Growth of GaN Films on (111)GaAs Substrates

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The wide bandgap semiconductor gallium nitride (GaN) is a promising material for the use in light emitting diodes, laser diodes, and UV detectors on the photonic side and microwave power and ultrahigh power switches on the electronics side. Since bulk GaN substrates are not available, films must be grown by heteroepitaxy on foreign substrates. Usually, sapphire is used as a substrate material for the heteroepitaxy of GaN because of its wide available, hexagonal symmetry, and its ease in handling and pregrowth cleaning. However, from the perspective of device technology, sapphire has severe problems as a substrate material because it is difficult to cleave. Moreover, since the sapphire substrate is not conductive, it is impossible to create optical devices which operate between the films and the substrates. Therefore, it is highly desirable to deposit the GaN films on other semiconductor substrates. GaAs is a desirable substrate due to its large role in the optoelectronic industry. Ross, Rubin, and Gustafson have shown oriented wurtzite GaN on (111)GaAs using reactive sputtering, however, no details were presented on the crystal structure of the films. In this paper we report the growth properties of wurtzite GaN film on (111)GaAs substrates.

The GaN films were deposited by reactive radio frequency (rf) magnetron sputtering in ambient of argon and nitrogen. The target was pure gallium held in a stainless-steel cup. The sputtering chamber was evacuated to a pressure of 10^{-7} Torr with a turbomolecular pump before introducing argon and nitrogen. Polished semi-insulating (111)GaAs substrates were employed and chemically cleaned, degreased in organic solvents, etched in a sulfuric acid solution, and then rinsed in deionized water. The nitrogen flow was varied from 0 to 100 % while the total flow of N_2 and Ar was maintained at 3 sccm. During the deposition, the rf sputtering power was kept at 100 W. The substrate temperature was monitored using a thermocouple and controlled at a given value between 500 and 750 ℃ using a heater located behind the substrate. A powder diffractometer equipped with a copper anode was used to acquire θ-2θ patterns to determine the crystal structures. For temperatures below 500 ℃, no diffraction peak of GaN was observed, suggesting the film is amorphous. However, when the temperature was increased up to 600 ℃, peaks for (0002) and (0004)GaN are clearly observed as shown in Fig.1, indicating the *c*-axis of GaN with a wurtzite structure is perpendicular to the substrate surface of (111)GaAs. The lattice constant *c*, which is twice the (0002) interplanar spacing for the GaN film, was obtained to be 5.2 Å, which has a good agreement with the literature value. Figure 2 shows the phi-scan from an asymmetric (10-13) peak of the GaN film using a high-resolution X-ray diffractometer (Philips X'Pert-MRD). The six-fold symmetry of the wurtzite structure crystal basal plane was clearly revealed by the six 60 ° -separated peaks. The film was found to be single crystal from reflection high-energy electron diffraction (RHEED) pattern as shown in Fig. 3. These results reveal that single crystal GaN films with wurtzite structure can be grown on (111)GaAs substrates by using rf magnetron sputtering .

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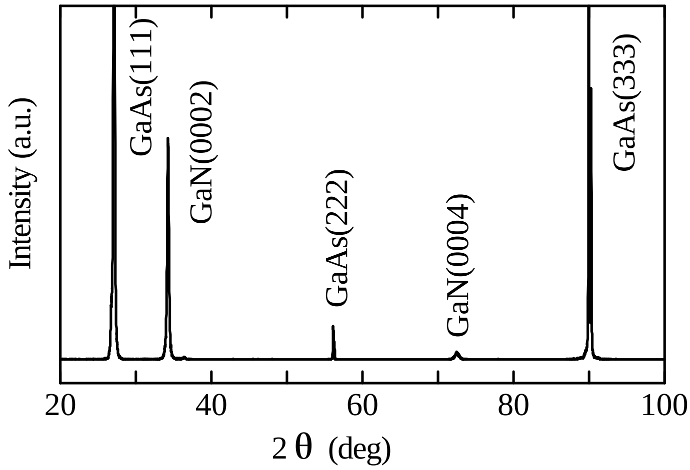

Figure 1. A typical θ-2θ XRD pattern of GaN films grown at temperatures above 600 ℃.

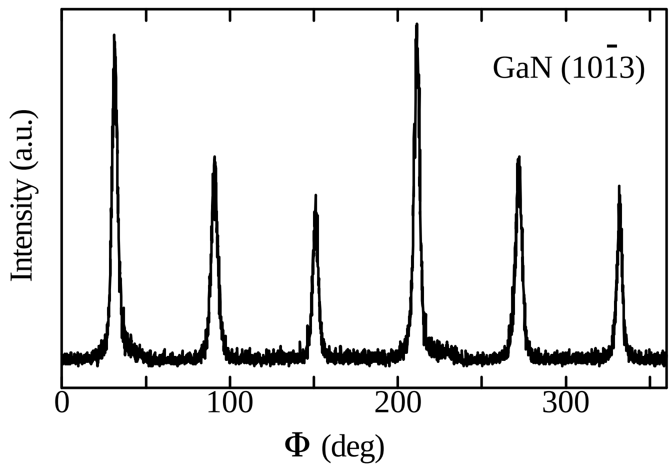

Figure 2. A phi-scan of the GaN (10$\bar{1}$3) diffraction peak from the GaN film.

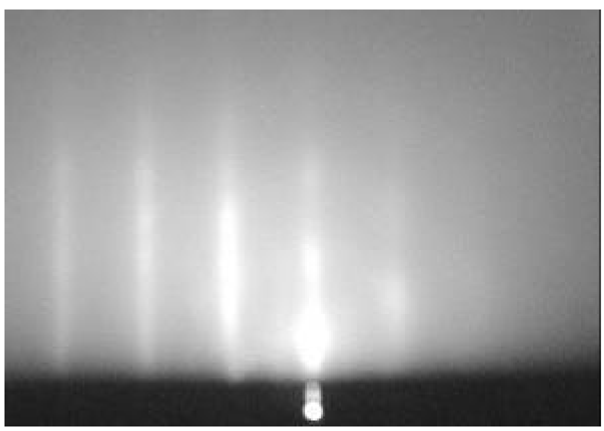

Figure 3. A typical RHEED pattern of GaN films grown at temperatures above 600 ℃.