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Effect of Substrate on GaN Growth

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Abstract

GaN films were grown on three differently oriented sapphire substrates; (0001), (11-20), and (1-102). GaN films on the (0001) and (11-20) substrates have a hexagonal structure and their growth rate was 0.6 ㎛/hr in both case. The film on the (1-102) substrate was too thin to identify its crystalline state. Growth rate was about the half of the others. Substrate orientation is one of the factor determining growth rate. The adhesion between GaN film and alumina substrate seems to be very good judging from the fractography.

Introduction

GaN have been considered as a promising material for a electronic and opto-electronic devices such as high performance transistors, light emitting diode(LED), and field-emission displays(FED) because of its wide band gap characteristic.

Research on GaN has greatly progressed during the last few years. High quality GaN has been grown by organo-metallic vapor phase epitaxy(OMVPE).[1-3] However, the lack of a suitable substrate material that is lattice matched and both thermally and chemically compatible with GaN was a major limitation to the further development of GaN-based devices. Moreover, exceptionally high growth temperature usually used for OMVPE is another main obstacle and limits extent of dopant incorporation.[4]

In this study, the GaN epilayers were deposited on three different orientations of sapphire substrates using OMVPE with the objective of studying the effects of substrate orientation upon the quality of the films.

Experimental

Highly polished α-Al_2O_3 surfaces with the orientations of {0001};(c-plane), {11-20}; (a-plane), {1-102};(r-plane) were used as substrates and these substrates had a ready-to-use grade surface condition which requires only a brief wash procedure before deposition.

The deposition pressure was maintained at 85 torr. Substrates were pretreated with N_2 gas at 850℃ for 10 minutes before deposition. For the formation of buffer layer, substrates were also pretreated with ammonia at 650℃ for 30 seconds. After the treatment, GaN films were grown at 850℃ for 90 minutes under the V/III inlet ratio 3324. A summary of growth conditions is given in Table 1.

Table 1. Summary of growth conditions.

Items	Specification
Reactor	A planar horizontal rotating susceptor
Substrate	Alpha-alumina c-, a-, and r-surfaces
Precursors	TEGa and ammonia
Carrier Gases	Nitrogen and Hydrogen: 2.5-3.0 slm
V/III Inlet Molar Ratio	3324
Growth Pressure (torr)	85
Growth Temperature(℃)	650-850

TEGa(tetra-ethyl gallium) and high purity ammonia(NH_3) were used as source gases. The OMVPE apparatus is schematically shown in Fig. 1. A downstream-type stainless-steel chamber was pumped by a combination of a mechanical booster and a rotary vacuum pump.

The morphologies of the GaN films were observed by scanning electron microscope(SEM) and the quality of the films was characterized using X-ray diffractometer(XRD).

Results and Discussion

Fig. 2 shows XRD patterns obtained from the GaN films which were grown on three differently oriented sapphire substrates. The structure of GaN films grown on c-plane (Fig. 2a) and a-plane (Fig. 2b) is hexagonal. The films on r-plane (Fig. 2c) could not be clearly determined by the pattern. Only a small (11-20) GaN peak is found at $2\theta=57.4°$(d=1.591Å). Judging from the XRD analyses, fair quality hexagonal type GaN films could be obtained when c- and a-plane were used as substrates.

