# ETMOS: Epitaxial Transition Metal dichalcogenides Onto wide bandgap hexagonal Semiconductors for advanced electronics

**Main area:** Synthesis and characterization of layered materials beyond graphene
**Keywords:** Transition metal dichalcogenides, wide bandgap semicductors, molecular beam epitaxy, pulsed laser deposition, characterization
**Duration:** 36 months
**Total project funding:** € 536.735

## Abstract

The ETMOS project aims at developing large area growth of electronic quality transition metal dichalcogenides (TMDs) by molecular beam epitaxy (MBE) and pulsed laser deposition (PLD). Moving from recent reports and initial results of the proponents on the epitaxial quality of MoS2 grown on hexagonal crystal substrates, we will promote epilayer growth of these materials on wide bandgap (WBG) hexagonal semiconductors (SiC, GaN, AlN, AlGaN alloys) and on insulating sapphire. Five partners are concerned with complementary skilling in thin film growth (CNRS, SAS), advanced characterizations and simulations (CNR, HAS, U-Pa), processing and electronic device prototyping (CNR). WBG semiconductors templates/thin films on different substrates (Si, sapphire, SiC, bulk GaN) will be grown to acquire full control on the starting materials properties and to prepare epi-ready surfaces allowing high quality and uniform MBE and PLD growth of TMDs. Depositions will be targeted from monolayer (1L) to few layers (up to 5) of MoS2 and WSe2 with sub-monolayer thickness control on wafers with diameter up to 100 mm. Substitutional doping of TMDs during MBE or PLD will be developed, with a focus on p+ doping of MoS2, strategic for device applications. Besides growth facilities, ETMOS consortium holds the entire set of morphological, structural, chemical, optical, and electrical scanning probe characterizations helping to achieve high quality at each step of growth. The electrical properties (doping, mobility, resistivity,..) of TMDs as well as the current transport across the TMDs/WBG heterojunctions will be investigated by specially designed test devices. Experiments will be complemented by growth simulations and by ab-initio calculations of the electronic band structure of TMDs on WBG. Multiscale characterization protocols will be settled to benchmark our epitaxial TMDs against other group's results with the same or complementary depositions methods. Finally, device prototypes exploiting the properties of TMDs/WBG heterojunctions will be fabricated, including: (i) band-to-band tunnelling diodes and transistors based on the atomically abrupt heterojunction of p+-MoS2 with n-GaN or n-SiC; (ii) MoS2/GaN and MoS2/SiC UV photodiodes; (iii) hot electron transistors with Al(Ga)N/GaN emitter and 1L TMD base. The developed materials/processes are targeted to TRL=5 at the end of the project. As ETMOS partners hold running collaborations with leading industrial players (STMicroelectronics, TopGaN, Lumilog) in SiC and GaN, representatives from industry will be part of ETMOS advisory board, providing guidelines on the processes compatibility with production environment. Our TMDs growth activities are highly complementary in respect to the commonly adopted CVD approach. We envisage strong synergies with groups in the divisions 1 and 3 of Graphene Flagship, thus contributing to European capabilities in large area growth of TMDs and devices applications.

## Consortium

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