Crystallographic Structure of FIELO-GaN Films Studied by Scanning Reflection Electron Microscopy

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1. Introduction

Facet-initiated epitaxial lateral overgrowth (FIELO) [1] is a promising technique to reduce the threading dislocation density in GaN films, thus helping to improve device performance [2, 3]. The propagation mechanisms of the threading dislocations have been studied by TEM [4], and the unique propagating behavior of pure-edge dislocations has been shown to cause crystallographic tilting in the overgrown regions.

The surface of GaN substrates is important both for understanding the growth mechanism and for practical applications. However, the crystallographic defects of GaN surfaces have not been studied in detail. In this study, we used scanning reflection electron microscopy (SREM [5]) to observe FIELO-GaN films and investigated the recovery process of surface defects during film deposition.

2. Experimental

Figure 1 shows our experimental setup. SREM images were obtained by recording the change in specular reflection spot intensity through an optical lens [5]. Since the Bragg condition was disturbed at the surface steps, SREM reveals atomic-steps on solid surfaces. The SREM contrast is also sensitive to local surface distortion accompanied by dislocations and to crystallographic tilting. The FIELO-GaN samples were formed on a sapphire wafer. After SiO_2 stripe masks were formed on MOVPE-GaN films, GaN layers were deposited by HVPE [1].

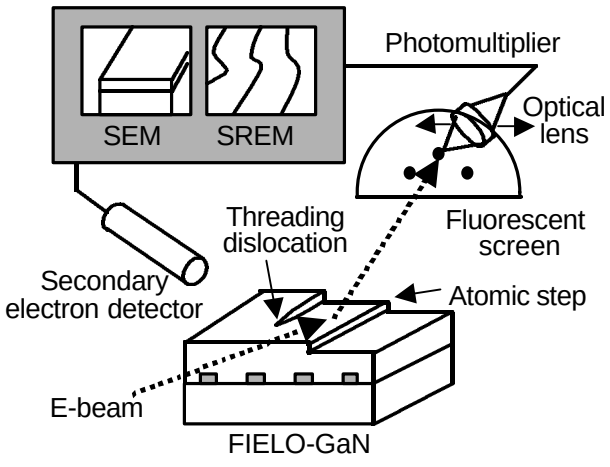

Fig. 1. Experimental setup of the SREM/SEM system.

3. Results and Discussion

Figure 2 shows SEM and SREM images of a 50-μm-thick FIELO-GaN film. In the SREM images, stripe contrast was clearly observed on the GaN surface. Comparing the SREM and cross-sectional SEM images (Fig. 2(a)), we observed that overgrown regions on the SiO_2 masks show dark contrast. We found that changing the position of the optical lens (see Fig. 1) caused the stripe contrast to disappear or reverse. These results indicate that the contrast in SREM images corresponds to a slight crystallographic tilting of the overgrown areas. The tilting angle estimated from the movement of the optical lens was less than 0.3°, which is consistent with findings in a previous x-

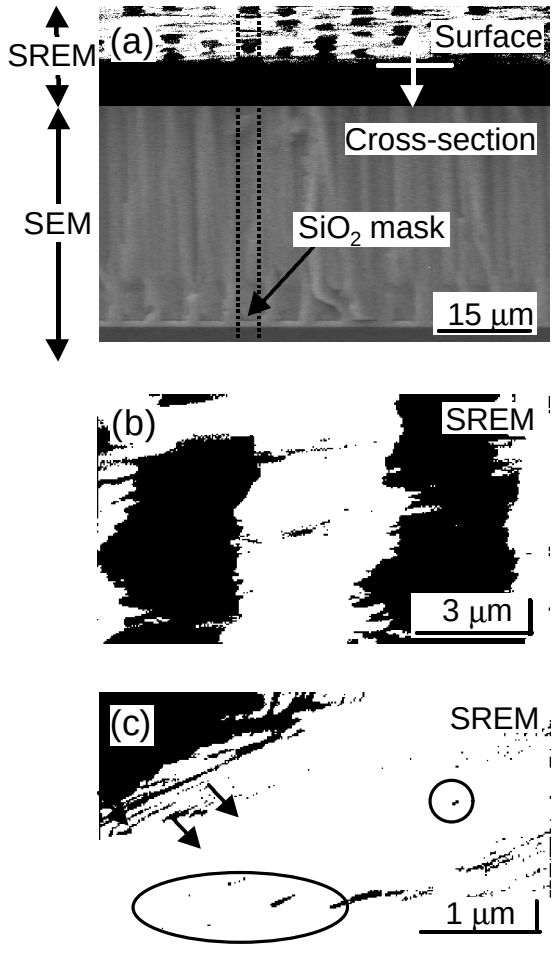

Fig. 2. SREM / SEM observation of a 50-μm-thick FIELO-GaN film. (a) SEM image combined with an SREM image of the surface. (b), (c) SREM images from the GaN surface.

ray diffraction study [6]. Considering that two adjacent GaN crystals, whose c-axis is symmetrically tilted by about 1°, are formed about 2 μm from the SiO_2 mask (Fig. 3(a)) [4], the uniform SREM contrast within the dark stripes in Fig. 2(b) implies that one of the two tilted GaN crystals became dominant after 50-μm-thick film deposition (Fig. 3(b)). Also, detailed SREM observations revealed that the crystal orientation of some portions in the overgrown areas rotated on the c-plane as shown in Fig. 3 (data not shown).

