Low Temperature Epitaxial Growth of GaN and InGaN on Atomically Flat ZnO Substrates

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ZnO has been regarded as a promising substrate for epitaxial growth of group-III nitrides because ZnO and group-III nitrides share the same crystalline symmetry elements and their lattice mismatches are quite small. In particular, epitaxial growth of $In_{0.18}Ga_{0.82}N$ on ZnO is attractive because we can expect dislocation-free thin films owing to the perfect lattice match.

However, it is also known that ZnO substrates easily react with group III nitride films, which spoils the advantages of the lattice-matched substrate. This problem is severe for conventional growth techniques such as MOCVD or MBE, which require high growth temperatures. Recently, we have found that the use of pulsed laser deposition (PLD) helps to reduce the growth temperature of group III nitrides dramatically and epitaxial growth occurs even at room temperature with this technique. [1, 2]

In this presentation, we will discuss the reduction of the substrate temperature during the epitaxial growth of group III nitrides on atomically flat ZnO substrates by the use of PLD in order to suppress the interface reactions between ZnO and the nitrides.

ZnO substrates were annealed in a box made of ceramic ZnO to make their surfaces atomically flat.[2] Group III nitride films were grown on this flat substrates at various substrate temperatures by PLD. Various measurement techniques which include RHEED, HRXRD, GIXR, AFM, and PL were utilized in order to characterize the films.

Figure 1 (a) shows an AFM image for the ZnO substrate annealed at 1150 °C. Atomically flat terraces and steps with a height of approximately 0.5 nm were clearly observed. We have confirmed successful epitaxial growth of GaN in the substrate temperature range from room temperature to 700 °C. Figures 1 (b), (c), and (d) show surfaces of GaN grown at room temperature, 380 °C, and (d) 530 °C, respectively. Although the surface of GaN grown at room temperature shows the clear step and terrace structure, it disappears with the increase of the growth temperature. This degradation in the surface morphology is probably related to the intermixing of atoms at the heterointerface. GIXR measurements also revealed the existence of interfacial layer at high growth temperatures. These results indicate that the reduction of growth temperature is inherently important for the use of ZnO substrates. As shown in Fig.2, we have observed clear oscillation in the RHEED intensity for the growth of GaN at room temperature, which indicates that the growth of GaN on ZnO proceeds with the layer-by-layer mode. HRXRD measurements revealed that group III nitrides grown on ZnO have high crystalline quality. Figure 3 shows 2*θ*-*ω* scan for an InGaN/ZnO structure which is fabricated to reduce the lattice mismatch further. The full width at half maximum of the rocking curve for the InGaN 0002 peak was as narrow as 72 arcsec.

[1] J. Ohta *et al*., Appl. Phys. Lett., **83**, 3060 (2003).
[2] A. Kobayashi *et al*., Jpn. J. Appl. Phys., **43**, L53 (2004).

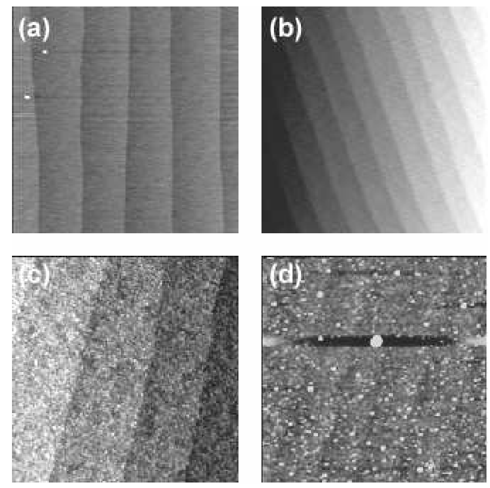

FIG. 1. An AFM image for the ZnO surface annealed at 1150 °C in a ceramic ZnO box (a). AFM images for GaN grown at room temperature (b), at 380 °C (c), and at 530 °C (d).

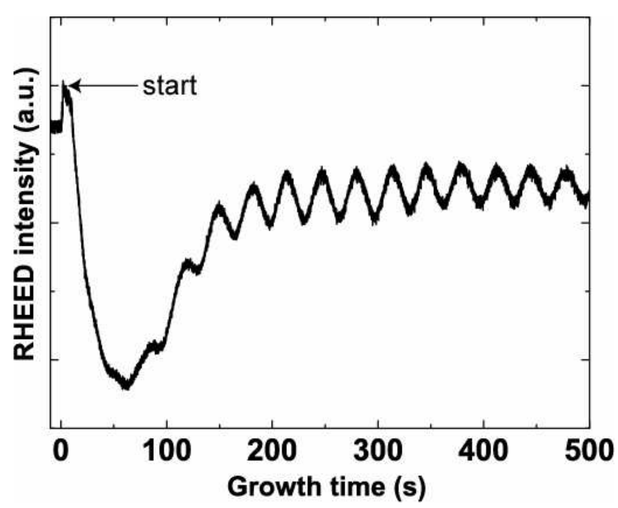

FIG. 2. RHEED intensity oscillation for GaN grown on atomically flat ZnO at room temperature.

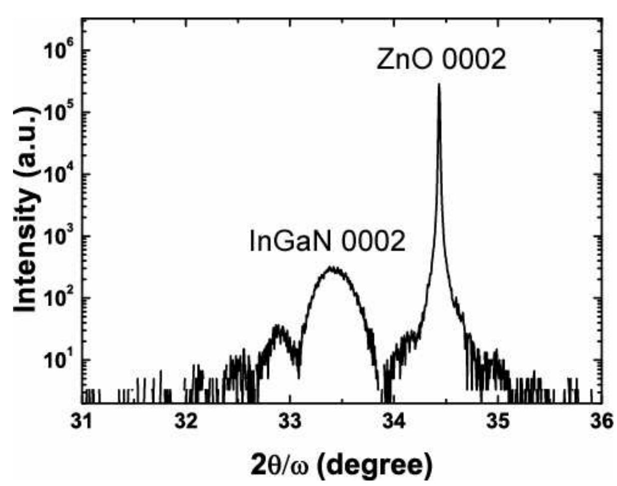

FIG. 3. 2*θ*-*ω* scan for the InGaN/ZnO structure.