LMGP
Laboratoire des matériaux et du génie physique
une vision des matériaux

2019-2020 Internship proposal at LMGP Lab.

Atomic-level control over ultrathin 2D layers of Transition Metal Dichalcogenides obtained by a Molecular Layer Deposition route

Synthèse de couches ultra minces de dichalcogénures de métaux de transition par dépôt moléculaires alternés en phase vapeur (ALD/MLD) et recuits.

Abstract

The main purpose of this research master internship is to implement an innovative fabrication of sulfide-based lamellar materials and ultimately 2D transition metal dichalcogenides (TMD), a recognized class of emerging materials. The student will achieve Atomic Layer Deposition/Molecular Layer Deposition of sulfide thiolates and the subsequent thermal treatment, in a dedicated reactor at LMGP, while monitoring the early stage of growth by ellipsometry. A specific equipment will be used to monitor the crystallization during annealing by Raman scattering. A great deal of the internship will be devoted to structural and chemical analysis of the 2D layer by various techniques.

Project description

2D-materials, especially transition metal dichalcogenides (TMD) [1], have recently received considerable attention since they are emerging as a class of exceptional semiconductor materials with many potential applications (supercapacitors, batteries, electronics and opto-electronics, flexible electronics, ...). However, a sizeable bottleneck for their full deployment stems from the lack of scalable fabrication methods with atomic scale precision. In the recent years, a 2-step Atomic Layer Deposition/Molecular Layer Deposition process and annealing has been used for the synthesis of 2D MoS_2 and WS_2 [2,3]. It has the advantage of being compatible with the manufacturing environment and avoid the use of toxic sulfur molecules as for instance H_2S (“green” chemistry). However, as far as MoS_2 and WS_2 are concerned, the 2D crystallization is obtained by an annealing at a rather high temperature (> 800°C), which severely hinder the integration capabilities of those materials. Alternatively, Tin disulfide (SnS_2), which is a semiconductor with a band gap in the range [2.2-2.35eV] (depending on the layer thickness), appears as a good candidate since it has a low melting point (865°C) in comparison to those of MoS_2 and WS_2. Moreover, Tin is an earth-abundant metal with almost all of its oxide and sulfide derivatives (SnS, Sn_2S_3, SnS_2, SnO et SnO_2) being semiconductors and non-toxic.

The internship takes part of the collaborative ULTiMeD project, funded by the French ANR, which aims at **the atomic-level control over ultrathin 2D layers of Transition Metal Dichalcogenides by a Molecular Layer Deposition route**. The project mainly focusses on the investigation of the early stage of deposition and crystallization of 2D TMDs films processed with organosulfides (as Sulfur source alternative to H_2S) in a custom-built portable reactor for Atomic Layer Deposition (ALD) [4-6].

Under the guidance of a post-doctoral fellow and PhD student, the successful Master candidate will prepare the ALD/MLD reactor at LMGP to receive the Tin precursor. He will achieve Atomic Layer Deposition/Molecular Layer Deposition of SnS_2 thiolates and the subsequent thermal treatment in the MOON reactor at LMGP. The growth will be monitored by ellipsometry (and possibly by residual gaz analysis). Some of the post ALD/MLD amorphous samples (thiolates) will be transferred to perform *in situ* Raman scattering measurements during thermal annealing at the LETI characterization platform. Post annealed samples will be checked by high resolution X-ray fluorescence (LETI), X-ray reflectivity, grazing incidence X-ray diffraction, X-ray photoelectron spectroscopy (CMTC, Grenoble INP) and Transmission Electron Microscopy (LMGP).

[1] Y.P. Venkata Subbaiah et *al* (2016), Adv. Funct. Mater **26**, 2046 ; [2] S. Cadot et *al*. (2017), Nanoscale **9**, 538 ; [3] S. Cadot et *al*. (2017)., J. Vac. Sci. Technol. A **35**, 061502. [4] R. Boichot et *al*. (2016), J. Chem. Mater. 28, 592. [5] M. H. Chu et *al*. (2016), Cryst. Growth Des. **16**, 5339. [6] E. V. Skopin et *al*. (2018), Nanoscale, 10, 11585.

Scientific environment:

The master candidate will work within the LMGP (Materials Science and Physical Engineering), in team **NanoMat** in close collaboration with a post-doc, in the framework of the ULTiMeD project and with the other partners of the ULTiMeD project (C2P2, Lyon ; IPVF, Palaiseau, SOLEIL), as well as scientists at CEA Leti. Located in the heart of an exceptional scientific environment, the LMGP offers the applicant a rewarding place to work.

Profile & requested skills:

The candidate must be engaged in a research master program in physics, chemistry or material science or closely related science. She/he should also have ability and initiative to get to the heart of the problem and take it effectively through to completion; good interpersonal, communication and scientific presentational skills; good organizational and planning skills. Self motivation.

Allowance: Internship allowance will be provided

CONTACT : Pr Renevier (last name), Hubert (first name) ; hubert.renevier@grenoble-inp.fr; Tel: 04 56 92 48