

## OPINION

by competition for the academic position of "professor" at the Institute of Engineering Chemistry, BAS by professional field 4.2. Chemical sciences, scientific specialty "Processes and devices in chemical and biochemical technology" for the needs of the laboratory "Transfer processes in multiphase media", announced in SG no. 66 of 16.08.2022

with candidate: Maxim Ivanov Boyanov, associate professor, Ph.D

The opinion was prepared by: Professor Dr. Plamen Kirilov Stefanov from the Institute of General and Inorganic Chemistry - BAS

### 1. Brief biographical data and characteristics of the candidate's scientific interests

Maxim Boyanov received his secondary education at the English Language High School in Sofia in the period 1986-1989 and at the "Marie Curie" High School in Chicago (1989-1990). He completed his higher education in 1995 at the Faculty of Physics of the University of Sofia "St. Kliment Ohridski" with a master degree in "Physics of the solid state", with the thesis topic: "Two new solutions to the inverse ellipsometric problem". In 2004, he defended his doctoral thesis on the topic "Determining the atomic structure of surface and bulk metal-organic complexes by X-ray spectroscopy" at the Faculty of Physics, University of Notre Dame, Notre Dame, Indiana, USA.

Assoc.Prof. Boyanov's scientific career began and developed initially in the USA, where he held the following academic positions: specialist (post doc), Institute of Environmental Studies, Argonne National Research Laboratory, Illinois (2003-2006); post doc, Institute of Molecular Ecology, School of Environmental Sciences Engineering, University of Notre Dame, Notre Dame, IN, (2006-2007), Physicist, Laboratory of Molecular Ecology, Institute of Biology, Argonne National Laboratory, Illinois, (2008-2014). In 2014, he joined the Laboratory "Transfer Processes in Multiphase Environments", Institute of Engineering Chemistry, BAS, as an assistant and in 2015 was elected as an associate professor in the same laboratory.

Assoc.Prof. Boyanov's scientific interests are in the field of molecular biogeochemistry, with an emphasis on heavy metals and radioactive pollutants such as Cd, Cr, Pb, and U. In his research, he applies the method of synchrotron X-ray spectroscopy to observe new reactions or to validate suspected reactions in mass transfer models in nature, and in particular specific reactions for modeling the spread of pollutants in real subsurface environments.

### 2. General characteristics of the candidate's scientific research and applied scientific activity

The detailed review of the results summarized by the candidate, reflected in the Author's Reference for Contributions and the relevant publications, outline a certain orientation of his scientific research activity towards elucidating the mechanisms of reactions in natural and laboratory environments, which are of importance both for the fundamental understanding of the processes at the solution- mineral or solution-biological surface, as well as for the development of engineering methods for soil and water purification. Assoc.Prof. Boyanov's scientific data includes a total of 80 scientific works, the majority of which have been published in renowned international journals, and this undoubtedly reflects the candidate's high professional and scientific level. Assoc.prof. Boyanov has been the head of 4 international projects and currently 1 ongoing project. The size of the funds attracted by the projects is very



impressive, which is a total of BGN 2,413,800, of which BGN 448,200 is directly for Institute of Engineering Chemistry. He was the scientific supervisor of 1 specialist and joint supervisor of 2 doctoral students at the Argonne National Laboratory, USA.

The results of Dr. Boyanov's research have been presented at numerous international scientific forums. For the period 2012-2022, a list of participations in 144 prestigious scientific forums is presented, which also include 27 invited reports. All this testifies to the importance of his scientific research and to his high authority among the international scientific community in his field. The candidate has presented evidence of significant scientific organizational activity, such as organizing and chairing conference sessions at prestigious forums of the American Chemical Society and the International Conference on Geochemistry. Prof. Boyanov was a long-time member of the American Chemical Society.

### **3. Evaluation of the presented materials**

For this competition, the candidate has submitted the complete set of required documents and supporting evidence, certifying: the fulfillment of the minimum requirements for the academic position "professor" according to LDAS and the Rules for its implementation, and the increased criteria of the BAS, as well as the fulfillment of the additional requirements according to the Methodology of scientist growth at IICChem-BAS.

Assoc. Prof. Maxim Boyanov is the author of 80 publications in refereed international scientific journals, 72 of them in journals with an impact factor,  $IF: 1.5 < IF < 30.1$ ). In the current contest, he participates with 25 of these articles, distributed among journals by quartiles as follows: Q1-17; Q2-1; Q3-1 and Q4-5 articles, 1 in a refereed scientific journal with IF and a book chapter indexed in Web of Science. Among those submitted for the competition are articles in the authoritative Environmental Science & Technology IF (Web of Science): 9.08, Energy & Environmental Science JCR-IF (Web of Science):30.067, Chemical Engineering Journal JCR-IF (Web of Science):10.652. In 9 of the presented articles, he is in first or second place in the author's team, which is indicative of his leading role in the conducted research and the processing of the obtained results.

The number of observed citations on all the candidate's publications is 2822 according to the Scopus database. The Hirsch index (Scopus) calculated on this basis is 27.

The presented data fully satisfy and significantly exceed the minimum number of points for meeting the minimum and additional requirements for occupying the academic position "professor" under the current competition.

