Call for applications – PhD candidate
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Ga_2O_3 MATERIAL AND DEVICE STUDIES - TOWARDS AN UWBG FOR POWER ELECTRONICS

Context: Electronic components based on wide-gap semiconductor materials (SiC, GaN) are experiencing considerable growth for medium-power electronic applications (10 kV / 100 A) such as the hybrid/electric automobile sector. Beyond this power range, the challenges to increase the power density and the **switching/conversion efficiency** are considerable from the point of view of the energy issues and the **reduction of CO_2 emissions,** with applications in particular in the field of power distribution (smart grid) and transport (rail). To meet these power requirements, it is necessary to turn to so-called **ultra-wide gap (UWBG)** materials with appropriate bandgap energies (>4 eV) and breakdown fields (>10 MV.cm-1) such as diamond, AlGaN or Ga_2O_3. Of these, Ga_2O_3 has the unique advantage of the availability of commercial substrates of 150 mm in diameter at a reasonable cost (3 times cheaper than SiC). A very strong challenge for UWBG materials remains their doping. Here again, Ga_2O_3 remains of great interest given that n doping can be easily achieved over wide ranges of values [1-3]. Unipolar power devices have been demonstrated with normally-on operation [4-6]. **The missing technological building block for normally off power devices is p-type doping for the production of bipolar devices. The development of an innovative technology sector for Ga_2O_3-based devices and the control of p-type doping requires the study of the electronic levels induced by traps or defects in the material.** These defects can also be induced by technological processes (implantations, engravings, metal contamination). It is on this main axis for the development of a bipolar technology that the PhD subject will mainly focus. Indeed, the INL laboratory and the "Functional Materials" team have an extensive and unique expertise in electrical and electro-optical techniques for studying electronic levels induced by traps and defects in wide-gap semiconductors.

References:

[1] M. Orita et al., Appl. Phys. Lett. 77 (2000) 4166
[2] N. Ueda et al., Appl. Phys. Lett. 70 (1997) 3561
[3] E. Chikoidze, et al, J. Appl. Phys. **120** (2016) 025109.
[4] J. Yang et al., *ECS J. Solid State Sci. Technol.* **7**, (2018)
[5] S. J. Pearton, et al., *J. Appl. Phys.* **124** (2018) 220901
[6] K. Tetzner e., *IEEE Electron Dev. Lett.* **40** (2019) 1503

Keywords: Ga_2O_3, UWBG, p-doping, deep traps, defect spectroscopy, DLTS, DLOS, power components, power conversion/switching.

Objectives of the thesis: The overall objective is **to characterize the properties of electrically active defects in Ga_2O_3 epitaxial layers.** These studies will be carried out initially to assist the GEMaC laboratory in charge of the growth of p-type material, then on vertical structures of the pin diode type in order to improve growth and technology in this sector. Particular attention will be paid to **identifying the origin of defects** in order to distinguish those due to growth from those induced by technological processes. The study will also aim **to correlate the spectroscopy data of the defects with possible anomalous electrical characteristics of the devices**. The characterization of generation-recombination type centers will be completed by electro-optical measurements such as the lifetime of minority carriers in photocurrent and electroluminescence measurements on pin structures. Finally, **the signatures of the traps (activation energy, capture cross section) determined can be used as injectable parameters for the modeling of the components.**

Importance of the subject in the strategic context of research on materials for the energy of the future:

This subject is part of a research project funded by the ANR, the GOPOWER project bringing together the GEMaC for the growth step, the INL and the University of Swansea for the technology aspects, and all partners for characterizations ranging from structural to fine analyses of defects by DLTS, DLOS, EPR. This project is part of Axis 2.1 **"Basic science for Energy".** Two distinct developments are needed to guarantee a stable energy supply in the near future: the identification of sustainable energy sources that are alternatives to fossil fuels and the efficient use of energy (transport, storage, conversion, switching). A concrete way to reduce energy losses during conversion and switching is to use power electronic components in a range of up to a hundred kV in reverse and ten amperes in the forward direction. The applications are varied and in high demand, covering: continuous current transmission (HVDC), distribution and conversion of electricity, control circuits for traction (automotive, rail), aeronautics and aerospace... According to the consulting firm Yole, specializing in part in semiconductors: "Increasing power density and optimizing power conversion for the reduction of CO_2 emissions are essential".

