

- **PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan, all in English)**

Project title: *Coordination compounds as gas phase deposited nanomaterials precursors*

.1. Project goals

- development of finding and synthesis of precursors dedicated to vapor deposition methods,
- studies of reactions in the gas phase using mass spectrometry and temperature-variable IR spectroscopy,
- understanding mechanisms of electron and ion beam interactions with thin films of compounds,
- selection of precursors promising for individual vapor deposition techniques,
- obtaining pure metallic 2D and 3D nanostructures of copper, silver, palladium, and gold.

.2. Outline

Compounds of semi-precious and precious metals (Cu, Ag, Pd, Au) constitute a topic of intensive studies because they show interesting physicochemical and structural properties and are significant for the development of nanotechnology. They have high electrical current and heat conductivity what cause applications in VLSI and ULSI microelectronic circuits. Palladium can be used at nanocatalysts and in sensors such as silver and gold, which are plasmonic materials. Moreover, gold, silver and copper show antibacterial and antiviral properties imply the production of aseptic coatings.

With the use of *Vapor Deposition Methods*, thin layers of metals and more complicated 2D and 3D nanostructures can be deposited on different substrates. However, these methods require applying compounds, which are a metal source (so-called precursors). This role is generally played by organometallic or coordination compounds. They have the ability to generate volatile metal carriers which are transported over a substrate on which they decompose forming the desirable material. New precursors, which easily generate metal carriers, demonstrate low evaporation temperature, and can be used in the one-step fabrication of materials, are still sought.

Materials formation can be induced by heating (CVD) but also using a focus electron (FEBID) or ion (FIBID) beam. The main aim of the proposed project is to find new volatile precursors and fast to fit them to the mentioned methods, next deposit pure nanostructures of Cu, Ag, Pd, Au and finally for selected deposits, to study: conductivity; optical properties; and antibacterial and antiviral activity.

.3. Work plan

- Synthesis of potential precursors and their composition and structure studies,
- Determination of volatility and thermal stability of the compounds,
- CVD experiments for selected compounds,
- Studies of sensitivity to electron and ion beams. Mechanisms of interaction propositions,
- FEBID and FIBID experiments for selected compounds.

.4. Literature

- 1) A. Grodzicki, I. Łakomska, P. Piszczek, I. Szymańska, E. Szlyk, *Coord. Chem. Rev.*, 249 (2005) 2232-2258.
- 2) I.B. Szymańska*, *Polyhedron*, 50 (2013) 200-207.
- 3) I.B. Szymańska*, *Polyhedron*, 65 (2013) 82-88.
- 4) I. Utke, S. Moshkalev, P. Russell, *Nanofabrication Using Focused Ion and Electron Beams: Principles and Applications*, Oxford University Press. 2011, 3; 11-14.
- 5) M. Lacko, P. Papp, I. B. Szymańska, E. Szlyk, S. Matejczik, *Beilstein J. Nanotechnol.*, 9 (2018) 384–398.
- 6) L. Berger, K. Madajska, I. B. Szymańska, K. Höflich, M. N. Polyakov, J. Jurczyk, C. Guerra-Nuñez, I. Utke, *Beilstein J. Nanotechnol.*, 9 (2018) 224–232.
- 7) K. Höflich, J. M. Jurczyk, K. Madajska, M. Götz, L. Berger, C. Guerra-Nuñez, C. Haverkamp, I. Szymańska, I. Utke, *Beilstein J. Nanotechnol.*, 9 (2018) 842–849.
- 8) L. Sala, I. B. Szymańska, C. Dablemont, A. Lafosse, L. Amiaud, *Beilstein J. Nanotechnol.*, 9 (2018) 57–65.
- 9) J. Warneke, M. Rohdenburg, Y. Zhang, J. Orszagh, A. Vaz, I. Utke, J. Th. M. De Hosson, W. F. van Dorp, P. Swiderek, *J. Phys. Chem. C*, 120 (2016), 4112–4120.
- 10) R. Córdoba, P. Orús, S. Strohauser, T. Torres, J. M. De Teresa, *Scientific Reports*, 9 (2019) 14076.

.5. Required initial knowledge and skills of the PhD candidate

- Analytical thinking
- Eager to learn
- Teamwork
- Experience in chemical synthesis and spectroscopy
- Understanding of materials synthesis and analysis
- Basic knowledge on deposition techniques
- Keen to learn new techniques and instrumentation
- Thinking oriented on innovation and application

.6. Expected development of the PhD candidate's knowledge and skills

- Improve of analytical thinking
- Understanding why still need to learn
- Organization of teamwork
- High experience in chemical synthesis and spectroscopy
- Fluency in materials synthesis and analysis
- Advanced knowledge on deposition techniques
- Knowledge of modern techniques and instrumentation
- Thinking highly oriented on innovation and application