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Thesis proposal

Study of plasmonic-electric coupling in quantum materials

Keywords : Quantum materials, Mottronics, plasmonics, insulator-metal transition

Location : Institut des Matériaux Jean Rouxel, CNRS-Université de Nantes, France (www.cnrs-imn.fr)

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Financial support : PhD grant from Nantes Université – Starting in September 2022

Context

Plasmonics is a very active field of research at the frontier between optics and condensed matter physics. It consists in the study of phenomena produced and associated with surface plasmons, elementary excitations linked to surfaces and interfaces of nanostructured metals: enhancement of the electromagnetic field, localized heating, emission of hot electrons, surface plasmon-polariton, etc. These plasmonic nanostructures have been associated for ten years with semiconductor materials in order to modulate their properties, improve the performance of devices or promote new behaviors. On the other hand, the exploitation of these plasmonic effects to modulate the properties of quantum materials is very promising but it has yet to be explored. These materials, whose properties can only be explained by taking into account collective effects, can lead to new and remarkable applications, particularly in (opto)electronics.

The Physics of Materials and Nanostructures group at IMN has developed expertise over the past 15 years in the fields of plasmonics (design and study of nanostructures for the study of localized surface resonance and plasmon-polariton phenomena) and Mottronics (elaboration and study of complex materials that have remarkable electrical properties such as insulator-metal transitions: resistive transition, Mott insulators and RRAM application induced under an electric field in particular).

Topic

In this context, we propose to explore and exploit the interactions between the surface plasmons of plasmonic nanostructures (0D or 1D) and the electrical properties of quantum materials. Among the vast family of quantum materials, we will focus in particular on:

- the Mott insulators
- 2D materials (boron nitride, dichalcogenides of transition metals).

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For Mott insulators, the plasmonic activation of the resistive insulator-metal transition is targeted, the objective being to optically control this transition in a localized way. For two-dimensional semiconductor materials, we will explore plasmon-exciton coupling effects.

In both cases, it is necessary to locally apply electrical and optical stimuli and simultaneously measure the optical and/or electronic responses of these new systems. This requires the implementation of methods to electrically characterize these systems under localized laser beam. The strategy will consist in using micro/nanostructured devices available in the laboratory.

This thesis will include a very complete experimental component with the deposition of (ultra)thin layers by plasma-enhanced chemical vapor deposition (PE-CVD) and sputtering, the transfer of two-dimensional systems, structural (DRX, TEM), morphological (SEM, AFM) and composition (UV-visible-nIR and Raman spectroscopy). The heart of the thesis will consist in studying the impact of the plasmonic effect on the electrical and optoelectronic properties of these new systems.

Profile

The candidate, with a solid background in solid state physics and/or nanosciences, must have a real motivation for experimental work and for fundamental exploration in connection with technological innovation. Previous experience in plasmonics or related to quantum materials will be highly appreciated.