SCIENCES SORBONNE UNIVERSITÉ

2024-2025

Master thesis proposal

INSP INSTITUT DES NANOSCIENCES DE PARIS

Campus Pierre et Marie Curie
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Director: Massimiliano Marangolo

Title: Tuning the properties of a 2D superconductor by epitaxial growth

Keywords: Epitaxy, 2D materials, superconductivity

Scientific description:

2D materials, which consist of sheets of atoms covalently bonded with weak van-der-Waals bonds between each layer have physical properties which depend strongly on the number of layers, on the stacking alignment between layers, and on the choice of substrate or capping material. This leads to the possibility of tuning the same material from, for example, an indirect band-gap to a direct-band gap semiconductor, from an antiferromagnetic state to a ferromagnetic state, or from an insulator/semiconductor to a metal/superconductor by simply tuning the layer thickness or by difference in the layer stacking.

Spectacular differences in crystal structure and composition of these layered materials can also occur during the thin film growth process itself. For example, some materials which exist as conventional covalently bonded materials in the bulk crystal can be stabilised by the substrate into a van-der-Waals bonded crystal structure during the deposition of a single layer. Similarly, in some materials significant self-intercalation can occur, and this incorporation of additional atoms between the layers leads to a change in film composition during growth. Finally, despite the lack of direct bonding of the thin film to the substrate, the substrate still determines the degree of in-plane alignment of the islands that form during the initial stages of thin film growth. This means that the crystalline quality of an epitaxial thin film depends critically on the choice of substrate even for van-der-Waals bonded materials.

During this internship we will study the epitaxial growth of the transition metal dichalcogenide; $NbSe_2$ which is superconducting only in a narrow growth window and whose Tc depends strongly on the layer thickness. In particular the aim here is to study the effect of different substrates and capping layers on the structural and superconducting properties of $NbSe_2$ under previously optimised growth conditions with the aim of improving the Tc by suitable heterostructure design.

Techniques/methods in use: Molecular beam epitaxy, X-ray diffraction, transport measurements

Applicant skills: Basic knowledge of condensed matter physics. Interest in thin film growth, diffraction techniques, background superconductivity and transport measurements

Industrial partnership: N

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Internship location: Institut des NanoSciences de Paris, tour 22, campus Jussieu

Possibility for a Doctoral thesis: Y (ecole doctorale)