Changes in Activation Energy for Dislocation Nucleation During Strain Relaxation of InGaN Epilayers Grown on Misoriented (0001) Substrates

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III-nitrides such as AlN, GaN and InN have gained an enormous importance in the production of optoelectronic devices. However, the development of light emitters with a green emission wavelength is hampered by the high mismatch between InN and GaN causing piezoelectric fields and reduced In incorporation. There are indications that using substrates with a larger lattice parameter may help to overcome these challenges and to shift the emission wavelength further into the red part of the spectrum.[1] Relaxed InGaN layers deposited on GaN substrates is the most obvious choice with this respect. To achieve good quality relaxed InGaN pseudo-substrates, it requires understanding and control of the dislocation formation process. While detailed studies on dislocation formation exist for semiconductor heterostructures crystallizing in the cubic lattice, only a preliminary work has been performed in case of III-nitrides group, crystallizing in hexagonal lattice.

In this work we study strain relaxation of InGaN layers deposited on (0001) GaN substrates by molecular beam epitaxy using transmission electron microscopy, high resolution x-ray diffractometry as well as cathodoluminescence imaging.

InGaN layers relax by formation of (**a**+**c**)-type dislocations gliding to the interface on pyramidal planes in the slip system $<11\bar{2}3>\{11\bar{2}2\}$.[2] These dislocations form a trigonal misfit dislocation network along $<1\bar{1}00>$ directions at the interface. Because of the peculiarities of the crystallographic system, dislocations lying along particular $<1\bar{1}00>$ direction may glide on two possible glide planes and are distinguished by the c-component of Burgers vectors. However, we reveal, that for layers grown on slightly (0.8°) misoriented substrates, all dislocations lying along particular $<1\bar{1}00>$ direction have the identical Burgers vector, which indicates that only one slip plane of the two possible planes is active. In the cubic epitaxial systems like SiGe/Si[3], such a preferential dislocation formation has been attributed to the miscut of the substrate that changes the acting shear stresses in the epitaxial layer and thus the activation energy for a dislocation formation. We demonstrate that strain relaxation of InGaN layers is a nucleation limited process. We estimate the activation energy for dislocation nucleation in the respective glide planes as dependent on substrate misorientation. We discuss consequences of the resulting dislocation distribution with respect to tilt of the layer with respect to the substrate as well as to the anisotropic strain state of the layer.

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