

REVIEW

regarding a competition for the academic position of “Professor” in the professional field 4.2. Chemical Sciences, scientific specialty “*Chemical Kinetics and Catalysis*”, for the needs of the Laboratory “New Heterogeneous Catalysts for Clean Energy and Environmental Protection,” within the thematic area “*Design of Metal and Metal Oxide Systems with Applications in Energy and Improvement of Quality of Life*,” published in the *State Gazette*, issue 82 of October 7, 2025.

Candidate: Assoc. Prof. Dr. Dimitrinka Aleksieva Nikolova, Institute of Catalysis – Bulgarian Academy of Sciences (IC-BAS)

Reviewer: Prof. DSc Margarita Dimitrova Popova, Institute of Organic Chemistry with Centre of Phytochemistry – Bulgarian Academy of Sciences

1. Personal and professional information about the candidate

Assoc. Prof. Dr. Dimitrinka Nikolova is the sole candidate in the competition. She completed her higher education in 1995 at the University of Chemical Technology and Metallurgy – Sofia, specializing in *Inorganic and Electrochemical Production and Technology of Inorganic Materials*. In 2005 she was awarded the educational and scientific degree “Doctor” after successfully defending a dissertation entitled: “*Influence of Potassium Addition on the Activity and Structure of NiO–MoO₃–Al₂O₃ Catalysts for the Water–Gas Shift Reaction in the Presence of Hydrogen Sulfide*.”

Since 1996 she has been working at the Institute of Catalysis, Bulgarian Academy of Sciences, successively as research chemist, chief assistant, and associate professor (since 2016). She has been a member of the Management Board of the Association “Center of Competence HITMOBIL” since 2024, Chair of the Bulgarian Catalysis Society since 2024 (Deputy Chair from 2019 to 2023), and Secretary of the Scientific Council of IC-BAS from 2019 to 2025.

Assoc. Prof. Nikolova is a sought-after partner in numerous national and international research projects. She has been highly active in contracts with the industry related to the development and industrial implementation of three catalysts for alkaline fuel cell generators, in long-term collaboration with GenCell Ltd., Israel (2012–2025). Through these projects she has gained experience working with pilot and industrial reactors, synthesizing industrial batches of catalysts, and operating catalytic testing installations.

She has led projects with GenCell Ltd., Israel, including: “*Development of a Low-Temperature Plasma Catalyst for Nitrogen Oxidation for GenCell’s Green Ammonia Product*” (2024–2025); “*Development of an Anode Catalyst for the Oxygen Evolution Reaction (OER)*” and “*Development of a Low-Temperature Cathode Catalyst for GenCell’s Green Ammonia Product*” (2021–2023).

Assoc. Prof. Nikolova has worked intensively on 2 projects funded by the National Science Fund and 9 projects under inter-academic exchange and bilateral cooperation with Romania, Serbia, Poland and Egypt, serving as project leader in 4 of them. She is the IC-BAS coordinator of

project No. BG16RFPR002-1.014-0009 “*Center of Competence HITMOBIL – Technologies and Systems for Production, Storage and Consumption of Clean Energy*”, funded under the Operational Programme “Science and Education for Smart Growth” 2014–2020 and co-financed by the European Regional Development Fund (since 2025). She also leads project BG-RRP-2.017-0007-C02 “*Clean Hydrogen Technology for Green Energy – A Step Toward Zero Emissions*” under the National Recovery and Resilience Plan (since 2024). She participated in the National Research Programme “Low-Carbon Energy for Transport and Households” (EPLUS) (2018–2022).

These projects convincingly demonstrate Assoc. Prof. Nikolova’s capacity to attract funding and manage research projects, including those with strong practical orientation.

Assoc. Prof. Dr. D. Nikolova was awarded a diploma for contributions to the establishment and development of the Institute of Catalysis, 2015, a diploma for Prof. DSc Sl. Rakovski, Assoc. Prof. Dr. M. Gabrovska, Assoc. Prof. Dr. D. Nikolova and Chem. L. Bilyarska for the most important scientific and applied achievement, 2016 and a diploma for Prof. DSc Sl. Rakovski, Assoc. Prof. Dr. M. Gabrovska, Assoc. Prof. Dr. D. Nikolova, and Chem. L. Bilyarska for a significant internationally funded project, 2017.

2. General description of the materials

Throughout her career, Assoc. Prof. Nikolova has authored 62 publications. For this competition she presents 21 publications, 1 book chapter, and 3 patents (two registered in the USA and one European patent application), none overlapping with those submitted for her associate professorship. She is first and/or corresponding author in seven of the submitted papers.

