PHD PROJECT 2023-2026

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STUDY OF OPTOELECTRONIC PROPERTIES OF Ga_2O_3 AND $ZnGa_2O_4$ THIN FILMS

This experimental PhD project goals the study of optoelectronic properties of « ultra-wide band gap (UWBG) » oxide semiconductors as Ga_2O_3 of different polymorphs and $ZnGa_2O_4$ spinel. While beta-Ga_2O_3 is now well mastered as n-type doped UWBG semiconductor up to free electron concentrations around 10^{19}-10^{20} cm^{-3}, a high p-type doping remains a scientific challenge [1]. Among the potential impurities, Zinc, revealed amphoteric, is very promising with the formation of acceptor complexes [2]. And with a higher zinc concentration, the spinel oxide $ZnGa_2O_4$ is stabilizing. This compound, as well UWBG, with new substitutional sites for Zn, open new p-type doping paths, as GEMaC team demonstrated recently [3].

The PhD student will study link of structural/chemical (crystallinity, morphology, chemical composition) and semiconducting (optical, electrical) properties. The main challenge will be related to identify/study donor and acceptor defects and their role in electrical and optical properties, in order to find a way to control electrical conductivity while keeping high optical transparency. Study conductivity mechanism and electrical contact preparation technology. The work will be dedicated also to compare different polymorphs (alpha, beta, epsilon,) of Ga_2O_3 and understand deeply the cation inversion mechanism in $ZnGa_2O_4$. Finely, proton radiation hardness of these material will be investigated.

Thin film studied samples will be grown in GEMaC (by a colleague grower) with metal-organic chemical vapor deposition (MO-CVD), and by other international research groups with whom the team is cooperating. PhD student will benefits of the large panel of experimental facilities available in GEMAC laboratory: /i/ structural and morphological (X-ray diffraction, atomic force microscopy, electron microscopy); /ii/ chemical and dopant level composition (secondary ions mass spectroscopy), XPS spectroscopy (in collaboration with ILV lab, Versailles and ICN2 lab , Spain) /iii/ optical characterizations: UV-visible-near IR absorption spectroscopy in broad range of temperature; photo-luminescence spectroscopy ; /iv/ Electrical transport measurements: Resistivity, Hall effect; Photoconductivity; C-V measurement; /v/ Electrical contacts (Ohmic/Schottky) preparation by lithography and I-V tests; DLTS spectroscopy (with collaboration INL, Lyon). Proton irradiation experiment will be carried in collaboration with INSP at Sorbonne Université, Paris.

At the end of this PhD project, the electronic properties of Ga_2O_3 polymorphs and $ZnGa_2O_4$ spinel oxides will be deeply known and understood, which is necessary for successful fabrication of p-n and metal- semiconductor heterojunctions. This will open paths for applications in opto-electronics. This work is inscribed in a large national and international consortium working on gallium oxide **(https://www.gallia-project.fr/)**.

Profile and skills required: MSc with strong background in materials science (characterizations) and in solid state physics/semiconductors science; strong motivation and experimental works; English language (read, write); Good skills of communication, organization and research curiosity.

Salary: Ministry of Research PhD 3 years grant (2 044 euros/month growth salary); additional teaching or scientific advice paid missions possible.

[1] *A review of Ga_2O_3 materials, processing, and devices*, S. J. Pearton, J. Yang, Patrick H. Cary, et al., **Applied Physics Reviews 5, 011301 (2018)** // *P-type β-gallium oxide: A new perspective for power and optoelectronic devices,* E. Chikoidze, A. Fellous, (...); Dumont Y., **Materials Today Physics 3, 118 (2017)**

[2] *Ultra-high critical electric field of 13.2 MV/cm for Zn-doped p-type beta-Ga_2O_3,* Chikoidze, E; Tchelidze, T; (...); Dumont, Y**., Materials Today Physics, 15 (2020) 18**

[3] *p-Type Ultrawide-Band-Gap Spinel $ZnGa_2O_4$: New Perspectives for Energy Electronics,* Chikoidze, E; Sartel, C; Madaci. I., et al., **Crystal Growth & Design 20 (2020) 2535** // *Bipolar self-doping in ultra-wide bandgap spinel $ZnGa_2O_4$,* Chi, Z; Tarntair, FG; (...); Chikoidze, E, **Materials Today Physics 20 (2021) 100466**