Synthesis & Properties of Functional Nanomaterials & Thin Films (SYNFONI)

Nanolamellar & 2D Materials

Context

- MAX, MAB, and MXene material family features nanolamellar structures with unique anisotropic physical properties
- Control elemental composition and surface chemistry to design dedicated physicochemical properties for targeted applications
- Lamellar metal dichalcogenides as 2D materials for next generation microelectronics

Objectives

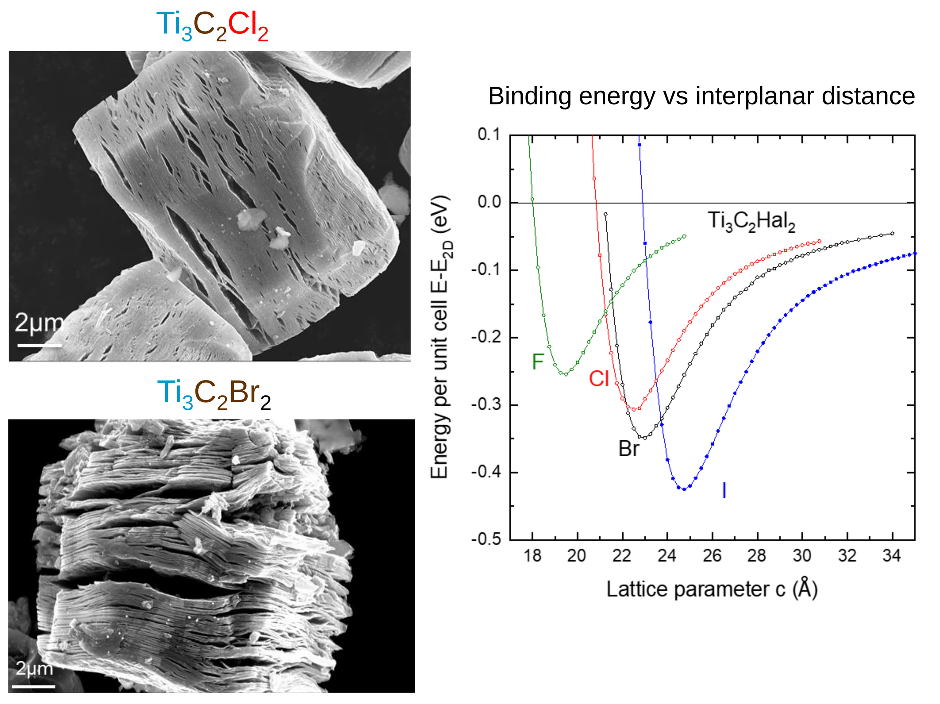
- Develop MAX phases & related MXenes with new chemistries and controlled surface terminations
- Investigate structural and anisotropic physical properties using advanced characterization techniques in lab- and large-scale facilities, which are further coupled with density-functional theory (DFT) calculations
- Synthesize lamellar metal sulfides ultra-thin films & dedicated heterostructures for microelectronics

Skills and competences

- Materials synthesis: single crystal growth and chemical exfoliation, atomic / molecular layer deposition (ALD / MLD)
- Advanced structural & physical characterization: Complementary *in situ* and operando studies during synthesis or not, using lab- & large-scale facilities (i.e. synchrotron radiation)

