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СОФИЯ

REVIEW

For the competition for the academic position „Associate Professor" in the professional field 4.1 Physical Sciences (Electronic properties of nano-sized thin layered systems), announced in State Gazette 36/29.04.2025 by the Institute of Mineralogy and Crystallography-BAS.

Candidate: Assist. Prof. Dr. Petar Yordanov, Institute of Mineralogy and Crystallography, BAS
Reviewer: Prof. Dr. Ruzha Harizanova, University of Chemical Technology and Metallurgy

1. Description of the materials submitted for the competition.
Only one applicant, Assist. Prof. Dr. Petar Yordanov Yordanov participates in the Associate Professor competition in the professional field 4.1. Physical Sciences (Electronic properties of nano-sized thin layered systems) announced in the State Gazette 36/29.04.2025 by the Institute of Mineralogy and Crystallography (IMC)-BAS.
Dr. Yordanov has submitted all the documents required by the Law for the Development of the Academic Staff in the Republic of Bulgaria (LDASRB) and the Regulation on the terms and the conditions for the acquiring of the scientific degrees and academic positions of IMC-BAS. The applicant has supplied a criminal record certificate and medical certificate, as well as a note from the IMC-BAS for employment duration in the specialty.
In the competition Assist. Prof. Dr. Petar Yordanov participates with 15 publications in referred and indexed scientific magazines, he has submitted a list with the participation in 4 conferences, 2 patents and 2 participations in scientific projects. The works submitted for the competition do not duplicate those used for awarding the scientific and educational degree "PhD".
The submitted documents comply with the minimal requirements of IMC-BAS for the occupation of the academic position "Associate Professor" in 4. Natural Sciences, Mathematics and Informatics, professional direction 4.1 Physical Sciences.

2. Professional and academic career.
Dr. Petar Yordanov acquired his Master degree in the specialty Chemistry and Physics from the Faculty of Chemistry of the Sofia university St. Kliment Ohridski in 2000. In 2003 he acquired a second Master degree in the specialty Integrated and discrete optoelectronics in the optical communications at the Semiconductors department of the Faculty of Physics of the Sofia university St. Kliment Ohridski. Between 2004 and 2009 he worked on and defended his PhD thesis entitled "Spectroscopic study of $CaMnO_3/CaRuO_3$ superlattices and $YTiO_3$ single crystals" under the supervision of Prof. B. Keimer and with the support of Prof. G. Denninger at the Max Planck Institute of Solid State Physics, Stuttgart and the Stuttgart university, Germany.
Dr, Yordanov has acquired ris professional experience during his work as a Physicist at the Semiconductor Physics Department, Sofia university St. Kliment Ohridski between 2000 and 2003 and as a Physicist at the Max Planck Institute of Solid State Physics,

Stuttgart, Germany between 2004 and 2022. At the latter he mainly acquired his skills in the field of the synthesis of polycrystalline materials and nano-sized thin layered systems and the investigation of their structure and electronic properties as well as estimation and model description of their thermoelectric properties (Seebeck coefficient). Here he also acquired his skills in developing of prototype devices whose work is based on the ultrafast transverse thermoelectric effect. From November 2024 till present he is occupying the position of an Assistant Professor – Physicist at the IMC "Acad. Ivan Kostov"-BAS.

3. Description of the publications submitted for the competition and fields of scientific interests of the applicant.

In the present competition for the occupation of the academic position "Associate Professor" announced by the IMC-BAS in the professional field 4.1 Physical Sciences (Electronic properties of nano-sized thin layered systems), Dr. Petar Yordanov applies with 15 publications (2 of the in total 17 submitted publications have been used during the defense of the PhD thesis) in referred and indexed scientific journals, 4 participations in scientific conferences, 2 patents and 2 participations in scientific projects. None of the 15 publications submitted for the competitions has been used for the defense of the PhD thesis and they mainly refer to the synthesis, studying and modelling of the transport properties of thin nano-sized films with advanced photoelectric, magnetic and thermoelectric properties and the additional characterization of their structure and morphology as well as the construction of devices operating based on the Seebeck effect.

I acknowledge and have prepared the review based on all the submitted publications though it is necessary to mention that the publication under number 14 in the List of publications submitted for the competition

P. Kaya, Y. E. Suyolcu, F. Baiutti, P. Yordanov, G. Christiani, F. Wrobel, E. Benckiser, B. Keimer, H.U. Habermeier, G. Gregori, G. Logvenov, P. Aken, J. Maier, **Atomic-scale Considerations on $LaNiO_3$-La2CuO_4 Heterostructures: Interface—thermoelectricity Relationship,** *Microscopy and Microanalysis* **26**, 2626 (2020), **DOI:10.1017/S1431927620022230**

as a volume and content rather resembles an extended abstract than a short communication. Nevertheless, this work is published in a high IF journal and it could be taken into account in the evaluation of the scientific publications.

