Electron Surface Accumulation Problem of Indium Nitride

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Present theories regarding the origin of the accumulation of electrons at InN surfaces are in disagreement with experimental data. In this paper we use high resolution X-ray photoelectron spectroscopy (XPS) to identify nitrogen related surface defects that may contribute to this electron accumulation in InN samples grown by different techniques: MBE, PRE-CVD, RF Sputtering and Reactive Evaporation (RE). The XPS signature of interstitial nitrogen was observed to be present for most of the samples examined. For MBE (Fig.1) and CVD grown materials another defect was observed by XPS with an N *1s* contribution shown to be present at ~ 396.9 eV. It has had some speculations [1] that this defect is possibly the nitrogen on indium anti-site defect or [2] that such a defect would be a deep level defect for InN and would not therefore contribute a significant number of electrons to the conduction band. It is shown in the paper that interstitial nitrogen is stronger candidate for the species responsible for surface electron accumulation in InN, though the nitrogen on indium anti-site defect, if it is acting as a deep level defect, could have a significant influence on the optical properties of the epitaxial material it has been observed in. We also point out that indium nitride grown by reactive evaporation does not show (Fig.2) the effects of electron surface accumulation and that consequently relatively low carrier concentrations can be achieved reproducibly. This result is attributed to the indium rich surface of the material. We show that high indium to nitrogen surface ratios are present in those situations where surface accumulation is not observed. X-ray diffraction results indicate that some reactively evaporated InN may represent rare instances where the presence of nitrogen vacancies dominates the electrical properties of the InN films. Subtle variations in the N *1s* spectra for these samples, were observed however these appear to be less significant than the changes in the (In *3d*)/(N *1s*) atomic ratios measured for the samples. For these ratios the N *1s* contributions for N-H and N-O/molecular nitrogen bonding at ~ 399.5 eV and ~403.7 eV respectively, were not included as these contributions were for surface absorbate species unrelated to the indium nitride matrix. The In *3d* peak related to In-OH bonding was also not included since it was a surface hydrolysis product unrelated to the underlying InN crystals, and because it could be clearly resolved from the indium peak due to indium nitride bonding. However, the In *3d* peak used included unresolved contributions from oxide and indium metal contributions, as well as the contribution related to indium nitride.

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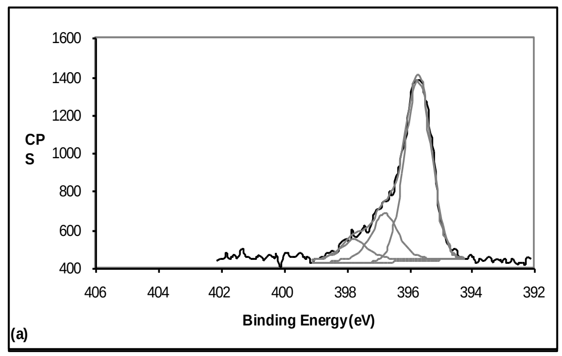

Fig. 1. XPS data for MBE sample

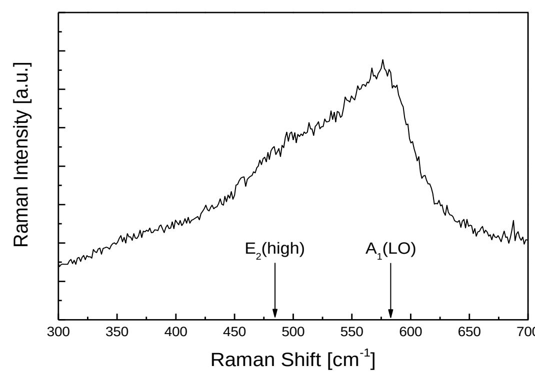

Fig. 2. Raman spectrum of RE InN sample.

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