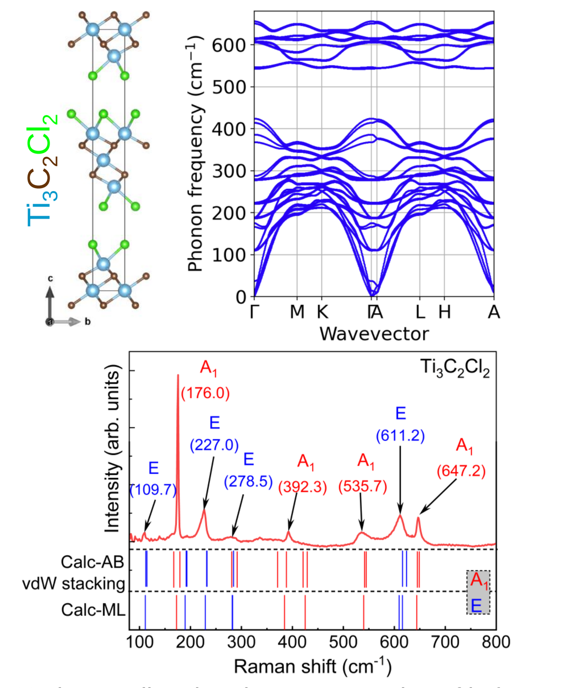
2D MXenes: Synthesis and Characterization

We develop sustainable and eco-friendly routes to synthesize 2D MXenes with varied transition metals, and precisely control surface chemistry to achieve targeted functional groups and properties.



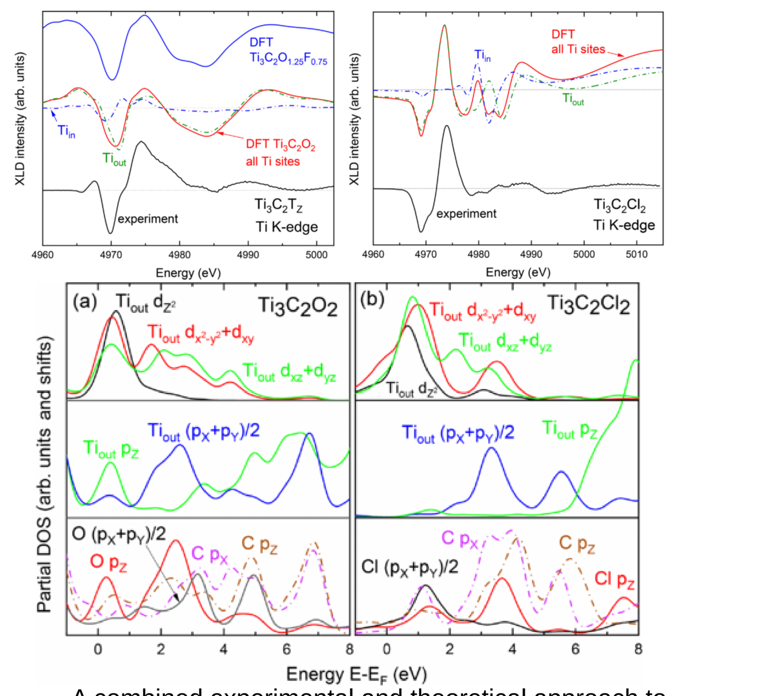
Towards the synthesis of highly ordered vdW multilayered MXenes with halogen terminations

*H. Pazniak et al. **Open Ceramics** (2024)*



Understanding the phonon properties of halogen-terminated MXenes: first experimental insight

*M. Riabov et al. **2D materials and applications** (2025)*

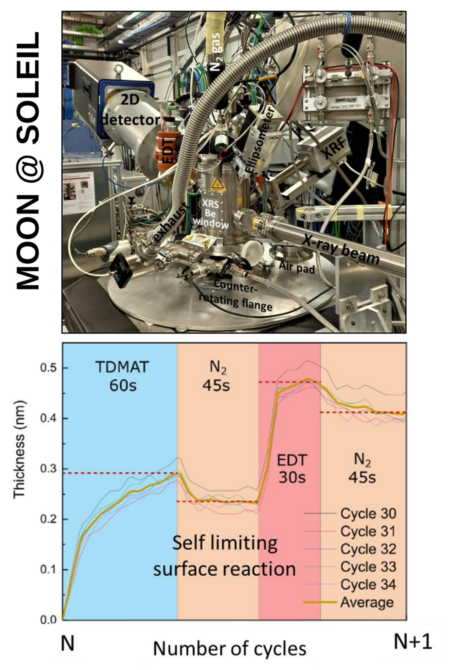


A combined experimental and theoretical approach to elucidate the anisotropy of MXenes with different terminations