The submitted scientific works are separated into two parts: the first one, containing 4 publications, is substituting for the habilitation thesis (indicator B) and the second one – contains 11 articles which are corresponding to indicator G (Г) as well as the works standing for the additional requirements of IMC-BAS. The 4 publications substituting for the habilitation thesis are all in Q1 journals with an IF and correspond to 100 points. For indicator G, 2 patents (50 points) and 10+1 publications (225 points+20 points) are submitted. Again all articles are published in IF journals and their quartiles are as follows: Q1 – 7 publications; Q2 – 2 and Q3 – 2.

According to the submitted materials, the total number of independent citations of the work of Dr. Yordanov is about 400, in approximately 1/3 of them he is the first author and in the rest of the 2/3 of the publications he has a significant contribution for the data acquiring and interpretation. According to Scopus, the candidate's h-factor is 12.

The citations' number for the publications submitted for the competition is 50 without direct and indirect self-citations (Scopus) which corresponds to 100 points. The most cited works are 13 (30 citations) and 10 (10 citations) submitted as habilitation thesis which are dedicated to the problems of the preparation of thin $PdCoO_2$ films on Al_2O_3 substrates and investigation of the Seebeck effect in them and the preparation of thin epitaxially grown $Ca_3Co_4O_9$ films onto different crystalline substrates aiming the realization of highly effective thermoelectric effect, respectively.
The total number of points for indicators B and G for the works of Dr. Yoedanov is thus 345 points which corresponds to and even exceeds the requirements imposed by IMC-BASS for these two indicators. For the rest of the indicators the points are as follows: indicator A – 80 points (80 required); indicator D (Д) – 100 points from 50 required. Thus, the total number of points of Dr. Petar Yordanov in the competition corresponds to the minimum requirements of IMC-BAS for all indicators – a total score of 525 from 450 points required.

4. Main fundamental and applied contributions.
The main contributions in the works of Dr. Petar Yordanov submitted for the competition concern the synthesis and characterization of the transport properties as well as developing of models describing these properties in case of polycrystalline samples and nano-sized thin films and heterostructures. These contributions are in the following fields: 1) synthesis of new functional materials combining two or more transport properties: polycrystalline samples, epitaxially grown nano-sized thin films and heterostructures onto single crystal substrates; 2) complex characterization of the obtained materials and 3) investigation and modelling of the transport properties of the obtained materials – magnetic properties, electrical conductivity and thermoelectric properties (mainly determining the Seebeck coefficients and the time parameters, and the efficiency of energy transformation in case of ultrafast transverse thermoelectric effect, generation of electromagnetic radiation in the terahertz range).

4.1. Scientific contributions in the publications substituting for the habilitation thesis.
The main contributions in the scientific works presented in stead of a habilitation thesis by Dr. Petar Yordanov could be summarized as follows.
Polycrystalline thin layers of $PdCoO_2$ have been grown onto *c*-oriented, as well as on irregularly oriented vicinal sapphire Al_2O_3 substrates which made possible the evaluation of the thermoelectric parameters and more precisely, of the Seebeck coefficient along the main crystallographic axes which is a task difficult to solve in practice due to the lack of large enough single crystals demonstrating the respective properties. The temperature dependence and the dependence of the thermoelectric properties on the conditions of preparation of the thin films have been studied and it has been shown that the experimentally obtained values correlated very well with the theoretically predicted ones (publications 13, 15 and 17). The importance of the research carried out in these works is determined by the necessity to prepare effective and powerful terahertz radiation emitters which could be some of the layered oxides of the transition metals due to the natural anisotropy in their electronic properties. It is believed that electronic devices obtained based on these materials have a significant potential for application in the field of the

terahertz imaging diagnostics, contactless flaw detection; fast communication with transfer of large amount of data, spectroscopy and investigation of non-linear phenomena. Another material prepared by the candidate and exhibiting promising thermoelectric properties with potential for the realization in it of ultrafast transverse Seebeck effect and thus, utilization as part of terahertz emitters, is $La_{1.84}Sr_{0.16}CuO_4$. This material has also been prepared as a thin film and the thermoelectric properties have been both modelled and experimentally measured in a wide temperature range (publication 17).
As a next contribution in the works submitted by Dr. Yordanov, the preparation and characterization as well as investigation of the thermoelectric properties of another complex transition metal oxide, $Ca_3Co_4O_9$ in the form of thin film deposited onto various crystalline substrates can be outlined. It has been concluded that the existence of an anomalously large Seebeck coefficient is combined with the occurrence of an additional conduction mechanism in the $SrTiO_3$ and $LaAlO_3$ substrates for temperatures higher than 450˚C. It has been established the nature of this conduction mechanism in the present materials and this served as a foundation for the justification of the extremely high Seebeck coefficient measured in the prepared materials. As a result, a hybrid material has been obtained which is a candidate for application in highly efficient thermoelectric convertor devices (publication 10).

