SCIENCES SORBONNE UNIVERSITÉ

Master thesis proposal

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Director: Massimiliano Marangolo

Title: Understanding how plasmonic excitation of single nanoparticles can couple to hot electron injection.

Keywords: gold nanoparticles, plasmonics, nanoelectronics, Atomic Force Microscopy

Scientific description:

Due to their *plasmonic* properties, gold nanoparticles behave as *nano-antenna* that concentrate the local electromagnetic field to nanometer scale dimensions [1]. The *localized surface plasmon resonance* (LSPR) occurs in gold nanoparticles and generate strong oscillations of the free electrons. In certain conditions some of these electrons can be expelled out of the nanoparticles and injected into a semiconductor. This corresponds to the recent field of research of the "hot electron physics". One key point for a successful injection of electrons or holes is the existence of a strong *built-in potential* at the junction between the nanoparticle and the surface.

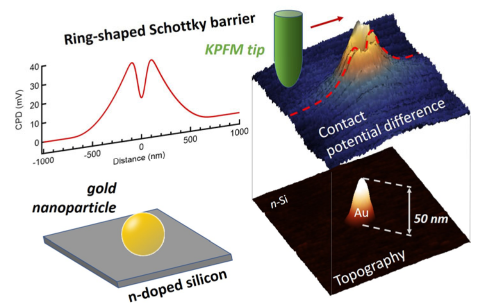

Fig. 1. Measure with Kelvin Probe Force Microscopy (KPFM) of the local electric field generated by a nanoscale Schottky barrier, made of a 50 nm gold nanoparticle on silicon ([Ref 2]. Upper images: electric potential profile. Lower images:

In our group we develop an approach based on advanced Atomic Force Microscopy (AFM) techniques such as conductive AFM or KPFM (Kelvin Probe Force Microscopy) to investigate this topic. Recently, we have demonstrated that we can measure the Schottky barrier at the interface between a gold nanoparticle and a doped semiconductor (Fig. 1) [2].

Moreover, we have also developed an optical microscope to measure dark field optical hyperspectral images of single nanoparticles and correlate the plasmonic properties with the KPFM images (Fig. 2) [3].

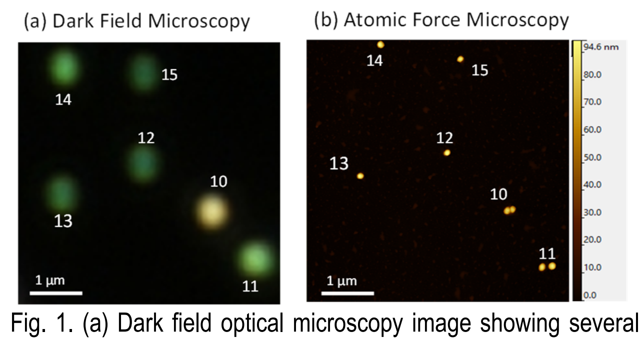

Fig. 1. (a) Dark field optical microscopy image showing several single or dual gold nanoparticles of size 90 mn (b) The same area observed with AFM. Both images are of size 5 µm x 5 µm [Ref 3]

The present internship will focus on understanding how to measure with accuracy the local electric field at the nanoparticle-semiconductor interface, using a KPFM. The candidate will learn how to use KPFM, how to interpret the data, and will compare them with existing electrical models. During the internship, the measure of the plasmonic response of these nanostructures will also be carried out using the dark field optical hyperspectral microscope. The final goal is to prove that the electron injection can be triggered with on optical beam and measured with KPFM.

[1] Pluchery, O. & Bryche, J.-F. *An Introduction to plasmonics*. (World Scientific, 2023).
[2] Lechaptois, L., Prado, Y. & Pluchery, O. KPFM visualisation of the Schottky barrier at the interface between gold nanoparticles and silicon. *Nanoscale* **15**, 7510-7516 (2023).
[3] Abadie, C., Liu, M., Prado, Y. & Pluchery, O. Hyperspectral dark-field optical microscopy correlated to atomic force microscopy for the analysis of single plasmonic nanoparticles: tutorial. *J. Opt. Soc. Am. B* **41**, 1678-1691,

Techniques/methods in use: Atomic Force Microscopy, dark field optical microscopy
Applicant skills: skills for experiment, dedication and passion for understanding experimental results
Industrial partnership: No
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Possibility for a Doctoral thesis: YES. Funding through Doctoral School ED397, after selection