxes up to 10^{15} neutrons/cm^2). Integration with carbon nanotube supercapacitors [12] for peak loads is possible. The technology is possible for implementation in autonomous NPP sensors monitoring temperature and pressure in the core.

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ADVANCED MAGNETICS FUNCTIONAL MATERIAL Fe_3O_4/PPE-2 FOR EFFICIENTLY PHOTOCATALYTIC DEGRADATION ORGANIC OF DYE RHODAMINE B

Eshtursunov D., Abdujalilov I., Bekchanov D., Mukhamediev M.
Department of Polymer Chemistry, National University of Uzbekistan, Tashkent
E-mail: eshtursunovd@gmail.com

The presence of organic dyes such as Rhodamine B (RhB) in textile wastewater poses significant environmental challenges due to their toxicity, persistence and potential carcinogenic effects. Conventional wastewater treatment methods, including adsorption and filtration, often prove ineffective in fully degrading these recalcitrant pollutants. This highlights the need for advanced photocatalytic approaches. Photocatalysis uses semiconductor nanomaterials to generate reactive radicals under light irradiation, thereby facilitating the mineralisation of organic pollutants. This study investigates the synthesis and performance of a magnetic Fe_3O_4/PPE-2 composite as a reusable photocatalyst for the efficient degradation of RhB, addressing the need for sustainable water purification technologies.

The Fe_3O_4/PPE-2 composite was synthesised by a hydrothermal method. The anion-exchange material PPE-2 (2 g) was dispersed in 50 mL of deionised water in a 250 mL three-necked flask, heated to 60°C and stirred at 400 rpm for 15 min. $FeCl_2 \cdot 4H_2O$ (0.88 g) and $FeCl_3 \cdot 6H_2O$ (0.6 g) were then added in a mass ratio of 0.44:0.3:1 relative to PPE-2, followed by flushing with nitrogen until dissolved. The pH was then adjusted to 10-11 using 20 mL of NH_4OH, resulting in the precipitation of black nanoparticles. The suspension was then subjected to hydrothermal treatment at temperatures of 140°C (2 h), 160°C (4 h) or 180°C (6 h), yielding samples designated FM140, FM160 and FM180, respectively. After treatment, the samples were subjected to magnetic separation, washed with deionised water and dried at 50°C for 24 hours. The materials were characterised using a range of analytical techniques including XRD, SEM, FTIR, UV-Vis spectroscopy and PL analysis. The photocatalytic activity was evaluated by degrading RhB (50 mg/L) under UV irradiation (5 W, λ=365 nm) in a PCX-50C photocatalytic reactor, with degradation monitored by UV-Vis spectrophotometry (Shimadzu UV-1900i).

The hydrothermal synthesis of Fe_3O_4 nanoparticles on the PPE-2 surface was carried out at different temperatures, resulting in the formation of different morphologies. The spherical (200-400 nm) phase was observed for FM140, the cubic (50-200 nm) phase for FM160 and the nanorod (5-25 nm) phase for FM180, as confirmed by SEM analysis. In addition, XRD analysis revealed high crystallinity in FM180 with an average crystallite size of 18 nm calculated using the Scherrer equation. UV-Vis spectroscopy revealed a band gap of 1.90 eV for FM180, narrower than that of FM140 (2.10 eV) and FM160 (1.92 eV), resulting in enhanced visible light absorption. Photocatalytic tests showed that FM180 achieved 98.2% RhB degradation in 160 min (k=0.03496 min^{-1}), significantly outperforming FM140 (56.5%), FM160 (64.7%) and virgin PPE-2 (28.4%). The improved performance of FM180 is attributed to its smaller crystallite size and branched nanorod morphology, which reduces carrier recombination (as evidenced by lower PL intensity) and increases reactive sites via enhanced light scattering. Reusability tests over 10 cycles showed only a 3.8% decrease in efficiency, with the magnetic properties of the compound facilitating easy separation. Application to real textile wastewater (RhB, 118 ppm) confirmed the efficacy of FM180, which maintained >94.4% degradation efficiency after 10 cycles at 308 K under UV light[1].

The Fe_3O_4/PPE-2 magnetic material optimised at 180°C (FM180) exhibited exceptional photocatalytic activity and reusability for RhB degradation, due to its nanorod morphology, narrow band gap and efficient charge separation. Its facile and efficient synthesis, magnetic separability and robust performance in real wastewater highlight its potential as a sustainable solution for textile wastewater treatment. This work represents a significant advance in the field of functional nanomaterials for environmental remediation.

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EFFECTIVE METHODS FOR PURIFICATION OF V+5 ION FROM INDUSTRIAL WASTEWATER.

Faizullayev Y.S., Murtozakulov M.R., Bekchanov D.J., Mukhamediev M.G.
National University of Uzbekistan named after Mirzo Ulugbek
E-mail: yusuffayzullayev9@gmail.com

Today, due to the progress of the human population and the rapid development of industry, the environment is increasingly polluted with various wastes. As the chemical industry develops, the amount of toxic anions and cations in industrial wastewater is increasing. Waste from all production processes remains a major problem worldwide. Especially due to the activities of the energy industry, up to 2.4 million tons of waste of toxic metals such as Cd, Cr, Cu, Pt, Pd, Au, Hg, Ni, Pb, Se, V and Zn are generated annually. The recovery of most of these metals released into the environment can greatly contribute to economic efficiency [1]. In particular, the demand for the extraction of vanadium is increasing.

Vanadium is the 22nd most abundant element in the Earth's crust, and is considered as toxic as lead, mercury, or arsenic [2]. This element can occur in oxidation states of -1, 0, 1, +2, +3, +4, and +5, and the V(V) ion, which occurs as an oxyanion, is the most stable and at the same time the most toxic of all forms found in the environment [3]. The presence of vanadium in the environment

is associated with the activity of volcanoes, ocean evaporation, forest fires, rock erosion, or soil-forming processes [4]. In nature, this element occurs in concentrations of about 97 mg/kg in the earth's crust, 90 mg/kg in soil, and in surface waters (dissolved) in the atmosphere. For rivers and oceans, the concentrations are 0.71 μg/L and 1.8 μg/L, respectively [5].

Since vanadium (V) exists in the anionic form in aqueous solutions, its separation is more difficult than that of metal cations. This requires the use of anion exchange materials.

This work presents information on ion exchangers that effectively adsorb VO2+ ions.

Di(2-ethylhexyl)phosphoric acid (D2EHPA, P204), 2-Ethylhexyl phosphonic acid mono-2-ethylhexyl phosphoric ester (EHEHPA, P507) Di(2,4,4-trimethylpentyl) phosphinic acid (Cyanex 272) Tributylphosphate (TBP) Secondary carbon primary amine (Primene JMT, N1923) Trialkylamine (Alamine 336, N235) 5,8-Diethyl-7-hydroxydodecane-6-oxime (LIX 63, N509) ushbu ion alamshinuvchi mareriallar sammarali hisoblangan.

In conclusion, ion exchangers containing a phosphonic group are effective for the separation of vanadyl ions.

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NANOCOMPOSITE FILMS BASED ON POLY(N VINYLCARBAZOLE) AND ZnSe/ZnS/ZnS TRIPLET QUANTUM DOTS

[1]Ishankulov A.F., [1]Islomova Z.R., [1]Abdibanotova G.B., [1]Khalilov K.F., [2]Shamilov R.R., [2]Galyametdinov Yu.G., [1]Mukhamadiev N.K.
[1]Uzbekistan, Samarkand, Samarkand State University
[2]Russian, Kazan, Kazan National Research Technological University

The growing interest in quantum dots is due to the fact that they are superior to traditional phosphors in terms of photostability, have a narrow and intense size-dependent luminescence, and absorb light in a wide region [1]. Quantum dots are attractive for use as light emitting devices, solar cells, and luminescent labels [2-4].

For practical applications, quantum dots are often embedded in polymer matrices, thus creating nanocomposite materials. In this case, not only the properties of polymers and quantum dots are combined, but also in composites, the polymer is able to additionally increase the luminescence efficiency of nanoparticles and protect them when interacting with the environment.

The emission and excitation spectra were recorded on a Cary Eclipse (Varian) spectrofluorimeter. The study of the optical properties of mixtures of QDs (constant concentration) and PVCL in toluene showed that an increase in PVCL concentration (radiation maximum at 370 nm) leads to a decrease in the QD radiation intensity (maximum at 520 nm). It can be seen from the excitation spectra that the greatest quenching of luminescence is observed at wavelengths corresponding to the absorption maxima of the polymer – 297, 333, and 345 nm.

Composite films of QD and PVC were obtained at different ratios on glass substrates by sputtering during rotation on a Laurell WS-650-23 Spincoater. The highest increase in the emission intensity of ZnSe/ZnS/ZnS nanoparticles was obtained at a mass ratio of QDs and PVC of 1:1.

Comparison of the excitation spectra of the composite films (1:1) and individual components showed that, in the composite, the excitation intensity of the polymer decreases ($\lambda_{radiation}$ = 410 nm), while the excitation intensity of quantum dots ($\lambda_{radiation}$ = 520 nm) increases. This fact indicates the process of nonradiative energy transfer from polymer to nanoparticles. In this case, the greatest increase in intensity is observed at wavelengths corresponding to the absorption maxima of the polymer.

The luminescence spectra were taken at a wavelength of 297 nm, which corresponds to the maximum increase in radiation. The luminescence spectra of the composite films show that the emission intensity of nanoparticles is 42% higher than that of films of pure quantum dots at the same concentration.

Thus, when preparing nanocomposite films based on poly(N-vinylcarbazole) and quantum dots, the optimum mass ratio is 1:1, at which the luminescence efficiency of triplet ZnSe/ZnS/ZnS quantum dots increases significantly.

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PREVENTING DEGRADATION OF VANADIUM FLOW BATTERY ELECTRODES BY MODIFICATION

Sh.Ch.Iskandarov, I.Kh.Ashurov, U.F.Berdiev, Kh.B.Ashurov
Arifov Institute of Ion-Plasma and Laser Technologies of Uzbekistan Academy of Sciences - Tashkent (Uzbekistan)
iskandarov@iplt.uz

The development of rechargeable batteries is important for modern energy systems, especially in ensuring the sustainability of renewable energy sources (for example, solar and wind power plants). Climate change is increasing the need for renewable energy sources, which in turn is further increasing the importance of energy storage systems. In this context, redox flow batteries (RFBs) are distinguished by their scalability, long service life and safety[1]. There are also several types of redox batteries. Among them, vanadium flow batteries (VFA) are characterized by high

cycle life (more than 10,000 charge-discharge cycles), long service life (up to 20 years), and high energy efficiency (75-85%) [2]. However, there are factors that prevent the widespread use of VFA. In vanadium flow batteries, the electrode material undergoes erosion due to mechanical and electrochemical effects during repeated charging and discharging. One of the main reasons for this problem is corrosion of the electrode surface and the separation of active materials [3].

There are possibilities to solve this problem by coating the electrode surface with nanocoating. Initially, the carbon fiber felt used as an electrode was cut to the required size. The prepared sample was placed in the SI PEALD device and titanium dioxide coating was performed. In this case, TiO2 is deposited on a specified, pre-prepared substrate using thermal ALD, using the SI PEALD setup. In this process, titanium tetraisopropoxide (TTIP) and deionized water were used as the initial precursors, and nitrogen was used as the transport and purge gas. After the titanium dioxide was coated in the ALD method, we can visually observe the color change of the fibers. This phenomenon is related to the interaction of light with the surface, the refractive index of titanium dioxide, and the optical dispersion.

For the purpose of testing after coating the electrodes with TiO_2, single-cell vanadium flow batteries were assembled and tested. The studies were carried out several times and the mass of the electrodes was measured after each study. Initially, samples coated with TiO_2 with a thickness of 50nm, 100nm, 200m, 300nm were selected and the mass loss (degradation) of each sample at the anode and cathode was measured over a period of 300 cycles.

Based on the results of the study, it was confirmed that the use of titanium dioxide (TiO_2) coatings is effective in increasing the mechanical and electrochemical stability of graft-felt electrodes.

TiO_2 coating plays an important role in protecting the electrode materials of vanadium flow batteries. The coatings protect the anode and cathode electrodes from mechanical and electrochemical corrosion, ensuring the long-term stability of the batteries. Therefore, TiO_2 coating is one of the promising methods for increasing the efficiency of energy storage systems in the future.

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INVESTIGATION OF THE EFFECT OF HVOF DEPOSITION PARAMETERS ON THE MECHANICAL PROPERTIES OF ZrCN COATINGS

Kurbanbekov Sh.R., Kambarbekov S. Kh., Kaldar B. S. Mussakhan N.P.
International Kazakh-Turkish University named after H.A.Yasavi, Turkestan, 161200, Kazakhstan; sardor.kambarbekov@ayu.edu.kz

This paper presents the results of a study of the effect of high-speed flame deposition (HVOF) modes on the microhardness and adhesion characteristics of a zirconium carbonitride ZrCN

coating. The microhardness of ZrCN coatings varies in the range of 1500-1800 HV depending on the deposition parameters. The adhesion test results showed that the maximum adhesion strength is 7.49 MPa. Optimal coating properties are achieved with the following spraying parameters: distance to the substrate 35-40 cm, propane pressure 1.7 bar, air 2.6 bar, oxygen 2.8 bar.

Keywords: HVOF, microhardness, adhesion, ZrCN coating

ZrCN coatings are of considerable interest due to their unique properties such as high hardness, wear resistance and oxidation resistance. ZrCN-based ceramics have been proven to be highly heat-resistant and resistant to physical and chemical environments, making them an excellent candidate for protective coatings for cutting tools and metal parts operating under extreme conditions [1]. One of the most effective methods of applying such coatings is HVOF technology, which is widely used in various industries due to its flexibility, cost-effectiveness and ability to form dense coatings with high performance characteristics [2, 3].

The purpose of this study is to study the effect of HVOF deposition parameters on the mechanical properties of Zr CN coatings.

The coatings were applied using the HVOF method at the Termika-3 installation [4]. Grade 65G steel was used as the substrate, which is widely used for the manufacture of cutting tools, including circular saws, due to its durability and resistance to abrasive wear, which makes it an economically advantageous alternative to more expensive grades of tool steels [5]. Spraying was carried out with the following parameters: the distance from the nozzle to the substrate is 35-40 cm, propane pressure is 1.7 bar, oxygen is 2.8 bar, ZrCN powder. The air pressure varied for three samples and was: a) 2.6 bar; b) 2.8 bar; c) 3.0 bar.

The microhardness of the coatings was investigated using the Vickers method in accordance with GOST 9450-76 using an HLV-1DT microhardness tester. In turn, tear-off tests performed in accordance with the ASTM D4541-22 standard were carried out to assess the adhesive characteristics of the coatings.Using an Elcometer 510 hydraulic adhesive. The strength of the adhesive coatings was determined under the following conditions: exposure time 0.50 s; target velocity 1.00 MPa/s; lining size 20 mm.

The microhardness of coatings and substrates plays an important role in determining their mechanical properties and operational characteristics. The initial value of the microhardness of the substrate is 330 HV, which corresponds to 65G hardened steel. After Zrn coatings are applied, the microhardness increases significantly depending on the spraying conditions. Sample A demonstrates 1600 HV, indicating a dense coating structure. Sample B reaches a maximum value of 1800 HV due to the optimal particle size and minimum porosity. Sample c shows microhardness in the range of 1500-1600 HV.

The adhesion tests of the coating by the tear-off method were carried out according to GOST 32299-2013 at a temperature of 20 ± 5 ° C three days after coating application. The tests were carried out 24 hours after gluing, recording the pull-off force using an adhesive meter. The adhesion strength values were 2.75 MPa for sample A, 7.49 MPa for sample B, and 4.75 MPa for sample C. In all cases, the destruction occurred along the adhesive layer, without damage or deformation of the coating, which indicates the high adhesive strength of the coatings.

As a result of the study, it was found that ZrCN coatings applied by HVOF method to 65G steel have high microhardness and adhesion. The optimal characteristics were demonstrated by sample b 1800 HV and 7.49 MPa with the following deposition parameters: distance to the substrate 35-40 cm, propane pressure 1.7 bar, air 2.8 bar, oxygen 2.8 bar. This makes this mode the most suitable for the operation of coatings under high mechanical loads. The results obtained confirm the effectiveness of HVOF technology for the formation of wear-resistant and heat-resistant coatings.