4.2.Scientific contributions in the materials presented as non-habilitation publications.

In the publication presented for indicator G the main contributions of the candidate are again related to the synthesis of polycrystalline materials, epitaxially grown nano-sized thin film systems – layers and heterostructures on single crystal substrates, X-ray diffraction structural characterization, spectroscopic investigation and studying of the transport properties and the main parameters corresponding to these properties – electrical conductivity, Seebeck coefficient, evaluation of the time characteristics in case of ultrafast transverse thermoelectric effect, generation of terahertz electromagnetic radiation, modelling the processes occurring in the prepared materials.
In publication 1 and 2 the scientific contribution can be defined as the preparation of thin semiconducting layers of β-$FeSi_2$ and Mg_2Si by ion implantation and their spectroscopic characterization by means of IR and UV-Vis spectroscopies.
Another scientific contribution in the works corresponding to indicator G is related to the investigation of the following two systems: single crystal ferromagnetic insulating $YTiO_3$, and superlattices composed of thin films of the paramagnetic, conducting $CaRuO_3$ and the antiferromagnetic insulating $CaMnO_3$. For both types of prepared materials, a detailed spectroscopic characterization has been carried out by utilizing methods such as IR and UV-Vis spectroscopy, X-ray absorption spectroscopy and scattering, as well as dichroism with circular polarized light and the main optical characteristics have been estimated along the different crystallographic directions (publications 5, 7). In the case of yttrium titanate, the temperature dependent behaviour in an external magnetic field as well as the dependence on the crystallographic direction and the magnetic field strength have been investigated (publication 6). For the superlattices of $CaRuO_3/CaMnO_3$, the charge distribution profiles for the free electrons and the magnetic behaviour have been determined. In publication 4 a detailed investigation of the photoconductivity along the c-axis of a series of single crystals of the high temperature superconductors $RBa_2Cu_3O_{7-\delta}$

(R=Y, Nd, La) has been studied. Next part of contributions for this indicator is related to the synthesis of complex transition metal oxides in the form of polycrystalline samples, thin films and heterostructures deposited onto single crystal substrates and investigation as well as modelling of their electrical and thermoelectric properties, in particular of the potential for realization of ultrafast transverse thermoelectric effect in the terahertz range in them in case of the following thin film materials: $PdCoO_2$; superlattices of $LaNiO_3/LaAlO_3$ (001), deposited onto $SrTiO_3$ substrates and La_2CuO_4 (publications 12, 13, 14 and 16).
In publication 7, a complex spectroscopic characterization of superlattices consisting of the paramagnetic conducting $CaRuO_3$ and antiferromagnetic insulating $CaMnO_3$, has been carried out aiming the detailed description of their transport and magnetic properties. The main contribution in this work is that it is established that the density of the free electron charge carriers and the valence state of Ru in the $CaRuO_3$ layers of the superlattice is the same as that in the case of bulk materials and that re-distribution of electrons from $CaRuO_3$ into $CaMnO_3$, has been observed. This finding correlates with the results from the theoretical evaluation of these parameters for the investigated combination of materials as performed by using the functional density theory (DFT). The electron penetration depth into $CaMnO_3$ has been found to be equal to about 3-4 unit cell parameters which is a distance significantly larger than the one expected and suggests the occurrence of magnetic polarons at the interface of the two materials.
In publication 9, a detailed investigation of the thermoelectric properties – Seebeck coefficient and thermal conductivity, which are the main factors determining the efficiency of transformation, for the composite systems SiAlON and SiC, with 5 and 10 vol % TiCN - has been performed. Another main contribution in the publications submitted for indicator G is the successful synthesis in the form of single crystals and by pressing of the unstable in air phosphide $Ag_6Ge_{10}P_{12}$ and its characterization as a structure, as well as thermoelectric properties by means of temperature-dependent X-ray diffraction analysis, quantum-chemical calculations and thermoelectric measurements. The hypothesis has been raised that the compound $Ag_6Ge_{10}P_{12}$ possesses a potential as a highly effective thermoelectric material (publication 11).
In conclusion, it should be mentioned that the contributions in the works of Dr. Yordanov could serve as a basis for future theoretical and experimental investigations in the field of thermoelectric phenomena occurring in complex metal oxides and to serve as a prerequisite for the synthesis of materials with controllable electrical and thermal conductivities.

