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Laboratoire des matériaux et du génie physique
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Grenoble INP

cnrs

2023-2024 Internship proposal at LMGP Lab.

Synthesis of metal chalcogenides by Atomic Layer Deposition/Molecular Layer Deposition

Abstract

The objective of this research internship is to synthesize lamellar metal chalcogenides (i.e. Ga_xS, SnS, SnS_2, TiS_2). The student will achieve Atomic Layer Deposition/Molecular Layer Deposition (ALD/MLD) and thermal treatment of hybrid organic-inorganic thin films in a dedicated reactor located in LMGP, while monitoring the process by *in situ* ellipsometry and residual gas analysis. Structural and chemical analysis of the thin films will be performed post deposition, by Raman scattering spectroscopy, X-ray photo-electron spectroscopy (XPS), X-ray fluorescence and Transmission Electron Microscopy. Specific equipment could be used to study thin film crystallization by *in situ* X-ray diffraction.

Project description

2D-materials, especially metal dichalcogenides (MDs) [1,2], have received considerable attention recently since they are emerging as a class of exceptional materials with many potential applications. Beside the prototypical transition metal dichalcogenide (TMDs) MoS_2, WS_2, TiS_2, … there are several interesting lamellar MDs to investigate as precursors of new hybrid composites for emerging devices. Atomic Layer Deposition, as well as Molecular Layer Deposition, are based on sequential, self-limiting surface reactions that allow conformal film growth with precise thickness control. They are ideal techniques for depositing scalable ultrathin inorganic, organic or hybrids thin films [3]. Indeed, since recently we develop at LMGP a 2-step process [4], in a custom-built portable reactor [5], which consists in depositing a metal-thiolate thin film by ALD/MLD on wafers. Then, the latter, which was formed after the reaction of the metal precursor and organic sulfide molecule (1,2-ethanedithiol, EDT, a precursor containing a terminating thiol group), is transformed into the target material by annealing in a controlled atmosphere [6]. This approach aims to find alternatives to the very toxic H_2S molecule currently used for the growth of 2D MDs by ALD/MLD and to improve the control on the thin film crystallization and texture. By continuing with this approach we want to try alternative organic sulfide molecules, as for instance dimethyldisulfide (DMDS), to synthesize layered titanium sulfide (TiS_2), tin sulfides (SnS_2, SnS) and gallium sulfide (GaS) materials, which open applications in optoelectronic devices such as solar cells or batteries.

The successful Master candidate will achieve ALD/MLD of thin films in a dedicated reactor in LMGP, on thermal SiO_2 and other substrates such as Si(111) or MoS_2, while monitoring the growth by *in situ* ellipsometry and residual gaz analysis. This latter has been recently purchased by LMGP and will have to be qualified by the intern. Post annealed samples could be investigated by high resolution X-ray fluorescence, X-ray reflectivity, in-plane X-ray diffraction and Transmission Electron Microscopy, at Grenoble-INP characterization platform (CMTC), and by X-ray photoelectron spectroscopy at CEA-Leti. If possible, some of the post ALD/MLD hybrid thin films could be transferred into specific equipment to perform *in situ* XRD at Grenoble-INP characterization platform (CMTC), to study the crystallization during the thermal treatment. Where appropriate, four-point-probes electrical measurements will be performed at LMGP.

[1] Y. P. Venkata Subbaiah et al. Adv. Funct. Mater. (**2016**) 26 2046 ; [2] W. Hao et al. 2D Mater. (**2019**) 6 012001 ; [3] Zaidi et al. Chem. Mater. (**2022**) 34 7106 ; [4] S. Cadot et al. Nanoscale (**2017**) 9 538 & S. Cadot et al. JVST. A (**2017**) 35 061502 ; [5] E. V. Skopin et al. Nanoscale (**2018**) 10, 11585 & R. Boichot et al. Chem. Mater. (**2016**) 28, 592 [6] P. Abi Younes et al. Chem. Mater. (**2022**) 34 10885 & P. Abi Younes et al. J. Vac. Sci. Technol. A (**2023**) 41 042403.

Scientific environment:

The master candidate will work within the LMGP (Materials Science and Physical Engineering), in team **NanoMAT**. She/He will interact on a regular basis with scientists from IPVF (N. Schneider) and CEA Leti (N. Gauthier). 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 must have the will to perform experimental research,** the 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

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