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SOL-GEL SYNTHESIS AND PROPERTIES OF Co AND Ni METALS MONO AND CO-DOPED TiO_2 NANOMATERIALS

Musaev Kh.B.[1], Yakubov I.R.[2], Ruzimuradov O.N.[3], Baglov A.V.[4], Khoroshko L.S.[4]
[1]Institute of Fundamental and Applied Research under TIIAME National Research University
[2]National University of Uzbekistan named after Mirzo Ulugbek
[3]Turin Polytechnic University in Tashkent
[4]Belarusian State University

Annotation. This study investigates the synthesis and characterization of titanium dioxide (TiO_2) nanomaterials doped with cobalt (Co) and nickel (Ni) metals, both individually and in combination. The sol-gel method was employed for the synthesis of these nanomaterials. The influence of metal doping on the crystalline structure, particle size, surface morphology, band gap energy, and magnetic behavior of TiO_2 nanoparticles is discussed. The results indicate significant alterations in the properties of TiO_2 upon doping, highlighting the potential of these modified nanomaterials for a variety application such as photocatalysis, energy storage, and magnetic devices.

Keywords: nanomaterials, titanium dioxide, sol-gel, chemistry.

Introduction. TiO_2 is a promising material for various applications, but its wide band gap (~3.2 eV) limits its light absorption to the UV region, reducing its photocatalytic efficiency under visible light. Additionally, rapid electron-hole recombination also reduces its photocatalytic activity and narrows the application scope. To overcome the limitations and tailor the properties of TiO_2 for specific applications, various modification strategies have been explored. Among these, doping with metal ions has emerged as an effective technique to alter the electronic structure, optical absorption, and surface characteristics of TiO_2 nanoparticles [1]. Transition metal doping, in particular, has shown promising results in enhancing photocatalytic activity, introducing magnetic properties, and modifying the band gap energy.

Synthesis. The sol-gel method was employed to synthesize cobalt (Co) and nickel (Ni) co-doped titanium dioxide nanomaterials. This approach is widely recognized for its simplicity, cost-effectiveness, and ability to precisely control the composition and structure of the material. Titanium isopropoxide (TTIP) served as the titanium precursor, while cobalt nitrate and nickel nitrate were used as doping agents. The aqueous dopant solution was then added dropwise to the

TTIP solution, maintaining continuous stirring to ensure uniform mixing. The resulting mixture was stirred at room temperature until gel formation occurred. The gel was aged to increase its stability, then dried at 100 °C to remove residual solvents. Finally, the dried gel was calcined at 450–600 °C in a muffle furnace to achieve crystallization and integrate Co and Ni ions into the TiO_2 lattice.

Characterization techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and UV-Vis spectroscopy were employed to confirm the successful co-doping of TiO_2 with Co and Ni, as well as to evaluate the structural, morphological, and optical properties of the synthesized nanomaterials. The increase in absorption range with different doped materials was registered. The saturation magnetization (MS) was higher for TiO_2 relative to doped materials. Cobalt and nickel co-doping effectively modified the structural, optical, and photocatalytic properties of TiO_2, enhancing its activity under visible light irradiation. Characterization results confirmed the successful incorporation of dopants into the TiO_2 lattice, improving light absorption and charge separation. This research highlights the importance of optimizing synthesis parameters and dopant concentrations to achieve desired properties in co-doped TiO_2 nanomaterials, with potential for future applications in energy conversion and storage, advancing sustainable solutions for environmental challenges.

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EFFECT OF SUPPORT MATERIAL ON STEAM DEACTIVATION OF COBALT-CATALYZED DEHYDROGENATION OF PROPANE

Sh.Muxamadqulov, Hawon Park, Yong Ki Park, Dae Sung Park*
Korea Research Institute of Chemical Technology, Daejeon, South Korea
Institute of Ion-Plasma and Laser Technologies of Uzbekistan
***shahbozmuhammad67@gmail.com**

Abstract. Propane dehydrogenation (PDH) has emerged as the most promising approach to satisfy the increasing global demand for propylene. Among the various reactors for PDH, the circulating fluidized bed (CFB) reactor stands out due to its short residence times (less than 1 minute) with a continuous reaction-regeneration cycle. The dehydrogenation in CFB reactor is advantageous for its efficient heat and mass transfer, uniform temperature distribution, continuous operation, and enhanced reaction rates and yields, alongside its ability to minimize the emission of NOx and CO2. Alumina (Al_2O_3) is widely used as a support material in dehydrogenation due to its high dispersibility, large surface area, and excellent thermal stability. However, during product separation, the steaming treatment leads to significant activity loss in CFB reactors. Alternatively, Silicalite-1, known for its high crystallinity and hydrophobic properties, exhibits resistance to steam deactivation. In this work, we developed steam-resistant silica-based support material with different sizes and we provide a better understanding of steam deactivation of aforementioned support materials and the effect of particle size.

Keywords: Propane dehydrogenation (PDH), Alumina, Silicalite-1, Steam-Deactivation, Circulating fluidized bed

MECHANICAL PROPERTIES OF POLYETHYLENE/CALCIUM CARBONATE COMPOSITES

Normuradov N.F., Berdinazarov K.N., Khaqberdiev E.O., Kudishkin V.O., Ashurov N.R.

Institute of Polymer Chemistry and Physics, Academy of Sciences of the Republic of Uzbekistan

Calcium carbonate (CaCO3) is one of the most abundant minerals in the earth's crust. It is available globally in a variety of particle sizes and purities, and can be used with or without organic coatings [1, 2]. The growing interest in polymer nanocomposites continues to search for alternatives to the widely used clay-based nanofillers. One such alternative is calcium carbonate nanoparticles [2, 3].

This study is devoted to studying the mechanical properties of the composite by introducing and increasing the proportion of calcium carbonate into polyethylene (PE) as an alternative filler. A composite of polyethylene and calcium carbonate was obtained using a Brabender plastograph device and the mechanical properties of each sample were studied. The polyethylene contained 5% to 15% calcium carbonate. The samples were obtained by fluidized bed mixing at a temperature of 180±5 ºC for the same time.

It was found that with an increase in the amount of calcium carbonate, significant changes were observed in the mechanical properties of polyethylene. Initially, the yield stress (σ) increased from 11.5 MPa to 13.4 MPa as a result of the addition of 5% $CaCO_3$, indicating an increase in strength. When the $CaCO_3$ content reached 10%, this stress increased to 15.4 MPa, but the elongation at break (ε) decreased significantly. The addition of 15% $CaCO_3$ increased the strength to the maximum level (17 MPa), but due to a significant decrease in deformation, the relative elongation at break decreased to 155.7%. Also, the Young's modulus increased to 215.4 MPa, indicating that the composite is stiff and strong.

The results obtained show that the addition of calcium carbonate significantly changes the mechanical properties of polyethylene. Samples with 5% and 10% $CaCO_3$ addition maintained the optimal balance between strength and flexibility. However, when the $CaCO_3$ content was increased to 15%, although strength increased, elasticity decreased. These results are consistent with previous studies, for example, studies on high-density polyethylene and calcium carbonate-based composites also showed an increase in Young's modulus and a decrease in elasticity with increasing $CaCO_3$ content [3].

This study aimed to evaluate the effect of $CaCO_3$ addition on the mechanical properties of composites prepared based on polyethylene and calcium carbonate, and the results showed that the addition of $CaCO_3$ increases the hardness and strength of the material, but reduces the elasticity. Samples with 5-10% $CaCO_3$ addition showed optimal results, which indicates that this may be the most suitable range for practical application.

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PREPARATION AND PROPERTIES OF POLYCOMPLEXONS CONTAINING AMINO AND CARBOXYLIC GROUPS (REVIEW)

M.N.Po'latova, S.Y.Khushvaqtov, D.J.Bekchanov, M.G.Muxamediev
National University of Uzbekistan
E-Mail:mpolatova907@gmail.comTel:+998934747737

Today, the synthesis of effective and inexpensive ion exchangers for a wide range of purposes is an urgent problem. Polyethyleneamine and epoxy resin-modified ion exchangers have been developed for the sorption of heavy metals [1]. Depending on the ion exchange group functionalizing the polymer skeleton, mixed-mode sorbents can be classified as strong cation exchange, strong anion exchange, weak cation exchange, or weak anion exchange [2]. In the literature, the sorption of not only heavy metals but also toxic gases has been studied with the help of ion exchangers obtained in the presence of polyethyleneamine. It was prepared by grafting acrylamide (AM) onto the surface of polypropylene (PP) fiber and then modified with polyethyleneimine (PEI). The success of the work was confirmed by infrared and scanning electron microscope examinations. The sorbent created in the work has good regeneration indicators [3].

To modify the carboxyl group of polyethyleneamine anion, a mixture of polyethyleneamine (0.25 g, 2 mmol) and dialkyl carbonate (8 mmol) was heated to reflux for 6 h. Unreacted dialkyl carbonate was distilled from the reaction mixture. The residue was washed with acetone, subjected to hot extraction with tetrahydrofuran, and dried to constant weight at 25 °C[4]. To perform the reactions at both ends of polyethyleneamine (PEPA), a Schiff base reaction must be performed. Polyethylene polyamine has many active sites[5]. PEPA reacts with the amino group, increasing the number of molecular attachment points and introducing a solvent chain[6]. A unique feature of amphoteric polymers is that electrostatic interactions change the nature of the changes in pH and ion concentration. For example, the adsorption of substances on charged surfaces has been studied extensively in recent years. Amphoteric polymers allow for the adjustment of the appropriate ratio between hydrophilic and hydrophobic polarities, and the resulting ionomers retain the chemical and physical properties of the inorganic and organic components in themselves[7]. Polyethylene polyamines can hydrolyze water with their nucleophilic nitrogens and generate OH- as shown in the following two reactions (Kirk-Othmer, 1986): Polyethylene polyamines are effective coating agents in preventing the oxidation of pyrite and pyrrhotite. All samples coated with TETA or DETA showed a significant reduction in oxidation [8]. Many adsorbents can be used for the adsorption of heavy metals, such as activated carbon, agricultural biomass, metal oxides, silica nanomaterials, clay minerals, etc. Based on the experimental data, adsorption kinetics, isotherms and thermodynamics were analyzed to determine the adsorption mechanism between the adsorbent and the adsorbate in the solid-liquid phase[9]. The protective properties of a composition based on boric acid, polyethylene polyamines (PEPA) and hexamethyleneamine have been studied in the literature at different temperatures, molar ratios and synthesis times. The synthesis of a quaternary ammonium salt based on a mixture of polyethylene polyamines and boric acid at a temperature of 60-110°C and continuous stirring by reaction[10].

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INTERFACIAL AND BULK DIFFUSION OF CO_2, H_2S, AND CH_4 IN [BMIM][SCN]: A COMPUTATIONAL STUDY

Akbar Kodirov,[1,2]* Jamoliddin Razzokov [1,2].
[1] Institute of Fundamental and Applied Research, National Research University TIIAME, Kori Niyoziy 39, 100000 Tashkent, Uzbekistan;
[2] Institute of Material Sciences, Academy of Sciences, Chingiz Aytmatov 2b, 100084 Tashkent, Uzbekistan.

Abstract

This study investigates the diffusion behavior of CO_2, H_2S, and CH_4 in the ionic liquid [BMIM][SCN]. Results show that CO_2 and H_2S diffuse faster at the IL-vacuum interface compared to the bulk, while CH_4 exhibits slower diffusion throughout. These findings underscore [BMIM][SCN]'s potential for selective gas separation, supporting the development of IL-based technologies for greenhouse gas capture and natural gas purification.

Introduction

The need to mitigate CO_2 emissions and purify natural gas (primarily CH_4) has driven research into ionic liquids (ILs) for gas separation[1, 2], owing to their low vapor pressure , high stability, and tunable properties [3, 4]. Imidazolium-based ILs like [BMIM][SCN] are promising for selective CO_2 and H_2S capture, but their gas transport mechanisms, particularly at interfaces, require deeper investigation. This study builds on prior work by calculating FEPs of CO_2, H_2S, and CH_4 in [BMIM][SCN] using Umbrella Sampling (US) simulations. We further compute position-dependent diffusion coefficients D(z) to elucidate gas transport dynamics at the IL-vacuum interface and in the bulk, aiming to enhance the design of IL-based gas separation technologies.

Computational Methods

MD simulations were run using GROMACS-2021.4 with GPU acceleration on [BMIM][SCN], initialized with Packmol (500 $[BMIM]^+$ and 500 $[SCN]^-$ molecules) [5]. The system was minimized, equilibrated for 100 ns in the NPT ensemble at 298 K and 1 bar, and extended along the z-axis to 15 nm for the IL-vacuum interface, followed by 100 ns NVT equilibration.

Free Energy Profiles (FEPs) for CO_2, H_2S, and CH_4 in [BMIM][SCN] were calculated using Umbrella Sampling (US). Three configurations from the NVT equilibration were used, with four replicas each. Six gas molecules were placed along the z-axis from −3.8 nm to -3.8. Each US simulation ran for 5 ns, with 576 windows total. FEPs were constructed using the weighted histogram analysis method (WHAM).

Position-dependent diffusion coefficients D(z) were calculated using the Generalized Langevin Equation (GLE) method based on the FEPs, averaging 96 profiles from 576 US simulations.

Results and Discussion

The position-dependent diffusion coefficients D(z) of CO_2, H_2S, and CH_4 in [BMIM][SCN] reveal distinct transport behaviors across the IL-vacuum interface and bulk phase. In the interfacial regions, approximately at $z=\pm1$ nm , CO_2 and H_2S exhibit high diffusion coefficients, reaching up to 8×10^{-9} m^2/s and 10×10^{-9} m^2/s respectively. This enhanced diffusion at the interface is attributed to favorable surface interactions, as indicated by the lower energy barriers in the FEPs. In contrast, within the bulk phase, between -1 nm$<z<1$ nm, the diffusion of CO_2 and H_2S decreases significantly to a range of $2-3\times10^{-9}$ m^2/s, reflecting greater resistance to movement in the denser IL environment.

CH_4, however, shows consistently lower diffusion across all regions. At the interface, its diffusion coefficient peaks at 12×10^{-9} m^2/s , and in the bulk, it averages around 4×10^{-9} m^2/s. This reduced mobility aligns with the FEPs, which indicate higher energy barriers for CH_4 due to its weaker interactions with [BMIM][SCN]. The diffusion trends suggest that CO_2 and H_2S experience facilitated transport at the interface, while CH_4 exhibits limited diffusion. This supports the potential of [BMIM][SCN] for the selective separation of CO_2 and H_2S in gas sweetening applications.

Conclusion

The diffusion profiles indicate that CH_4 exhibits the highest diffusion coefficient at the interface, which suggests weak interactions with the [BMIM][SCN] ionic liquid and minimal retention at the interface. On the other hand, CO_2 and H_2S show relatively lower diffusion coefficients at the interface, which implies stronger interactions with the ionic liquid and suggests that facilitated transport through selective retention is likely. This behavior highlights the potential of [BMIM][SCN] as a selective material for separating acidic gases, particularly CO_2 and H_2S, from natural gas mixtures. Its ability to selectively retain CO_2 and H_2S over CH_4 makes it a promising candidate for gas sweetening applications, particularly in processes designed to remove acidic gases from natural gas streams.

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HYBRID PLASMA GENERATOR WITH KLYSTRON-BASED QUANTUM ENERGY CONVERTER: PROSPECTS FOR COMPACT ANEUTRONIC ENERGY SYSTEMS

V.V. Radenko[1], A.V. Radenko[1], V.B. Svirkov[1]
[1]«Atomic and subatomic technologies» Technological Platform

Abstract. This study proposes a novel hybrid plasma energy system utilizing beryllium tetra hydroborate ($Be[BH_4]_2$) as a fuel, integrating magnetohydrodynamic (MHD) plasma acceleration, aneutronic fusion (p-^{11}B, p-^{9}Be), and an ion-driven klystron for direct ion-to-microwave energy conversion. The system targets compact aneutronic fusion (p-^{11}B, σ_{max} = 0.6 barn) via a helicon plasma source (13.56 MHz) generating high-density ion streams ($n_i \sim 10^{19}$ m^{-3}) at low temperatures (<10 eV).

