Epitaxial growth of AlN films on Si (111)

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Abstract. Plasma assisted molecular beam epitaxial growth of AlN on Si(111) at various substrate temperatures with the same III-V ratio is investigated. The epitaxial structures were characterized by high resolution X-ray diffraction (HR-XRD), scanning electrical microscopy (SEM) and atomic force microscopy (AFM). With the increase of the growth temperature, the full-width at half-maximum (FWHM) of the AlN (0002) reflection peak in HR-XRD rocking curve measurements decreases from 5898.5 arcsec for films grown at 575 °C to 1784.9 arcsec for films grown at 900 °C, respectively. AFM images show that the surface roughness decreases with increasing growth temperatures. Though the AlN films are grown with same III/V ratio, the AlN films grown at 575 °C shows nitrogen rich feature and the ones grown at higher temperatures show the metal rich features. The presence of the film morphology can be explained by al mobility.

Keywords: nitrides, molecular beam epitaxy, x-ray diffraction, reflection high energy electron diffraction, atomic force microscopy

PACS: 81.05.Ea, 81.15.Hi, 61.05.cp, 61.05.jh, 68.37.Ps

INTRODUCTION

Nitrides have become an important group of semiconductors for building electronic or optical devices. Growth on Si(111) substrates is attractive due to lower costs, high thermal conductivity and the possibility for incorporation with standard CMOS technology. Due to the high reactivity of Si with nitrogen and group III elements as well as the large lattice mismatch, the growth of high quality films remains challenging. With AlN serving as a buffer layer, a better film quality of GaN[1] and InN films can be achived.[2] However, the growth of AlN itself is still under investigation. For instance, the optimal starting conditions for growth of the AlN buffer layer are still discussed.[3, 4] Furthermore, the influence of the growth temperature will also play a key role.

We therefore present here a detailed study on the structural properties of AlN films grown on Si(111) at various temperatures.

EXPERIMENTAL

All samples were grown by plasma-assisted molecular beam epitaxy on Si(111) substrates. The substrates were pre-degased for 60 min at 130 °C prior to transfer into the growth chamber. The native oxide layer on the substrates was removed by heating up the samples to 900 °C and monitoring changes in the surface reconstruction by reflective high energy electron diffraction (RHEED) and meanwhile the temperature is characterized by a transition in the surface reconstruction of Si(111) from 1×1 to 7×7 at 823 °C. Activated nitrogen N_2^* was supplied by an Oxford plasma cell, operated at 400 W with a N_2 flow of 0.5 sccm. The samples were grown at temperatures ranging from 575 °C to 900 °C with the same metal to nitrogen ratio.

Characterization was performed by high resolution X-ray diffraction (HR-XRD), scanning electrical microscopy (SEM) and atomic force microscopy (AFM).

RESULTS AND DISCUSSION

Figure 1 shows HR-XRD measurements. With the increase of the growth temperature, the full-width at half-maximum (FWHM) of the AlN (0002) reflection peak in HR-XRD rocking curve decreases from 5898.5 arcsec for films grown at 575 °C to 1784.9 arcsec for films grown at 900 °C, respectively, indicating better film quality for higher growth temperatures.

AFM images (Fig. 2) show that at 575 °C, the AlN film is composited by small grains. With the increase of the growth temperature, the grain size increases.

