MAR05-2004-010069

Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Toward a Self-Consistent Model of Carbon States, Semi-Insulating Conductivity and Yellow Luminescence in GaN:C Grown by Molecular Beam Epitaxy

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Carbon doping of GaN is of great interest to generate semi-insulating (SI) buffer layers used in AlGaN/GaN heterojunction field effect transistors grown by molecular beam epitaxy (MBE). However, the specific mechanism(s) responsible for SI behavior involving C-related bandgap states in GaN until recently had been un-verified experimentally due to difficulties in determining deep level properties within SI wide bandgap materials. Moreover, C-related states in GaN are under increasing scrutiny due to the observation of yellow luminescence (YL) in *both* n-type and SI GaN:C since the prevalent model for YL in GaN requires requires gallium vacancy (V_{Ga}) defects, which are not expected to form in significant concentrations for SI GaN. However, the fact that YL is observed for SI GaN doped with C while not being observed for SI GaN doped with Fe, suggests additional roles for C-related states in the GaN bandgap that may also have implications for potential parasitic effects in GaN electronics. Hence a full understanding of C-related deep states in SI GaN:C is necessary. This presentation will focus on each of the aspects noted above. First, our recent development of a lighted capacitance-voltage defect profiling measurement that allows full quantification of deep level concentrations and energy levels within SI GaN throughout its bandgap will be described. By applying this method with deep level optical spectroscopy (DLOS) to a systematic MBE-grown GaN sample set with well-controlled carbon doping, carbon states responsible for the SI behavior are identified. From this knowledge and by comparing to photoluminescence studies of these same samples to monitor the YL dependence on both conductivity and carbon concentration, the controversy over the existence of YL in SI GaN:C is addressed. A model based on a coordinate configuration diagram will be presented, showing the first self-consistent picture of C-related bandgap states and how they influence both SI behavior and deep level YL.