The impact of the surface morphology of AlN/sapphire templates on the structural and optical properties of AlGaN/AlGaN multiple quantum wells

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The higher efficiency and the longer lifetime make light emitting diodes (LEDs) operating in the ultraviolet wavelength region < 280 nm (UV-C) attractive for the replacement of UV-lamps in applications like water purification, sensing, spectroscopy and many others. To reduce the costs, such LEDs are mainly produced on sapphire substrates covered with AlN. Generally, the threading dislocation density (TDD) in the AlN layer determines the optical properties of the subsequently grown AlGaN based active layers and thus the output power of the LEDs. Different approaches have been applied to reduce the TDD. One of them is epitaxial lateral overgrowth (ELO) of patterned AlN/sapphire templates with an up to 10 μm thick AlN layer. This way it was possible to reduce the TDD by more than an order of magnitude. On the other hand it has been shown that also the surface morphology of the AlN layers, namely the surface steps, play an important role for the homogeneity of the subsequently grown AlGaN layers [1]. In this study we present results on $Al_xGa_{1-x}N/Al_yGa_{1-y}N$ multiple quantum wells (MQWs) emitting at a wavelength of 235 nm grown in the same growth run on different types of planar AlN as well as on ELO AlN/sapphire templates.

All layers were grown by metalorganic vapor phase epitaxy (MOVPE) in a planetary reactor at a growth temperature of 1250°C. Before the deposition of the MQWs a 50 nm thick AlN layer was grown. The MQW structure consists of a 3-fold sequence with 7 nm thick $Al_{0.9}Ga_{0.1}N$ barrier layers and 3 nm thick $Al_{0.78}Ga_{0.22}N$ quantum wells. The structure is capped with a 7 nm thick $Al_{0.9}Ga_{0.1}N$ barrier layer.

The surface morphology of the AlN/sapphire templates as well as of the MQW samples was studied using atomic force microscopy (AFM). The structural properties were investigated by high resolution X-ray diffraction (HRXRD) and transmission electron microscopy. For the determination of the optical properties cathodoluminescence in plan-view was applied.

We will show that the highest CL intensity of the $Al_{0.78}Ga_{0.22}N$-MQWs grown on planar AlN/sapphire templates was obtained for AlN with a step height of 1 nm, whereas a very smooth surface with a root mean square (RMS) roughness < 0.4 nm resulted in local intensity fluctuations due to a 3D nucleation observed in the CL images. On the other hand, a step bunching on the AlN with step heights of about 2–4 nm leads to a higher Ga incorporation at the steps resulting in periodic inhomogeneities in the MQWs. However, compared to the planar templates, the MQWs grown on ELO AlN showed a much higher CL intensity due to the reduced TDD. Therefore, MQWs grown on ELO AlN are promising for enhancing the light output of UV-C LEDs.

References

[1] U. Zeimer, V. Kueller, A. Knauer, A. Mogilatenko, M. Weyers, M. Kneissl, J. Cryst. Growth 377 (2013) 32-36