Key innovations include:

1. $Be[BH_4]_2$ as a multifunctional ion source fuel – compact source of boron, beryllium, and hydrogen ions.
2. Ion-driven klystron-based quantum energy converter (QEC-2) with high-temperature superconducting (HTS)-coated resonators (T_C = 92 K), achieving 65% efficiency at 25 Hz, leveraging classical klystron design principles [1].
3. Magneto-optical confinement via solenoidal-quadrupole magnetic systems.

Theoretical efficiency reaches 30%, surpassing conventional tokamak-based systems. Challenges include plasma stability under pulsed MHD acceleration and low reaction cross-sections (σ < 1 barn). Future designs propose polarized fuels ($\uparrow p + {}^{11}B^*$) to boost reaction cross-sections ($\sigma\uparrow \times 10$) and terahertz klystrons with HTS resonators for grid-compatible wireless power transmission. Future directions involve integration with renewables.

Methodology

1. Plasma Generation:

Helicon RF source (13.56 MHz, B = 0.1 T) vaporizes $Be[BH_4]_2$, generating plasma with $n_i = 10^{19}$ m^{-3} [2].

Quadrupole lenses focus the ion beam, reducing emittance to 0.1 mm·mrad , leveraging advancements in helicon thruster design for fusion applications [2].

2. Fusion Chamber:

Aneutronic reactions include:

$p + {}^{11}B \rightarrow 3\,{}^{4}He$ (8.7 MeV, σ = 0.6 barn at 0.675 MeV) [3].

$p + {}^{9}Be \rightarrow {}^{10}B + \gamma$ (low neutron yield).

3. Klystron Energy Conversion:

HTS resonators convert He^{2+} kinetic energy into microwave oscillations (12–25 GHz), following advanced klystron principles for high-efficiency energy transfer [1].

Modeling. Plasma dynamics were modeled using COMSOL Multiphysics (MHD module), with fusion cross-sections validated against the TENDL-2024 library. Discrete ion beam formation was simulated via trajectory moment equations: $dQ/dz=P(z)Q(z)$, where $Q=(x,y,x',y')^T$ represents phase-space coordinates. Quadrupole lenses minimized emittance growth ($\epsilon_n<0.1$ mm·mrad).

Results

1. Key Parameters:

Power: 10 kW (steady-state), Efficiency: 30%, Frequency: 12–25 GHz.

Comparison with analogs:

ITER: 15–20% efficiency, requiring heavy neutron shielding due to D-T reactions [4].

HB11 Energy: Relies on petawatt lasers for proton-boron p-^{11}B fusion , as described in [3].

2. Advantages:

Aneutronicity: Negligible neutron flux reduces shielding requirements by 80% compared to tokamaks [4].

Compactness: 50% smaller footprint than conventional systems, suitable for microgrids and mobile applications.

Fuel Efficiency: 1 kg of $Be[BH_4]_2$ sustains ≈100 hours of operation.

3.Limitations:

Plasma instability during pulsed MHD acceleration.

High fuel purity requirements for $Be[BH_4]_2$ (≥99.95%).

Discussion

1.Technological Trends:

Polarized Fuel: Spin-aligned p+^{11}B∗ could increase σ by 5–10×, as demonstrated in tokamak experiments with polarized D-T fuel [5].

QEC-2 Performance: The quantum energy converter (QEC-2) design achieves 65% efficiency, as detailed in [6], using (multi)resonator klystron technology derived from classical Soviet-era advancements [1]. To increase the efficiency of converting the energy of fusion products into electrical energy, it is used in a quantum energy converter (QEC), which is an ion–emission electrovacuum device QEC-2 [6].

Renewable Integration: Hybrid "plasma-solar" microgrids systems for off-grid regions (e.g., Indonesia, Iran).

2.Market Applications:

Defense: Portable power units for radar systems (10 kW range).

Industry: Microwave heating for metallurgical processes (e.g., alloy sintering, sintering refractory alloys).

Conclusion. The system provides a viable pathway to neutron-free energy. Critical milestones include: 1. Experimental validation of plasma stability. 2. Cost reduction ($Be[BH_4]_2$ production <$500/kg). 3. Collaboration with Kurchatov Institute (Russia) and ASIPP (China).

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SONIFYING THE BIG SOLAR FURNACE: BRIDGING SCIENCE, SUSTAINABILITY, AND ART THROUGH AUDITORY DATA REPRESENTATION

G.Rogozinski[1,2], J.Shermatov[3], H.Vastiala[4]

[1]Herzen University, St. Petersburg, Russia
[2]Institute of Transport Problems of Russian Academy of Sciences, St. Petersburg, Russia
[3]Institute of Materials Science of Academy of Sciences of Uzbekistan, Parkent, Uzbekistan
[4]Aalto University, Espoo, Finland

The integration of emerging technologies into renewable energy systems presents a unique opportunity to enhance both functionality and public engagement. This project explores the application of *sonification* [1], as a process of converting data into non-verbal sound, in the context of high-temperature solar furnaces, with a particular focus on the Big Solar Furnace in Parkent, Uzbekistan. The project aims to bridge the gap between science, sustainability, and art by transforming real-time data from the solar furnace into auditory experiences. This approach not only facilitates process monitoring for specialists but also serves as an educational and artistic tool to promote public understanding and adoption of green technologies.

The Big Solar Furnace, a significant symbol of Uzbekistan's renewable energy potential, showcases the country's commitment to innovative and sustainable energy solutions. While the facility is a remarkable feat of engineering, there is an opportunity to further enhance its capabilities through advanced digitalization and data integration. The proposed sonification system aims to build on the existing infrastructure by leveraging available data sources and introducing additional IoT solutions at both consumer and industrial levels [2]. This approach is designed to ensure robust performance, even in environments with limited network coverage, by functioning seamlessly in both offline and real-time modes.

The sonification project is part of a broader expertise in multimodal data presentation, as demonstrated by previous initiatives. Notably, the experience gained from several projects in the Baltic region has been instrumental in advancing sonification techniques, particularly in creating accessible and user-friendly interfaces [3, 4]. These efforts have showcased the potential of sonification to transform complex data into intuitive auditory experiences, making it a valuable tool across various domains. The current project extends this expertise to the realm of renewable energy, aiming to create a functional and artistic tool that can detect anomalies and trends in the furnace's performance through auditory cues.

Key challenges include the large distances between complex blocks, heterogeneous data, and equipment issues. Proposed solutions involve a layering approach to data integration, the use of open protocols, and the implementation of project-friendly equipment. The ultimate goal is to shift from a mono-modal sound-only approach to a bi-modal audiovisual representation, enhancing the interpretability and accessibility of the data [5].

The digitalization of the solar furnace complex is expected to unlock the full potential of IoT, enabling stable real-time sonification streams. Once implemented, the project will provide an open data feed, allowing sonification enthusiasts worldwide to create their own performances. This initiative not only advances the technical capabilities of solar furnace monitoring but also fosters a deeper connection between renewable energy technologies and the broader community.

In conclusion, the sonification of the Big Solar Furnace represents a pioneering effort to merge scientific innovation with artistic expression. By transforming complex data into accessible auditory experiences, this project aims to enhance both operational efficiency and public engagement, contributing to the broader adoption of sustainable energy solutions.

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SYNTHESIS OF TiO_2 NANOTUBES AND DOPING WITH LANTHANUM (La) METAL

A.A.Samiyev, Sh.E.Mirzayev, O.N. Ruzimuradov, A.M.Nasimov

Samarkand State University
ahtam.samiyev7101@gmail.com

Abstract: Lanthanum-doped titanium dioxide (TiO_2) nanotubes were successfully synthesized through a two-step electrochemical approach. Initially, well-ordered TiO_2 nanotubular arrays were fabricated on the surface of high-purity titanium substrates via controlled electrochemical anodization under optimized conditions. This was subsequently followed by a secondary cathodic electrochemical treatment, during which lanthanum ions were introduced into the nanotube structure using an aqueous lanthanum nitrate [$La(NO_3)_3$] solution as the dopant precursor. The incorporation of La ions into the TiO_2 lattice was confirmed by advanced characterization techniques such as scanning electron microscopy (SEM), X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDX). The analytical and photoelectrochemical results clearly indicate that lanthanum doping plays a crucial role in enhancing the light absorption properties, charge separation efficiency, and overall photoelectrochemical conversion performance of TiO_2 nanotube-based electrodes.

Keywords: TiO_2 nanotubes, electrochemical anodization, voltage, temperature and time, anatase, rutile, La, photoelectrocatalytic.

In recent years, titanium dioxide (TiO_2) has been widely studied and applied as a photocatalyst due to its environmental friendliness, low cost, non-toxicity, and high photocatalytic activity. TiO_2 nanotubes have attracted significant attention in fields such as photocatalysis, gas sensors, environmental remediation, and solar cells. Unfortunately, their application has revealed certain limitations, including the high recombination rate of photogenerated electron-hole pairs and the wide band gap (3.2 eV for anatase and 3.0 eV for rutile), which restrict processes driven by visible light. These factors may hinder the widespread application of TiO_2 nanotubes to address this issue, various metals can be incorporated into the TiO_2 structure. Some studies have reported that the incorporation of La metal into TiO_2 can effectively stabilize the structure and enhance its

photoactivity [1]. Many studies have reported that the energy conversion efficiency of La/TiO_2 composite samples is relatively low. Due to its good mechanical adhesion, electronic conductivity, and large surface area for photoelectrochemical reaction, La-doped TiO_2 nanotubes provide a better system to overcome the above problems. In this study, La-doped TiO_2 nanotubes were successfully synthesized and their photocatalytic properties were improved to some extent. Meanwhile, there are several scientific reports on the preparation of La-doped TiO_2 nanotubes using electrochemical approaches and the study of their photocatalytic properties.To overcome these limitations, extensive investigations have been dedicated to the advancement of semiconductor materials with superior photoelectrocatalytic performance. Titanium dioxide nanotube arrays (TNTs) have garnered significant attention as a promising candidate due to their large specific surface area, excellent mechanical robustness, and one-dimensional architecture, which facilitates efficient charge transport. These nanotube arrays are typically synthesized via electrochemical anodization, yielding vertically oriented structures with tunable morphology and dimensional characteristics [2]. Furthermore, this study presents an in-depth and critical review of the prevailing synthesis strategies for TiO_2 nanotubes, along with a detailed examination of the fundamental physicochemical parameters that influence the nucleation, growth, and morphological control of the nanotubes[3]. Emphasis is placed on the influence of anodization voltage, electrolyte composition, pH, temperature, and anodization time, all of which significantly impact the structural, optical, and electronic properties of the resulting nanostructures. Additionally, the paper outlines the theoretical and experimental models that have been proposed to explain the formation mechanisms of TiO_2 nanotubes, including field-assisted dissolution, ion migration, and self-organizing growth theories. Collectively, the findings contribute valuable insights toward the rational design of doped TiO_2 nanostructures for high-performance applications in photocatalysis, solar energy conversion, and environmental remediation[4].

In this experiment, titanium foil (100 μm thick, 99.6% purity, Sigma-Aldrich) was cut into 2×2 cm pieces. The samples were then subjected to ultrasonic cleaning for 10 minutes in acetone, ethanol, and distilled water to remove surface contaminants. Cleaned titanium foil was air-dried for 50 minutes. Subsequently, the sample was subjected to electrochemical anodization for 4 hours using a constant Direct Current (DC) power source. The electrolyte composition consisted of 0.5% NH_4F, 2% H_2O, and ethylene glycol (EG). The synthesis process was carried out at a constant voltage of 60 V. Key parameters, such as electrolyte temperature (30 °C) and pH (5–5.5), were monitored throughout the process. Graphite (C) was used as the counter electrode. The resulting TiO_2 nanotubes were annealed at 400 °C for 2 hour to induce phase transformation from the rutile phase to the anatase phase.

To introduce La metal into the calcined foil, 0.5 M solution of $La(NO_3)_3 \cdot 6H_2O$ was prepared. Subsequently, doping was carried out using a galvanostat. According to the X-ray fluorescence (XRF) elemental analysis results, La metal content in these samples reached up to 1.1%

In conclusion, TiO_2 nanotubes were synthesized using the electrochemical anodization method. Throughout the process, parameters such as voltage, temperature, electrolyte concentration, and other factors were strictly controlled. Various properties of the synthesized TiO_2 and La/TiO_2 nanocomposite materials were investigated. Lanthanum was doped into TiO_2 nanotubes using the cyclic voltammetry method. The La/TiO_2 nanocomposite material exhibited photocatalytic properties, making it suitable for various applications. We have successfully synthesized TiO_2 nanoparticles using a versatile, non-toxic, and biocompatible approach conducted at ambient temperature, entirely free from any chemical reagents. This green, single-precursor, catalyst-free method is straightforward, cost-effective, and environmentally sustainable, rendering it highly suitable for a broad range of applications. X-ray diffraction (XRD) analysis confirmed

that the synthesized nanoparticles exhibit a tetragonal anatase phase of TiO_2 with nanoscale dimensions. Furthermore, XRD characterization provided insight into key physicochemical parameters, including specific surface area, dislocation density, and morphology index.

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BIOPOLYMER-SILICA NANOCOMPOSITES

Begimkulova Ch. K., Shakarova D.Sh.
Institute of General and inorganic chemistry, Uzbek Academy of Sciences

Biopolymer-silica nanocomposites are innovative materials that combine the properties of biopolymers with silica nanoparticles, and these materials represent a constructive alternative for the development of new materials. Due to the diversity of these properties, they are of interest in fields such as optics, electronics, and catalysis, in the production of membranes, coatings, catalysts, sensors, and adsorbents for various purposes [1].

Currently, biopolymer-silica nanocomposites are regarded worldwide as promising, with their nanostructure, degree of organization, and properties depending on the chemical nature and synergy of the components included in these materials [2].

A universal approach for the synthesis of biopolymer-silica nanocomposites is the sol-gel method. The mild conditions for conducting the hydrolytic polycondensation of the silica precursor, which is most often alkoxysilanes, allow for the introduction of functional monomers and biopolymers into the reaction system. Such diverse components of inorganic and organic nature can be mixed on a nanometer scale in virtually any ratios, leading to the formation of nanocomposite biopolymer-silica materials.

The structural nano-level characterizes not only the dimensionality of the dispersed system but also the special structural organization of the material, meaning a transition to a fundamentally new quality with new properties. The formation of nanosized structures in the liquid phase and at the phase boundary during the sol-gel process occurs due to self-organization processes, which directly influence the thermodynamic and hydrodynamic characteristics of the system. Depending on the chemical nature of the starting compounds, their relative concentrations, and the conditions of the sol-gel process, the final nanocomposite can have a morphology consisting of silica particles within an organic polymer matrix, interpenetrating phases, or polymer domains within a silica matrix.

Our research is to develop a scientific basis for one-pot synthesis of biopolymer-silica (fibroin-silica) nanocomposites with controlled nanostructure, functionality, and surface properties using the sol-gel process in situ. The use of sol-gel process in situ allows us to get in one step a new generation of nanocomposites (adsorbents) differing principally from those used in chromatographic separation practice by the presence of functional groups not only on adsorbent surface but also inside of matrix. It will give a common increase of functionality and a significant increase of adsorbents selectivity, but also allows increasing significantly the separation effectiveness while maintaining the other properties of sorption materials other properties. Such approaches of sol-gel technology use in the course of nanocomposites obtaining for various applications begin to attract specialized attention.

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METHOD FOR THE MANUFACTURING AND OPTIMIZATION OF DYE-SENSITIZED SOLAR CELLS BASED ON TiO_2

Sharipbaev S.S.
Namangan State Technical University, 160115, Namangan, Uzbekistan
E-mail: sharipbayev1999@mail.ru

Abstract

This paper presents a method for the manufacturing of dye-sensitized solar cells (DSSC) based on titanium dioxide (TiO_2). It describes the preparation processes of the photocathode layer, gel electrolyte, and the use of Ruthenizer 535 dye. The optimization of these technologies increased both the efficiency and stability of the cells while reducing their production costs, making DSSC a promising solution for renewable energy sources.

Keywords: Dye-sensitized solar cells (DSSC), titanium dioxide (TiO_2), liquid electrolyte, gel electrolyte, photoanode, Ruthenizer 535, light absorption, energy efficiency, graphite, renewable energy.

