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MOVPE Selective Growth of Cubic GaN in Small Areas on Patterned GaAs(100) Substrates

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The MOVPE growth of cubic GaN in small areas on SiO_2-patterned GaAs substrates has been performed. We have succeeded in the selective growth without deposition on the SiO_2 mask within the growth temperatures (620–675 °C) and the window sizes used in this study. The crystal quality of cubic GaN has been improved by growing in small areas on patterned GaAs substrates. It is found that the grain size becomes larger and the FWHM of cubic GaN(200) peak of X-ray diffraction becomes narrower on patterned substrates than on unpatterned ones.

1. Introduction

GaN is a direct wide-bandgap semiconductor (Eg=3.4 eV) and is intensively studied as a candidate for blue or ultraviolet light emitting devices[1]. GaN usually has a hexagonal (wurtzite) structure (α-GaN), and good quality α-GaN and its heterostructures with (Ga,Al)N have been fabricated on sapphire substrates[2].On the other hand, since the first successful growth of cubic (zincblende) GaN on GaAs[3], several attempts have been made to grow cubic GaN on cubic structure substrates such as GaAs[4)-8)], SiC[9], and Si[10]. We have been studying the MOVPE growth of cubic GaN on GaAs substrates[7),8)], but have obtained only the cubic GaN films which consisted of well-oriented grains with relatively small dimensions. The crystal quality is expected to be impoved by growing cubic GaN in small areas, as suggested by the poly-GaAs growth in small areas on poly Si(100)[11].

In this study, we attempted to grow cubic GaN in small areas on the SiO_2-patterned substrates. The selective growth on the patterned substrates was successful, and the improvement of the crystal quality of cubic GaN was realized, giving larger grain sizes and narrower FWHMs of X-ray diffraction.

2. Experimental

For the selective growth in small areas, we fabricated mask patterns on GaAs(100) substrates as shown in Fig.1. As a mask, we deposited 0.2 μm-thick SiO_2 on the substrate by sputtering, and square-shaped windows were opened by photolithography and wet-etching. The window size, w, and the spacing between the windows, d, were 2-20 μm and 2-10 μm, respectively. As a parameter which express how windows are opened, we define open window ratio, R, as $R = w/(w+d)$. We fabricated the patterned substrates where R = 0.3–0.9.

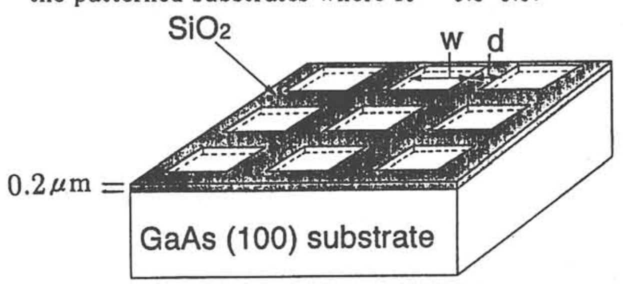

Fig.1 Schematic view of a SiO_2 patterned GaAs(100) substrate.

The cubic GaN film was grown by low-pressure (60 Torr) MOVPE with H_2 carrier gas using trimethylgallium (TMG) and dimethylhydrazine (DMHy) as Ga and N sources, respectively. The flow rate of TMG, the growth temperature, and the V/III ratio were 0.7–1.4 μmol/min, 620–675 °C, and 160, respectively. Those values were based on 1.4 μmol/min, 650 °C, and 160, the optimum values for the growth on unpatterned substrates we obtained previously[8]. The thickness of all specimens was 0.2 μm. The samples were characterized by scanning electron microscope (SEM) and X-ray diffraction.

3. Results and Discussions

Figure 2 shows the surface and cross-section SEM images of the samples with w=5μm and d=10μm (R=0.33) grown at 650 °C with the TMG flow of 1.2 μmol/min. The growth of cubic GaN occurred only in the windows without deposition on the SiO_2 mask. Moreover, the selective growth was possible in all growth temperatures and mask pattern sizes used in this study.

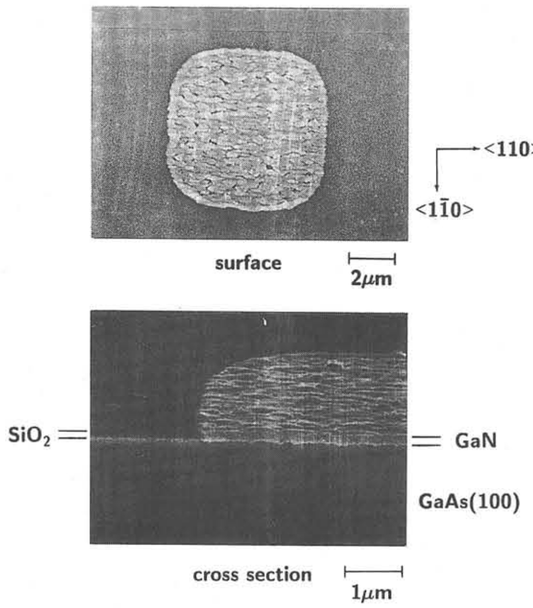

Fig.2 Surface and cross-section SEM images of the sample (d=10μm w=5μm).

