β-SiC Growth on AlN-on-SiC

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Abstract:

Available forms of silicon carbide exist as 6H-SiC and 4H-SiC polytypes, but suffer from crystal defects such as micropipes, which affect the electrical properties of the material. Because of its advantageous properties, lack of micropipe defects, equivalent high electron and hole mobilities, and non-anisotropic nature, cubic silicon carbide (3C-SiC), also called β-SiC, has potential applications in semiconductors and microelectronics. In this project, the production of high quality β-SiC, is grown on an AlN-on-SiC substrate by chemical vapor deposition. The growth of SiC was successful, but we were unable to characterize the growth.

Introduction:

Due to silicon's inability to work at high temperatures and the increased need for semiconductor materials to withstand harsh environments, alternatives to silicon are becoming increasingly popular. Silicon carbide (SiC), over the past several years, has become popular as a semiconductor material to meet these requirements. Some of its properties, which include a wide bandgap, high saturated electron drift velocity, high electric breakdown field, high thermal conductivity, high bonding energy, and resistance to oxidation, creep, and corrosion, make SiC very useful. This is especially true when used in high frequency, high temperature, and high power devices, as well as in harsh and high radioactive environments. SiC has over 200 different polytypes, but the most commonly known forms are 3C, 4H, and 6H. Production of SiC mostly exist as 4H and 6H polytype forms, but these polytypes suffer from micropipe defects, which hampers the electrical properties of these polytypes. 3C-SiC, or β-SiC, properties, which include the lack of micropipe defects, a non-anisotropic nature, and equivalent high electron and hole mobility, give it an advantage over the 4H and 6H polytypes. 3C-SiC can be used in CMOS electronics and in field effect transistors (FET's), but are thermodynamically unstable. Growth of 3C-SiC is a major developmental challenge, given that most SiC wafers are 4H and 6H. Growth methodologies for β-SiC growth include seed-sublimation, electron cyclotron resistance, and epitaxial growth methods such as and liquid phase epitaxy and vapor phase deposition [3,4]. In the literature, the growth of 3C-SiC has been done on silicon substrates but the quality of the growth has led to discovering voids and other crystal defects [2]. This project's aim is to produce high quality β-SiC on an AlN-on-SiC substrate via chemical vapor deposition (CVD).

Experimental Procedure:

Growth of silicon carbide was done in a horizontal cold wall CVD reactor. The first group of trials were done using silicon wafers of <100> and <111> orientations, and the second using Si <100>, 6H-SiC, and AlN-on-SiC wafer substrates. All trials used 8 slpm of H_2 as the carrier gas and a chamber pressure of 200 Torr. For our trials of SiC on silicon <100> and <111>, a buffer layer was grown using 20 sccm of propane for 2 minutes. After the buffer layer was grown on the substrate, the reactor was ramped up to its growth temperature, which ranged from 1050-1300°C, and growth times were 10 and 30 minutes. The second set of trials used 120 sccm

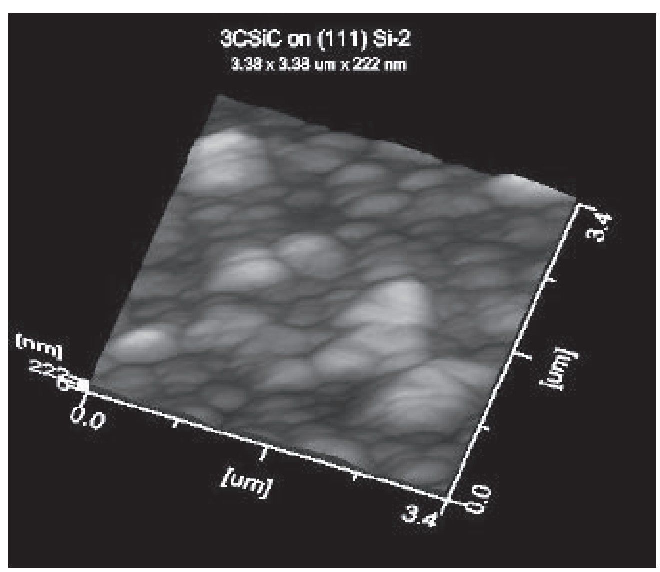

Figure 1: Silicon carbide growth on Si <111> substrate.

of hydrogen chloride (HCl) gas, for the *in situ* etching of the oxide layers on our substrates, for 10 minutes at temperatures from 1000-1020°C. Growth temperatures for the three substrates ranged from 1160-1305°C, and the growth time was 30 minutes.