Physics of Semiconductors
AIP Conf. Proc. 1399, 241-242 (2011); doi: 10.1063/1.3666344
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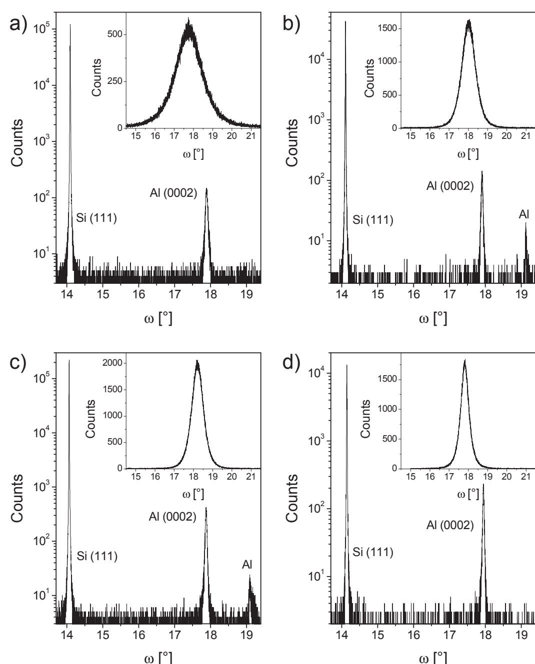

FIG 1. HR-XRD ω-2θ curves of AlN films grown at a) 575 °C, b) at 675 °C, c) 795 °C and d) 900 °C. The insets show rockings curves measured at the AlN (0002) peak.

At 900 °C, grains are no longer distinguishable and small holes are present.

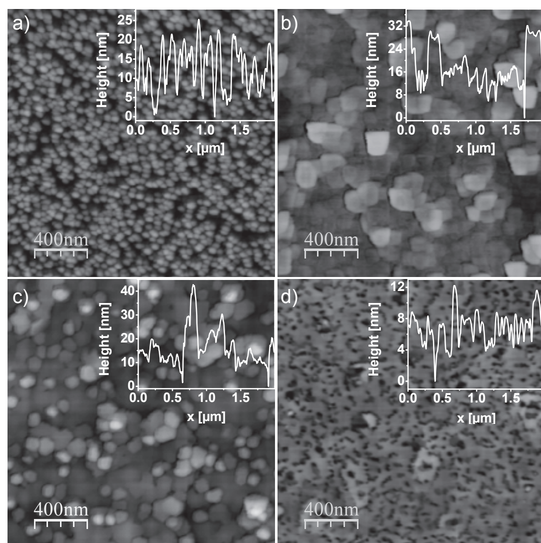

FIG 2. AFM images of AlN/Si(111) grown at various temperatures, a) at 575 °C, b) at 675 °C, c) 795 °C and d) 900 °C. The insets show a typical height profile for each film.

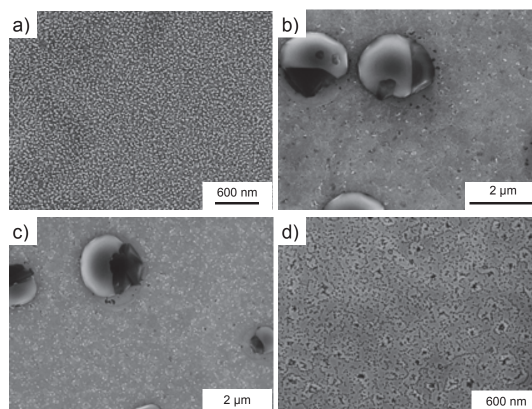

FIG 3. SEM images of AlN films grown on Si(111) at a) 575 °C, b) 675 °C, c) 795 °C and d) 900 °C, respectively.

SEM images, as shown in Fig. 3., reveal that there are no metal droplets on top of the AlN films grown at 575 °C and 900 °C, respectively, while there are metal droplets present on the films grown at 675 °C and 795 °C, respectively. This information is further confirmed by HR-XRD spectra in Fig. 1, where an Al peak appears for the films grown at 675 °C and 795 °C.

CONCLUSIONS

AlN films grown on Si(111) at various temperatures are investigated. The AlN film grown at 900 °C has the smallest surface roughness and lowest FWHM, indicating that the higher mobility of Al at higher growth temperatures leads to smooth films.

ACKNOWLEDGMENTS

The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft (DFG) and the State of Baden-Württemberg through the DFG-Center for Functional Nanostructures (CFN) within the subproject A4.5.

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