GROWTH AND CHARACTERIZATION OF HEXAGONAL AlN(100) AND GaN(100) ON Si(111) USING SURFACE-RECONSTRUCTION INDUSED EPITAXY

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AlN is a direct wide bandgap (6.2 eV) material suitable for applications in UV emission and detection. In addition, it has a close lattice constant to GaInN alloys, which provides a tunable band gap for emission in the blue to red region. Moreover, integration of group III-nitrides with Si would enable optical interconnects as well as high power device fabrication on Si. Single crystalline hexagonal AlN(100) and GaN(100) were grown on Si(111) using hybrid molecular beam epitaxy (MBE) from solid Al (Ga) source and atomic nitrogen. The growth is conducted using surface-reconstruction induced epitaxy in which the Si(111)7x7 surface, generated by thermal etching under UHV, was transformed into Si(111)$\sqrt{3}$x$\sqrt{3}$-Al by deposition of ~0.3 monolayer (ML) of Al at 650-700 ^{o}C. Aluminum is trivalent and bonds to 3 Si atoms on the surface, thus passivating the Si(111) surface. This process minimizes the interaction of Si with N and provides a template for growth of AlN. Al was thermally evaporated using an effusion cell while atomic N was supplied from an RF atomic source, which was fitted by a dual plasma chambers to enhance the atomic fraction in the beam. The domination of atomic N in the nitrogen beam was confirmed from measurements of plasma emission. Epitaxial growth was achieved over a wide range of Al/N flux ratio and growth temperatures extending from 350 to 850 ^{o}C. Figure 1 shows X-ray diffraction taken from AlN/Si(111) grown at 650 ^{o}C. The diffraction pattern shows well defined peaks for the Si(111) and Al(100) orientations. No other orientations or phases can be seen in the diffraction pattern. Also, the full width at half maximum (FWHM), measured from the layer peak, is equal to that of the Si substrate indicating highly oriented AlN layer. X-ray Pole figures measurements shows the following in-plane orientation relationship: h-AlN[$\bar{1}$00] or AlN[$\bar{2}$110]// Si[$\bar{2}$11]. GaN layers grown on AlN were also epitaxial and follow the same orientation relationship to Si as indicated by reflection high energy electron diffraction (RHEED) pattern (see Fig. 2). The RHEED diffraction spots were streaky and elongated normal to the surface, which indicate a mall surface roughness. Scanning electron microscopy showed no signs of cracks in the grown layers. Finally, AlN/Si heterojunction diode, fabricated using this method showed a breakdown voltage in excess of 400 V and a leakage current below 100 nA indicating a good AlN/Si interface (see Fig. 3).

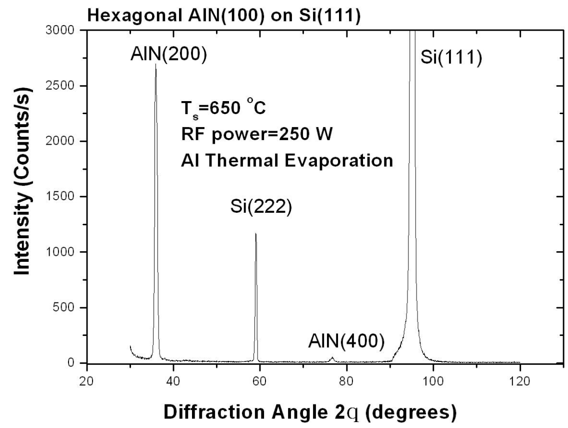

Figure 1. X-ray diffraction from AlN/Si(111). Only reflections from Si(111) and Al(100) can be seen. The FWHM of the AlN peak is equal to that of the Si(111) substrate peak indicating good crystalline quality of the AlN layer.

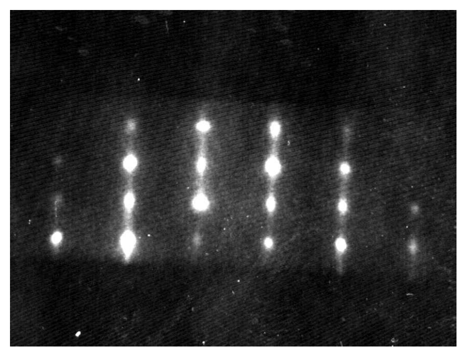

Figure 2. RHEED diffraction pattern from GaN layer on AlN. The pattern indicates growth of hexagonal GaN(100). The bulk nature of the diffraction pattern is due to surface roughness while the streaky nature of the diffraction spots indicates that the surface roughness is not large.

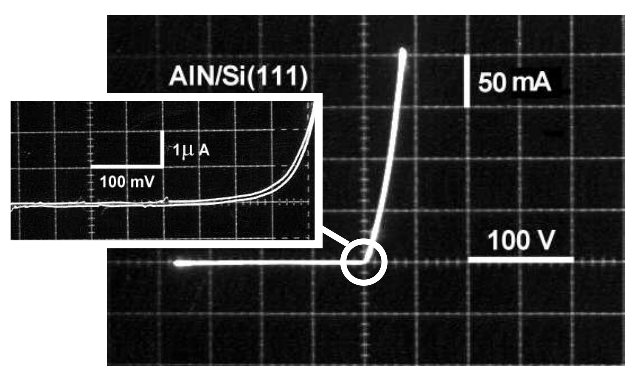

Figure 3. I-V measurement taken from AlN/Si(111) heterojunction diode. A breakdown voltage in excess of 400 V were obtained.

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