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Synchrotron Based Techniques for the Characterization of Chemical Vapour Deposition Overgrowth Diamond Layers on High Pressure, High Temperature Substrates

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Abstract : The ability to grow boron-doped diamond epilayers of high crystalline quality is a prerequisite for the fabrication of diamond power electronic devices, in particular high voltage diodes and metal-oxide-semiconductor (MOS) transistors. Boron and intrinsic diamond layers are homoepitaxially overgrown by microwave assisted chemical vapour deposition (MWCVD) on single crystal high pressure, high temperature (HPHT) grown bulk diamond substrates. Various epilayer thicknesses were grown, with dopant concentrations ranging from 1021 atom/cm³ at nanometer thickness in the case of 'delta doping', up 1016 atom/cm³ and 50µm thickness or high electric field drift regions. The crystalline quality of these overgrown layers as regards defects, strain, distortion… is critical for the device performance through its relation to the final electrical properties (Hall mobility, breakdown voltage…). In addition to the optimization of the epilayer growth conditions in the MWCVD reactor, other important questions related to the crystalline quality of the overgrown layer(s) are: 1) what is the dependence on the bulk quality and surface preparation methods of the HPHT diamond substrate? 2) how do defects already present in the substrate crystal propagate into the overgrown layer; 3) what types of new defects are created during overgrowth, what are their growth mechanisms, and how can these defects be avoided? 4) how can we relate in a quantitative manner parameters related to the measured crystalline quality of the boron doped layer to the electronic properties of final processed devices? We describe synchrotron-based techniques developed to address these questions. These techniques allow the visualization of local defects and crystal distortion which complements the data obtained by other well-established analysis methods such as AFM, SIMS, Hall conductivity…. We have used Grazing Incidence X-ray Diffraction (GIXRD) at the ID01 beamline of the ESRF to study lattice parameters and damage (strain, tilt and mosaic spread) both in diamond substrate near surface layers and in thick (10–50 µm) overgrown boron doped diamond epi-layers. Micro- and nano-section topography have been carried out at both the BM05 and ID06-ESRF) beamlines using rocking curve imaging techniques to study defects which have propagated from the substrate into the overgrown layer(s) and their influence on final electronic device performance. These studies were performed using various commercially sourced HPHT grown diamond substrates, with the MWCVD overgrowth carried out at the Fraunhofer IAF-Germany. The synchrotron results are in good agreement with low-temperature (5°K) cathodoluminescence spectroscopy carried out on the grown samples using an Inspect F5O FESEM fitted with an IHR spectrometer.

Keywords : synchrotron X-ray diffaction, crystalline quality, defects, diamond overgrowth, rocking curve imaging
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