Atom probe tomography of AlGaN alloy

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The opto-electronic devices using AlGaN such as UV light emitting diode and high electron mobility transistor are widely investigated. Since those devices use the feature of larger bandgap energy of AlGaN compared to GaN. The bandgap energy of ternary AlGaN alloy varies with Al content, therefore it is quite important to analyze the Al compositional distribution and clarify the relationship with device property. Atom probe tomography (APT) is well known as the powerful tool to provide the three-dimensional tomography of atoms with sub-nanometer scale. However, one of the technical issues of the APT is artifact of the compositional deviation due to the difference of evaporation behaviors of each elements. Several groups already reported on this issue of compound semiconductors [1-3]. Although previous studies clarified the relationship between the deviation of measured composition and the surface electric field, the effect of assist laser was not well-understood.
In this work, the sample was AlGaN/GaN Multi Quantum Well (MQW) film grown on sapphire (0001) substrate. The film consisted of a 3μm thick GaN layer and 5 pairs of a 10nm thick GaN quantum well and a 20nm thick $Al_xGa_{1-x}N$ barrier with different Al concentration each other (x=0.05, 0.10, 0.15, 0.20, 0.25 from bottom to top) and 100nm thick GaN, i.e., GaN(3μm)/ [GaN (10nm)/ $Al_xGa_{1-x}N$ (20nm)]$_5$/ GaN(100nm). Needle shaped specimens were prepared by Focused Ion beam milling. Systematic laser assisted APT measurements with different laser power (0.01-60nJ/pulse) and wavelength (UV:343nm and Deep UV:255nm) and specimen temperature (21K, 50K, 80K) were carried out.
Figure 1(a) shows the BF-TEM image of needle shaped specimen. Figure 1(b) shows the APT elemental map of the red rectangular region in Fig.1 (a). Figure 1(c) shows the measured 1D-Al composition(x) profile along the crystal growth direction. The thickness of AlGaN/GaN MQW structure was almost designed value. However, measured Al compositions deviate from the nominal Al compositions. Figure 2 shows the correlation between measured Al compositions and nominal values. Each different color symbol corresponds to the different assist laser power and wavelength. As the UV laser power increased, deviation of the measured Al composition increased. Further investigation such as Deep UV laser assist measurement and the interpretation of relationship between measured Al composition and with/without electronic excitation will be discussed in detail.

References:
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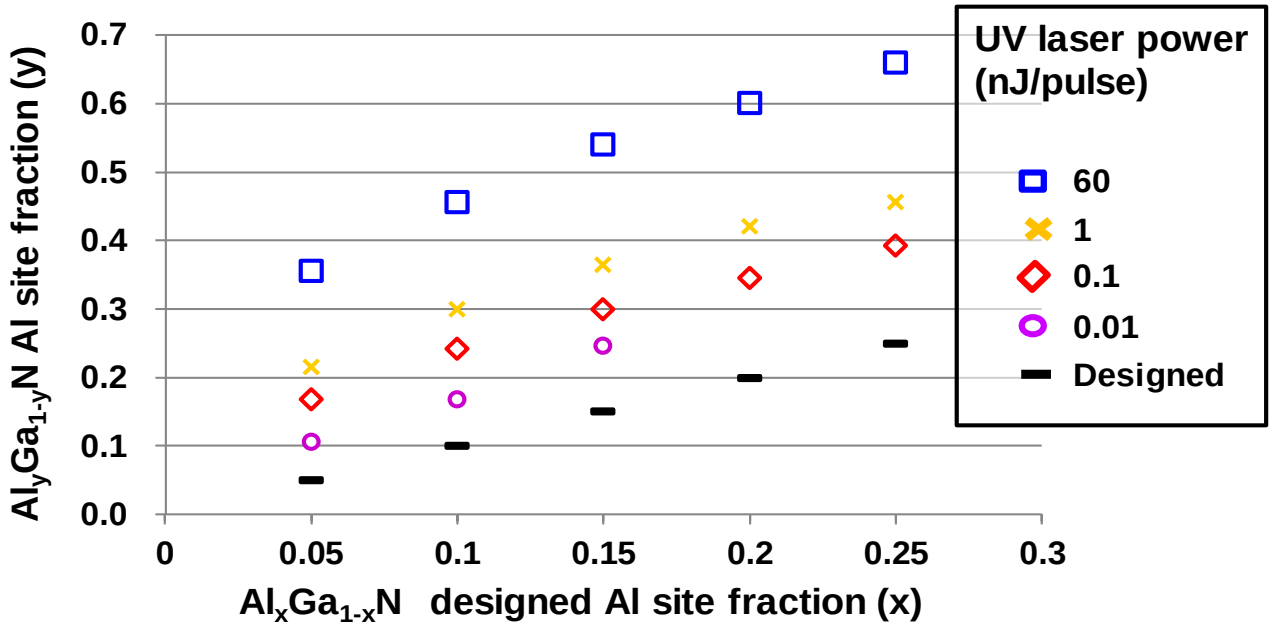
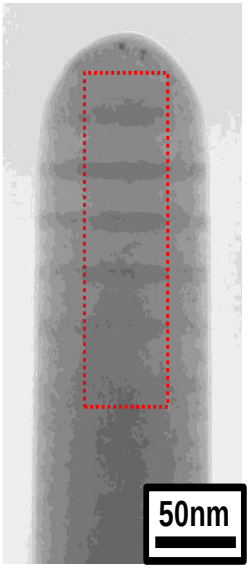
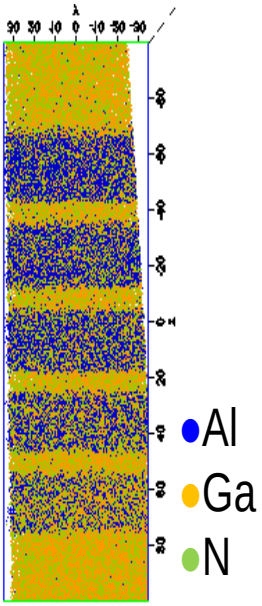
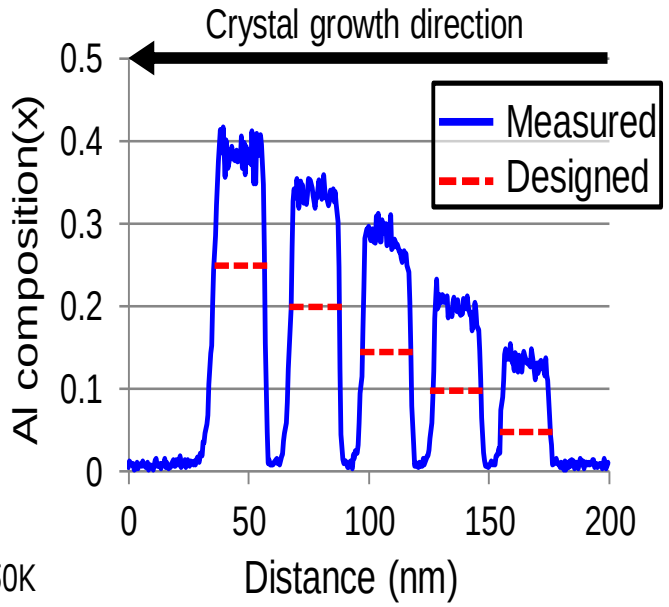
[2] L. Mancini et al., J. Phys. Chem. C 118, 24136 (2014)
[3] L. Rigutti et al., J. Appl. Phys. 119, 105704 (2016)









Specimen temperature: 50K
Laser power: 0.1nJ/pulse
Laser wavelength: 343nm