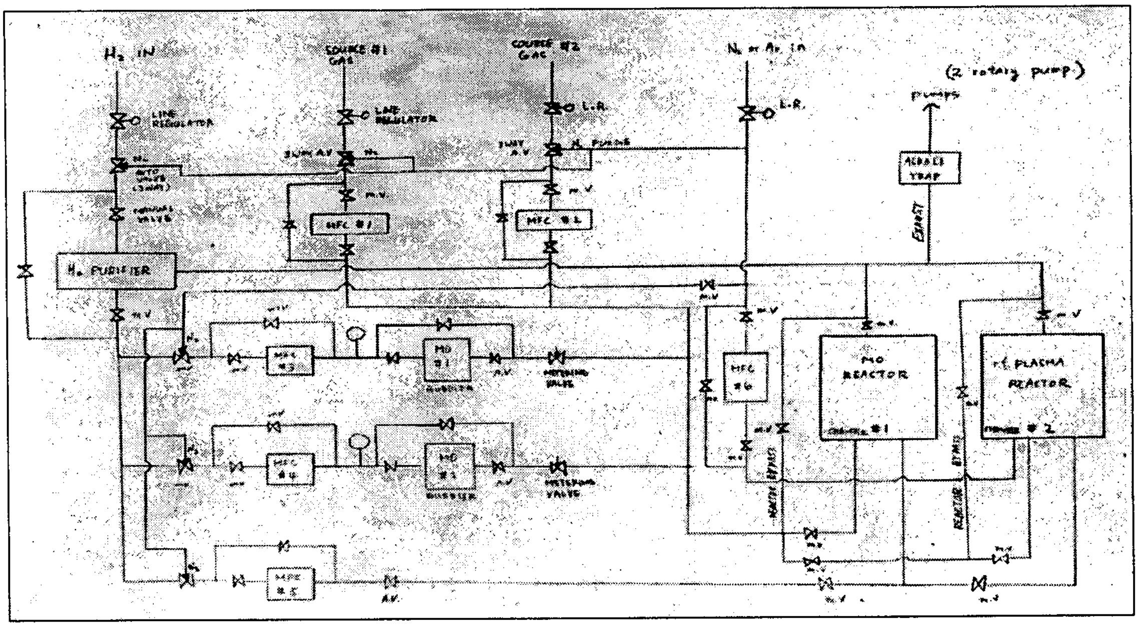
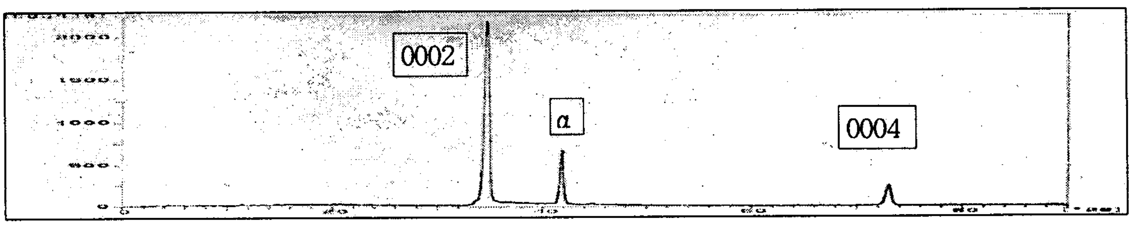
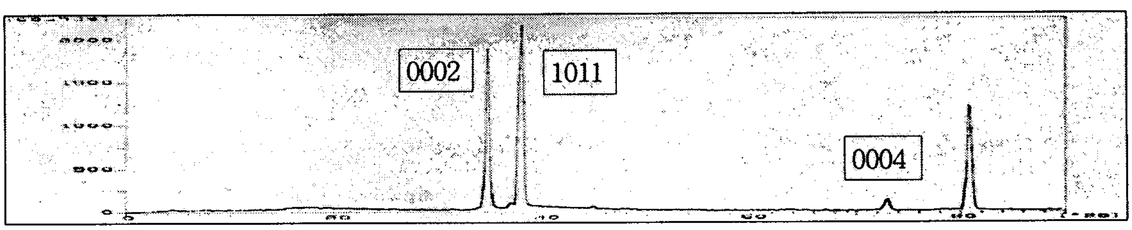


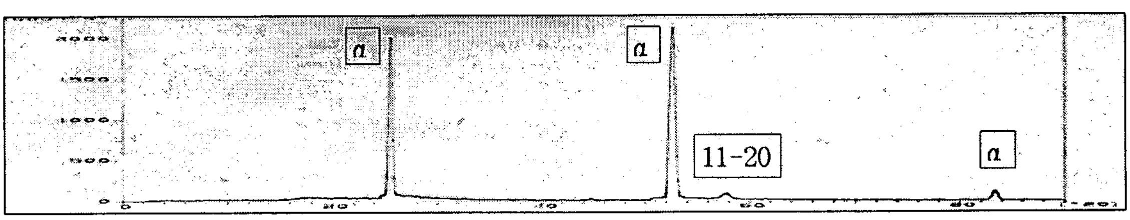
Fig. 1. A schematic drawing of OMVPE apparatus



(a)



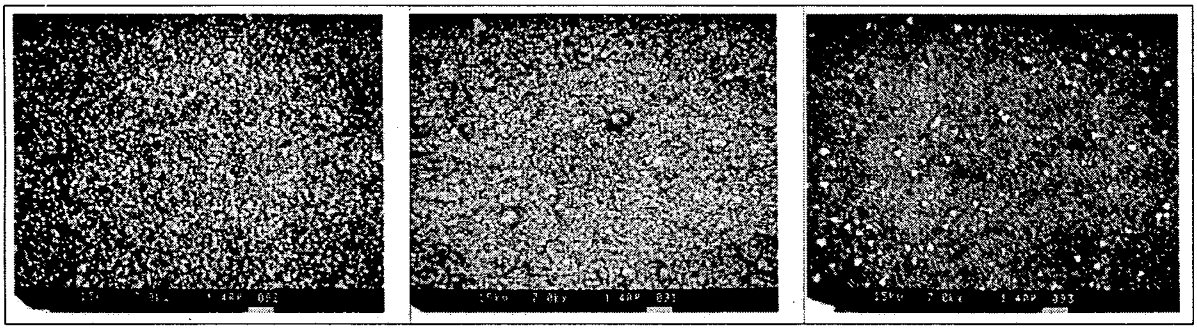
(b)



(c)

Fig. 2. XRD patterns from GaN films using (a) c-plane, (b) a-plane, (c) r-plane.

