2024-2027 PhD proposal at LMGP/CEA-Leti Labs

Atomic layer deposition of vanadium sulfide contacts for next-generation transistors based on 2D dichalcogenides. Dépôt par ALD de couches ultra-minces en sulfure de vanadium pour la réalisation de contacts performants dans les transistors à base de dichalcogénures 2D

Abstract

The main purpose of this research is to develop and evaluate the potential of atomic layer-deposited vanadium sulfide as an efficient contact on next-generation transistors based on 2D dichalcogenide semiconductors. The student will achieve atomic layer deposition (ALD) of VS_x films in a dedicated reactor at LMGP allowing *in situ* optical and chemical characterization along with structural and chemical characterization with synchrotron radiation, in order to get an insight into the growth mechanisms and structural changes occurring during the crystallization. She/he will investigate the electrical properties of the VSx films and VSx/MoS_2 heterostructures.

Project description

As the silicon electronics approach their physical limits with a collapse of the channel mobility at the sub-10 nm scale, semiconducting transition metal dichalcogenides (s-TMDs) such as MoS_2 or WS_2 offer new perspectives for the **fabrication of low-power and ultimately downscaled transistors** (channel thickness down to 0.65 nm) due to their excellent electrostatic control and immunity to short-channel effects. However, contact engineering on such material is still challenging due to the high contact resistance obtained with most metals (Fermi level pinning), and damages that are created at the metal/s-TMD interface [OBR2023]. In this context, the use of semi-metallic transition metal dichalcogenides (m-TMDs) such as **vanadium disulfide (VS_2) represents an excellent option for the realization of low resistance (ohmic) Van der Waals contacts on semiconducting TMDs** [QUIN2017]. Furthermore, the incorporation of vanadium into MoS_2 can generate a p-type doping, allowing a fine-tuning of carrier polarity from n-type undoped MoS_2 to p-type V-doped MoS_2 [ZHA2022]. Such a low contact resistance of VS_2 on MoS_2 together with the ability of vanadium to reverse the charge carrier polarity in MoS_2 through doping may be a **key enabler for the realization of next-generation logic devices based on transition metal dichalcogenides.** The proof of concept of a VSx/MoS_2 stack was recently demonstrated a LETI using a novel ALD process. However, the complexity of the vanadium-sulfur phase diagram and the limited stability of the as-deposited vanadium sulfide thin film requires a dedicated study in order to find the right balance between **(1)** - contact resistance at the VSx/MoS_2 interface, **(2)** - resistivity, work function and atmospheric stability of the VSx contact, and **(3)** - p-type doping induced by vanadium diffusion into the MoS_2 channel. The selected candidate will achieve the development of ultra-thin VSx films by ALD in a dedicated reactor allowing *in situ* optical and chemical characterizations during the growth and crystallization phases (ellipsometry and residual gas analysis), and thoroughly investigate the chemical composition, structural and electrical properties of the film using various techniques such as Raman scattering and X-ray photoelectron spectroscopies. Moreover, the ALD reactor will be operated at the synchrotron facility [CIA2019, ABI2022], enabling *in situ* x-ray studies during the whole process.

References: **[OBR2023]** Nat Commun (2023) 14, 6400. DOI: 10.1038/s41467-023-41779-5 ; **[QIN2017]** Nano Letters (2017) 17, 4908. DOI: 10.1021/acs.nanolett.7b01914 ; **[ZHA2022]** Adv. Funct. Mater. (2022) 32, 2204760. DOI: 10.1002/adfm.202204760 ; **[CIA2019]** J. Synchrotron Rad. (2019). 26, 1374. DOI: 10.1107/S1600577519003722; **[ABI2022]** Chem. Mater. (2022), 34, 24, 10885. DOI: 10.1021/acs.chemmater.2c02369]

Scientific environment:

The master candidate will work within the LMGP (Materials Science and Physical Engineering), in the NanoMat team in close collaboration with CEA-Leti (in the framework of the µElec LabEx). This work will strongly support the 2DFET Carnot project (whose aim is to develop MoS_2-based field effect transistors). Located in the heart of an exceptional scientific environment (Access to the CMTC and PFNC platforms and Leti's clean room), the LMGP and CEA-Leti offer to 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 sciences. She/he should also have ability and initiative to get to the heart of the problem and bring it to completion; good communication, organizational and scientific skills are required.

Allowance: PhD allowance will be provided by Université Grenoble Alpes (Microelectronic Labex)

Start date: from October 2024

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