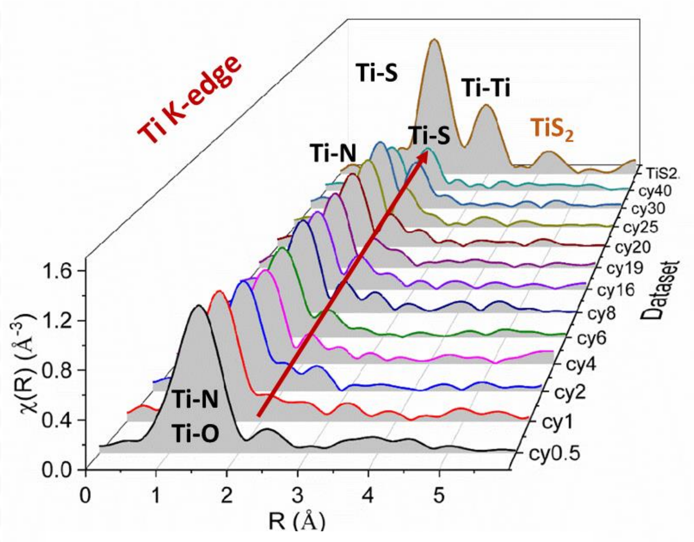
*T. Ouisse et al. **Physical review B** (2025)*

Advanced Characterization for *in Situ* / *Operando* & Fundamental Studies

We combine *in situ*, *operando*, and synchrotron-based characterization techniques to elucidate thin-film growth mechanisms and to probe the intrinsic electronic structure of lamellar materials.

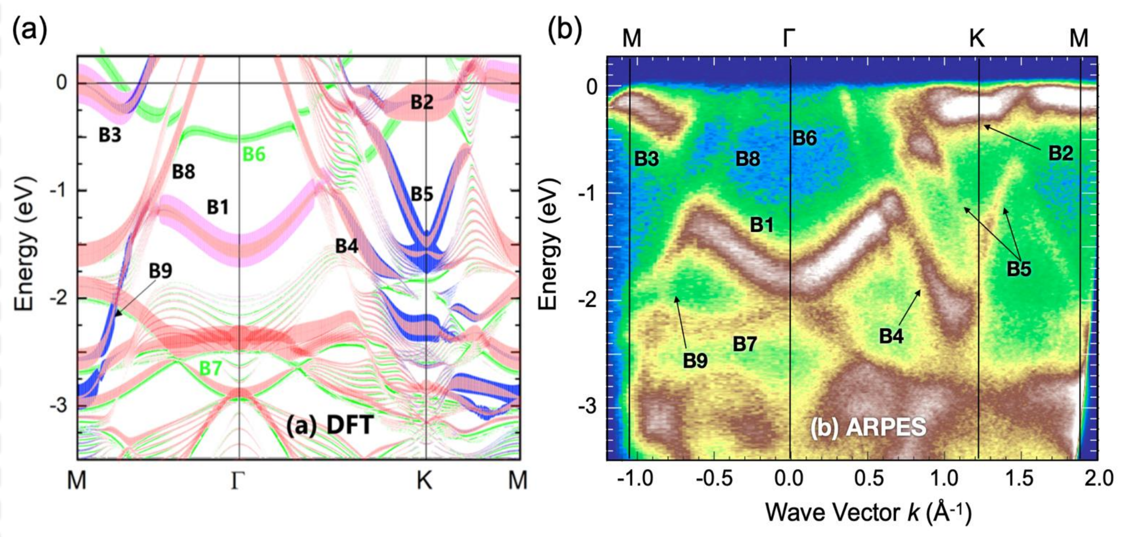


ALD/MLD reactor built for surface-sensitive *in situ* synchrotron X-ray studies



In situ extended X-ray absorption during ALD/MLD growth of TiS_2 ultrathin films

*P. Abi Younes et al. **Chemistry of Materials** (2022)*
*A.-K. Yadav et al. **Nanoscale** (2024)*
*P. Abi Younes et al. **J. Vac. Sci. Technol. A** (2023)*