Introduction

Modern trends in energy technology development are aimed at finding alternative and environmentally friendly energy sources. One of the promising directions is the application of dye-sensitized solar cells (DSSC), which have several advantages compared to traditional silicon photovoltaic cells, including lower production costs, simple manufacturing, and stable operation under diffused light conditions [1.1]. However, DSSCs have lower efficiency and durability compared to their silicon counterparts, requiring further research and the development of new manufacturing approaches.

This work presents a comprehensive approach to the development and production of DSSCs based on titanium dioxide (TiO_2), including the modification of the photocathode layer, the optimization of the gel electrolyte composition, and the selection of an effective Ruthenizer 535 dye. The aim of the research is to improve the efficiency and stability of DSSCs through the introduction of new materials and technological solutions.

Main Part

1. Theoretical Fundamentals of DSSC

DSSC are thin-film photovoltaic devices where light absorption occurs through dye molecules deposited on a semiconductor substrate—titanium dioxide (TiO_2). The main components of DSSCs include a transparent electrode, a TiO_2-based photoanode, a dye-sensitizer, an electrolyte, and a cathode [1.1, 1.2].

The advantages of DSSCs are their ability to operate under low light conditions, their flexibility in substrate choice, and the use of inexpensive materials. However, issues such as dye degradation and electrolyte leakage limit their lifespan [1.1].

2. Electrolyte Preparation Technology

To enhance stability and ionic conductivity, a gel electrolyte based on polyethylene oxide (PEO) and polymethyl methacrylate (PMM) was developed, with the addition of tetrapropylammonium iodide (TPAI) and iodine (I_2). The manufacturing process includes vacuum drying of the components, dissolving PEO, EC, and PC in dimethylformamide (DMF), adding TPAI and iodine, mixing at 70°C, and holding the mixture for 24 hours for stabilization [1.3].

3. Preparation of the TiO_2 Layer

The photoanode layer was obtained by applying a TiO_2 paste (P25 grade) onto conductive glass with an FTO coating. The paste was prepared by mixing TiO_2 nanoparticles with nitric acid, polyethylene glycol, and Triton X-100. The resulting paste was then applied to the glass and thermally treated at 450ºC for 30 minutes to form a stable porous layer.

4. Dye Impregnation of the Photoanode

Ruthenizer 535, a ruthenium-based dye, was used as the sensitizer. The prepared photoanode was immersed in an ethanol-based dye solution and subjected to ultrasonic treatment for 15 minutes. To ensure effective dye molecule fixation, the samples were kept in a dark environment for 24 hours.

5. Assembly of the Solar Cell

The cathode was made of FTO glass coated with graphite, serving as a catalyst. After assembling the photoanode and cathode, the space between them was filled with the prepared gel electrolyte, forming a complete working system.

6. Results and Discussion

Experimental results showed that the proposed method ensures uniform TiO_2 coverage and reliable fixation of the sensitizer. The use of gel electrolytes improved the cell's stability and reduced electrolyte leakage. The photovoltaic parameters demonstrated enhanced short-circuit current and fill factor compared to traditionally manufactured cells [1.2, 1.4].

Conclusion

The developed method for producing DSSCs based on TiO_2, with the use of a gel electrolyte and Ruthenizer 535 dye, enhances solar energy conversion efficiency, reduces production costs, and increases the lifespan of solar cells. Future research should focus on transitioning from liquid and gel electrolytes to solid-state systems, as well as developing new dyes with an expanded light absorption spectrum.

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FORMING A HIGHLY ORDERED POLYSTYRENE TEMPLATE

M.A.Sobitov[2], B.B.Gulamov[1], G.B.Khojieva[1,2], O.M.Tursunkulov[1], Sh.G.Khojiev[1].

[1]Center for Advanced Technologies.
[2]National University of Uzbekistan.

Materials exhibiting a uniform pore arrangement offer a wide range of applications, such as photocatalysis, electronics, energy storage and conversion system, which rely on the solid matrix's chemical properties and the properties specific to the pore size and arrangement [1]. Templates play a central role in the synthesis of 3DOM structures, serving as a matrix for the formation of the desired porous architecture [2]. The template method is one of the most common approaches to obtaining 3DOM materials. In this process, the template is typically an ordered structure, such as a colloidal crystal consisting of monodisperse spheres (polystyrene, silica, etc.). The space between the template particles is filled with a material precursor, which is then cured, and the template is removed, leaving behind a porous structure with ordered pores [3]. Without such an ordered template, it is impossible to obtain 3DOM structures since the random arrangement of particles will lead to irregular porosity, devoid of the advantages of three-dimensional ordering. These features make the ordering and structure of the template fundamental for the application of 3DOM materials in catalysis, photonics, sensors, and other areas where optimization of mass transfer, light scattering, or conductivity is required. Thus, the selection and preparation of the template are key steps in the synthesis process.[4]

In this work, monodisperse polystyrene spheres of uniform size were synthesized by the surfactant-free emulsion polymerization method, and a highly ordered PS template was obtained. The degree of ordering and surface morphology of the obtained PS template were studied using SEM. In traditional emulsion polymerization, surfactants form a stabilizing shell around the polymer particles, preventing their coagulation. However, in the polymerization without emulsifier using potassium persulfate, stabilization occurs due to electrostatic repulsion between charged particles. The emulsion is stabilized by the charge formed by sulfate groups on the surface of the polymer particles. Electrostatic repulsion prevents the particles from sticking, but the system is sensitive to the pH and ionic strength of the solution.

The obtained polystyrene spheres size is very close to monodisperse, and they are densely packed with high order. From this conclusion, it can be concluded that the morphology of the PS template with an opal structure has been obtained. This study was carried out as a joint project funded by KOICA, in collaboration with the Korea Research Institute of Chemical Technology (KRICT) and the Advanced Technology Center (ITC).

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STRUCTURE AND OPTICAL ABSORPTION PROPERTIES OF TiO_2 THIN LAYER OBTAINED BY ATOMIC LAYER DEPOSITION

T.K. Turdaliev*, F.I. Abdurakhmanov, K.K. Medvedeva
Arifov Institute of Ion-Plasma and Laser Technologies, Uzbekistan Academy of Sciences
e-mail: turdaliev@iplt.uz

TiO_2 is one of the most promising wide-bandgap semiconductors, widely used in photovoltaics, photocatalysis, gas sensing, and optical devices due to its excellent transparency, chemical stability, and strong UV absorption [1–2]. The structural and optical properties of TiO_2 thin films largely depend on the deposition technique, crystalline phase, defect concentration, and post-deposition treatments.

In this work, TiO_2 thin films were synthesized using plasma-enhanced atomic layer deposition (PEALD), which ensures superior thickness control, surface conformity, and uniformity. The deposition was carried out at a substrate temperature of 250°C using titanium isopropoxide (TTIP) and water as precursors, with nitrogen as the carrier gas. Quartz glass (JGS1) substrates were selected due to their high optical transparency in the 185–2500 nm range. The number of deposition cycles varied from 750 to 1250, allowing film thickness to be tuned from ~150 to 250 nm.

Raman spectroscopy was employed to analyze the crystal structure of the films. The spectra revealed characteristic peaks at 143, 194, 392, 514, and 637 cm^{-1}, corresponding to the Eg, B1g, and A1g modes of anatase TiO_2 [4]. No features indicative of the rutile phase (such as peaks at 447 or 612 cm^{-1}) were observed, confirming the single-phase anatase structure across all samples.

The optical absorption spectra, measured using a UV-Vis spectrophotometer in the 250–650 nm range, showed strong absorption in the UV region ($\lambda < 400$ nm), typical for anatase TiO_2. Normalized spectra across different samples maintained a consistent shape, indicating stable material composition and minimal variation in electronic transitions. The absorption edge exhibited a slight redshift with increasing cycle number, likely due to thickness effects and defect-related band tailing. The optical bandgap (Eg) was calculated using Tauc plots assuming a direct allowed transition ($n = 2$). Linear extrapolation of the $(\alpha h\nu)^2$ vs. $h\nu$ curves yielded an average Eg of 3.3 eV, which is consistent with the anatase phase [3,5]. A slight exponential tail in the absorption edge suggested the presence of localized states associated with structural disorder, oxygen vacancies, or grain boundary effects.

These findings highlight that ALD is a reliable method for fabricating nanostructured TiO_2 films with controlled thickness, well-defined anatase phase, and stable optical properties. The resulting films are suitable for integration into optoelectronic devices, UV filters, and photocatalytic systems where high transparency and tunable absorption are required.

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CARBOTHERMAL REDUCTION OF ZnO IN A VERTICAL OPTICAL AXIS SOLAR FURNACE.

Sulaymonov S.H., O‘rinboyev R.R.
Institute of Materials Science, Uzbekistan Academy of Sciences, Chingiz Aytmatov St. 2B, Tashkent, 100084, Uzbekistan
E-mail: rahimjonravshanovich1990@gmail.com

Keywords: H_2O water, ZnO zinc oxide, Zn zinc, O_2 oxygen, H_2 hydrogen, (Al_2O_3) aluminum oxide, CO carbon (II) oxide, C carbon.

This scientific work gives priority to the technology of obtaining H2 by thermochemical decomposition of H_2O. This is due to the fact that the thermochemical method consists of two stages. For example, for the ZnO/Zn system, initially the ZnO dissociation process occurs and metal Zn is obtained. In this reaction, free O_2 is released. In the next stage, metal Zn is oxidized at a temperature of ~ 350 - 450 °C and free H_2 is obtained[1]. This reaction is good because the processes of H2 and O_2 formation are separated and there are no conditions for the formation of explosive mixtures of H_2 - O_2. This is especially important for our institute, which does not have experience working with pure H_2 and the necessary infrastructure.

Based on this, we chose the safest, with minimal risk, technology of thermochemical decomposition of H2O.

A laboratory-scale solar reactor for the carbothermic reduction of ZnO has been designed and fabricated[2]. The reactor is designed to operate at the focal point of a solar furnace with a vertical optical axis.

Compared to thermal dissociation of ZnO, the addition of carbon to ZnO offers two major advantages:

1) it reduces the required process temperature by about 600 K;

2) the resulting gas consists mainly of Zn and CO (rather than Zn and O_2). Condensation of Zn from such a gas mixture largely prevents the recombination of zinc vapor and oxygen to form ZnO.

Similar to the thermal dissociation process of ZnO, carbothermic zinc using solar heat provides a flexible storage of solar energy. Zn metal can be stored and transported, which allows its energy content to be further utilized in various processes that close the material cycle[3].

A simplified chemical reaction for the carbothermic reduction of ZnO is:

$$ZnO + C = Zn + CO;\ \Delta H\ 1500K = 350kJ/mol$$

Thermodynamically, the reaction is completed at temperatures above 1220 K.

To achieve an appropriate reaction rate, it is recommended to operate at temperatures around 1400 - 1500 K.

The concentrated solar radiation enters the reaction chamber through a quartz glass with a diameter of 70 mm and a thickness of 6 mm to obtain the optimal temperature at which the reactants react. The reaction chamber is made of graphite in the form of a cylindrical glass with an outer diameter of 65 mm and an inner diameter of 55 mm. At the bottom of the glass there is a hole with a diameter of 11 mm, into which a graphite plate piston is inserted to supply ZnO to the reaction zone. At the top of the reaction chamber there are two holes with a diameter of 7 mm, one of which is intended for supplying argon, and the other for discharging the reaction products to the cooling device. The material of the reaction chamber, graphite, also serves as a reducing agent for ZnO[4]. In the case of carbothermic reduction, the reaction surface of the upper ZnO layer is deposited during the reduction process (“reducing layer”), which allows the gaseous products to easily escape from the reaction layer. Otherwise, the growing layer of residual material on top of the unreacted feedstock acts as an insulator, reducing the temperature and therefore the reaction rate below it.

The reaction chamber is enclosed in a fireproof heat-insulating tube made of corundum (Al_2O_3) with an outer diameter of 89 mm, an inner diameter of 68 mm, and a height of 84 mm. The

internal thermal insulation serves to retain heat in the reaction chamber and protect the reactor vessel.

The inner surface of the cooling chamber is blown with argon to prevent Zn condensation on the inner surface. Argon causes rapid cooling of the Zn vapor and subsequent crystallization.

The crystallized Zn metal powder is collected at the bottom of the cooling chamber. The exhaust gases pass through a gas filter, where a fine fraction of Zn nanoparticles settle. The cooling chamber has a H_2O cooling system to increase the cooling rate of the reaction products.

The initial test of the solar reactor was carried out at the focus of a solar furnace with a vertical optical axis. The experiment showed that the quartz window is located far from the argon supply point and, accordingly, is poorly ventilated. Partial sputtering with zinc occurs on the surface of the quartz window, which reduces the share of solar radiation and lowers the temperature in the reaction zone. The reduction efficiency of ZnO was lower than expected.

The experiments showed that it is necessary to change the design of the high H_2O-cooled flange and increase the argon flow to the quartz inlet window.

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ION-EXCHANGE SYSTEMS FOR THE SORPTION OF RARE AND PRECIOUS METALS

X.Usmonova, M.Mukhamediev
Department of Polymer Chemistry, Faculty of Chemistry, National University of Uzbekistan, Tashkent, Uzbekistan
xurshidau02@gmail.com

Ion exchange is a cornerstone technique in the chemical extraction and separation of heavy, toxic, and precious metal ions, widely applied in industries ranging from metallurgy to environmental remediation. The scarcity of precious metals (e.g., gold, platinum group metals) and rare earth elements (REEs), coupled with the depletion of natural deposits, underscores the importance of recovering these elements from secondary sources such as spent catalysts, anodic slimes from copper and nickel electrorefining, and industrial wastewater from oil refineries and electronics manufacturing [1]. These sources often contain trace amounts of valuable metals, necessitating selective and efficient extraction methods. The separation of precious metals from complex matrices, including geological samples and industrial byproducts, remains a critical challenge due to their low concentrations and the presence of interfering ions [2]. This study reviews ion-exchange technologies for precious metal recovery and presents experimental findings on the sorption of cerium ions using interpolymer systems, addressing the urgent need for advanced wastewater treatment in chemical industries.

The study utilized synthetic ion-exchange resins КУ-2-8 (a sulfonic acid cation exchanger) and AN-31 (a quaternary ammonium anion exchanger), commonly employed in industrial applications across Uzbekistan and globally (e.g., analogs like Dowex and Amberlite) [3]. Interpolymer systems were prepared by combining КУ-2-8 and AN-31 in molar ratios ranging from 1:1 to 3:3. Cerium sorption was investigated using a nitric acid solution of $Ce(NO_3)_3$ (initial concentration: 100 mg/L). Batch experiments were conducted at 25°C with continuous stirring (200 rpm) for up to 48 hours. Ion-exchange dynamics were analyzed via electrical conductivity (using a Hanna HI-98129 meter), pH-metry (Mettler Toledo FiveEasy), and inductively coupled plasma atomic emission spectroscopy (ICP-AES, Agilent 5110) to quantify cerium concentrations. Sorption efficiency was calculated as:

$$S\ (\%) = C_0 - C_t/C_0 \times 100$$

where (C_0) and (C_t) are initial and residual cerium concentrations, respectively.

Ion-exchange resins are high-molecular-weight, cross-linked polymers with functional groups (e.g., $-SO_3H$ for cationites, $-NR_3^+$ for anionites) that facilitate ion exchange, complexation, and redox reactions [4]. In this work, the interpolymer system КУ-2-8:AN-31 at a 3:3 molar ratio exhibited optimal performance. After 6 hours, this system achieved a 1.5-fold increase in cerium sorption compared to AB-17-8 alone (44% vs. 28%) and a 7-fold increase compared to КУ-2-8 (38% vs. 5%) after 24 hours. Total sorption after 48 hours reached 51% for the 3:3 system, surpassing individual resins (38% for КУ-2-8, 44% for AN-31). This enhancement is attributed to mutual activation within the interpolymer matrix, where the cationite and anionite synergistically increase the availability of active sites through two-stage dissociation in aqueous media, as evidenced by conductivity shifts from 0.15 to 0.22 mS/cm over 24 hours.

