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Allocations de Doctorat du China Scholarship Council :

Soumission d'une proposition pour 2019

PhD proposal for 2019

Objet : *Detailed subject for PhD thesis :*

Title : ***Studies of electronic properties of wide band gap semiconductor related materials and nanostructures by electrical mode scanning probe microscopy for electronics and optoelectronics device applications.***

Wide band gap semiconductors as GaN (gallium nitride) or ZnO (zinc oxide) reach a real maturity for their growth control and exciting electronical properties as high speed carrier velocity, high power energy capacity and optical properties and for a lot of various functionalities used for sensors. Nanowire structures issued from these wide band gap semiconductors combine great potentiality of application and a real need of new analysis approaches and methodologies in order to well-control their electronic properties.

Group-III nitride semiconductors and heterostructures have been recognized as belonging to the most promising materials for high-temperature high-power high-electron mobility transistors (HEMTs), optoelectronic devices in the short wavelength region (photodetectors and LEDs), monolithic microwave and optoelectronic integrated circuits heterojunction FETs, MISHFETs, MOSFETs, microwave, heterojunction and switched diodes (heterojunction diodes, lasers as well as other devices, which will have a great impact on the future world. The superior physical and chemical stability of the nitride semiconductors will enable them to operate in harsh environments. In contrast, ZnO, because it is not possible up to now to dope it with acceptor for p-type conversion, is mainly used for sensor applications (gaz sensors, piezo actuators…) thanks to its great chemical sensitivity and its piezo electrical properties.

To produce such novel devices, it is essential to grow high wide band gap single crystals and to control their electrical conductivity. For instance, important research works are developed on p-doping ZnO using nanowire approach, thanks to their better crystalline quality and less-sensitivity to substrate. For other example, it was quite difficult to grow high-quality epitaxial GaN films with a special crack-free surface. The recent progress in growth technology of extremely high-quality GaN single crystals with such a surface, the discovery of p-type GaN and the ability to fabricate a p–n junction light emitting diode have led to such developments as high-performance blue and green LEDs, violet laser diodes, ultraviolet (UV) photodetectors and field effect transistors. GaN and related III–N materials are typically grown on lattice mismatched substrates such as Si, sapphire and SiC. A consequence of this mismatch is that III–N epitaxial layers contain a high density of threading dislocations causing degradation of laser diodes, which operate at a high current density (2–4 kA cm^{-2}). They may give an obstacle to the high-performance of photodetectors and transistors. Various technologies have been developed for the reduction of the dislocation density. These approaches include lateral epitaxial overgrowth and cantilever epitaxy], and significantly reduced dislocation densities in the range 10^6–10^7 cm^{-2} have been achieved. Theory and experiment indicate that a further reduction in defect density is possible if the lateral overgrowth approach is extended to the nanoscale, like nanowire fabrication. Therefore the Wide Band Gap (WGB) semiconductor technology is today less developed than the mature silicon based semiconductor technology. WBG materials and devices are less reproducible and more expensive compared with silicon ones. Anyway, the main driving force for this resurgent interest is the following: i) devices and systems made of WBG materials will become widely available on a large variety of automotive, aerospace, deep-well drilling, shipboard and other industrial systems; ii) these materials are promising candidates for blue and ultraviolet light emitting diodes (LED) and lasers; iii) WBG devices used in low-power transistors at ambient temperatures exceeding 300 ◦C are commercially available.

Into this large scientific and technological context we propose to contribute to understand the performances and the (dis)functioning of wide band gap electronic or/and optoelectronic devices by developing electrical characterization techniques based on space charge depletion zone measurements. The INL (Institute of Nanotechnology from Lyon) laboratory at INSA Lyon is well recognized on space charge spectroscopy for heterojunction semiconductors and devices characterization. The "spectroscopy and nanomaterial" team of INL had developed a lot on space charge measurement techniques devoted to the study of defect in close relation with III-V electronic transistors as MESFET, MISFET, HEMT and heterobipolar transistors. Professor G Bremond is an expert of such domain. The techniques used up to now are electrical spectroscopy technique called deep level transient spectroscopy (DLTS) based on capacitance and current analysis on p-n or Schottky devices, on gate and drain-source capacitance and conductance spectroscopy on FET transistors. This team develops also very original nanoscale electrical characterization based on atomic force microscopy (AFM) approach using conductive AFM tip. They use scanning capacitance microscopy (SCM)/ spectroscopy(SCS), scanning spreading resistance microscopy (SSRM) and conductive AFM (CAFM) on nanostructure structures and devices based on semiconductors quantum dots or nano island and also more recently on nanowires (ZnO) . One of the main objectives of this subject research is to extend such nanoscale technique approach to space charge measurement on such nanostructures which could be potentially integrated on device technology.

The main purpose of the work will be to study the electrical defect and their influence on the doping mechanism and on the functioning of the devices in 2D (high mobility channel, heterostructure interfaces,…) 1D (nanowire and technology structure related) and 0D (quantum dot devices) by using space charge techniques coupled with nanoscale technique.

Strong collaborations developed by INL with the French group-III nitride industry and CNRS laboratories for ZnO and GaN will be one of the main sources of materials, devices and technology problematics.

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