

STRUCTURE FOR THE HABILITATION THESIS ASSESSMENT

Author (name and surname): Dr. Surjyakanta Rana

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Field of habilitation: *Inorganic Technology and Materials*

Title of habilitation thesis: *"Graphene-Based Metal Nanocomposites: Harnessing the Synergy of Graphene and Metal Nanoparticles in Coupling Reactions"*

Reviewer (name, surname, titles): Dr. Jadra Mosa

Reviewer's affiliation (institution): Instituto de Cerámica y Vidrio (ICV-CSIC)

Introduction

The submitted habilitation thesis entitled "*Graphene-Based Metal Nanocomposites: Harnessing the Synergy of Graphene and Metal Nanoparticles in Coupling Reactions*" addresses a highly topical and scientifically relevant research field situated at the intersection of nanotechnology, materials science, heterogeneous catalysis and sustainable chemical synthesis.

The work focuses on the rational design, synthesis, physicochemical characterization and catalytic application of graphene-based metal nanocomposites incorporating both noble and earth-abundant metals. The thesis responds to current scientific and technological challenges associated with the development of efficient, reusable and environmentally benign catalytic systems for industrially important organic transformations.

The topic is fully consistent with the field of habilitation "Inorganic Technology and Materials" and reflects current international research trends aimed at replacing conventional homogeneous catalysts with advanced heterogeneous systems exhibiting improved stability, recyclability and sustainability.

The thesis is submitted in the form of a commented collection of previously published scientific papers supplemented by a comprehensive scientific commentary that successfully integrates the

individual studies into a coherent and logically structured body of work. The presented research demonstrates the candidate's long-term scientific commitment to the field of advanced functional materials and heterogeneous catalysis.

Assessment of the pedagogical activities of the candidate

Dr. Surjyakanta Rana has accumulated substantial pedagogical and mentoring experience throughout his academic career at several internationally recognized institutions.

His teaching activities encompass undergraduate, master's and doctoral education, including courses in Physical Chemistry, Nanomaterials, Research Methodology and advanced characterization techniques. Particularly noteworthy is his teaching experience at the University of KwaZulu-Natal (South Africa), where he was actively involved in delivering lectures and practical training in Physical Chemistry and Nanomaterials for postgraduate students.

Beyond classroom teaching, the candidate has demonstrated a strong commitment to student supervision and mentoring. He has participated in the supervision and co-supervision of several Bachelor's, Master's and PhD theses and has contributed significantly to the scientific training of young researchers. His involvement in guiding students through experimental design, material synthesis, characterization techniques and catalytic applications highlights his ability to transfer both theoretical knowledge and practical research skills.

The candidate's pedagogical profile is further strengthened by his participation in extracurricular educational activities, workshops and specialized training programs. His international experience across several countries has allowed him to contribute to multicultural educational environments and to interact with students possessing diverse academic backgrounds.

Overall, the pedagogical activities of Dr. Rana demonstrate both breadth and depth and are fully compatible with the expectations placed upon candidates applying for the scientific-pedagogical title of Associate Professor.

Assessment of the publication activities of the candidate

The publication record of Dr. Rana reflects a mature, productive and internationally visible scientific career.

The candidate has established a coherent and well-defined research profile focused on heterogeneous catalysis, graphene-based materials, nanocomposites, porous materials and environmentally relevant catalytic transformations. His research contributions have been disseminated through numerous peer-reviewed international publications and book chapters.

Particularly impressive is the scientific impact of his work, reflected by more than 1,400 citations excluding self-citations and approximately 1,750 citations including self-citations. Such citation metrics demonstrate significant international recognition of his research contributions and confirm the relevance of his work within the scientific community.

The publication activity also demonstrates a high degree of international collaboration, involving institutions from Slovakia, Belgium, Germany, Spain, South Africa and India. This international dimension is an important indicator of scientific maturity and visibility.

An additional strength of the candidate's publication profile is the consistency of his research line over time. Rather than pursuing isolated topics, Dr. Rana has systematically developed expertise in the design of advanced catalytic materials, progressively moving from conventional catalyst systems toward sophisticated graphene-based nanocomposites with enhanced functionality.

The quality, quantity and impact of the candidate's scientific publications clearly fulfil and exceed the standards generally expected for habilitation in the field of Inorganic Technology and Materials.

Comments on the structure and the content of the thesis

The habilitation thesis is very well organized and presents a clear and coherent scientific narrative. The structure follows a logical progression from fundamental concepts and scientific background to material synthesis, characterization, catalytic evaluation and mechanistic interpretation.

The introductory chapters provide a comprehensive overview of heterogeneous catalysis, graphene-based materials and coupling reactions. The literature review is well balanced and demonstrates a strong understanding of both historical developments and recent advances in the field.

The research objectives are clearly formulated and directly address important scientific challenges related to catalyst efficiency, stability and sustainability. The objectives are subsequently fulfilled through a systematic experimental approach.

One of the major strengths of the thesis lies in the successful integration of materials science and catalytic chemistry. The candidate demonstrates a thorough understanding of how structural and surface properties influence catalytic performance and applies this knowledge effectively in the design of novel nanocomposite catalysts.