Globally, ion-exchange technologies are pivotal for rare metal recovery. For instance, Dowex resins have been used to extract REEs from acid mine drainage, achieving up to 90% efficiency under optimized pH conditions [5]. Similarly, the strategic importance of REEs—e.g., gadolinium and erbium in nuclear reactors or cerium in catalytic converters—underscores the need for efficient sorbents [6]. The interpolymer approach in this study aligns with trends toward hybrid systems that enhance selectivity and capacity, offering a scalable solution for industrial wastewater treatment in regions like Uzbekistan, where chemical pollution is a growing concern.

The interpolymer system КУ-2-8:AN-31 (3:3) significantly improves cerium sorption efficiency compared to individual resins, demonstrating the potential of combined ion-exchange materials for rare metal recovery. Its enhanced performance, driven by synergistic activation, positions it as a promising tool for wastewater purification and resource recovery. Further optimization could broaden its application to other precious and rare metals, supporting sustainable industrial practices.

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PRODUCTION OF AMORPHOUS Cu NANOPARTICLES USING A CHEMICAL METHOD UNDER THE ACTION OF ULTRASOUND AND MAGNETIC FIELD

A.Yarbekov
Turin Polytechnic University in Tashkent, a.yarbekov@polito.uz

Chemical methods for obtaining copper nanoparticles are based on the processes of reducing copper compounds. Copper ions can be reduced to Cu, Cu2O or CuO depending on the reducing ability of the reducing agent (1). In the chemical reduction of copper nanoparticles, reducing agents are used that have a lower oxidation-reduction potential than copper (II) ions. The list of reducing agents are given in research paper (2).

Effect of ultrasound on the reaction. Ultrasonic waves create bubbles that encapsulate copper(II) ions and ascorbic acid. The reduction of these ions releases hydrogen, forming bubbles that burst and release copper nanoparticles. The rapid collapse of these bubbles generates extremely high temperatures((5000–25000 K)) and cooling rates((over 10^{11} K/s)), leading to the formation of amorphous nanoparticles due to inhibited crystallization.

In our experiment, ascorbic acid acts as a reducing agent. It is an organic compound with an oxidation-reduction potential of -0.25 V, which is lower than that of copper (II) ions (+0.34 V).

Three methods were used: **Method 1.** Copper nanoparticles were synthesized without using a stabilizer. **Method 2.** Copper nanoparticles were synthesized using the stabilizer polyvinylpyrrolidone (PVP). **Method 3.** Synthesis of nanoparticles using a combination of ultrasound and a magnetic field.

Experimental setup: Ultrasonic transducer with maximum power of 200 watts has 4 transducers. Each transducer has a power of 50 watts and ultrasound is directed vertically upward from four sides to ensure the uniformity of ultrasound and create a complex acoustic field.

Method 1: Synthesis of copper nanoparticles was carried out without using a stabilizer. To obtain copper nanoparticles, a solution of CuSO4 5H2O in an aqueous solution with a salt concentration of 0.16 mol / l and a volume of 400 ml was prepared and 200 ml of ascorbic acid was added to the solution with continuous stirring on a magnetic stirrer. In the work (3), to determine the optimal ratio between copper salt and the reducing agent ascorbic acid, solutions stabilized with polyvinylpyrrolidone were prepared with a ratio of copper sulfate: ascorbic acid = 1:50, 1:75, 1:100, 1:150 and a concentration of CuSO4 5H2O of 0.01 mol / l. As an alkaline agent, a concentrated solution of NaOH was added dropwise to pH 10-11. In our work, we used the ratio copper sulfate: ascorbic acid = 1:10 in each method.

Result: Copper synthesis under the influence of ultrasound continued for 1 hour. At first, the color of the solution was green; after adding the precursor, the color of the solution became yellowish. After 20-30 minutes from the start of the experiment, the color became bright brown. It can be said that the chemical reduction method can be carried out in combination with ultrasound.

Analysis. XRD analysis confirmed the presence of 81.07% amorphous structures and 18.93% crystalline structures in the synthesized samples. Morphology analysis (SEM) shows that the nanoparticles are mostly spherical with some degree of faceting. Non-uniform size distribution with minimal agglomeration. To prevent agglomeration of nanoparticles during synthesis, stabilizers should be used. The duration of ultrasound exposure is inversely proportional to the particle size. Therefore, the optimal reaction time is 30 minutes.

Method 2: Additional to substances used in Method 1 the stabilizer polyvinylpyrrolidone (PVP) was added to the solution. The ratio of copper sulfate: ascorbic acid = 1:10 was used. But the duration of the reaction under the influence of ultrasound lasted 30 minutes.

SEM analysis was taken. Comparing Method 1 with Method 2, we can see that the size of the nanoparticles is smaller than method 1. This indicates that the optimal reaction time is 30 minutes as mentioned above. The presence of PVP prevents excessive agglomeration and growth.

Method 3: The reaction took place using a combination of ultrasound and a magnetic field. The duration of the reaction under the influence of a magnetic field lasted 60 minutes. SEM analysis of the synthesized honey nanoparticles was obtained. Comparing Method 1, Method 2, Method 3 one can see that the size of the nanoparticles obtained by Method 3 is smaller than the particles synthesized method 1 and method 2. However, Method 3 shows nanoparticles with more uniform shapes, suggesting that the magnetic field may promote more uniform crystal growth.

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CRYSTALLINE AND COMPOSITION STRUCTURE OF $CsPbBr_3$ PEROVSKITE THIN FILMS OBTAINED BY VACUUM THERMAL EVAPORATION METHOD

R.R. Kabulov, S.Yu.Gerasimenko, F.A. Akbarov, M.U. Khajiev, F.T.Pulatova, N.R.Homidova, L. O‘.Shuhratova, A.X.Tursunova.

Physical-technical Institute named after S.A.Azimov of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

The demand for photovoltaic devices based on perovskites, which are powered by low-cost renewable energy sources, is increasing year by year. Therefore, the choice of a technology for producing perovskite thin films on large surfaces is important. Small deviations in the technological processes of perovskite thin films prepared using many solvent-based technologies, changes in their parameters can lead to a decrease in the efficiency of electronic devices. Vacuum thermal evaporation (VTE) technology can effectively solve the problems arising from the use of solvents. The vacuum environment reduces contamination during the layer growth process, ensures the formation of high-purity and low-defect layers in perovskite thin films [1,2]. Devices created on the basis of layers obtained by the VTE method have shown good optical and electronic properties [3,4].

Currently, there are two methods of growth of the VTE method using a single evaporation source (SES) [5-7] and two evaporation sources (TES) [8]. In the TES technology, two perovskite precursors are simultaneously evaporated from independent sources at different temperatures for each precursor in the reactor. In the SES technology, two perovskite precursors are simultaneously evaporated from a single evaporation source at the same temperature in the reactor. It has been shown that high-quality organic CH_3NH_3I/BiI_2 [9] and inorganic $CsPbBr_3$ [10] layers were obtained using the SES technology. Organic perovskite layers have shown the property of changing their parameters (degradation) over time. Inorganic $CsPbBr_3$ perovskite structural layers demonstrate their relatively non-degradation properties and are considered as unique materials for various optoelectronic devices. It can currently be used as a tandem or buffer-intermediate layer element in high-efficiency light-emitting devices (LEDs) [2], green light-emitting diodes, and solar cells [3].

In the presented work, non-gamic perovskite thin films of $CsPbBr_3$ were grown on glass substrates using the SES vacuum thermal evaporation method, and their crystal structure was

studied by X-ray diffraction (XRD Diffractometers Empyrean Malvern Panalytical), surface morphology by scanning electron microscope (SEM - Scanning electron microscope - JSM IT 510LV), and chemical composition by energy dispersive elemental analyzer (EDX (Oxford Instrument) - Aztec Energy Advanced X-act SDD). Before the layer growth process, the glass substrates were cleaned of various chemical elements using an ultrasonic bath. The cleaning process was carried out in three consecutive stages for 13 minutes. Three substances were used in these stages, namely acetone, deionized water, and isopropyl alcohol. After the substrate cleaning processes were completed by drying in a nitrogen stream, the glass substrates were placed in a vacuum thermal spray device. The precursors of the $CsPbBr_3$ perovskite, CsBr and $PbBr_2$, were placed in a thermal source with a purity of 99.999% in the ratio Cs:Pb = 50:50. The process of depositing the perovskite layer began with a gradual increase in the heater temperature until sublimation began and reached 400 °C. The CsBr and PbBr2 molecules sublimated from the sources condensed on the surface of a glass substrate at a temperature of 200 °C, forming a thin layer. The color of the synthesized $CsPbBr_3$ thin layer was yellow, and the band gap was ≈ 2.3 eV. The X-ray diffraction results and SEM images of the surface morphology of the $CsPbBr_3$ perovskite thin layers with a thickness of ≈ 500 nm showed that the synthesized layers have a polycrystalline structure, and the crystallite sizes ranged from 0.2 μm to 2.5 μm. The arrangement of crystallites in the resulting $CsPbBr_3$ perovskite layers is uniform across the surface.

Energy dispersive X-ray analysis of the $CsBrPb_3$ layer grown on a glass substrate by evaporation from CsBr and PbBr2 precursors in the ratio of SES Cs:Pb = 50:50 showed that the Cs:Pb:Br ratio was 27:13:60. That is, in the grown $Cs_xPb_{(1-x)}Br_3$ layer, x=0.675 was obtained. This indicated an abundance of Cs in the grown layer. This result is explained by the higher boiling point of CsBr (T ≈ 635oC) compared to the boiling point of $PbBr_2$ (T ≈ 360 °C), that is, less $PbBr_2$ with high kinetic energy settles in the growing layer, and more CsBr with lower kinetic energy is released. The X-ray diffraction results of the grown $CsPbBr_3$ layers showed that the microcrystalline layer consists of two main phases: CsPbBr3 and Cs4PbBr6. Considering the EDX results, the ratio of $CsPbBr_3$ and Cs_4PbBr_6 phases ($CsPbBr_3$:Cs_4PbBr_6) in the $Cs_{0.675}Pb_{0.325}Br_3$ layer grown on a glass substrate by evaporation from CsBr and PbBr2 precursors in the ratio BBM Cs:Pb = 50:50 is ≈ 0.5:0.5.

There are opinions in the literature that larger crystal grains in $CsPbBr_3$ perovskite layers lead to lower recombination losses, however, compared to layers grown using solution, the crystallite sizes of the obtained devices are not significantly smaller. In currently available perovskite-based LED devices, the thickness of the photoactive layers is about ≈ 500 nm. In light-emitting diodes with a simple structure (anode, electron transport layer (ETL), perovskite emission layer, hole transport layer (HTL) and cathode), this perovskite thin film can be used as an emission layer, in which an electric voltage is applied to the device in the right direction, electrons and holes are injected from the ETL and HTL into the perovskite layer, respectively. The ETL and HTL layers send charges to the perovskite emission layer. The electrons and holes injected into the perovskite layer move towards each other under the influence of an electric field and, upon meeting (simultaneously and in space), emit light equal to the band gap (Eg) of the perovskite semiconductor during the recombination process. The more charge carriers, the more recombination occurs and the higher the light output. When charge carriers move in the vertical direction, if the size of the crystallite grains matches the thickness of the perovskite, they recombine without recombining at defect states at the crystallite boundaries, releasing energy equal to Eg.

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MICRO PORE FORMATION DURING REDOX OF IRON FOAM MATERIAL USED AS ENERGY STORAGE UNIT IN METAL-AIR BATTERIES

Paizullakhonov M.S., Abduraimov S.M.
Institute of Materials Science

This research aimed to investigate the problems arising in the energy storage unit for iron air batteries. In particular, the coefficients of expansion and contraction at different temperatures observed when using iron foam materials in the energy storage unit when reduced with hydrogen gas. Reduction reactions conducted at temperatures ranging from 700 to 1000◦C under hydrogen. The expansion and contraction process, which is one of the main problems encountered in the reduction of iron oxide with hydrogen and its use as an energy storage unit, has investigated. Microstructure and porosity of iron foam material used as energy storage unit analyzed. In this study, we examined the porosity structures formed during the reduction of iron oxides. The formation of microstructure and porosity and their amount calculated using computer programs.

In the above-mentioned microstructures, the contact surface of a single oxide particle with a reducing gas (pure hydrogen) was analyzed. In the experiment, iron oxide particles with a size of 100-1000 microns were reduced at a temperature of 700-1000 ºC.

From the microstructural analysis of samples selected in different modes and Table 1 filled out on its basis, it is clear that the reduction of oxides in accelerates with increasing process temperature.

In order to determine the influence of the reducing environment (H_2), time and temperature of the process on the porosity of particles of reduced iron powder, the microstructure of samples selected in different modes was determined. In Fig. Figure 1 shows the pore microstructure of iron particles regenerated in various modes in an environment of pure hydrogen H_2.

From the microstructure in Figure 1 it is clear that an increase in the reduction temperature in a pure hydrogen environment (700-1000 °C) had a great influence on the shape of porosity and the particle size of the reduced iron. At relatively low temperatures, the pore size is small and the pores are not connected to each other. As the temperature increased, the pore size increased and as a result, the pores connected with each other. S. H. Kim provided detailed information on the effect of pore size based on his experiments on not only the reduction temperature but also the duration of the process [1].

To determine the influence of the reduction medium, time and temperature of the process on the porosity of particles of reduced iron powder, completely reduced particles were determined from the microstructure of samples taken in different modes. Only in the sample reduced at 700 ºC were no completely reduced particles found. The reason, as we said above, is that the depth of the reduction is too shallow.

Before designing the microstructure of iron foam materials used as energy storage units (including laminar structures), it is necessary to take into account the volume change coefficients of iron oxide during hydrogen reduction and steam oxidation. In addition, regardless of the microstructural architecture, the iron oxide particle forms pores throughout its grain during

reduction. Research should be conducted on the use of other metal additives (eg Cs, Be, Mg, Sr, Ba) as ligatures to prevent the formation of these pores.

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DEVELOPMENT OF COATINGS ON TITANIUM ALLOYS FOR PROTECTION AGAINST HIGH-TEMPERATURE OXIDATION

Batirov Davlatjon Mamirjonovich
Turin polytechnic university in Tashkent

Abstract

This study investigates the development of protective coatings on titanium alloys aimed at enhancing resistance to high-temperature oxidation, a critical issue in high-performance automotive applications. Conventional exhaust materials such as stainless steel begin to weaken above 800°C, exhibiting problems like thermal cycling-induced cracking/warping and oxidation rates up to 10 times higher under nitro-enhanced combustion. This study investigates glass-ceramic coatings deposited to enhance oxidation resistance. Titanium samples were prepared via cutting, polishing, and contamination removal, followed by coating deposition and heat treatment. This paper presents a comparative analysis of various surface coating methods, experimental results from laboratory trials, and evaluations of coating effectiveness in mitigating oxidation and thermal damage. The findings demonstrate that specific coatings can significantly extend the service life of titanium components under extreme operating conditions.

Introduction

Titanium and its alloys are widely utilized in aerospace, biomedical, and automotive sectors due to their superior properties, including low density, high strength, and corrosion resistance [1-2]. However, their application in high-temperature environments, particularly in automotive exhaust systems, is limited by poor oxidation resistance [3-4]. In high-performance sports cars, especially those using nitro systems, exhaust gas temperatures can exceed 1,600 °C, causing thermal degradation, material fatigue, and oxidation [5]. The formation of brittle TiO_2 layers on unprotected titanium surfaces leads to structural failure and performance loss [6]. To overcome this, surface coatings are applied to enhance oxidation resistance, thermal stability, and overall durability [7-9].

Materials and Methods The experimental part of the study involved titanium alloy substrates prepared by cutting, polishing, and ultrasonic cleaning to remove contamination.

The preparation of the glass-ceramic begins with a batch containing the following components: SiO_2 (45–55 wt%), CaO (20–30 wt%), P_2O_5 (5–10 wt%), and optional modifiers such as Na_2O or K_2O (5–10 wt%) [10]. Combine all powders in a clean container and mix thoroughly for homogeneity, either manually or mechanically. Transfer the mixture to a crucible, place it in a preheated furnace, and heat gradually to 1250–1300 °C for 1–2 hours. Stir to ensure uniformity. Pour the molten glass onto a steel or graphite plate to cool rapidly, forming a frit, or quench in water to produce granules. Dry (if water quenched), grind the glass frit or granules into fine powder using a ball mill or mortar, then sieve to achieve a particle size of 50–200 microns. Crushed glass is passed through a sieve to achieve a particle size of 50–60 microns.

