Abstract #1923, 224th ECS Meeting, © 2013 The Electrochemical Society

MultiScale Modeling of III-Nitride Materials and Power Devices

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Invited Talk

The remarkable progress made during the last ten years in developing the III-nitride material system has propelled this class of semiconductors to the forefront of electronics and optoelectronics device applications. Although a number of technological hurdles still need to be overcome (for example p-type doping in ternary alloys, the growth of high In content compounds and the reduction of defects and dislocations) their unique properties have led these semiconductors to be a contender for device applications where silicon and conventional III-Vs are currently the preferred choice. The desirable properties of GaN and its alloys, such as high carrier drift velocity and high breakdown field, will inevitably make them the materials of choice for power electronics. Due to the large energy gap range offered by this material system a whole gamut of heterostructure configurations can be obtained to satisfy device requirements. Although point and extended defects present in these materials seem to be quite benign for optoelectronic devices, they are a major roadblock for the development of electronic devices especially for power electronic applications. Furthermore, the electronic structures of III-nitrides are significantly more complex than those of conventional III-Vs and lead to new transport properties that have to be understood to effectively design electronic devices. As a result of the large energy gap, carriers in these materials can reach energies as high as 10eV. Consequently, a prerequisite to understanding the physics of carrier transport in these materials is to be able to quantify the carrier-phonon and carrier-carrier interaction strength at energies several electronvolt above the band edges with a certain degree of accuracy and a full-band approach is mandatory. In this talk we will present the state of the art in multiscale numerical modeling approaches used to assess the material properties of the III-Nitrides and elucidate the new physical phenomena that characterize this material system. Specifically, we will consider the high field transport properties of GaN and its ternary alloys that need to be understood in order to design power electronic devices. Furthermore, we will describe an atomistic approach we have developed to study the impact of dislocations and defects on the material properties and device performance. Finally we will apply the simulation model to the study of realistic device structures.

The work at Boston University and Politecnico di Torino has been supported in part by the U.S. Army Research Laboratory through the Collaborative Research Alliance (CRA) for MultiScale multidisciplinary Modeling of Electronic materials (MSME).