Her work is published in leading Q1 international journals indexed in WoS/Scopus, including *International Journal of Hydrogen Energy*, *Catalysis Today*, and *Nanomaterials*.

The submitted publications are grouped according to institutional criteria (Indicators B and Γ). The habilitation work (Indicator B) includes nine publications (Q1 - 5, Q2 - 1, Q3 -1, Q4 - 2) and one patent, totaling 184 points compared to the required 100 (*papers 2, 5, 7, 8, 12, 13, 14, 15, 20, patent US 12,230,809 B2/18.02.2025, patent application EP 4046217 A1/24.08.2022*).

Indicator Γ includes 12 publications: Q1 - 5, Q2 - 2, Q3 - 1, Q4 - 4 (*papers 1, 3, 4, 6, 9, 10, 11, 16, 17, 18, 19, 21*), one book chapter, two granted patents, and one patent application, totaling 308 points (required: 220).

She reports 68 participations in international and scientific forums, among which 1 plenary report at an international forum, 12 reports at international forums, 1 plenary report at a national forum, 10 reports at national forums, 3 reports at seminars in our country, 23 posters at international forums and 18 posters at national forums.

The significance of the scientific results of Assoc. Prof. Dr. Dimitrinka Nikolova's research is indicated by the large number of citations of her works. The attached reference presents 217 citations in WoS or Scopus, with which, according to indicator Д, Assoc. Prof. Dr. Nikolova receives 434 points out of the required 120 points for the position of professor according to the

Regulations on the conditions and procedure for acquiring scientific degrees and for occupying academic positions at the Institute of Catalysis - BAS.

According to indicator E, which covers defended doctoral students, implementation and management of national and international projects and attracted funds for them, Assoc. Prof. Dr. Nikolova has 639.63 points out of the required 150 points, according to the above-cited regulations.

The scientometric indicators in the submitted materials, with which Assoc. Prof. Dr. Dimitrinka Nikolova participates in the competition, convincingly show that she significantly exceeds the requirements set for candidates for the position of professor.

3. Evaluation of research activity

The research activity of Assoc. Prof. Dr. Dimitrinka Nikolova is in extremely relevant areas of modern catalysis, related to environmental protection and development of effective catalysts for obtaining green hydrogen.

The candidate's contribution to the presented research is undeniable for clarifying the fundamental scientific connections between catalytic activity and the state of the applied active components in the developed catalysts in the studied processes, as well as the possibilities for their scaling.

4. Evaluation of teaching and expert activity

The teaching activity of Assoc. Prof. Dr. Dimitrinka Nikolova is related to the training of students, as she has supervised two graduates from the University of Chemical Technology and Metallurgy-Sofia. The expert activity of Assoc. Prof. Dr. Dimitrinka Nikolova includes preparing reviews of articles for a number of renowned journals such as *Journal of Energy & Fuels*, *Fuel Processing Technology*, *International Journal of Hydrogen Energy*, *Journal of Environmental Chemical Engineering*, *Journal of Physical Chemistry Letters*, *ASC Omega*, etc. Assoc. Prof. Nikolova has participated in preparing reviews and opinions in 9 procedures for occupying the academic positions of chief assistant and associate professor, as well as in procedures for defending the educational and scientific degree of doctor.

5. Assessment of the scientific and applied scientific contributions

The scientific results presented in the habilitation report fall into two main research directions:

1. Development and investigation of rhenium-containing catalysts for clean hydrogen production via the water–gas shift reaction (conversion of CO to CO₂ with steam), studied both in conventional gas mixtures and in gas mixtures containing sulfur compounds.
2. Development and investigation of non-noble metal electrocatalysts for green energy production through hydrogen fuel cells and green hydrogen technologies, including solid oxide fuel cells, alkaline fuel cells, and electrolysis.

The first research direction addresses the industrial production of hydrogen via the water–gas shift reaction (WGS), which is traditionally carried out in two consecutive stages - a high-temperature stage (350–450°C, Fe₂O₃–Cr₂O₃) and a low-temperature stage (180–250°C, CuO–ZnO–Al₂O₃). This leads to technological complexity, the need for intermediate cooling, and limitations for application in low-temperature energy systems and fuel cells. Consequently, research efforts are focused on developing highly efficient catalysts for single-stage low-temperature WGS.