Glass-ceramic coatings were applied using various methods, including Physical Vapor Deposition (PVD). This process is deposited atom-by-atom or molecule-by-molecule. The thickness changes between one atom to millimeters and it is possible to obtain multiple layers by depositing different materials. There are two main techniques for vapor deposition: PVD and CVD. In Physical Vapor Deposition (PVD) process, the material is vaporized from a solid or liquid source, where atoms or molecules obtained are transported in the form of vapor on the substrate and here they condense. This process occurs in vacuum or low pressure. This technique allows them to deposit thin films in the range of a few nanometers to several nanometers

Chemical vapor deposition (CVD) is a method which utilizes chemical vapor precursors, transformed into atoms or molecules by reduction or decomposition, which react on the surface creating the coating. The atoms can also react with the gas in the system to obtain a compound which is deposited on the substrate [11-12]. Plasma-Enhanced Chemical Vapor Deposition (PECVD), plasma spraying, and droplet techniques, among others [13].

A comparative substrate of glass was also used to study adhesion characteristics. Post-deposition, heat treatments were applied to stabilize the microstructure and improve bonding. The coating processes were analyzed through adhesion mechanisms, including mechanical interlocking and chemical bonding. Coated samples underwent thermal cycling to simulate exhaust conditions [14-15].

Conclusion

This research confirms that protective coatings significantly enhance the performance of titanium alloys under high-temperature oxidative environments, such as those in nitro-fueled sports car exhaust systems. The findings support the use of advanced coatings to extend component lifespan, improve safety, and boost vehicle performance. Future studies should focus on optimizing coating thickness and exploring nanostructured films for improved adhesion and thermal resistance [16].

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CLEANING OF CARBON NANOTUBES WITH ACID: EFFECTS ON PHASE AND MORPHOLOGICAL PROPERTIES.

S.G. Gulomjanova, I.J. Abdisaidov, Kh.B. Ashurov.
Arifov Institute of Ion-Plasma and Laser Technologies of Uzbekistan Academy of Sciences - Tashkent (Uzbekistan)
sevara@iplt.uz

Carbon nanotubes (CNTs) are widely utilized in various fields due to their high surface area, mechanical strength, and electrical conductivity [1]. However, after synthesis, CNTs often contain residual amorphous carbon, metal catalyst residues, and other contaminants. These impurities negatively affect the physicochemical properties of CNTs. Therefore, the purification process is a crucial step in achieving high quality and enhancing the practical properties of carbon nanotubes (CNTs). The purification process is aimed at removing metallic residues, amorphous carbon, and other impurities from the nanotube structure [2]. These processes are carried out using chemical, thermal, and physical methods. Chemical methods, such as the use of acids or oxidizing agents, help to dissolve impurities, while thermal methods involve the removal of amorphous carbon at elevated temperatures. Additionally, physical methods, such as plasma or ultrasonic cleaning, can be used to separate residues from the nanotubes [3].

This study investigates the cleaning properties of carbon nanotubes obtained by chemical vapor deposition (CVD) from residual contaminants. Specifically, the separation of by-products such as amorphous carbon, carbide compounds of catalytic metals, and catalytic components used during synthesis is discussed.

The cleaning of CNTs using H_2O_2 and HCl acids was studied. Following the cleaning process, a significant reduction in metal residues in the nanotubes was confirmed by Raman spectroscopy and X-ray diffraction (XRD) analysis.

In the X-ray diffraction spectrum of the sample before cleaning, peaks around $2\theta = 26°$ and 43° were characteristic of carbon, representing the crystalline structure of the CNTs. Additionally, additional peaks in the $2\theta = 35°–80°$ range indicated the presence of metal catalyst residues and amorphous phases. After cleaning, these additional peaks nearly disappeared, and the main graphite peaks remained intact.

Raman spectroscopy was employed to study changes in the CNTs during the cleaning process. Three main peaks—D, G, and 2D—were identified. The D peak (~1350 cm^{-1}) indicated defects and the presence of amorphous carbon, while the G peak (~1580 cm^{-1}) corresponded to graphitic structure and sp^2 carbon bonds. The 2D peak (~2700 cm^{-1}) provided information about the ordering of the CNT structure and its crystallinity. Following the cleaning process, the D/G intensity ratio decreased, and the 2D peak intensified, suggesting an improvement in the crystallinity and ordering of the CNT structure. The results confirm that the cleaning process partially reduced amorphous carbon and defects while increasing the crystallinity.

In conclusion, the acid cleaning method significantly enhances the quality of CNTs and their potential for practical applications.

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TiO_2 NANOCOATINGS WITH ENHANCED PROPERTIES FOR SELF-CLEANING AND PHOTOCATALYSIS, OBTAINED BY ATOMIC LAYER DEPOSITION.

Kh.Kh. Zokhidov, E.E. Mukhtorov, R.B. Ashurov.
Arifov Institute of Ion-Plasma and Laser Technologies of Uzbekistan Academy of Sciences - Tashkent (Uzbekistan)
zokhidov@iplt.uz

In the context of the rapid development of energy-efficient and environmentally friendly technologies, special attention is given to materials that enhance the functional characteristics of various surfaces, including solar panels. Coatings with photocatalytic, hydrophilic, and hydrophobic properties are particularly in demand. Oxide materials such as zinc oxide (ZnO), tin oxide (SnO_2), and tungsten oxide (WO_3) exhibit interesting properties but also have certain limitations that hinder their widespread application. ZnO demonstrates high photosensitivity but is susceptible to photodegradation. WO_3 performs well in acidic environments but loses stability with pH fluctuations. SnO_2 provides good transparency and conductivity, yet it falls short in photocatalytic efficiency.

Against this backdrop, titanium dioxide (TiO_2) stands out due to its unique combination of properties: high chemical and thermal stability, photocatalytic activity, UV-induced surface wettability control, non-toxicity, and broad availability. These features make TiO_2 particularly promising for the development of self-cleaning, antibacterial, and moisture-repellent coatings. One of the key advantages of TiO_2 is its ability to become superhydrophilic under ultraviolet (UV) irradiation, causing water to spread uniformly across the surface and form a thin film that effectively removes contaminants. With appropriate chemical modification, the same surface can become hydrophobic, offering water resistance under limited sunlight conditions.

Numerous scientific studies confirm the potential of TiO_2 across various applications. Research has shown that coatings produced via atomic layer deposition (ALD) exhibit high resistance to contamination and pronounced self-cleaning effects [Smith et al., 2018]. ALD enables excellent uniformity and reproducibility due to its sequential, self-limiting surface reactions with gas-phase precursors, making it ideal for the fabrication of nanometer-scale films with precisely controlled thickness and structure. ALD parameters such as temperature and cycle number allow control over phase composition—for example, low-temperature deposition promotes the formation of the anatase phase, which enhances catalytic activity [Kim et al., 2020]. Further modification of TiO_2 with nitrogen [Zhang et al., 2021] or silver nanoparticles [Garcia et al., 2019] extends its photocatalytic activity into the visible spectrum and introduces antibacterial properties. Studies by

Johnson et al. [2022] demonstrated that TiO_2 coatings mitigate UV- and pollution-induced degradation of solar panels, thereby extending their operational lifespan.

In this study, TiO_2 coatings will be deposited on glass substrates and solar panel surfaces using the atomic layer deposition technique. The objective is to develop nanometer-thick coatings with tunable hydrophilic, hydrophobic, and optical properties. The ALD process will be conducted under varying conditions—including temperature, precursor type, and cycle number—to obtain materials with different morphology and structure.

The resulting films will be analyzed using scanning and transmission electron microscopy (SEM, TEM), X-ray diffraction (XRD), and spectroscopic methods. Spectroscopic ellipsometry will be employed to determine optical parameters and film thickness. Wettability will be assessed by measuring the water contact angle to evaluate hydrophilic and hydrophobic behavior under various conditions, including UV exposure. Photocatalytic activity will be examined under ultraviolet and solar irradiation. Special attention will be paid to investigating the correlation between surface morphology, phase transitions (anatase–rutile), grain size, defect density, and the functional properties of the material. It is expected that TiO_2 deposited via ALD will exhibit pronounced superhydrophilic properties under UV irradiation, ensure effective removal of surface contaminants, and demonstrate high potential for use in durable, self-cleaning coatings for solar panels and other functional surfaces.

INFLUENCE OF INTRODUCING A THIN LAYER OF SILVER ON THE CURRENT VOLTAGE CHARACTERISTICS OF A CIGS BASED SOLAR CELL

R.R. Kabulov, S.Yu.Gerasimenko, F.A. Akbarov, M.U. Khajiev, F.T.Pulatova, N.R.Homidova, L.U.Shuhratova, A.X.Tursunova.
Physical-technical Institute named after S.A.Azimov of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

Environmental pollution during the period of intensive scientific, technical and industrial development requires the world community to increase the production of electrical energy through environmentally friendly renewable solar energy. Over the past few years, solar photovoltaic energy has been growing at an accelerated pace. In 2024, it accounted for more than three quarters of the growth in renewable energy capacity, or 451.9 GW. Including 278 GW were installed in China and 24.5 GW in India. In 2023, solar energy surpassed hydropower in installed capacity for the first time and became the largest renewable energy source, and in 2024, the share of solar in global renewable energy capacity reached 42% [1].

Currently, crystalline silicon-based photovoltaic modules account for 95% of the total photovoltaic volume in the photovoltaic market. For further widespread commercial implementation of photovoltaic stations in large-scale energy production, it is necessary to increase the competitiveness of photovoltaics with traditional methods of generating electric energy. This can be achieved through the use of energy-saving and material-saving technologies in the production of solar cells, which will lead to a significant reduction in costs associated with the production of photovoltaic modules. Semiconductor materials based on a multicomponent chemical compound of copper-indium-gallium and selenium - CIGS or CuInGaSe2 are one of the promising and environmentally friendly materials due to their unique properties [2], such as direct band gap, high absorption coefficient values and thin-film structure of the entire structure. Currently, on a laboratory sample of a CIGS-based solar cell with an area of about 1 cm2, the Japanese company Solar Frontier has obtained a solar energy conversion efficiency (COP) of 23.35% under AM1.5 conditions [3]. On a 526.7 cm2 photovoltaic module, the photovoltaic

module manufacturer Avancis achieved a value of 20.3% [4]. However, in solar cells that achieve high conversion efficiency values, rather expensive technologies are used, which leads to an increase in the cost of the entire process of producing large-area photovoltaic modules.

For commercial wide implementation of CIGS-based solar technologies, it is necessary to use cheaper technologies for producing CIGS-based layers and structures. One of such technological methods is vacuum evaporation of CIGS precursors from two evaporators. In this case, Cu, In and Ga metals, due to the fact that their evaporation temperatures in vacuum differ insignificantly, evaporate from one evaporator, and selenium, due to a large difference in evaporation temperatures, from another evaporator. Studies conducted on a solar cell based on a thin-film CIGS layer synthesized using two evaporators, with an area of 0.16 cm2, which had a glass-Mo/p-CIGS/n-CdS/SnO2/Ag structure, under AM1.5 illumination on an Oriel - 94043A solar simulator had an efficiency of 12.5%. The solar cell was created as follows: a metallic molybdenum (Mo) layer with a thickness of ~0.5 μm was applied to a glass substrate with a thickness of ~1 mm using the direct current magnetron ion sputtering method. Then, a CIGS layer with a p-type conductivity and a thickness of ~2 μm was synthesized in a quasi-closed volume using two evaporators in a vacuum. A layer of cadmium sulfide (CdS) with an n-type conductivity and a thickness of ~150 nm was used as a buffer layer in the created heterostructure. A layer of tin oxide (SnO2) with an n-type conductivity and a thickness of ~200 nm was used as a transparent-conductive layer in the heterostructure [5]. A layer of silver (Ag) was applied to the surface of the n-SnO2 layer as a current-collecting contact.

The study and analysis of the dark current-voltage characteristic showed that in the area of the front contact of n-CdS/p-CIGS there is an accumulation barrier, which is formed as a result of the difference in the energy of electron affinity (χ) of the semiconductor layers of n-CdS and p-CIGS. In the area of the back contact of p-CIGS/Mo, a potential barrier appears, which is connected counter (reverse) to the main potential barrier of the n-CdS/p-CIGS heterojunction, which is most likely formed due to salinization of the Mo surface and the formation of a wider-bandgap monolayer of MoSe2, with respect to the CIGS layer [6]. The accumulation and counter-connected barrier negatively affects the output energy parameters of the CIGS-based solar cell, worsening such parameters as short-circuit current, open-circuit voltage, fill factor of the current-voltage characteristic and conversion efficiency.

In this work, in order to prevent the influence of parasitic barriers on the output energy parameters of the SC based on a thin-film CIGS layer, it was proposed to introduce a small amount of silver atoms into the CIGS layer. For this purpose, a thin layer (≈ 10 nm) of silver (Ag) was deposited on the Mo surface by thermal evaporation in a vacuum during the SC creation. To improve the contact properties, the front transparent-conducting SnO2 layer was replaced by a transparent-conducting ZnO layer. The study of the dark I-V characteristic of the created glass-Mo/p-CIGS/n-CdS/ZnO/Ag structure shows the absence of an accumulation region at the n-CdS/p-CIGS(Ag) heterojunction. Also, near the back contact, there is no potential barrier, which is connected opposite to the main potential barrier of the n-CdS/p-CIGS(Ag) heterojunction. The study of the light current-voltage characteristic of the created glass-Mo/p-CIGS(Ag)/n-CdS/ZnO/Ag structure shows that the output energy parameters of the created solar cell have improved, that is, the efficiency of the CIGS-based solar cell has increased. Under AM1.5 conditions (P_{rad}=100 mW/cm2), the CIGS structure has an efficiency of 15.7%. Experimental studies of the dependence of the efficiency of CIGS solar cells on the incident radiation power of the solar simulator P_{rad} showed that the efficiency increases with increasing radiation power and reaches a maximum value of 16.2% at P=40 mW/cm2, then decreases and, as indicated above, at P_{rad}=100 mW/cm2 has an efficiency of 15.7%. Silver atoms on the Mo surface prevent the formation of the MoSe2 layer, preventing the occurrence of a counter-connected barrier. During the growth of the CIGS layer, silver atoms diffuse and accumulate at the frontal boundary of the

CIGS layer, increasing the band gap of the photoactive CIGS layer, which leads to the removal of the accumulation region. This leads to an increase in the efficiency of the solar cell.

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SOLAR RADIATION CONCENTRATORS IN CLIMATIC CONDITIONS OF THE MIRZACHUL REGION OF THE REPUBLIC OF UZBEKISTAN

F. Sh. Kasimov[1,3], D. A. Allayorova[2]

Physical-technical institute named after S. Azimov of the Academy of Sciences RUz, 2- Gulistan State University 3- "TIIAME" National Research University

e-mail: fahri2002@mail.ru

Overview of Solar Radiation Concentrators. Solar radiation concentrators are devices designed to focus sunlight onto a smaller area, thereby increasing the energy density and enabling efficient thermal or photovoltaic energy conversion. Common types include:

Parabolic troughs: Curved mirrors concentrate sunlight onto a receiver tube.

Dish concentrators: Parabolic dishes focus light to a focal point.

Fresnel reflectors: Use multiple flat mirror segments to mimic a curved surface.

These systems are particularly attractive in regions with high solar insolation, such as Uzbekistan, where maximizing energy capture is critical.

The increasing global demand for renewable energy sources has accelerated the deployment of solar technologies. Solar radiation concentrators, in particular, are highly relevant due to their ability to focus solar energy to achieve high temperatures for electricity or heat generation. The Mirzachul region of Uzbekistan presents favorable climatic conditions, including high levels of solar insolation, making it an attractive location for such projects [1]. This study evaluates the prospects of using solar radiation concentrators based on literature analysis and case studies from regions with similar climatic conditions.

Main Section. Climatic Characteristics of the Mirzachul Region. The climatic conditions of the Mirzachul region are characterized by the following factors:

- High solar insolation: A significant number of clear-sky days throughout the year ensure a stable supply of solar energy.

- Arid climate with low humidity: These conditions minimize the scattering of solar rays and reduce energy losses.
- Extreme temperature fluctuations: The region experiences substantial temperature variations between day and night.