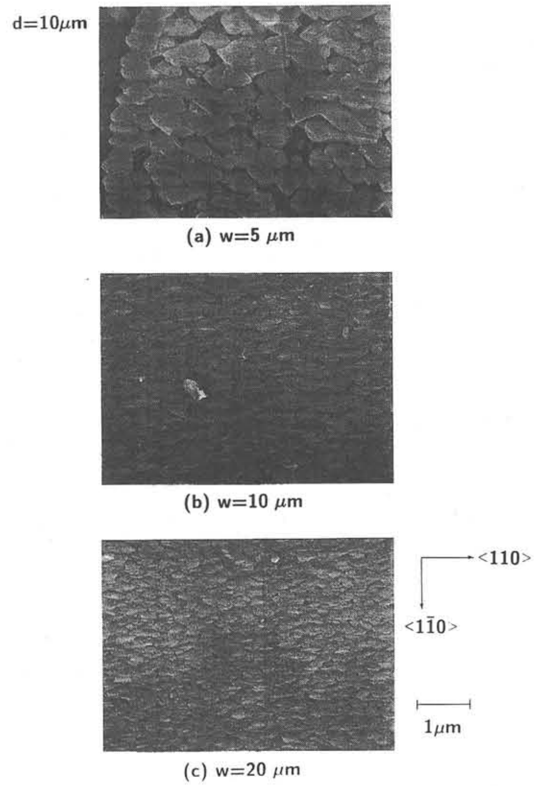

Fig.3 Surface morphology of cubic GaN with different window sizes.

Figure 3 shows the surface morphology of the samples with different window sizes. w=5, 10, 20 μm, where d=10 μm in all cases. These samples were grown at 650 °C with the TMG flow rate of 1.4 μmol/min. The grown films consist of many small GaN grains as in the case of growth on unpatterned substrates[8]. It is obvious, however, that the grain size becomes larger as w decreases.

In Fig.4, the relationship between the growth rate of GaN films and the open window ratio, R, is shown. The growth rates are 0.4 μm/hour and 0.3 μm/hour under the TMG flow rate of 1.4 μmol/min and 1.2 μmol/min, respectively, which are almost independent of R. This tendency does not agree with the simple concept that the Ga atoms on the SiO_2 mask migrate to the window area so that the growth rate increases as R decreases. Figure 5 shows the R dependence of the grain size of cubic GaN. R=1 indicates the case on the unpatterned substrates. When d is constant, the grain size becomes larger as w decreases (R decreases). However, we can say from Fig.5 that the grain size is closely related with R rather than w, when we consider the cases for different d's. The increase of the grain size is remarkable in the range of $R \leq 0.4$, and the grain size for R=0.33 is two or three times larger than that for R=1. In order to see the influence of the growth rate on the grain size, we performed the growth with different TMG flow rates. From Fig.5 it seems that the grain size becomes a little larger as the growth rate increases for the same R. However, considering that the growth rate is almost the same among different R's (0.33, 0.50 and 0.67) for the same TMG flow rate, we can say that the growth rate does not affect the grain size. Figure 6 shows the R depen-

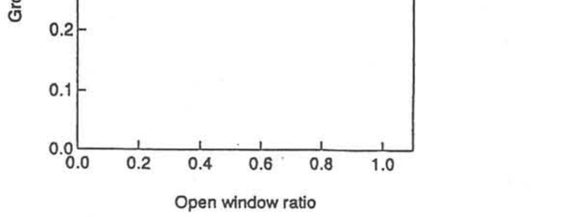

Fig.4 Open window ratio dependence of the growth rate.

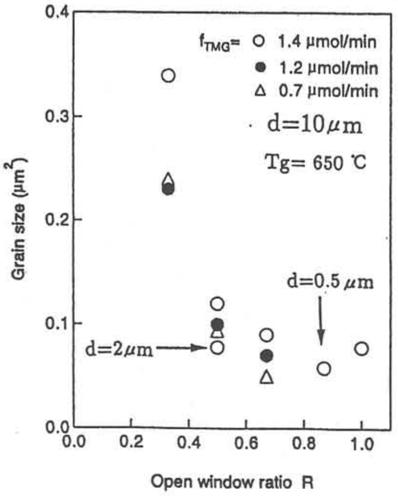

Fig.5 Open window ratio dependence of the grain size

dence of the FWHM of the cubic GaN(200) peak of X-ray diffraction. The GaN films for small R, that is, with large grain size, give the small FWHM. We obtained the smallest value of the FWHM, 0.45°, for R=0.33. This value is smaller than 0.65° that is the smallest value on the unpatterned substrates in our previous work[8]. Thus it is obvious that we can obtain high quality GaN films using patterned substrates, compared with unpatterned substrates.

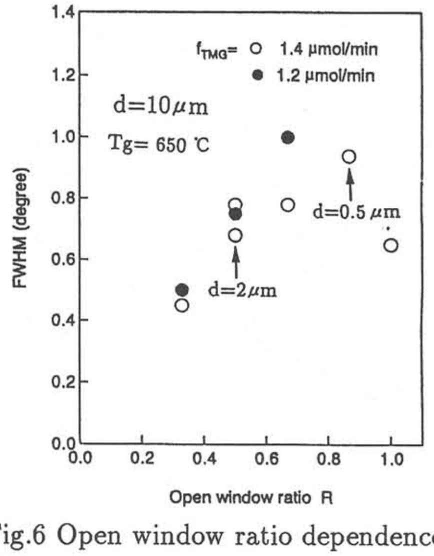

Fig.6 Open window ratio dependence of the FWHM of the X-ray (200) diffraction peak.

4. Conclusion

We have grown cubic GaN on SiO_2-patterned GaAs(100) substrates by MOVPE and succeeded in the selective growth without deposition on SiO_2 mask. In the growth of cubic GaN in the small areas on patterned GaAs(100) substrates, the grain size of cubic GaN becomes larger and the FWHM of the (200) X-ray diffraction peak becomes narrower as the open window ratio, R, decreases. Thus it is obvious that we can improve the crystal quality of cubic GaN films by growing in small areas on GaAs(100) substrates.

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