Kinetic mechanisms of RF-MBE epitaxy of InGaN(0001) alloys across the entire ternary composition range

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Development of high quality InGaN epilayers, in the whole ternary composition range, is of great importance for existing and emerging applications, ranging from higher wavelength emitters to photovoltaic cells and polarization engineered devices. Such a goal is hampered by the large lattice mismatch and the immiscibility of the constituent binaries, GaN and InN. Plasma-assisted molecular beam epitaxy offers a way to address such bottlenecks by taking advantage of its “far from equilibrium” growth mode characteristics. However, understanding in details the epitaxial kinetic mechanisms is of paramount importance since they are particularly complicated in the case of InGaN(0001) epitaxy. At any given substrate temperature, the growth regime is dictated by the balance between the desorption of In and the thermal decomposition of InGaN. Furthermore InGaN decomposition is a surface phenomenon and consequently strongly related to the effective surface conditions.

In this work, both mechanisms are studied in details. For the case of indium desorption, *in-situ* RHEED intensity curves in adsorption-desorption experiments were used to measure in depth the kinetics of desorption of the indium surface bilayer, in conjunction with *ab-initio* DFT calculations. InGaN decomposition was studied by *ex-situ* measurements of a number of films grown in a wide range of growth conditions and was found to depend on the surface effective surface stoichiometry, rather than the epilayer composition. Understanding in depth thess mechanisms permit the formulation of a phenomenological universal model that fully describes the epitaxy of InGaN(0001) alloys in the entire growth parameter space. This model provides a practical guide towards achieving any desired composition across the alloy range, as well as tuning the growth mode characteristics.

Furthermore the epilayers were studied by HR-XRD, HR-TEM, SEM, AFM, PL, spectroscopic ellipsometry and Hall effect measurements. The strain relaxation of the films is correlated associated with the epitaxial kinetics. Film optical and electronic properties are also found to be strongly affected. It is demonstrated that with careful tuning of the epitaxial conditions improved characteristics can be achieved, including reduced Stoke’s shift, and narrow photoluminescence peaks, as well as increased carrier mobilities, with record high values (>200 cm^2/Vs) achieved.