  Climate data indicate that the region holds strong potential for the deployment of solar energy systems [2].

Solar Concentrating Technologies. There are several key approaches to solar concentration technologies, each with distinct characteristics and applications:

- Parabolic concentrators: These focus solar radiation onto a heat-transfer fluid, generating steam to drive turbines. They are widely used in solar thermal power plants and exhibit high efficiency in areas with stable solar radiation [3].
- Fresnel lenses: Featuring a compact design, these lenses achieve high radiation concentration using optical technology, making them suitable for small-scale and distributed energy installations [4].
- Hybrid systems: These integrate photovoltaic and thermal technologies to enhance overall energy efficiency by simultaneously generating electricity and heat. Research indicates that such systems significantly improve energy conversion efficiency [5].

Economic Feasibility. The utilization of solar radiation concentrators offers several economic advantages:

- Reduction in energy production costs: The region's high solar radiation potential ensures stable energy output with relatively low operating expenses.
- Enhanced energy security for remote areas: Compact concentrator systems provide an effective energy solution for rural and hard-to-reach locations [6].

Environmental Benefits

Reduction in carbon dioxide emissions: Transitioning to renewable energy sources mitigates climate impact.

Increased resilience to climate change: The integration of solar concentrators diversifies the regional energy mix and reduces dependency on fossil fuels [7].

A review of the literature suggests that in high-insolation regions, these technologies contribute significantly to cost reduction and improved environmental sustainability of energy systems [8].

Technical Challenges and Mitigation Strategies. Despite the promising potential, the implementation of solar radiation concentrators faces several challenges:

Dust accumulation and contamination of optical surfaces: Dry climates contribute to dust buildup, reducing concentrator efficiency. Solutions include self-cleaning surface technologies and regular maintenance [9].

Temperature fluctuations: Extreme temperature variations necessitate the use of heat-resistant materials with strong mechanical properties.

High initial investment: To lower financial barriers, government support programs and private investment incentives are recommended.

Innovative materials and advanced monitoring technologies offer viable solutions to these challenges, as supported by recent research [10].

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INFLUENCE OF Ti_3C_2 MXene ON RHEOLOGICAL PROPERTIES

J.I. Mamanazirov[1,2], Sh.I. Mamatkulov[1]

[1]Institute of Material science under the Academy of Science of Uzbekistan 102226, Tashkent region, Uzbekistan
[2]National Research Institute of Renewable Energy Sources under the Ministry of Energy 100084, Tashkent, Uzbekistan

Abstract

This research explores how the MXene, typically $Ti_3C_2T_x$, affects the rheological characteristics of alumina-based inks used in 3D printing. 2D MXene, particularly titanium carbide, shows promise in colloidal processing due to its excellent electrical conductivity, chemical and mechanical properties, high temperature stability, and easy dispersibility in water. The inclusion of 2D MXene improves the printability of the ink. The Flow sweep test reveals a shear-thinning behavior in alumina inks containing 2D MXene. The interaction between 2D MXene and alumina ink enhances shape accuracy during printing.

Introduction

Alumina-based inks, composed of alumina particles, binders, dispersants, and additives, are good option as a model material for direct ink writing due to its low cost, availability, and ease of densification [2]. The formulation of alumina-based inks presents a complex challenge due to the material’s inherent characteristics. The limited fabrication methods, for ceramics due to their brittleness, strength and hardness make it challenging to produce complex geometrically shaped objects. This difficulty is further compounded by the fact that post hard machining’s nearly impossible on ceramics. However, thanks to advancements, in manufacturing it is now possible to create ceramic based objects of high precision and accuracy [3]. One specific sub-category within additive manufacturing is extrusion-based 3D printing. In this method, highly concentrated ceramic particle suspensions are employed to create a stable extrusion. These extrusions are then stacked

layer by layer to construct the desired shapes [4,5]. In this work alumina nanopowder used as a ceramic. The primary goal in this work was to elucidate how the introduction of 2D MXene influences the rheological characteristics of the resulting ink. The exploration extended to the behavior of the inks under varying shear rates, emphasizing the importance of shear-thinning behavior for favorable extrusion during printing. Moreover, the contributions of 2D MXene were particularly remarkable in enhancing printability of the inks, significantly influencing their extrudability and the ability to maintain shape fidelity. The knowledge gained from this research has the potential to improve the capabilities of ceramic based 3D printing and offer guidelines for creating customized ink formulations suitable for a wide range of applications.

Results and discussion

Analysing the result involved conducting an amplitude sweep test in a conventional manner. This test entailed incrementally elevating the shear strain to a maximum of 100%, while assessing the storage and loss moduli. The acquired data from this test facilitated the subsequent calculation of essential rheological parameters. The key rheological parameters are storage modulus, yield stress and flow stress determine inks behaviour. Storage modulus in the linear viscoelastic range (G'_{LVR}) characterizes the elastic modulus at rest – determines shape fidelity. Yield stress (τ_y) denotes the stress at which plastic deformation initiates within the material – determines shape fidelity. And flow stress (τ_f) represents the stress level at which the material commences flowing – determines extrudability. A high yield stress, in conjunction with a high elastic modulus, serves to minimize the extent of ink deformation post-deposition, consequently prevention the structural collapse of the printed construct. Conversely, a lower flow stress diminishes the stress required for inducing ink extrusion. Nonetheless, it is crucial to acknowledge that these two parameters are interconnected. When one of them changes, it affects the rest of the key parameters. By analyzing these results, it is possible to compute significant rheological parameters, including the storage modulus within the linear viscoelastic region (LVR), yield stress, flow stress, yield strain, and flow strain. Among the examined scenarios, the alumina ink featuring a 35 vol% alumina content exhibits the lowest yield strain, measuring 0.04. Conversely, the "Alumina-MXene" composite characterized by a 35 vol% alumina content registers the higher yield strain value of 0.2, a magnitude 5 times greater. This pronounced contrast is indicative of the substantial influence of MXene additive on augmenting the yield strain, which extends the linear viscoelastic range and enhances the overall viscoelastic performance of the alumina ink.

Among the examined scenarios, it is notable that the alumina ink records the high flow stress value of 521 Pa. In contrast, the "Alumina-MXene" composition exhibits the low flow stress at 67.3 Pa. This substantial reduction in flow stress indicates the beneficial impact of MXene additive on the flow behavior of the alumina ink. When considering the alumina ink, it exhibits a yield stress of 709 Pa and a G'_{LVR} of 1241 kPa. In contrast, the ink formulated with MXene shows lower results – 56.4 Pa for yield stress and 35 kPa for G'_{LVR}. These differences highlight the significance of MXene additive in reducing the shape fidelity of the alumina ink, as demonstrated by the notable decreases observed in both yield stress and G'_{LVR} values.

Conclusion

In conclusion, this study focused on investigating the rheological properties of alumina-based inks with particular emphasis on the incorporation of 2D MXene. The results demonstrated a complex interplay between MXene content, rheological parameters (such as yield stress and G'_{LVR}), and flow behavior. The addition of 2D MXene generally led to enhanced flowability and a reduction in rheological parameters, signifying improved printability and stability.

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FEASIBILITY STUDY OF THE APPLICATION OF THE ADSORPTION SEPARATION PROCESS IN A NATURAL GAS PROCESSING PLANT

Odilova N.N., Ji Sub Yun, Zhen Hao Lee, Jiho Shin, Kiwoong Kim

Abstract

Natural gas is a vital source of energy and a key feedstock for chemical synthesis, enabling the production of high-value-added products. Uzbekistan, a country in Central Asia, possesses 650 mln (MMcf) of the world's natural gas reserves, making natural gas a critical component of the economy. A large portion of Uzbekistan's Natural gas is being consumed for transportation, electricity generation and construction, with a smaller portion related to the chemical industry. However, Uzbekistan imported a large quantity of plastic raw materials from overseas countries due to the lack of feedstock. Addressing this issue requires an economically efficient purification process to maximise the utility of natural gas resources. Traditionally, the acid gas removal process has relied on amine absorption, which is energy-intensive and environmentally detrimental due to the toxicity of amine solutions. This study proposes the use of pressure swing adsorption (PSA) as a more economical and environmentally friendly alternative for acid gas removal.

This research investigates the performance of Cu-exchanged zeolite materials, specifically Cu-CHA and Cu-SSZ-13, in PSA processes for CO_2 removal. Breakthrough experiments and PSA simulations demonstrated that Cu-CHA exhibits superior CO_2 adsorption capacity and selectivity, achieving 1.49 mmol/g at a flow rate of 45 ml/min. PSA is shown to offer significant potential for reducing both costs and environmental impacts, making it a promising replacement for the traditional amine process in Uzbekistan's natural gas industry.

Keywords: plastic raw materials, feedstock, acid gas removal, amine absorption, zeolite, Cu-CHA, Cu-SZZ-13, simulation, adsorption capacity, selectivity.

Adsorption Isotherm Experiment and Modeling

The Pressure Swing Adsorption (PSA) process offers several advantages over the traditional amine sweetening process for natural gas sweetening.

Energy efficiency

Safety

Operational cost

Environmentally Friendly

In this study, Zeolite was selected for the "Acid Gas Removal " section to optimize a lower environmental footprint process and achieve lower capital cost and higher CO_2 selectivity. There were two Cu-exchanged zeolites, They were Cu-SZZ-13 and Cu-CHA (powder form). To find out the adsorption capacity and selectivity of these sorbents, adsorption isotherm analysis was conducted in the Autochem Micrometrics Tri-Star. Adsorption isotherm modelling, the Dual site Langmuir model was employed to find out the maximum adsorption capacity of the sorbent for single gases, and adsorption affinity.

Experimental and setup

In the Autochem II Micrometrics 2920, powder forms of CHA and Cu-SSZ-13, pellet form CHA adsorption capacity were tested with three different fractions of CO_2 and CH_4. Measuring the gas adsorption and desorption on the surface area of the pellet CHA was conducted using the gravimetric method. A small amount of pelletised CHA measured weight has been calibrated by heating until 250 ℃ under a 50 ml/min He flow rate for 3 hours. He used it as a preparation gas during the pretreatment process because it can easily reach all the pores of the sample without being adsorbed. After pretreatment, the temperature decreased to 50 ℃ and was held for 90 min. Then experiment recording was started, and He was used as a carrier gas for around 30 min to create a baseline. After 30 minutes Loop gas (pure CO_2) flow rate was started over 20 min at the next step, the Temperature was increased to 25050 ℃ for desorption capacity, and only carrier gas and preparation gas (He) flowed to the reactor over 30 min. Overall, 6 stages are required for all fractions of CO_2. Uptake calculation was executed by Origin Pro 9.0 software. Based on the comparative analysis of various adsorbents, chabazite (CHA) zeolite was selected as an alternative for CO_2 and CH_4 adsorption in natural gas purification. While literature data showed high adsorption capacities for materials like Zeolite 13X, our experimental results with CHA demonstrated its effectiveness, particularly in pallet form. CHA's performance in pellet form showed increasing adsorption capacity with gas fraction, reaching 0.0005311831 mol/g for CO_2 at 10% concentration. This trend, coupled with CHA's known high selectivity for CO_2 over CH_4, supports its potential as an efficient adsorbent for pressure swing adsorption (PSA) processes in natural gas sweetening. The choice of CHA aligns with the development of more energy-efficient and selective adsorption materials for gas purification applications. In this experiment, conducted using the Autochem II Micrometrics equipment, the flow rate was set at 50 mL/min, and the adsorption capacity was measured at a pressure of 1 bar and a temperature of 50 °C.

Conclusion

The main target was a reduction of CO_2 and H_2S levels in natural gas. The PSA method offers lower energy consumption and higher versatility. Among the adsorbent materials tested, zeolites, particularly chabazite (CHA), demonstrated superior CO_2 adsorption capacity and selectivity. Zeolite 13X showed the highest adsorption capacity for CO_2 at 0.017901 mol/g. Autochem II Micrometrics 2920 demonstrated the effectiveness of chabazite (CHA) zeolites as adsorbents, with CO_2 adsorption capacity increasing at higher gas concentrations.

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PROPERTIES OF FUNCTIONAL ION EXCHANGE MATERIALS CONTAINING NITROGEN AND SULFUR

Karshibayeva M[1]., Erkinova M[1]., Kodirova K.A[1]., Khushvaktov S.Y[2]., Bekchanov D.J[2].

[1]Chirchiq State Pedagogical University
[2]National University of Uzbekistan named after Mirzo Ulugbek
Email: suyunkhushvaktov91@gmail.com

The Commonwealth of Independent States (CIS) ranks second globally in the production of ion-exchange materials, which are widely used for purifying contaminated wastewater [1]. These ion-exchange materials help soften water hardness, remove toxic metals, and desalinate both natural wastewater used by industrial enterprises and the waste effluents discharged from these industries [2].

Researchers have synthesized thermo sensitive copolymers with sorption properties toward metal cations through free radical copolymerization of N-n-propyl acrylamide (NnPAAm) and methyl 2-methylacrylate (MAPC) for the removal of metal ions from wastewater [3]. Vincent Beaugeard and other scientists have studied the efficiency and selectivity of sorption in artificial solutions by directly investigating metal ion removal from water via complex formation or ion exchange [4]. In recent years, research has been conducted on water-resistant metal-organic ion exchangers for the adsorption of hazardous heavy metal ions in water and the reduction of photocatalytic degradation [5].

Chinese researchers have prepared a series of activated palygorskites through acid treatment and heat treatment. When these activated samples were tested as adsorbents for the removal of Cd (II) from aqueous solutions, they were found to form selective ion-exchange materials specifically for cadmium ions [6].

Several researchers have also conducted studies on the adsorption of nickel and zinc from mineral water and wastewater using natural and modified zeolite, bentonite, and vermiculite-based sorbents. These materials have been widely used for metal ion removal. This study focuses on the adsorption behavior of nickel and zinc in both natural and modified forms [7].

This study examines the effect of temperature on the modification reaction of various amines with the industrial ion-exchange resin KU-2 cationite, based on the static exchange capacity (SEC) of the functional ion-exchange material. The modification process was carried out under identical conditions, using the same amount of materials and reaction time, but at different temperatures. The obtained functional ion-exchange materials were first activated in acid, then in alkali, and subsequently washed with distilled water until reaching a neutral state.

The neutralized polyampholyte was immersed in a 0.1 N HCl solution for 24 hours. The acidic solution containing the functional ion-exchange material was then titrated with a 0.1 N NaOH solution to determine the SEC value for anion exchange. Similarly, the neutralized polyampholyte was placed in a 0.1 N NaOH solution for 24 hours, and the alkaline solution containing the ion-exchange material was titrated with a 0.1 N HCl solution to determine the SEC value for cation exchange.

The static exchange capacity (SEC) of the polyampholyte is calculated as follows:

$SAS_{anionite} = \frac{100 \bullet k_1 - \frac{100}{10} \bullet k_2 \bullet a}{10 \bullet g}$	$SAS_{cationite} = \frac{100 \bullet k_1 - \frac{100}{10} \bullet k_2 \bullet a}{10 \bullet g}$
k_1 – V(alkali)/V(acid)=1 theoretical, k_2 – V(initial acid)/V(alkali), α – volume of alkali consumed per sorbed HCl, g – sorbent mass, SEC mg*eq/g.	k_1 – V(acid)/V(alkali)=1 theoretical, k_2 – V(initial alkali)/V(acid), α – volume of acid consumed per sorbed NaOH, g – sorbent mass, SEC mg*eq/g.

The calculations were performed using the formulas above, and the obtained results are presented in the following table.

Calculations were made using the above formulas, and it was also found that the static exchange capacity of the cationic materials at 413K is $SEC_{(NaOH)}$ =3.42 mg·eq/g and $SEC_{(HCl)}$ =3.65 mg·eq/g. It can be seen from this table that the SAS value of the functional cationic material obtained on the basis of the industrial cationic KU-2 cationite depends on the temperature. With increasing temperature, the SEC values of the ionite increase, the alternative temperature is 413-423 K.

The decrease in SEC values at higher temperatures can be explained by the destruction of the obtained polymer.