Experimental observation of the electronic structure of nanolamellar Zr_3SnC_2 single crystal measured by ARPES with the DFT predictions

*T. Ouisse et al. **Physical review B** (2023)*

Wide & Ultra-Wide Bandgap Semiconducting Oxides

Context

- ZnO & Ga_2O_3 and related materials
- Remarkable structural and physical properties, opening the way for next generation devices
- Understand the fundamental mechanisms related to their nucleation, epitaxial growth, doping, and alloying to control their morphology & properties

Objectives

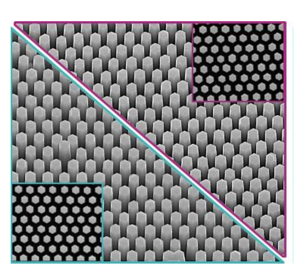
- Develop the epitaxial growth of semiconducting oxide nanowires & thin films by chemical deposition techniques, including CBD, ALD & PLI-MOCVD
- Elucidate the physicochemical processes for the nucleation, epitaxial growth, doping, and alloying by combining with thermodynamic computations
- Explore & control their physical properties: defects, doping, alloying, interface / surface
- Combine nanowires and thin films into innovative heterostructures: piezoelectric, power electronic and optoelectronics devices
- Assess raw materials criticality & process impact

Skills and competences

- Growth modelling, doping, alloying
- Thermodynamic simulations, green chemistry
- Structure-property relationship: polarity, interface / surface, epitaxy
- Techniques: sol-gel process, CBD, SILAR, ALD / ALE, PLI-MOCVD, and morphological / structural / chemical / optical characterization

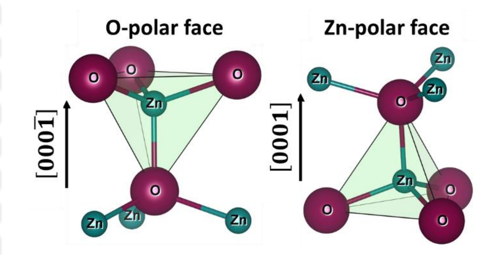
Epitaxial ZnO Nanowires: Growth & Properties

We develop the spontaneous & selective area growth of ZnO nanowires by chemical bath deposition to thoroughly control their morphology & physical properties for piezoelectric & photocatalytic devices.



