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REVIEW OF THE FOREIGN SCIENTIFIC CONSULTANT

for the dissertation thesis of DANIEL MEKONNEN ZELLELE

of the dissertation work on the title: "ELECTROCHEMICAL SYNTHESIS AND FUNCTIONAL PROPERTIES OF METAL AND ALLOY-BASED COMPOSITION COATINGS" presented for the degree of Doctor of Philosophy (PhD) in the educational program 8D07103 "Materials Science and Technology of New Materials"

This doctoral dissertation, devoted to nanocomposite and nanocrystalline coatings obtained by electrochemical methods, is exceptionally timely and crucial for modern materials science and surface technology. This topic aligns directly with the global trends in the search for high-performance protective and functional coatings that can replace expensive or ecologically problematic solutions (such as technical chromium).

The work focuses on several advanced material systems, such as Cr-Graphene, Ni-Cu, and Co-V alloy coatings. This research directly contributes to solving industrial challenges: optimizing hardness and corrosion resistance and developing new electrocatalytic strategies. This topic is not only timely but also contributes new, original knowledge to the mechanisms of deposition in complex nanostructured systems.

The work is excellently planned and organized, reflecting the structure of its research objectives. The objectives are logically formulated and constitute a complete research framework that has been fully implemented:
1. Design and Optimization of Deposition Parameters: The focus was on designing and optimizing electrochemical parameters (bath composition, pH, current density) to obtain uniform and adhesive coatings.
2. Material Characterization: Detailed morphological, structural, and compositional characterization of the coatings was performed using advanced analytical techniques (SEM, EDS, XRD, AFM).
3. Functional Properties Assessment: A comprehensive assessment of key properties, such as hardness, corrosion resistance, tribological behavior, and adhesion strength, was performed, and their correlation with synthesis parameters was analyzed.
4. Establishment of Structure-Property Relationships: Structure-property relationships were established, explaining how electrochemical synthesis methods affect the quality and functional performance of the coatings. 5. Optimization Proposals: The work culminates in a proposal for optimized electrochemical strategies aimed at producing high-performance coatings for industrial applications.

The work contains a number of groundbreaking achievements constituting new knowledge, which are very well documented, conducted, and summarized in the appropriate section.
3.1. Cr-Graphene Coatings

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Scientifically, 45°C has been demonstrated to be the optimal bath temperature for the effective incorporation of graphene nanocomponents into a chromium matrix. This optimum has been proven to achieve maximum carbon content, minimum grain size, highest microhardness, and a compact microstructure, which is crucial for a synergistic anti-corrosion barrier.

3.2. Ni-Cu Coatings

Experimentally, a current density of 40 mA/cm² was proven to be optimal for Ni-Cu deposition on an AISI 304 substrate, leading to the densest morphology and a nanocrystalline structure with a domain size of 17 nm. It was determined that 17 nm nanoparticles aggregate to form microscale nodules, which provides a hierarchical surface topography favorable for enhanced wear resistance.

3.3. Co-Fe-V Alloys (Pulsed Electrolysis Method)

A new mechanism for the deposition of a Co-V alloy in pulsed electrolysis was established and verified, demonstrating that vanadium incorporation is enhanced during the pause stage due to the chemical reduction of vanadyl by adsorbed hydrogen atoms. It has been shown that enrichment of the alloy with vanadium leads to a significant increase in microhardness (up to 100-200 kg/mm2 compared to pure Co) and to a reduction in the hydrogen evolution overpotential (HER), bringing the parameters closer to the kinetics of Pt (platinum).

Based on the presented achievements, it can be concluded that the doctoral dissertation was exceptionally well conducted and summarized. The research is of a very high standard and fully meets the requirements for modern doctoral theses in the fields of nanotechnology and materials electrochemistry. The use of advanced research methodology and detailed analysis of the relationship between synthesis parameters and functional properties constitute a valuable scientific achievement.

The results and conclusions obtained during the study reflect the content of all sections and are confirmed by the publication of the main scientific results in peer-reviewed international and national scientific publications. The credibility of the scientific conclusions of the work is confirmed by its consistency with the results of independent research and conclusions obtained by other authors.

The doctoral dissertation is rigorous and logical, presenting scientific, qualifying, completed research, and is of interest to a large group of scientists in the field of materials science and nanotechnology. This dissertation corresponds to the priority directions outlined in the following strategic documents of the State Program for the Development of Science of the Republic of Kazakhstan (2020-2025). Additionally, Daniel Zellele's study supports the objectives of the National Project "Technological Leap Through Digitalization, Science, and Innovation" and the Industrial-Innovative Development Program (IISD-2020/2025).

Daniel Zellele presented the primary results of his dissertation at several international and national conferences. He is the author of several scientific papers, including publications in journals listed in Scopus and Web of Science databases or recommended by the Education and Science Control Committee of the Ministry of Education and Science of the Republic of Kazakhstan. The doctoral student completed a research internship at Wrocław University of Science and Technology, where tribological studies were conducted.

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Daniel Zellele's personal contribution included planning and conducting the experiments, conducting theoretical and experimental studies, discussing and summarizing the results. The results presented in this thesis were obtained by the author and in collaboration with faculty from the Faculty of Mechanical Engineering of Wrocław University of Science and Technology (Poland).
From the above said I may summarize that the scope, execution level, accuracy and scientific and practical significance of the results achieved by corresponding to all the requirements defined for dissertations by the Control Committee in Education and Science under the Ministry of Education and Science of the Republic of Kazakhstan, for PhD dissertations. Daniel Zellele highly deserves a PhD degree of a Doctor of Philosophy (PhD) in the educational program 8D07103 "Materials Science and Technology of New Materials"

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