The synthesis strategies employed for the preparation of graphene-supported Pd, Ni and Cu nanocomposites are scientifically sound and carefully optimized. The materials were comprehensively characterized using an extensive range of advanced analytical techniques, including XRD, FTIR, Raman spectroscopy, SEM, TEM, HRTEM, EDS and XPS. The characterization data convincingly confirm the successful fabrication of the targeted nanocomposites and provide valuable insights into their structural and electronic properties.

The catalytic studies represent the core scientific contribution of the thesis. The developed materials were successfully applied to a broad range of industrially relevant C–C and C–heteroatom coupling reactions, including Ullmann, Suzuki–Miyaura, Mizoroki–Heck, Kumada–Corriu and C–S coupling reactions.

The reported catalytic performances are highly competitive when compared with previously published systems. In several cases, excellent product yields, reduced reaction times and improved catalyst recyclability were achieved. Particularly noteworthy is the successful utilization of earth-abundant metals such as nickel and copper as alternatives to palladium, which aligns well with current sustainability objectives in catalysis research.

Another important contribution of the work is the investigation of catalyst stability and heterogeneity through recyclability studies, hot-filtration experiments and ICP analyses. These studies strengthen the scientific reliability of the presented results and provide convincing evidence regarding catalyst robustness.

The thesis successfully demonstrates how rational engineering of graphene-metal interfaces can improve catalytic performance through enhanced nanoparticle dispersion, stronger metal-support interactions and improved resistance against leaching.

Overall, the scientific quality of the work is high. The thesis presents original contributions to the field and significantly advances current knowledge on graphene-based catalytic nanocomposites.

Assessment of the formal side of the work (language, style, structure)

The thesis is written in a clear, professional and scientifically appropriate style.

The manuscript is logically organized and easy to follow. Individual chapters are well connected and create a coherent scientific story despite being based on multiple published papers. The transition between the different studies is smooth and supported by an effective integrative commentary.

The English language quality is generally very good. Scientific terminology is used correctly and consistently throughout the document. The level of detail provided is appropriate for a habilitation thesis and demonstrates the candidate's ability to communicate complex scientific concepts effectively.

Figures, tables, reaction schemes and graphical illustrations are of good quality and significantly facilitate understanding of the presented material. The visual presentation of the experimental results is clear and informative.

The bibliography is extensive and demonstrates familiarity with the relevant international literature. References are appropriately cited and support the scientific discussion effectively.

From a formal perspective, the thesis fully satisfies the standards expected for a habilitation thesis submitted within an international academic environment.

Reviewer's questions for discussion to be answered during the thesis defense

1. The thesis demonstrates excellent catalytic performance using graphene-supported Pd, Ni and Cu nanoparticles. What are the main scientific and technological barriers that currently limit the industrial implementation of these catalytic systems?
2. Amine functionalization was shown to improve nanoparticle dispersion and catalyst stability. Have alternative functionalization strategies been considered, and what advantages might they offer compared with amine-based surface modification?
3. The catalyst systems were mainly evaluated under batch reaction conditions. How do you anticipate their performance would change under continuous-flow reactor conditions relevant to industrial production?
4. Graphene oxide synthesis often involves aggressive oxidizing agents and significant chemical consumption. How would you evaluate the overall environmental sustainability of the developed catalysts when considering their entire life cycle?
5. Which advanced in situ or operando characterization techniques would you employ in future studies to gain deeper insight into metal-support interactions and catalyst deactivation mechanisms?
6. Among the Pd-, Ni- and Cu-based nanocomposites investigated, which system do you consider the most promising for large-scale industrial applications, and what factors support your assessment?
7. How could the knowledge and methodologies developed in this thesis be extended toward other emerging applications such as photocatalysis, electrocatalysis, hydrogen production or carbon dioxide valorization?

Conclusion

The submitted habilitation thesis of Dr. Surjyakanta Rana entitled “*Graphene-Based Metal Nanocomposites: Harnessing the Synergy of Graphene and Metal Nanoparticles in Coupling Reactions*” fulfils the requirements for habilitation in the field of “*Inorganic Technology and Materials*”.

The thesis presents original and scientifically valuable results that contribute significantly to the fields of heterogeneous catalysis, nanomaterials and advanced functional materials. The candidate demonstrates a high level of scientific independence, methodological competence and international scientific visibility. The research is characterized by sound experimental design, comprehensive characterization, critical interpretation of results and clear relevance to contemporary scientific challenges.

Furthermore, the candidate possesses an excellent publication record, substantial international research experience and significant pedagogical achievements, all of which support his qualification for the scientific-pedagogical title of Associate Professor.

Based on the quality of the submitted habilitation thesis, the scientific achievements presented therein, the publication activity and the pedagogical experience of the candidate, I recommend acceptance of the habilitation thesis for the habilitation procedure at the Alexander Dubček University of Trenčín and, following its successful defense, the awarding of the scientific-pedagogical title of Associate Professor in the field of “*Inorganic Technology and Materials*”.

Place and Date

Madrid, Spain, June 3, 2026

Reviewer’s Signature