Results:

After growth of the silicon carbide on Si <100> and Si <111>, thickness measurements were taken for each trial using an ellipsometer. Growth measurements indicated thicknesses up to 200 nm. We were unable to obtain thickness measurements for the 6H-SiC, and AlN-on-SiC group, because the refractive indexes of both were close. Surface morphology measurements of the substrate and epilayer growths were done by atomic force microscopy (AFM). For the Si group, the crystal growth was moderate and it took on the orientation of the substrate, as seen in Figure 1 and 3. In the AlN-on-SiC group, the HCl etching decreased the substrates surface roughness, before growth. When the SiC/AlN-on-SiC was observed, as seen in Figures 2 and 3, at a temperature of 1160°C, crystal growth shows clearly defined geometrical shapes as well as a tendency for the substrate crystal structure to be near the <111> orientation of Si. As the growth temperature increased, the crystal grain size tended to decrease, except for layers grown at 1305°C.

Conclusions/Future Work:

Growth of SiC on AlN-on-SiC substrate was successful, but we were not able to characterize β-SiC on the substrate. When observed by AFM, the crystal grain size decreased, as the temperature increased. Future work includes determining growth rates with and without HCl etching, and comparing the electrical characteristics of 3C-SiC, when grown on different substrates.

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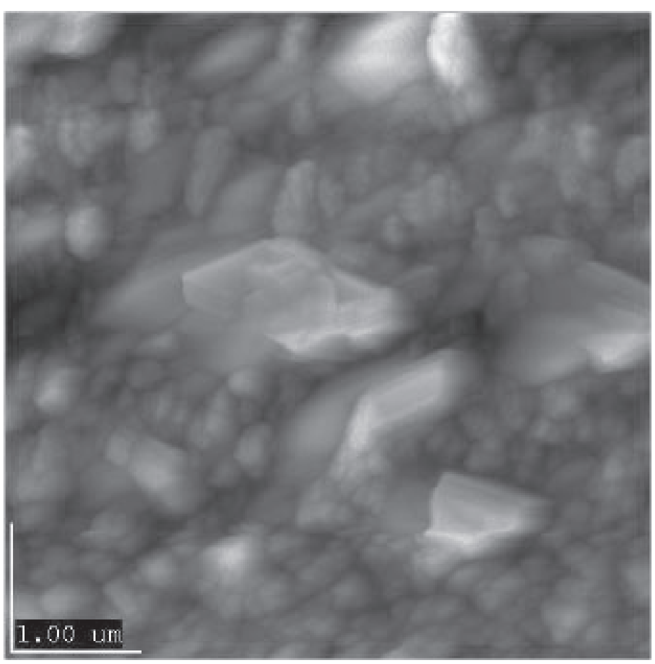

Figure 2: Silicon carbide growth on AlN-on-SiC at 1160°C.

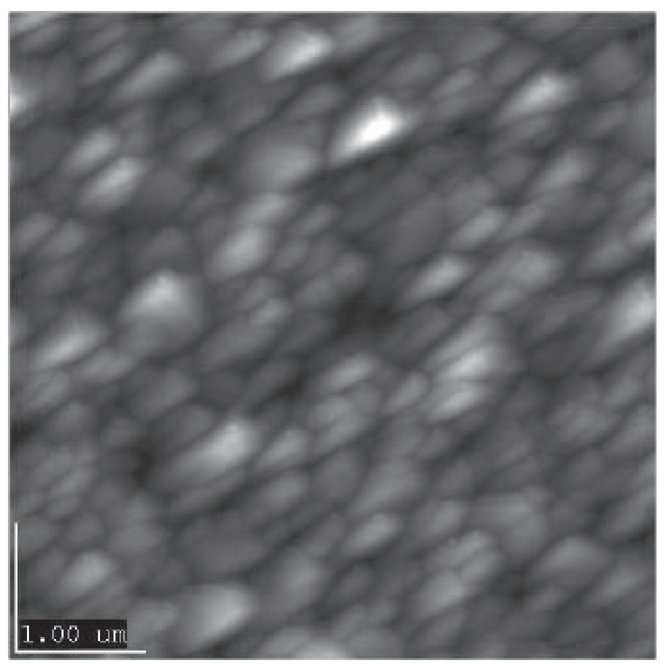

Figure 3: Silicon carbide growth on AlN-on-SiC at 1250°C.