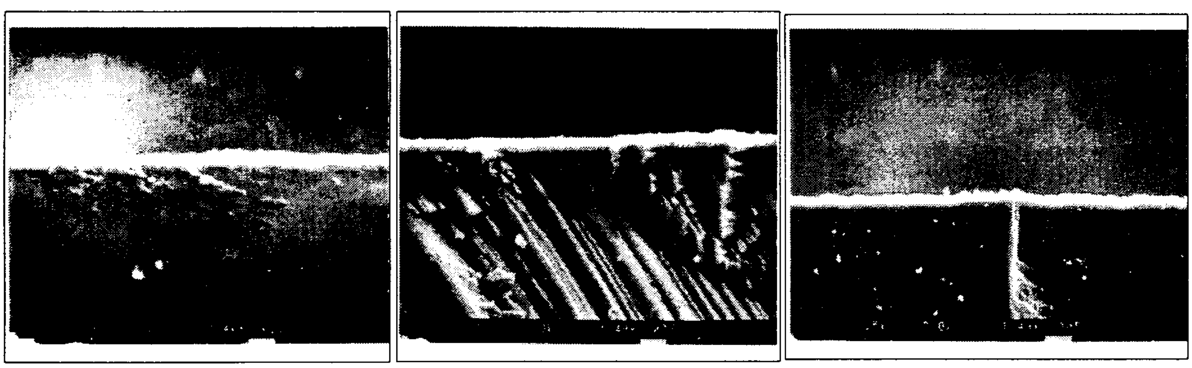
Surface morphologies of GaN films on c-, a-, and r- plane were shown in Fig. 3a, 3b, and 3c, respectively. The film quality on c- and a-plane looks nearly same; however, the one on r-plane is lower and grain size is smaller than the others. Planar SEM observation is coincident with the results from the XRD. The overall grains are small and seem to be less dense comparing to other published results.[5] The reason is that the growth temperature was lower than that normally used for GaN film growth in other researches.



(a) (b) (c)

Fig. 3. Planar SEM micrographs. Substrate orientations are as follows: (a) c-plane, (b) a-plane, (c) r-plane, respectively.

Fig. 4a, 4b, 4c show SEM fractographies of GaN films on c-, a-, and r-plane, respectively. From the figures, the growth rate of GaN films was 0.6μm/hr in both c- and a-plane cases. This growth rate is a little faster than that from other researches. In r-plane case, the growth rate was about the half of c- or a-plane cases, as expected form the XRD results, so that only a very thin layer of GaN film was deposited. This suggests that one of the factors which may affect the growth rate of GaN film is substrate orientation. Well developed facets as shown in Fig. 4b are the typical characteristic of fractured a-plane.[6]



(a) (b) (c)

Fig. 4. Cross sectional SEM micrographs. (a) c-plane, (b) a-plane, (c) r-plane.

Fig. 5 shows a perspective view of the fractured GaN film on a-plane. A boundary between GaN film and alumina substrate is clearly seen from the figure. When the specimen was fractured, GaN film and alumina substrate were fractured nearly parallel. From this face, it is concluded that the adhesion between GaN film and alumina substrate is good.

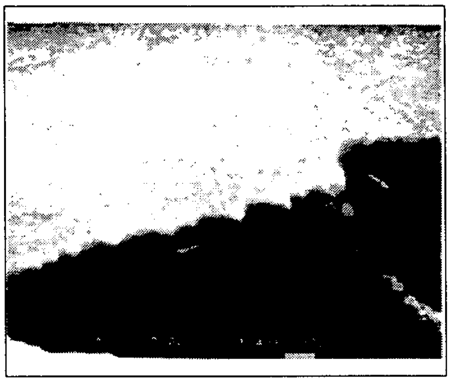


Fig. 4. Perspective view of fractured surface. Boundaries between GaN layer and alumina substrate can be clearly seen.

Conclusions

1. Hexagonal type GaN films were grown on c- and a-plane of α-Al_2O_3 single crystals, and their growth rate was 0.6 μm/hr.

2. Judging from the fractography, the adhesion between GaN film and alumina substrate seems to be good enough for the practical use.

3. The growth rate of GaN film is affected by the orientation of substrate.

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