1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Implementing metallic nanostructures for electrically and optically active sensing platforms

1.1. Project goals

The research aim of the PhD project is twofold: on the one hand it concerns development of photochemical deposition (printing) of silver nanostructures on arbitrary transparent substrate, including their post-processing, while on the other hand, these substrates should be applied for simultaneous electric and optical detection of biologically relevant structures, such as proteins, viruses, or bacteria. Fabrication of such plasmonic chips would be a qualitative step towards designing novel sensing platforms for any arbitrary application.

1.2. Outline

In particular, this interdisciplinary project bridges three distinct aspects related to fabrication of the printed plasmonic nanostructure, controlled functionalization thereof for a particular analyte, and demonstration of biorecognition using optical techniques, primarily fluorescence microscopy and imaging.

Recent publication [1] gives the proof-of-principle, as it describes the method of photochemical deposition of silver nanostructures. There are, however, further important steps required for applying this approach as a viable sensing platform design. As we would like to exploit both electrical and optical activity of such a platform, a way of making the silver nanostructure lines conductive is an outstanding challenge. This can be achieved – presumably – by adjusting parameters of photochemical deposition or by post-processing of silver nanostructures, for instance using thermal or laser annealing. At the same time, it is important to develop robust methods of surface functionalization, including streptavidin – biotin linkage, His-tag – based attachment, antibody - based recognition, etc. The efficiency of surface functionalization can be tested on model protein systems, and further extended towards more complex, yet medically relevant, objects. We intend to use fluorescence-based methods for initial testing of biorecognition of optically active species. This method is fast and very sensitive, which should allow for achieving good values of limits of detection. Upon successful demonstration of optical sensing for the photochemically synthesized silver nanostructures, electrical detection will be performed, analyzed, and optimized.

1.3. Work plan

Fabrication of nanostructures, including their morphology characterization
Functionalization of the nanostructures with suitable chemical groups for required biorecognition protocol
Demonstration of biorecognition using coupled electrical and optical detection.
This interdisciplinary project touches upon fundamental aspects of nanostructure fabrication and surface functionalization, but – assuming that desired functionality is indeed achieved – it can also provide insight into designing actual sensing platforms, being thus considerably relevant from the application point of view.

1.4. Literature

[1] M. Szalkowski, K. Sulowska, M. Jönsson-Niedziółka, K. Wiwatowski, J. Niedziółka-Jönsson, S. Mackowski, D. Piatkowski, "Photochemical Printing of Plasmonically Active Silver Nanostructures", International Journal of Molecular Sciences 21, 2006 (2020); doi:10.3390/ijms21062006

1.5. Required initial knowledge and skills of the PhD candidate

Basic knowledge on the optical properties of materials, English language - communication level, previous experience in studying nanostructures using fluorescence techniques would be highly beneficial, previous experience in working in chemistry lab would be beneficial.

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

The PhD student will learn advanced techniques of fluorescence based characterization methods of nanostructures, including biological nanostructures and inorganic materials. This project will also provide an opportunity for working in interdisciplinary ecosystem for developing materials and structures for possible applications.