Gallium oxide, thanks to its intrinsic properties and the availability of bulk substrates, is predicted to be the material of choice for next-generation high-power devices suitable for harsh environments. The GOPOWER project, unique in France, aims to accelerate the demonstration of the exceptional potential of gallium oxide through a breakthrough in the technology of p-type materials, thus allowing France to remain highly competitive at the international level, given the considerable efforts made in research projects deployed in the United States and Japan.

Scientific breakthroughs: Many scientific questions remain to be clarified:

- Understand the mechanisms of p doping in Ga_2O_3 and the associated defects.

- Interpret the fine characterization of defects (nature, structure) correlated with EPR (electronic paramagnetic resonance) measurements at the INSP.

- Set up techniques for characterizing defects on a material with a very wide band gap (4.9 eV). Indeed, the classic DLTS technique will be supplemented here by optical or electro-optical techniques such as ODLTS (Optical DLTS) and DLOS (Deep Level Optical Spectroscopy), allowing the activation and observation of very deep defects thanks to their photoionization.

- DLTS measurements under high field on pin devices.

Research program and proposed scientific approach: The thesis work will begin with the DLTS study of n-type epitaxies in order to characterize the defects of this material, then by the implementation of the optical extensions (DLOS, ODLTS) necessary for the study of the UWBG material. This part will support the project for the production of n-type power Schottky diodes. We will then apply these techniques to the study of p-type materials, which are currently under development. The work in the second year and the beginning of the third year will consist of studying p/i/n structures with the objective of correlating the defects with the electrical characteristics (ideality factor, for example) and of classifying the problems linked to the technology and those related to the material. These results will be supplemented by specific measurements of photocurrent and electroluminescence.

Expected original contributions:

Obtaining p-doping in Ga_2O_3 will be a major step forward for the development of this sector. The characterization of this material will be a key element in obtaining it.

The expected correlation between the fine characterization of the defects and the electrical characteristics of the components is also an original issue in this subject.

All these advances are essential building blocks for the development of a high power electronics industry based on Ga_2O_3 bipolar devices.

About INL: The INL is a 250-strong research institute based in Lyon, France, carrying out fundamental and applied research in electronics, semiconductor materials, photonics and biotechnologies. Within the INL laboratory, the "Functional Materials" team has extensive and unique expertise in electrical and electro-optical techniques for studying the electronic levels induced by traps and defects in large bandgap semiconductors. Professors Bremond and Bluet who have a more than 20 years' experience in wide band gap semiconductor physics will supervise the study.

Profile of the candidate (prerequisite):

- Last year in Engineering School or Master 2 in Electrical Engineering, Materials Engineering, Microelectronics, Nano-Technology, Semiconductor Materials Physics, Condensed Matter Physics.

You must have strong theoretical knowledge in the following areas: semiconductor physics, semiconductor devices physics, device electrical characterizations. Very good skills in experimental measurement integrating electrical measurements and optical measurements.

- Curious, rigorous and autonomous. Willingness to get involved in a collaborative project between academic partners.
- Spirit of synthesis.

- Excellent written and verbal communication skills in English is required. Fluency in French is also a plus but is not mandatory

Required knowledge:

-Semiconductor Physics, Electronic Devices Physics, Clean Room Technology, Electronics

Elements to be provided for the application:

-CV

- Motivated cover letter, recommendation letter if possible
- University cursus results transcripts for Master (and Bachelor) in English or French

Send your application to: georges.bremond@insa-lyon.fr or jean-marie.bluet@insa-lyon.fr

Objectives of valorization of research work:

Publications in journals associated with the field, i.e. either general journals of applied physics of the APL and JAP type, or more specialized journals on electronic components of the IEEE TED type.

Presentation of the work at general conferences on semiconductors and defects (ICPS, ICDS, EXMATEC,MRS) and specialized in the field (IWGO).

Extraction of trap signatures that can be used in compact component models.

Skills that will be developed during the doctoral course:

Academically: mastery of the physics of elementary electronic device components and their characterizations. Electro-optical characterizations of defects in semiconductors.

- Scientific methodology
- Management of a research project
- External collaborations ...

Professional prospects after the doctorate: The doctorate can open both to the pursuit of a research activity in the academic world and to an insertion in industry. Industrial sectors for power electronics (SiC, GaN) are developing very rapidly at the industrial level, for example in ST-Tours at the national level and at the european level (ST Catane,Infineon..)

Send CV, letter of motivation and University cursus transcripts (in English or French) to:

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