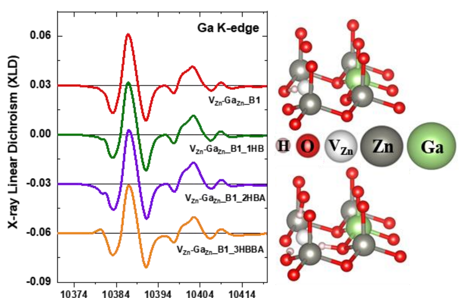
Chemical bath deposition

*V. Consonni et al., **ACS Nano** (2014)*



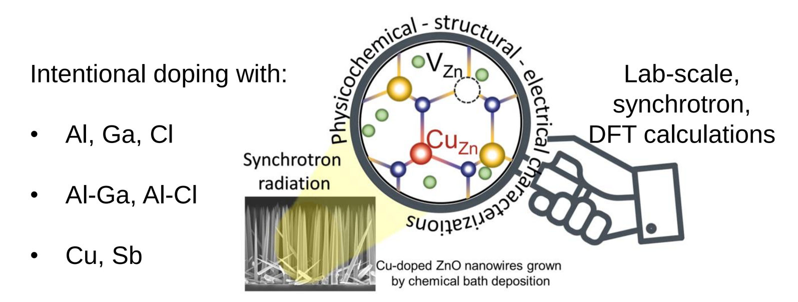
Controllable crystal polarity

*V. Consonni et al. **Nano Energy** (2021)*



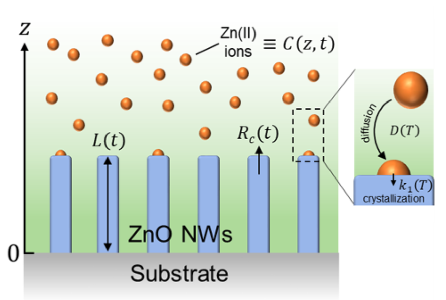
Hydrogen-related defects

*E. Sarigiannidou et al. **Physical Review Materials** (2023)*

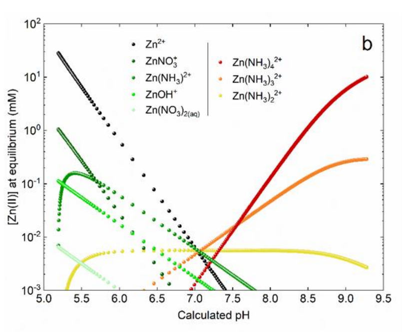


Intentional doping processes

*M. Manrique et al. **Small Structures** (2025)*

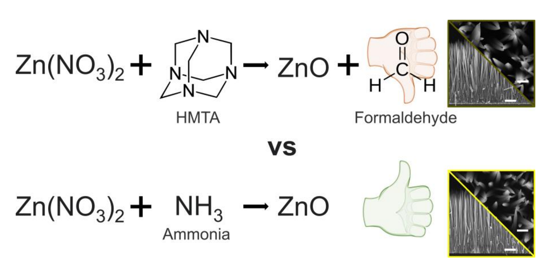


Modeling the nanowire growth



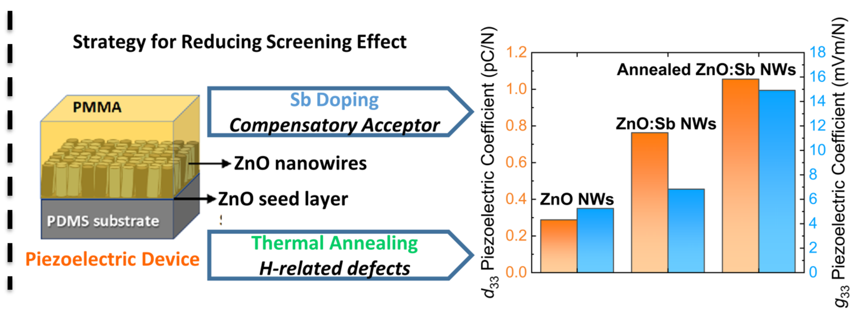
Thermodynamic simulations

*C. Lausecker et al. **The Journal of Physical Chemistry C** (2019)*



Towards green chemistry

*A. Baillard et al. **Nanomaterials** (2025)*

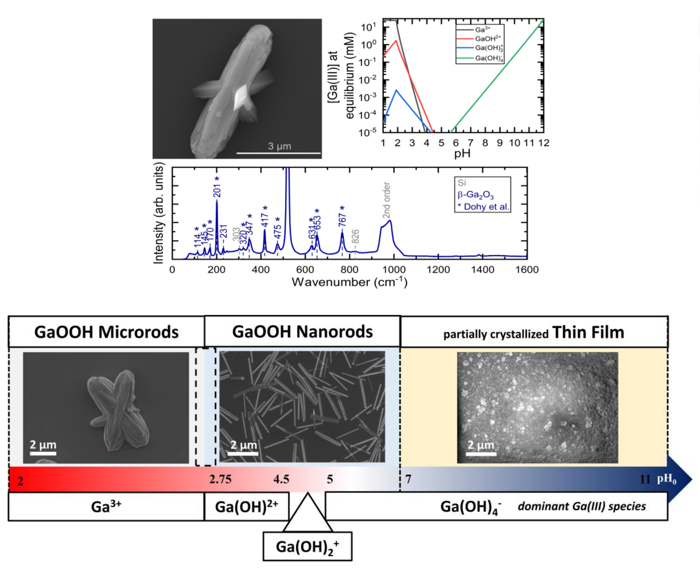


Special emphasis on piezoelectric devices