### **4. Basic scientific and scientific-applied contributions.**

For the most part, the candidate's scientific research is aimed at elucidating the transformations of uranium in subsurface environments with the aim of a more comprehensive understanding of the factors that influence the mobility of uranium in natural systems and the inclusion of the relevant reactions in transport models describing the distribution of pollutants. In this regard, the candidate's use of the Extended X-ray Absorption Fine Structure Spectroscopy (EXAFS) method to determine the chemical specification of adsorbed heavy and radioactive metals can be noted as an innovative approach.

The presented results are up-to-date and of interest, both from a fundamental and from a scientific-applied point of view, and correspond to the subject of the announced competition. From the presented materials, significant scientific contributions can be noted in the following directions:



### **Conducting research in natural environments on the reduction-oxidation transformations of uranium**

It was established that the presence of phosphates in biological systems leads to the formation of complexes with  $U^{4+}$  which are significantly more labile than  $UO_2$

An  $U^{6+}$  was found to be reduced to  $U^{4+}$  in biofilms of bacteria cultured from soils near a former uranium enrichment plant, even when the external conditions were oxygenated.

It has been established that in soils rich in iron oxides, located in humid humid conditions, the so-called "green rust", from reactive ferro-oxides with a layered structure, and which have a major role in the partial reduction of  $U^{6+}$  to  $U^{4+}$  in this type of soil

In practical terms, these studies find realization in purification technology through the application of stimulated microbial reduction. For this, nutrient solutions (emulsified vegetable oil) were injected into underground wells in order to stimulate the local microbial flora, which in turn would create reducing conditions for the present  $U^{6+}$ . EXAFS studies revealed the presence of reduced  $U^{4+}$  in the solid phase. It is believed that the approach used can be applied under field conditions in bio-technology for the purification of groundwater from uranium.

### **Conducting research in laboratory conditions on model systems**

A number of studies have been carried out under laboratory conditions on model systems of synthesized aluminum and iron minerals with different porosity, with the aim of a more detailed understanding of the mechanisms of reduction and formation of the observed  $U^{4+}$  complexes in subsoil environments. It was found that uranium adsorbed on macro-porous minerals is easily reduced to  $UO_2$ , while uranium adsorbed on micro-nano-porous structures is not reduced under the same conditions, probably due to blocking the access of reducing agents to the adsorbed uranium.

Magnetite and alumina surfaces were found to stabilize adsorbed  $U^{4+}$  in mononuclear surface complexes and prevent the formation of  $UO_2$

The interlayer anion in green rusts (carbonate, chloride, or sulfate) was found to influence the reactivity toward  $U^{6+}$  reduction and the  $U^{4+}$  phase formed.

The influence of combinations of minerals, bacteria, and complexants (citrate and EDTA) on the molecular structure of  $U^{4+}$  was investigated. An interaction between EDTA, U, and the mineral surface has been established, and in the presence of iron-rich clays, EDTA binds to U on one side of the molecule and to Fe on the other, thus serving as a bridge between U and the mineral and retaining uranium in the solid phase.

The studies of the metabolism and anaerobic transformation of various iron oxides by the newly isolated bacterium *Orenia metallireducens* strain Z are also original. By means of synchrotron X-ray spectroscopy, the formation of the different iron phases was determined quantitatively, which is not possible with other methods due to the amorphous nature of some of them and the formation of several phases at the same time.

### **5. Reflection of the candidate's scientific publications in Bulgarian and foreign literature.**

A strong impression is made by the high citation rate of the candidate's publications. According to the data submitted by the applicant, 4670 citations (Google Scholar) of all publications were observed. When I checked the Scopus database, after subtracting the self-citations of all authors, the number of citations was 2882. The number of noticed citations on the publications included in the competition was 1024. Of these, 765 are in the WoS or Scopus databases, suggesting that the citing articles are in reputable international journals. There is a particularly high response to publication number 19 with 430 independent citations. The large

number of citations of the candidate's works is an indisputable indication of the relevance and significance of his scientific research.

#### **6. Critical notes and recommendations**

I have no critical notes. I recommend Assoc.Prof. Boyanov to direct part of his research towards solving the problems of soil and water pollution on the territory of the country, which is a serious ecological problem.

#### **7. Personal impressions of the reviewer about the candidate.**

I do not know the candidate personally, but from the presented materials I get the impression that he is a prominent scientist with a high international authority.

#### **CONCLUSION**

On the basis of the materials submitted for the competition by Assoc. Prof. Dr. Maxim Ivanov Boyanov, I believe that his candidacy fully meets the criteria for occupying the academic position "Professor", defined by the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Rules for its Implementation, the Regulations for the terms and conditions for occupying academic positions at the BAS, as well as the Methodology for the growth of scientists at IICChem-BAS. The candidate is a recognized scientist, with a clearly defined scientific profile and proven scientific and scientific-applied contributions. The direction in which he works is current and has a great scientific and applied perspective. This gives me reason to confidently recommend that Assoc. Prof. Maxim Ivanov Boyanov, PhD, be elected to the academic position of "**Professor**" in professional direction 4.2."Chemical Sciences", scientific specialty "Processes and apparatus in chemical and biochemical technology".

29.12.2022

Member of the Scientific Jury:

/prof. Dr. Plamen Stefanov/