Atomic scale investigations of In incorporation in the InGaN/GaN quantum wells by transmission electron microscopy

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Optoelectronic properties of the InGaN-based light-emitting devices (LED) largely depend on the local variation of the chemical composition in their active region. In some cases InGaN/GaN quantum wells (QW) with sophisticated compositional profiles are produced intentionally in order to better control optoelectronic properties of LEDs. In other cases, local composition variations might appear in a natural way due to a change of the In incorporation dynamics during the growth process. This is particularly true for the Metalorganic Vapour Phase Epitaxy (MOVPE), which is a major process in the manufacture of optoelectronics. However, it is quite difficult to measure experimentally such small and local composition changes.

A QW composition is commonly determined by means of high-resolution transmission electron microscopy (HRTEM). The local lattice parameter of an alloy is measured with respect to a lattice parameter of a region with a known composition (e.g. substrate). The strain is then converted into the chemical composition via Vegards and Hooks laws. The accuracy and the spatial resolution of the obtained composition maps are given by a combination of two factors: the microscope performance and the characteristics of the HRTEM image processing, which is done either in real, or in reciprocal spaces. The latter approach, called "geometric phase analysis" (GPA), is widely used thanks to an efficient noise reduction via suppression of all the spatial frequencies except the one that represents the measured lattice parameter. Such image treatment considerably improves measurement precision at the cost of the spatial resolution reduction. In particular, smoothing effect caused by the strain averaging limits application of GPA for studying composition change at the heterointerfaces.

Recently we have developed a real space treatment method, which allows similar to GPA measurement accuracy, while keeping atomic scale resolution. Application of this new technique to the HRTEM images acquired at the aberration-corrected microscope enables reliable measurement of the chemical composition profiles at the QW interfaces. Besides, recent invention of the high-resolution dark-field electron holography (DFEH) allows further improvement of the measurement precision.

We use above-mentioned techniques to study local distribution of In in a set of the MOVPE samples. In particular we study effect of the temperature rise directly after the InGaN/GaN QW growth on the incorporation of In inside the GaN barriers. DFEH and HRTEM experiments are carried out on the Hitachi HF3300 in-situ interferometry TEM (I2TEM) equipped with cold-field emission gun, imaging aberration corrector (CEOS Aplanator) and multiple biprisms. The factors governing incorporation of In during the InGaN alloy growth will be discussed.