Rhenium has emerged as a promising active component due to its high catalytic activity, tunable redox properties, and lower cost compared to platinum-group metals. The developed oxorhenium catalytic systems supported on γ -Al₂O₃ with a surface density of 2 Re atoms/nm² demonstrate high activity at 200–260°C. The bimetallic CoRe system exhibits near-equilibrium CO conversion (up to 94% at 260°C and 4000 h⁻¹), stability under increased load, and pronounced synergism between the redox pairs Re⁴⁺/Re⁷⁺ and Co²⁺/Co³⁺ (*publication 14*). Rhenium acts as an electronic promoter, facilitating CoO reduction, activation of CO and H₂O, stabilization of formate intermediates, and acceleration of H₂ formation. Modification of the CoRe system with potassium and molybdenum leads to significant changes in electronic properties, oxide nanostructure size, and catalytic activity. A correlation has been established between band gap energy (E_g) and activity, with lower E_g values for K–CoReMo (3.26 eV) indicating strong metal–support interaction. However, excessive shifting of the redox balance toward more reduced forms (Re⁴⁺, Co²⁺) may decrease activity, emphasizing the need for precise control of composition and activation conditions (*publication 14*).

In parallel, rhenium catalysts supported on Ni–Al layered double hydroxides have been developed as a cost-effective alternative to Au-containing systems (*publication 15*). The addition of CeO₂ improves the Re⁴⁺/Re⁷⁺ redox balance and resistance to deactivation. Although their activity is lower than that of Au analogues, the Re systems show potential for further optimization.

Particular attention has been given to the development of sulfur-resistant catalysts for WGS in “sour” synthesis gas. The trimetallic KCoRe system, activated by reductive sulfidation treatment, demonstrates high activity (>90% CO conversion at 250–300°C), stability, and resistance in the presence of H₂S (*publications 7, 8*). The optimal ratio between sulfide and oxysulfide rhenium species (Re⁴⁺/(Re⁷⁺+Re⁶⁺) $\approx$ 2), high dispersion, and strong synergism among K, Co, and Re are key factors governing catalytic performance. Stress tests at high temperatures and extreme space velocities confirm the resistance of KCoRe to the oxidative effects of H₂O and CO₂.

In conclusion, rhenium-based catalytic compositions, particularly the trimetallic KCoRe system, represent a promising alternative to noble metals for low-temperature single-stage WGS, including in the presence of sulfur impurities. The key to high activity and stability lies in precise control of redox balance, electronic properties, and activation conditions, opening prospects for practical application in modern hydrogen energy systems.

The second research direction focuses on the development of innovative electrocatalytic systems for solid oxide fuel cells (SOFC) (*publications 2, 5, 12, 13*), alkaline fuel cells (AFC)

(*patent US 12,230,809 B2/18.02.2025 and patent application EP 4046217 A1/24.08.2022*), and bifunctional electrocatalysts for water electrolysis aimed at green hydrogen production (*publication 20*). These works reflect current trends toward emission-free, sustainable, and economically efficient energy technologies based on PGM-free catalysts.

In the field of proton-conducting solid oxide fuel cells (pSOFC), nickel cermet anodes Ni/BCY15 ($\text{BaCe}_{0.85}\text{Y}_{0.15}\text{O}_{2.925}$) have been developed for electrochemical hydrogen oxidation (publications 2, 5, 12, 13). An original low-temperature chemical synthesis via wet hydrazine reduction (80–95°C) is proposed as an alternative to the conventional energy-intensive method of mechanical mixing, sintering, and high-temperature H_2 reduction. The use of ethylene glycol as an anhydrous medium and additional reducing agent leads to well-dispersed nanosized Ni^0 particles (~9 nm), increased specific surface area, and stronger metal–support interaction through stabilization of Ni^0 on partially reduced Ce^{3+} centers. Electrochemical impedance spectroscopy (EIS) measurements show lower polarization resistance and higher activity compared to anodes synthesized in aqueous media or by classical methods. Accelerated redox cycling and extreme reoxidation treatments at 1100°C demonstrate high structural and electrochemical stability, with residual metallic Ni^0 playing a key role in hydrogen dissociative adsorption, autocatalytic NiO reduction, and stable electronic conductivity. The developed methodology represents an energy-efficient and practically applicable approach for producing durable pSOFC anodes.

Within the collaboration with GenCell Ltd. (Israel), innovative PGM-free anode catalysts for alkaline fuel cells have been developed and implemented. The NiMoReW/C system demonstrates electrochemical activity and stability comparable to Pt/C and NiPd/C catalysts under conditions of 6.6 M KOH and 70°C. Long-term operation in a real module (1800 h, 375 W) with stable anode potential during repeated start–stop cycles has been achieved. The development is protected by international patents and successfully transferred to industrial production (*US patent 12,230,809 B2, 18.02.2025; EP patent application 4046217 A1, 24.08.2022*).

Parallel studies have been initiated on bifunctional electrocatalysts for hydrogen evolution (HER) and oxygen evolution (OER) reactions in water electrolysis. NiCo and NiCoP coatings with varying composition have been synthesized by co-electrodeposition onto conductive substrates (3D-structured Ni foam and 2D-structured Fe steel sheets). The $\text{Ni}_{50}\text{Co}_{50}\text{P}/\text{Fe}$ steel configuration shows the best performance, exhibiting exceptionally high bifunctional activity ($\eta_{\text{HER}} = 23 \text{ mV}$ and $\eta_{\text{OER}} = 400 \text{ mV}$ at 10 mA cm^{-2}), comparable to Pt-based catalysts, and high stability at industrially relevant current densities (100 mA cm^{-2}). A key factor in performance is the formation of a Co–Ni–P phase providing a large number of accessible active sites and efficient mass transport.

In summary, the developed electrocatalytic systems demonstrate strong potential for practical application in fuel cell and electrolysis technologies, offering sustainable, cost-effective, and scalable solutions for clean energy and green hydrogen production.

The work under Indicator 1 encompasses fundamental and applied research focused on the design of efficient and promising metallic and metal oxide catalytic systems, with emphasis on

human health protection, quality-of-life improvement, and applications in energy and environmental technologies. A major portion of the publications is devoted to the development of nickel-containing catalysts, mainly based on hydrotalcite-like and silicate supports with controlled structure, texture, and surface properties.

Within the first sub-direction, highly efficient Ni-based catalysts have been developed and studied for partial hydrogenation of vegetable oils to produce high-quality hardened fats for the food industry. Through structural design, use of synthetic silica gel supports, and introduction of modifying additives (Mg, Ag, CeO₂), precise control over hydrogenation activity, cis-isomer selectivity, and suppression of harmful trans-fatty acid formation has been achieved. The key role of the mesoporous structure and easily reducible Ni²⁺-O species in achieving high activity and improved diffusion characteristics has been established. Kinetic models have been developed to predict catalytic behavior and optimize the process in line with modern concepts of healthy food production.

The second sub-direction targets catalysts for fuel production and purification and clean energy generation, including WGS, dry methane reforming, CO₂ methanation, ethanol dehydrogenation, and applications in alkaline fuel cells. Ni-Al and Ni-Mg-Al layered double hydroxides have been investigated as precursors to active catalytic systems modified with gold and/or CeO₂. Optimization of composition and promoter introduction improves active phase dispersion, oxygen mobility, and resistance to deactivation. Particularly significant are the results in low-temperature CO conversion and dry methane reforming, as well as the development of platinum-free NiPd electrocatalysts for alkaline fuel cell anodes, protected by an international patent and implemented in practice (*US patent 10,522,844 B2, 31.12.2019*).

The third sub-direction focuses on catalysts for clean and safe industry, including removal of synthetic dyes from industrial wastewater and air purification through catalytic ozone decomposition. Co-Al₂O₃ and Ni-Cu-Al oxide systems have been developed, showing high efficiency in oxidative degradation of persistent organic pollutants and ozone under mild conditions. The mechanisms of action and the influence of phase composition, calcination temperature, and modifying additives on catalytic activity have been established.

In summary, the research demonstrates a systematic approach to the development of nickel-containing and metal oxide catalysts, revealing clear structure-property-function relationships and offering sustainable solutions for healthy food production, clean energy, and environmentally oriented industrial processes.

6. Personal impressions

I know Assoc. Prof. Nikolova through her participation in the Scientific Council of IC-BAS and as Chair of the Bulgarian Catalysis Society. I have excellent impressions of her scientific and organizational qualities. She is a deeply committed and enthusiastic researcher, an impression reinforced by the materials submitted for this procedure.

Conclusion

Based on the review of the submitted documents, Assoc. Prof. Dr. Dimitrinka Nikolova is an authoritative scientist with significant contributions in green hydrogen production, environmental protection, and healthy food technologies. Her materials meet and substantially exceed all requirements for the academic position of Professor under the Act on the Development of the Academic Staff in the Republic of Bulgaria (ADSRB), the Regulations for the Implementation of the ADSRB, the Regulations of the Bulgarian Academy of Sciences for the Implementation of the ADSRB and the Regulations of the IC-BAS.

I therefore give my strong positive evaluation and recommend that the Scientific Jury propose to the Scientific Council of IC-BAS the election of Assoc. Prof. Dr. Dimitrinka Aleksieva Nikolova to the academic position of **Professor** in professional field 4.2. Chemical Sciences, specialty *Chemical Kinetics and Catalysis*.

09.02.2026

Reviewer:

/Margarita Popova/