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DEVELOPMENT OF THE FUNDAMENTALS OF SOLAR TECHNOLOGY FOR THE SYNTHESIS OF HIGH-TEMPERATURE BISMUTH-BASED SUPERCONDUCTORS

D.D. Gulamova, E.B. Eshonkulov, S.Kh. Bobokulov, A.B. Gafurova

[1]Materials Science Institute, Academy of Science, Republic of Uzbekistan, Tashkent, Uzbekistan
e-mail: elyoreshonkulov94@mail.ru

High-temperature superconductors (HTSC) are important for reducing energy consumption and improving efficiency in modern power systems. They are also used in medicine for creating high-precision diagnostic tools such as magnetic resonance imaging (MRI), and they play a key role in the development of quantum computing and advanced electronics. However, their wide application is still limited due to the difficulty of producing stable and repeatable superconducting phases with high critical temperatures (T_c). Traditional solid-state synthesis methods often result in grainy structures and uneven phase distribution, which negatively affect their performance [1]. Developing efficient synthesis methods for Bi/Pb-based high-temperature superconductors remains

a pressing challenge for their broader application [2]. Recent studies have shown that heliotechnology methods using solar energy can produce highly textured and stable superconducting materials [3]. Since some photochemical reactions that occur under solar radiation cannot be replicated through conventional technologies, solar furnaces offer a promising approach for obtaining high-temperature superconductors with improved properties [4]. This study explores the scientific basis and results of using solar energy to synthesize high-temperature superconductors in the $Bi_{1.7}Pb_{0.3}Sr_2Ca_{n-1}Cu_nO_\gamma$ (n = 9–20) series.

Using the "Super Fast Alloys Quenching-T" (SFAQ-T) technology at the Big Solar Furnace (BSF) in Parkent, highly textured and stable superconducting materials were synthesized through melt processing under concentrated solar radiation. Stoichiometric mixtures of Bi_2O_3, PbO, SrO, CaO, and CuO were melted under high-intensity solar flux (150–260 W/cm²) at the BSF. The melt was poured onto a water-cooled substrate, resulting in glass-ceramic precursors reinforced with nanocrystalline nuclei (15–18 nm). Unlike samples obtained via the conventional solid-state method, these precursors exhibited a plate-like microstructure.

To ensure the formation of superconducting phases, the precursors were fired at temperatures ranging from 840 to 853°C for durations between 3 and 120 hours. Phase transformations were monitored using X-ray diffraction (XRD) and scanning electron microscopy (SEM). Homologous phases were identified through characteristic [00L] reflections. XRD results confirmed the dominance of the Bi/Pb 2223 phase (T_c = 107–138 K) in all samples.

The critical temperatures of the samples were determined using four-probe resistance and magnetic susceptibility measurements. The superconducting transition temperatures (T_c) were observed at approximately 126K, 129K, 135K, and 142K for the Bi/Pb 2289, Bi/Pb 221112, Bi/Pb 221415, and Bi/Pb 221920 samples, respectively.

The use of heliotechnology in the synthesis of Bi/Pb-based high-temperature superconductors offers advantages such as the formation of highly textured microstructures and the realization of high-temperature superconducting effects. The developed heliotechnology presents an energy-efficient and environmentally friendly alternative to conventional solid-state methods, expanding the potential for application in high-current devices and power systems. In the future, industrial-scale implementation of this technology may contribute to the development of high-efficiency energy systems.

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METHODS OF MEASUREMENT OF HIGH-CONCENTRATED SOLAR ENERGY FLOWS

O.Parpiev, S.Bakhronova
Institute of Materials Science of the Uzbekistan Academy of sciences

High-concentrated solar energy flows (HCSEF) are a critical component of many modern solar thermal technologies, including solar furnaces, concentrator systems, and thermochemical

reactors. These systems are capable of generating energy densities of up to several megawatts per square meter, enabling processes such as material testing, high-temperature synthesis, hydrogen production, and direct solar metallurgy. Accurate measurement of these concentrated energy flows is essential to evaluate performance, improve designs, ensure safety, and optimize solar thermal systems.

Methods of measurement

Calorimetric Techniques. Adiabatic and Isochoric Calorimeters. These methods rely on measuring the temperature rise in a known mass or volume, often using insulated chambers. They provide integrated power values but have low temporal resolution.

Water-Flow and Heat-Flux Calorimeters. These systems involve circulating a fluid through a target exposed to solar flux. By measuring inlet and outlet temperatures and flow rates, the absorbed energy is calculated. Advantages include high repeatability and scalability.

Limitations: Heat losses through radiation and convection must be minimized or corrected; Measurement delay due to thermal inertia; Complex calibration procedures

Radiometric and Thermoelectric Sensors. Gardon and Schmidt-Boelter Heat Flux Sensors These sensors use thermopiles to detect temperature gradients caused by absorbed solar radiation. Widely used for mapping power distribution and calibrating other devices [1].

Thermocouples and Thin-Film Sensors Embedded or surface-mounted thermocouples can monitor surface temperature, from which heat flux can be inferred through inverse modeling [2].

Limitations: Limited spatial resolution; Sensor saturation under extreme flux; Need for protective cooling or shielding

Optical and Photographic Methods. Lambertian Target Imaging By capturing the illuminated spot on a diffuse reflective surface, the spatial energy distribution can be reconstructed. CCD or CMOS cameras, combined with radiometric calibration, provide high-resolution flux maps [3].

UV/VIS/NIR Spectrophotometry Spectral analysis provides data on energy distribution across wavelengths, useful for spectral-selective absorber design.

Laser-Based and LIDAR Techniques Experimental approaches using probe beams to reconstruct energy density through scattering analysis. Still under research.

Infrared Thermography. Principle Infrared (IR) cameras detect thermal emissions from surfaces in the focal zone. The intensity is mapped to temperature distribution.

Applications: Detecting hot spots and beam non-uniformities; Assessing absorber performance: Monitoring transient events during tracking or cloud passage

Limitations: Emissivity dependence and environmental interference; Need for in-situ calibration;

Chemical and Photochemical Methods. Actinometry Uses chemical reactions with known quantum yields to determine solar flux exposure [4].

Photodegradation-Based Indicators Experimental films or coatings that discolor or degrade upon solar exposure, providing qualitative flux distribution.

Hybrid and Advanced Measurement Techniques. Sensor Fusion and Data Integration Combining thermographic, calorimetric, and radiometric data improves accuracy and spatial resolution [5].

Real-Time Monitoring Systems Integration of sensors with feedback control for adaptive optics and flux stabilization.

Machine Learning for Data Interpretation AI-based methods are emerging to model and predict flux behavior based on multi-sensor input.

Applications and Case Studies. Solar Furnaces (Uzbekistan, France, China) Application of measurement techniques to monitor test zones, calibrate experimental rigs, and assess optical alignment [6].

Concentrating Solar Power Towers and Dishes Use of water calorimeters and IR thermography to optimize receiver design and evaluate thermal efficiency.

Laboratory Test Benches Flux mapping using CCD-based systems to design micro-scale concentrators for MEMS and nano-material synthesis.

Future Directions

- Development of robust, high-dynamic-range sensors
- Autonomous calibration under solar flux
- Integration with solar simulation tools (e.g., SolTrace, Tonatiuh)
- Application of deep learning for inverse heat flux problems

As shown an analyze, accurate measurement of HCSEF remains a multidimensional and evolving challenge, pivotal for the advancement of solar thermal technologies. Traditional calorimetric, radiometric, and optical methods continue to provide valuable insights into flux density, spatial distribution, and system performance. However, as solar systems scale in complexity and application scope—from materials research to industrial-scale solar metallurgy and hydrogen production—so too must the precision, adaptability, and intelligence of diagnostic tools evolve.

The integration of modern information technologies (IT) and digitalization is becoming increasingly essential to meet these demands. Real-time data acquisition systems, advanced sensor fusion techniques, and high-resolution imaging platforms now allow for dynamic, multi-parametric characterization of solar flux. Furthermore, the application of artificial intelligence (AI), particularly machine learning algorithms, enables predictive modeling and automated interpretation of complex measurement datasets, improving both the spatial and temporal resolution of diagnostic capabilities.

Digital twins of solar furnaces and concentrator systems—virtual replicas powered by real-time sensor data—offer a powerful means to simulate, calibrate, and optimize energy flows under variable solar conditions. Coupling these with cloud-based platforms facilitates remote diagnostics, long-term performance monitoring, and collaborative research across international solar research facilities.

Thus, the future of HCSEF measurement lies in the convergence of physical metrology with computational intelligence. Continued research and development should focus not only on creating robust, high-dynamic-range sensors, but also on embedding them within digitally integrated ecosystems. Such systems will enable precise control, safety assurance, and design optimization across a broad range of solar thermal applications, ultimately accelerating the deployment of solar technologies in the global energy transition.

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PRODUCTION OF Ti-6Al-4V ALLOY POWDER BY EDM METHOD

B.A G'oipov, A.A Zaripov, Kh.B Ashurov
Institute of Ion Plasma and Laser Technologies, Academy of Sciences of the Republic of Uzbekistan, Tashkent -100125, Uzbekistan

Ti-6Al-4V alloy has attracted significant attention in advanced manufacturing processes, particularly in the aerospace, biomedical, and automotive industries due to its outstanding mechanical properties [1]. This titanium alloy is one of the most widely used materials because of its excellent combination of high strength, low density, and superior corrosion resistance. In particular, this alloy is used in dental implants, orthopedic implants, as well as cardiovascular stents, medical devices and equipment. Its main feature is that it quickly adapts to the human body and integrates with tissues. Despite its advantages, the high hardness and the tendency to form an oxide layer quickly make it difficult to machine using conventional methods, complicating its application in industrial processes.

Taking into account the above, we propose to process the hard material Ti-6Al-4V alloy by the electrical discharge machining (EDM) method. The EDM method allows for complex, high-precision machining of various metals, metal alloys, glass, ceramics and composite materials, as well as obtaining metal, metal alloy, micro and nano particles [2].

The method of obtaining micro particles of metals using electrical discharges is simpler, more efficient and more environmentally friendly than other mechanical and physicochemical methods. In addition, the use of various media, such as gas, liquid, vacuum, and intermediate states, in the process of EDM-based particle production significantly expands the capabilities of this method.

The ability to use various media (distilled water, distilled water, kerosene, vegetable oil) during the production of micro particles has a positive effect on such important properties of the particles as their size, shape, quality, surface structure and agglomeration behavior. Furthermore, by controlling the discharge parameters such as frequency, duration, rise and fall times, voltage and current intensity, the morphology and flow ability of the resulting micro particles can be tailored to meet specific requirements.

The environmental benefits of the EDM method are much higher than those of other mechanical or physicochemical methods. First, the reduction or waste of materials in the EDM process is minimal. Second, the fluids used in particle production are also environmentally friendly, reducing harmful emissions. In addition, the energy efficiency and high level of precision of the EDM method, which increases the speed of the production process, are also economically beneficial.

In conclusion, the high mechanical properties of the Ti-6Al-4V alloy, coupled with its rapid adaptation to the human body, make it a key material in advanced industries and medicine. The EDM method offers an effective solution for processing this alloy. This method provides high precision and technological flexibility, providing control over the size, shape and quality of micro particles. In addition, the environmental friendliness and cost-effectiveness of the EDM method help to make production processes more efficient.

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WAVE PACKET DYNAMICS IN GRAPHENE WITH SQUARE AND TRIANGULAR PATTERNED CIRCULAR POTENTIAL BARRIERS

Kh. Rakhimov[1,*], H.T. Yusupov[2], M.U. Nosirov[1], M. Yusupov[3], A. Chaves[4]

[1] Institute of Materials Science, Academy of Sciences of Uzbekistan, Tashkent, Uzbekistan
[2] Kimyo International University in Tashkent, Tashkent, Uzbekistan
[3] Institute of Fundamental and Applied Research, NRU TIIAME, Tashkent, Uzbekistan
[4] Departamento de Física, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil
* e-mail: kh.rakhimov@gmail.com

Keywords: *graphene, wave packet, potential barrier, square pattern, triangular pattern*

The behavior of charge carriers in graphene has been extensively studied in the context of disordered potential landscapes, such as those created by randomly distributed scatterers [1,2]. These investigations show that disorder significantly affects charge transport, often leading to reduced transmission probabilities and increased interaction times due to enhanced scattering. Related studies [3] have explored wave packet propagation through periodic potential landscapes, revealing complex phenomena such as non-monotonic variations in transmission probability with respect to barrier height and sensitivity to the geometric arrangement of the barriers. For instance, staggered or asymmetric [4] periodic structures tend to enhance scattering and suppress transmission more effectively than symmetric ones [5]. These findings underscore the importance of periodicity and geometric configuration in modulating the electronic behavior of graphene.

While wave packet dynamics in pristine graphene have been thoroughly investigated, theoretical studies specifically focusing on propagation through square and triangular patterned potential barriers remain limited. In this study, we investigate wave packet dynamics in graphene under the influence of square or triangular arrays of circular potential barriers, mimicking 2D crystal geometries. We further extend our investigation to include the influence of one and two-lines defects within these crystal-like structures. This configuration introduces a new degree of control over charge carrier dynamics in graphene, enabling novel functionalities for graphene-based nanodevices. Our approach utilizes the Dirac continuum model [6,7] and numerical simulations to analyze how parameters such as barrier height, radius, and spacing between the circular potentials influence wave packet transmission and scattering behavior.

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BIOGAS PRODUCTION FROM VARIOUS BIOMASS SOURCES

M.Maqsutxonova[1], A.Begdullayev, H.Abdukarimov, Sh.Kuchkanov[12], Sh.Sheraliyev[2], D. Gafurov[3]
[1]Tashkent State Technical University, University Street 2, Tashkent, Uzbekistan
[2]"Eco-Energy" Scientific Implementation Center LLC, 21-A Choshtepa Street, Sergeli District, Tashkent
[3]"SOLAR NATURE TRADE HOUSE" LLC
Email: wwwpanpanchik@icloud.com.

Abstract

The importance of renewable energy sources in conserving natural energy resources has become paramount. In our republic, solar energy and biomass energy have proven highly effective. Biogas production represents an innovative technology that combines environmental protection and energy conservation while enabling comprehensive energy utilization.

Biogas production is a crucial method for efficiently utilizing agricultural waste. Research indicates that methane yields vary significantly across different biomass sources [1]. The composition and physicochemical properties of feedstock directly impact biogas production efficiency.

1. Introduction

Biogas is produced through anaerobic digestion of organic matter in sealed reactors. Biogas plants process manure (plant residues and animal waste) to produce combustible gas and high-quality organic fertilizer.

Biogas is generated naturally or in specialized installations. It results from biological decomposition reactions of organic materials, typically occurring in landfills where all deposited organic matter decomposes.

2. Biogas Composition and Production Process

Biogas primarily consists of methane (CH_4), produced through anaerobic digestion. The production process depends on feedstock type, as different biomass materials vary in organic content, decomposition rate, and gas production capacity [2].

Key factors influencing biogas yield:

Organic matter content: Biomass with higher organic content yields more methane.

Decomposition rate: Easily degradable biomass produces gas faster and more efficiently.

C/N ratio: Optimal carbon-to-nitrogen balance is 20:1 to 30:1. Excess nitrogen leads to ammonia release, inhibiting fermentation [1].

Moisture and fiber content: Fibrous biomass (e.g., straw) decomposes slowly, while insufficient moisture slows fermentation.

3. Comparative Analysis of Biomass Sources

3.1 Livestock Waste

Cattle manure: 25-30% dry matter, methane yield 50-60% [1].

Poultry manure: Higher nitrogen content (55-65% methane), but low C/N ratio may cause ammonia inhibition [3].

3.2 Crop Residues

Straw: High lignin content reduces efficiency (40-50% methane).

Corn stalks: Contains cellulose/hemicellulose (45-55% methane), slower decomposition.

3.3 Food Waste

Fruit/vegetable waste: Fast decomposition, high moisture, 60-70% methane yield.

Kitchen waste: High fat/starch content enables 65-75% methane production [2].

4. Discussion

Food waste and poultry manure demonstrate the highest biogas potential due to rapid decomposition and high methane content. Crop residues require additional pretreatment or co-digestion. Mixed feedstock systems are recommended to optimize production efficiency.

5. Conclusion

Biogas technology offers sustainable solutions for:

✓ Waste-to-energy conversion

✓ Organic fertilizer production

✓ Greenhouse gas reduction

Future research should focus on:

Feedstock pretreatment methods

Optimized C/N ratios

Large-scale implementation in Uzbekistan's agricultural sector references.

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