*J. Villafuerte et al. **Nano Energy** (2023)*

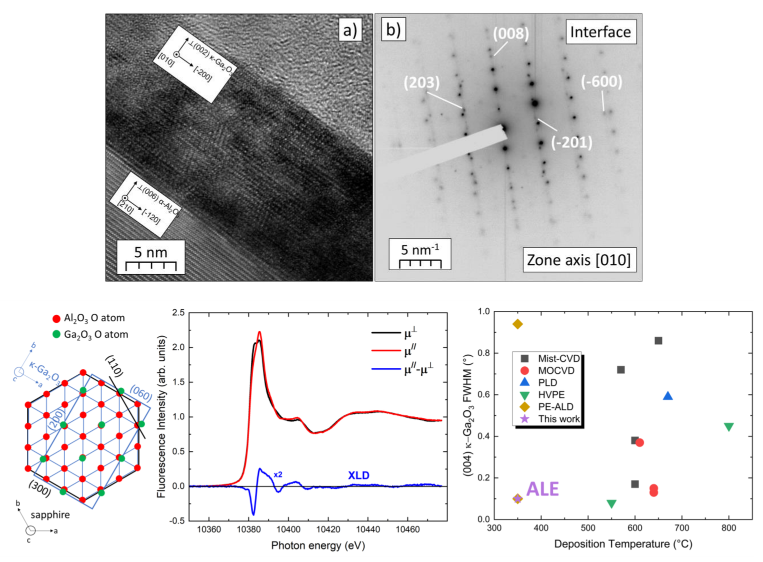
Ga_2O_3 Nanomaterials & Epitaxial Thin Films: Growth & Properties

We develop the chemical bath deposition of Ga_2O_3 nanomaterials and the epitaxial growth of Ga_2O_3 thin films by ALD & PLI-MOCVD to thoroughly control their morphology & physical properties for power electronics & optoelectronics.



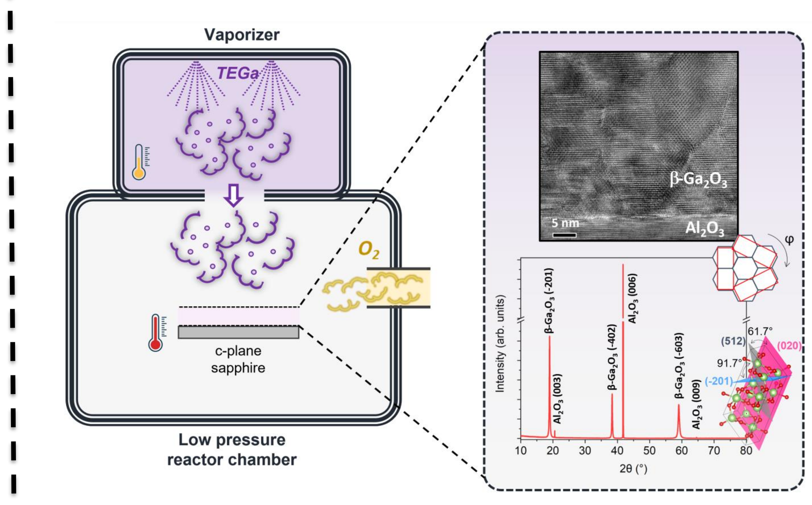
Chemical bath deposition of Ga_2O_3 nanomaterials

*G. Hector et al. **Inorganic Chemistry** (2020) & (2023)*



ALD of epitaxial κ-Ga_2O_3 thin films on sapphire

*A. Séguret et al. **Chemistry of Materials** (2025)*



PLI-MOCVD of epitaxial β-Ga_2O_3 thin films on sapphire

*M. Velasco-Enriquez et al. **ACS Materials Au** (2025)*

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More information: