

OPINION

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regarding the PhD thesis for the acquisition of the educational and scientific degree "Doctor"
Professional field: 4.1. "Physical Sciences", doctoral program "Condensed Matter Physics".
Author of the dissertation: Stefan Dimitrov Kolchev from CLAP-BAS. Topic of the dissertation: "Development and research of wear-resistant nanocomposite coatings with modulated composition for multifunctional applications".
Scientific supervisor: Prof. Lilyana Kolaklieva

The documents submitted by the PhD student show that he meets the minimum national requirements set by the LDAS and the relevant national and institutional regulations for its implementation.

1. Relevance of the topic of the dissertation

The dissertation is in a current area of scientific and applied research, relating to the application of coatings with the widest application in industry to improve the hardness, wear resistance, corrosion resistance and thermal stability of parts, tools and surfaces. The development of nanocomposite structures containing nanocrystals from a multicomponent solid solution is a new stage in the creation of coatings with increased hardness, wear resistance and oxidation resistance. This trend determines the goal of the dissertation, which is, through an innovative approach to modulating the composition of the coating, to develop and study a superhard coating with a nanocomposite structure and multilayer architecture, combining improved mechanical and tribological properties, stability at high operating temperatures, with a focus on multifunctional industrial applications. From here arises the need to solve the following problems: achieving hardness of the order of 40 GPa and higher (superhardness); combining superhardness with high elasticity; stability of mechanical and tribological properties at high temperatures.

2. General overview of the dissertation work

The literature review of 107 sources examines in detail the advantages and disadvantages of known synthetic methods and composite materials for obtaining hard and superhard coatings. As an innovative approach to achieving multifunctionality, a multilayer structure is proposed, built from periodically alternating sublayers with a certain thickness. In this way, an architecture is built with varying structure and composition of the different sublayers, combining the desired properties of the coating.

Aiming at a methodology suitable for the purpose, the doctoral student successfully mastered, applied and further developed the methodology for cathodic arc evaporation for obtaining multilayer coatings. With the active participation of the doctoral student, a technology for nanocomposite coatings with modulated composition was developed, and reference single-layer coatings sl-TiAlSiN and sl-AlSiN were deposited to determine the growth rates. Using this technology, multilayer ml3-TiAlSiN/AlSiN and ml30-TiAlSiN/AlSiN coatings have been successfully deposited, ensuring good repeatability of their structure in the deposition process. The experimental part includes the necessary data on the materials used, equipment, synthetic methods and methods for characterizing the obtained coatings. An appropriate set of analysis methods was used, including X-ray photoelectron spectroscopy (XPS), Scanning electron microscopy (SEM), Energy dispersive spectroscopy (EDS), X-ray structural analysis, which allows for detailed phase-structural characterization of the deposited coatings. The thickness,

mechanical (hardness, modulus of elasticity, resistance to elastic and plastic deformations, adhesion) and tribological (wear resistance) properties and thermal resistance of the deposited coatings were studied in detail.

The Results and Discussion sections present the results of the large volume of experimental work, on the basis of which an optimized technology for applying the multilayer nanocomposite coating TiAlSiN/AlSiN was created.

3. Scientific and scientific-applied contributions of the dissertation

The dissertation formulates one scientific and several scientific-applied contributions, which can be noted as significant:

- 1) The mechanism that allows overcoming the fragility of superhard coatings and achieving high elasticity is explained. This is the combination of a multilayer architecture with nanocomposite structured sublayers of TiAlSiN/AlSiN in which the strength of the Ti-N bonds (464 kJ/mol) and Al-N (297 ± 96 kJ/mol) determine the elastic modulus of the material
- 2) For the first time, a technology for a nanocomposite multilayer coating consisting of a superhard nanocomposite (TiAlSiN) and a nanocomposite with greater elasticity (AlSiN) has been developed and optimized.
- 3) It was found that the mechanical properties and wear mechanism of the coating depend on the modulation period
- 4) It was found that the wear rate decreases with increasing treatment temperature, which correlates with the decrease in coating hardness

4. Evaluation of publications on the topic of the dissertation

The author has attached a list of 2 publications, which are in a journal Coatings, IF 2.8. with a quartile Q2. To date, these publications have 5 citations, noted in the international database Scopus. A useful model “Planetary carousel for driving samples in a physical vapor deposition device”, registered in 2023, is also attached. The publication activity meets the requirements for obtaining the educational and scientific degree “doctor”.

5. Opinions, critical notes, recommendations

In some places in the dissertation work, inaccuracies have been made, for example: When interpreting photoelectron spectra, in many places the term bond energy is used instead of binding energy. The term bond energy refers to the bonds between atoms, and binding energy is the attraction of electrons in the electronic shell by the atomic nucleus. There are also technical errors such as on page 82 “Ti atoms (with a radius of 47.867 Å). Also, for me, the conclusion on page 126 “A multilayer architecture has been proposed for the first time, in which the period has a completely nanocomposite structure”, does not sound good in terminology, because the term period refers to a time interval. These critical remarks relate entirely to the gaps in the text of the dissertation, but do not belittle the quality of the scientific achievements and contributions of the candidate, so the positive impression of their high scientific level remains.

CONCLUSION

Based on the analysis, I believe that in terms of the volume of the experimental work performed and the results achieved, the presented dissertation work meets the requirements for acquiring the educational and scientific degree “doctor”, formulated in the LDAS, the Regulations for its application and the relevant Regulations of the Institute of Electronics of the Bulgarian Academy of Sciences. My opinion on the dissertation is positive. I propose to the

esteemed jury to award Stefan Dimitrov Kolchev the educational and scientific degree "Doctor" in the professional field: 4. 1. Physical Sciences, specialty "Condensed Matter Physics".

12.09.2025,

Member of the scientific jury:

/Prof. Dr. Plamen Stefanov/

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