Characterization of $(Al_xGa_{1-x})_2O_3$ Thin Films Grown on <010> β Ga_2O_3 by MBE

CNF Project Number: 2443-16

Principal Investigators: Huili Grace Xing, Debdeep Jena

Users: Nicholas Tanen, Vasanth Balakrishnan

Affiliations: Materials Science and Engineering, Electrical and Computer Engineering; Cornell University

Primary Source of Research Funding: NSF -Designing Materials to Revolutionize and Engineer our Future

Contact: grace.xing@cornell.edu, djena@cornell.edu, ntj47@cornell.edu, vb322@cornell.edu

Website: http://grace.engineering.cornell.edu

Primary CNF Tools Used: Veeco Icon AFM

Abstract:

Electronic devices, made of wide bandgap semiconductors, show low current leakage and high breakdown fields. Oxides of aluminum, gallium, and indium (Al, Ga and In) form a class of semiconductors with promising properties. Currently HEMT transistors, fabricated of Ga_2O_3 and $(Al_xGa_{1-x})_2O_3$ semiconductors have high breakdown voltages and low leakage currents. Hence, it is of immense interest to study and understand the growth parameters for $(Al_xGa_{1-x})_2O_3$. Here we report our preliminary growth and surface morphology results for $(Al_xGa_{1-x})_2O_3$ films grown on <010> - β phase Ga_2O_3 substrates by plasma-assisted molecular beam epitaxy (PAMBE). We correlate the growth parameters with quality and surface morphology of $(Al_xGa_{1-x})_2O_3$ films.

Summary of Research:

We grew $(Al_xGa_{1-x})_2O_3$ films with the Veeco GEN930 PAMBE system on <010> UID β Ga_2O_3 substrates at substrate temperature 500°C and O_2 flow 3 sccm. Based on AFM scans performed over a 2 μm × 2 μm sample area, the surface structure of the film is elongated along the <100> direction.

At a lower Al content, Al gets incorporated in the films smoothly and for $x < 0.2$, we observe corrugated and smooth surface having very low RMS roughness. As the Al content the layers increases above a certain limit the films become amorphous and the surface roughness increases significantly. Figures 1 and 2 indicate good surface morphologies with smooth surfaces. Figure 3 on the other hand, is for a Ga rich growth regime (high Ga BEP) which led to poor surface morphology due to Ga_2O desorption mechanism, this increased the Al incorporation in the film and made the film surface rough.

References:

[1] Kaun, S.W., F. Wu, and J.S. Speck. "β-$(Al_xGa_{1-x})_2O_3/Ga_2O_3$ <010> heterostructures grown on β-Ga_2O_3 <010> substrates by plasma-assisted molecular beam epitaxy." J. of Vacuum Science and Technology A: Vacuum, Surfaces, and Films 33.4 (2015): 041508.

[2] Vogt, Patrick, and Oliver Bierwagen. "Reaction kinetics and growth window for plasma-assisted molecular beam epitaxy of Ga_2O_3: Incorporation of Ga vs. Ga_2O desorption." Applied Physics Letters 108.7 (2016): 072101.

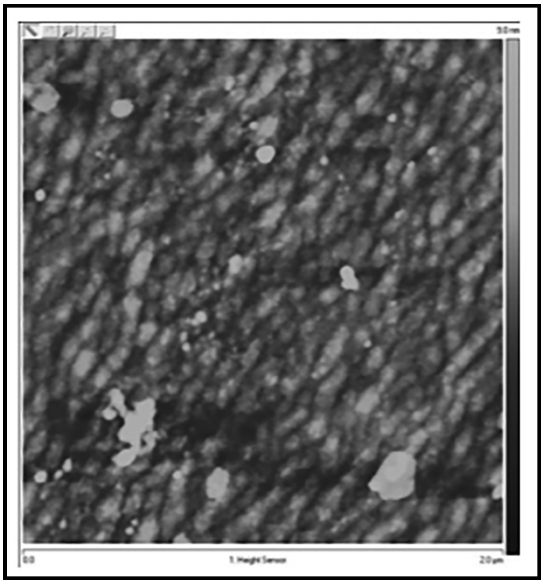

Figure 1: 2 µm × 2 µm AFM scan for Ga BEP = 3 × 10^{-9} (RMS = 1.08 nm).

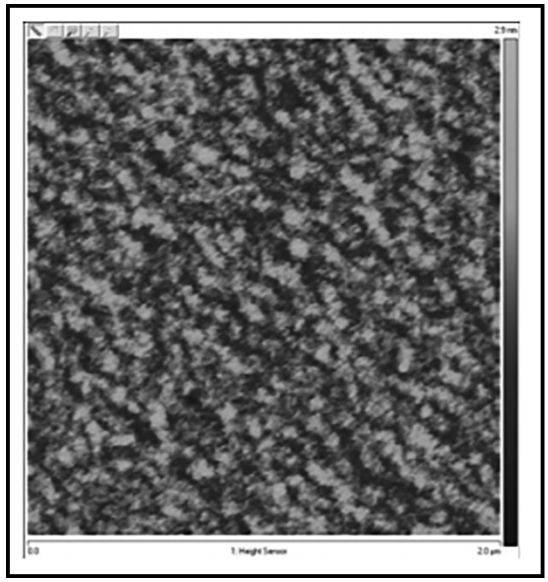

Figure 2: 2 µm × 2 µm AFM scan for Ga BEP = 5 × 10^{-9}. (RMS = 0.272 nm).

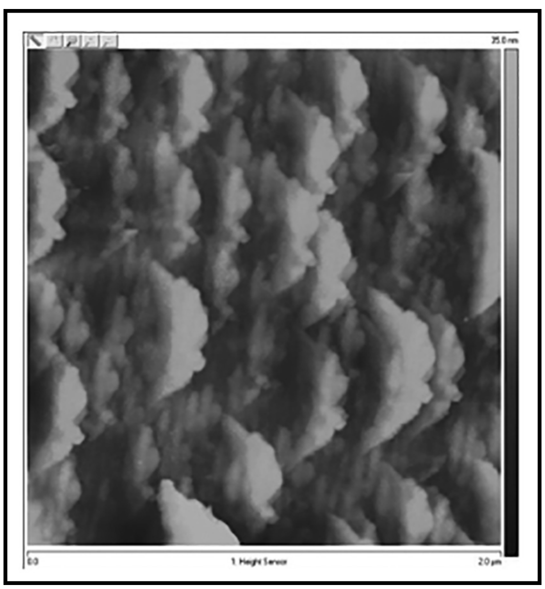

Figure 3: 2 µm × 2 µm AFM scan for Ga BEP = 30 × 10^{-9} (RMS = 4.45 nm).

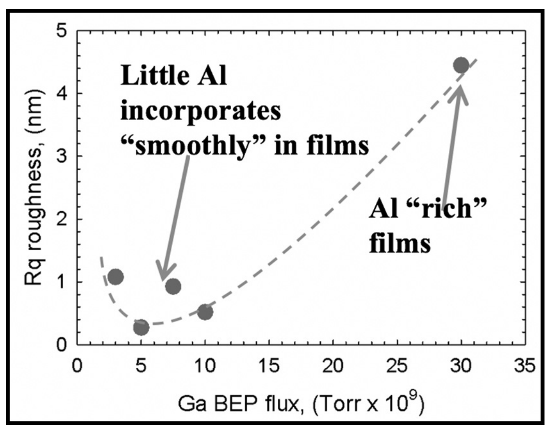

Figure 4: Graphical plot of $(Al_xGa_{1-x})_2O_3$ film roughness R_q vs Ga flux.