Correlation between Surface Morphology and Hall Mobility between AlGaAs/GaAs <111> Heterojunctions

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Abstract:

Most of modern electronics are composed of a silicon (Si) metal-oxide semiconductor field-effect-transistor (MOSFET). The rate at which we can improve the Si MOSFET is decreasing due to leakage current and power dissipation from quantum tunneling effects as we make the MOSFET dielectric thinner. Changing the channel material in the MOSFET can provide a resolution to this problem. Indium gallium antimony (InGaSb) grown by molecular beam epitaxy (MBE) serves as a candidate for outperforming Si as a channel material by providing multiple conducting energy states when grown in the <111> orientation. However, crystal defects occur when growing InGaSb on gallium arsenide (GaAs) <111> substrates because of their lattice mismatch. In this work, we studied aluminum gallium arsenide (AlGaAs) and GaAs grown on GaAs <111> substrates, in order to understand future growth of InGaSb materials. Experiments that involved varying V:III beam equivalent pressure (BEP) ratios of GaAs grown on GaAs <111> substrates could assist the process of increasing surface quality in the growth of InGaSb material systems. Experiments that involved varying Si dopant temperatures of AlGaAs on GaAs <111> substrates were also performed to identify similar methods we can incorporate to control the electrical and growth properties of InGaSb.

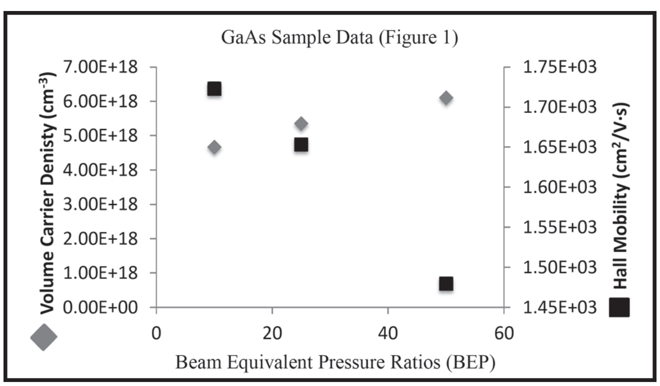

Figure 1: Plot of mobility and carrier concentration as the V:III ratio of GaAs increases, mobility drops and carrier concentration increases.

Introduction:

This project observed the surface characterization and electrical properties of AlGaAs and GaAs individually grown on GaAs <111> substrates. Successful growth of InGaSb material systems was the ultimate goal, however this could be very difficult. Relative to InGaSb, growth of AlGaAs and GaAs on GaAs substrates were more straight forward and simply easier to utilize. Optimized processes could be achieved that ideally can be applied to future growths of InGaSb.

Experimental Procedures:

The main characterization techniques used in this project were atomic force microscopy (AFM) and Hall measurement. AFM uses a cantilever that runs across the surface of the sample detecting any changes in surface morphology. The Hall measurement system analyzes the carrier concentration and Hall mobility of the sample. It was desired to know Hall mobility and the surface characterization, so we could attempt to provide a correlation between them. AFM scans of 20 × 20 μm^2, 5 × 5 μm^2, and 2 × 2 μm^2 areas of the samples were taken and analyzed.

The Hall measurements were conducted with a magnetic field generator, four contact probes that would be measuring Hall voltage as well as the power source used to flow current perpendicular to the measured Hall voltage. From the Hall voltage, we calculated the number of charge carriers flowing through the sample.

Results and Conclusions:

Experiments consisted of varying ratios of elemental components Ga and As which determined the surface quality of GaAs. Initial growths consisted of BEP ratios of 10, 25 and 50. Varying BEP ratios lead to changes in electron mobility as well as electron concentrations. Refer to Figure 1.

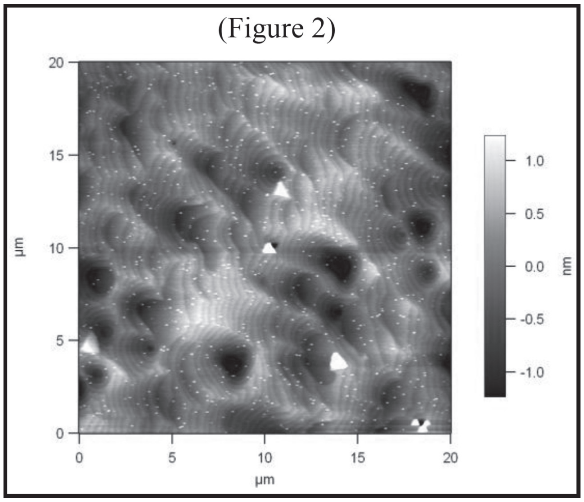

Figure 2: AFM image of GaAs sample with BEP ratio of 10. The surface is smooth relative to higher BEP samples.

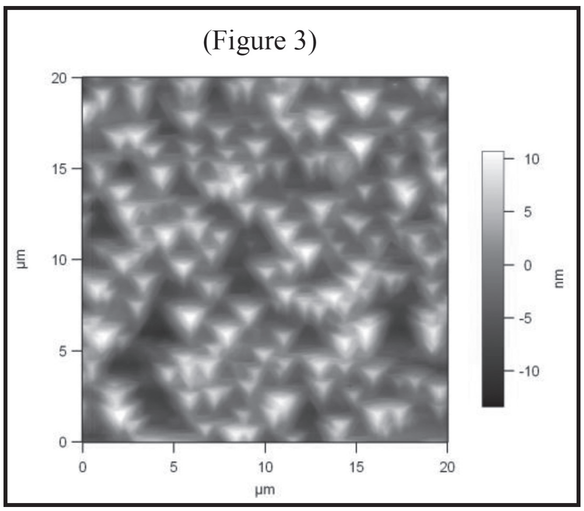

Figure 3: AFM image of GaAs sample with BEP ratio of 50. The surface contains stacking faults or a rougher surface.

Low BEP ratios contributed to smoother surfaces as well as more relatively controlled growth. Refer to Figure 3 for a sample with close-to-ideal surface properties. High BEP ratios led to pyramidal stacking faults and higher carrier concentrations as well as low mobility, which was undesirable. Figure 2 shows this scenario. Results showed no direct correlation between surface morphology and Hall mobility. It was inconclusive to assume whether the Hall mobility became dependent on the actual surface morphology or the amount of transport carriers.

In conclusion, Hall mobility can depend solely on the amount of electrons present for transport, surface morphology or a combination of both.

Future Work:

Future work consists of continued experiments of AlGaAs and GaAs with measurements being done at lower temperatures to eliminate the possibility of having the number electrons effect the mobility and isolate the correlation between surface morphology and Hall mobility. Other potential experiments consist of growing InGaSb materials to identify sources of undesired properties. From these results, we hope to determine better processes that can be implemented into the close-to-perfect material growths of InGaSb.

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