5. Personal contribution of the candidate.
In the materials submitted for the competition, the personal contributions of Dr. Petar Yordanov can be outlined as follows. Performing of spectroscopic measurements and interpretation of the data from IR and UV-Vis spectroscopies and data from X-ray structural analysis, and measurement and modelling of the electrical and magnetic properties of the studied systems – thin films deposited on single crystal substrates and single crystal specimens (publications 1-8). The next personal contribution of the candidate is the detailed investigation and the analysis of the thermoelectric properties of the materials prepared and reported in publications (9, 11, 12, 14).

In publication 10, Dr. Petar Yordanov is the leading researcher and has a main contribution in the synthesis of polycrystalline $Ca_3Co_4O_9$, the deposition of a large number of thin films of $Ca_3Co_4O_9$ from a polycrystalline target by means of PLD on various types of single crystal substrates and the detailed investigation and interpretation of the data concerning the thermoelectric properties and parameters as well as the development of the model explaining the observed phenomenon.
In paper 13 the personal contribution of Dr. P. Yordanov is related to the deposition of thin nano-sized $PdCoO_2$ films on an Al_2O_3 substrate, establishing the optimal parameters during the PLD process, experimental measurement of the Seebeck coefficient and the electrical resistance along the different crystallographic directions in a wide temperature range, X-ray diffraction structural characterization of the samples, including the degree of directed growth, investigation of the topology by AFM, estimation of the potential possible generated voltage in the thin films during the carried out experiment using laser pulses.
In publication 15, Dr. Petar Yordanov has a leading part and contribution in the Seebeck coefficients and electrical conductivity measurement for the prepared polycrystalline samples from $PdCoO_2$ in the temperature range 300 -1000 K in dependence of the ambient and in the formulation of a model describing the observed thermoelectric effects.
Publication 16 is a review article in which the main contribution of Dr. Petar Yordanov is in the parts concerning the investigation and characterization of the systems showing anomalous increase of the Seebeck coefficient at high temperatures in the case of thin films and heterostructures based on $LaNiO_3$ and in the part summarizing the investigation on $PdCoO_2$.
In paper 17, the candidate has a major contribution in the growth of the nano-sized thin films of $PdCoO_2$ on an Al_2O_3 substrate, measurements by means of nanosecond pulsed laser aiming the realization and determining the main characteristics of the transverse Seebeck effect observed in the obtained materials. As an additional personal contribution in this work, the candidate has taken an active part in the data interpretation and the manuscript preparation.
As a next contribution of the candidate the holding of two patents can be pointed out for which he is the principal inventor – European and World patent (П1,П2), concerning the work on the elucidation of the mechanism of terahertz electromagnetic generation based on an ultrafast transverse thermoelectric effect in thin films of $PdCoO_2$; analysis and modelling of the generated terahertz radiation; development and modelling of the non-equilibrium thermal diffusion; evaluation of the parameters influencing the power and the spectral distribution of the generated radiation. The method has been demonstrated and modelled also for other materials – as for example, thin films of $La_{1.84}Sr_{0.16}CuO_4$.
It should be noted that Dr. Yordanov has taken an active part in the interpretation of the obtained results and the manuscripts' preparation for all publications submitted for the competition.

6. Critical remarks and recommendations regarding the applicant's research activity.

I have no significant critical comments on the materials submitted for the competition and the candidate's competence demonstrated in them.

7. Conclusion

Assistant Professor Dr. Petar Yordanov Yordanov has presented in the competition materials which correspond and even, for some of the criteria, exceed the criteria recommended for the occupation of the academic position "Associate Professor" at the Institute of Mineralogy and Crystallography – BAS. Based on all of the above – the well-selected and modern scientific topic, the quantity and quality of the presented scientific publications, the well-defined personal scientific contributions of the applicant as a scientist, I recommend with conviction

Assist. Prof. Dr. Petar Yordanov

to be appointed at the academic position of Associate Professor in the professional field 4.1 Physical Sciences (Electronic properties of nano-sized thin layered systems) at the Institute of Mineralogy and Crystallography-BAS.

Date:

Reviewer: Заличено съгласно чл. 2 от ЗЗЛД

Prof. Dr. Ruzha Harizanova

03.09.2025