Figure 2(c) shows steps on the GaN film. The termination of surface steps by threading dislocations confirmed that the steps observed in the image were atomic steps on the GaN surface (see arrows in Fig. 2(c)). The presence of the clear steps and the terrace structure means that the growth process was governed by the step-flow mode. We could also identify each threading dislocation on the GaN surface from the change in SREM contrast (see arrows and circles in Fig. 2(c)) without the troublesome sample preparation needed for TEM observation or etch-pit analysis.

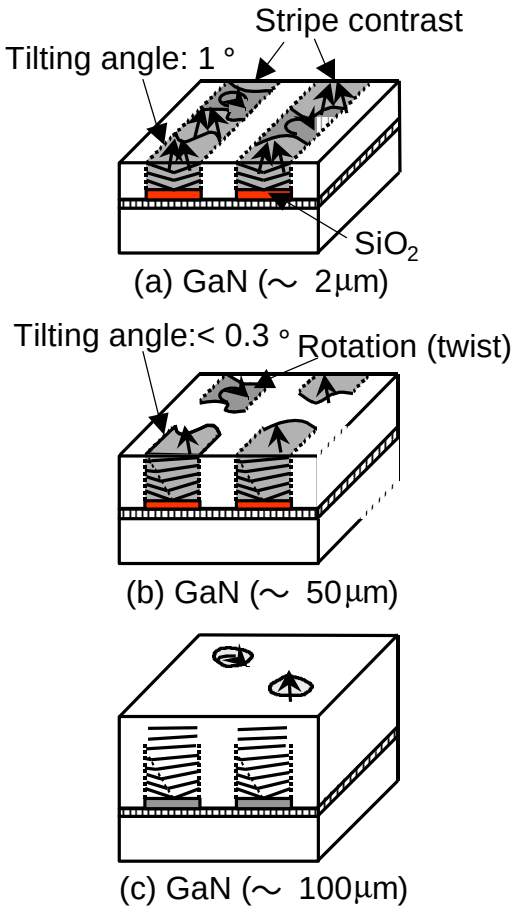

Fig. 3. Changes in the crystallographic structure of FIELO-GaN films. (a) Interfacial structure between the masks and GaN film. (b) After 50-μm-thick GaN deposition. (c) Recovery of the crystallographic structure after 100-μm-thick deposition.

Figures 4 show SREM images of a 100-μm-thick FIELO-GaN film. Although a few areas that showed faint contrast were observed within the solid circles in Fig. 4(a), we could not detect the stripes originating from the crystallographic tilting that we observed for the thinner GaN film. Considering the detection limit of the SREM method, we can conclude that the tilt angle of the overgrown regions was recovered to less than 0.05° after 100-μm-thick GaN deposition (Fig. 3(c)). Also, we could observe atomic steps and threading dislocations in Fig. 4(b). The dislocation density was 3 to 4 x 10^7 cm^{-2}; this is half that observed from the 50-μm-thick GaN film (Fig. 2).

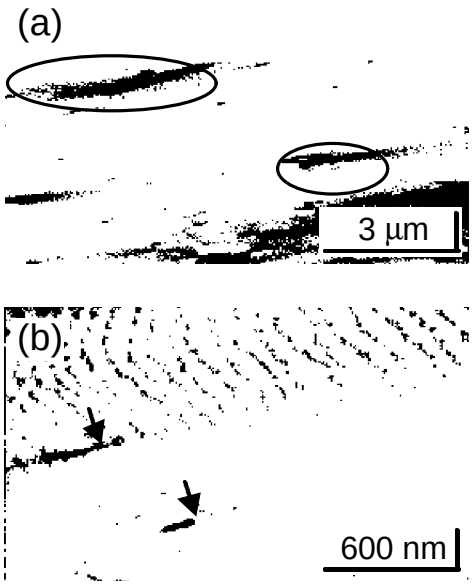

Fig. 4. SREM images of a 100-μm-thick FIELO-GaN film. (a) Low magnification image. (b) Atomic-step image from the GaN surface.

4. Conclusions

We have used SREM to observe surface defects in FIELO-GaN films. SREM observation revealed atomic-steps, individual threading dislocations and the recovery process of the crystallographic tilting in the overgrown areas by thick GaN film deposition. Our results demonstrate the advantages of SREM method for studying the crystallographic structure in GaN films.

References

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