Transmission electron microscopy study of selective area growth of GaN on (111)Si using AlGaN as an intermediate layer

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Selective area growth (SAG) and epitaxial lateral overgrowth (ELO) of GaN are attractive technique to produce high-quality epitaxial layers with low threading dislocation densities as well as to fabricate various structures. Recently, Kawaguchi et al.[1] have demonstrated, by metalorganic vapor phase epitaxy (MOVPE), SAG of GaN directly on (111)Si by using AlGaN as an intermediate layer. In this growth technique, after the formation of AlGaN grain structures on a patterned Si substrate, the growth of GaN is carried out. Without the AlGaN intermediate layer, no growth of GaN was obtained on a patterned Si. The surface morphology and crystalline quality were characterized by means of scanning electron microscopy (SEM) and cathodoluminescence. However, the growth process especially in relation with crystalline structure has not been understood. In this paper, transmission electrom microscopy (TEM) characterization of the growth process of SAG GaN is presented.

The samples were grown by MOVPE, using AlGaN as an intermediate layer, on (111)Si substrates with a stripe patterned structure of a silicon dioxide (SiO_2). After the deposition of a SiO_2 film by RF sputtering on the substrate, stripe windows of 5 μm width, with a periodicity of 10 μm, were developed by the conventional photolithographic method. The AlGaN intermediate layer was grown on the patterned Si substrate at 1200℃ for 3 min, and then GaN was grown at 1200℃ for a time duration between 0 and 60 min. Details of the growth procedure were described in Ref.1.

Figure 1 shows a cross-sectional TEM image of the AlGaN intermediate layer. Both the window region and the mask region are imaged. AlGaN islands can be seen in the window region. But unexpectedly, AlGaN islands are also seen on the mask. The size of the islands is approximately 30-60 nm for the window region (except large one at the mask edge), and 10-20 nm for the mask region, respectively. Plan-view TEM observation revealed that the crystalline orientation of the AlGaN islands on the mask is randomly distributed. On the other hand, the AlGaN islands in the window region have a standard oeientation relationship with the Si substrate as determined by high resolution TEM, and they serve as a nucleation center for the subsequent GaN growth. It is also noted that the size of the AlGaN island in the window region in the vicinity of the mask edge is very large compared with other islands in the window region. This is considered to be an effect of the surface migration of growth species from the mask region to the window region.

Growth of GaN occurs dominantly on the AlGaN islands in the window region. Then GaN islands in the window region increase in size, and coalescence with each other. Threading dislocations are generated at boundaries where two islands meet. By continuing the growth of GaN further, coalescence of GaN islands are completed, and GaN stripes are formed as shown in fig.2. The growth time of GaN for this sample was 60 min. In this structure, mainly observed defects are threading dislocations that are generated by coalescence of GaN islands as described earlier. No newly created threading dislocations are observed at the interface between the nitride and the mask, indicating that lateral growth occurred in the mask region. The type of the threading dislocations was determined by contrast analysis. In the structure shown in fig.2, threading dislocations with burgers vectors **b**=1/3$[11\bar{2}0]$ and **b**=1/3$[11\bar{2}3]$ were found. It is also seen that once the threading dislocations intersect the $(1\bar{1}01)$ plane along the growth windows, almost all of them change direction and become parallel to the $[1\bar{1}00]$ direction. These dislocations thread through the lateral growth part of GaN. Thus the density of threading dislocations is effectively reduced.

Reference

[1] Y. Kawaguchi, Y. Honda, H. Matsushima, M. Yamaguchi, K. Hiramatsu and N. Sawaki, Jpn. J. Appl. Phys., Part 2 **37**, L966(1998).

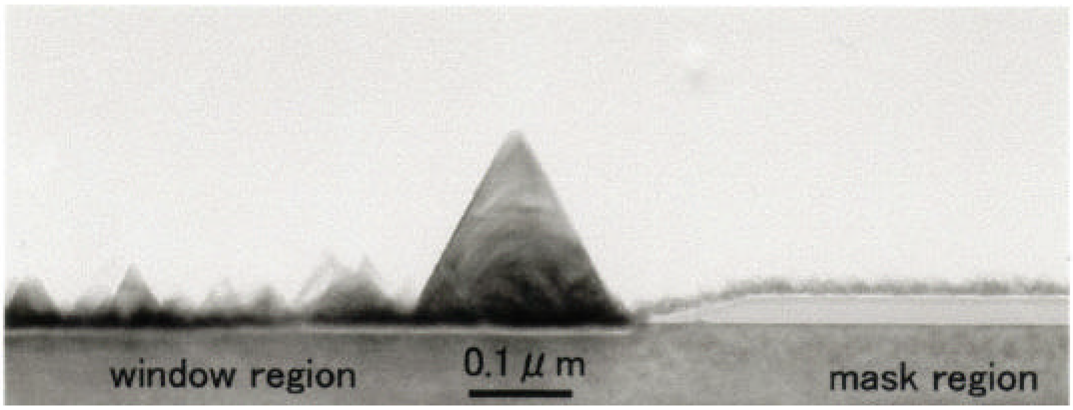

FIG.1 cross-sectional TEM image of the AlGaN intermediate layer

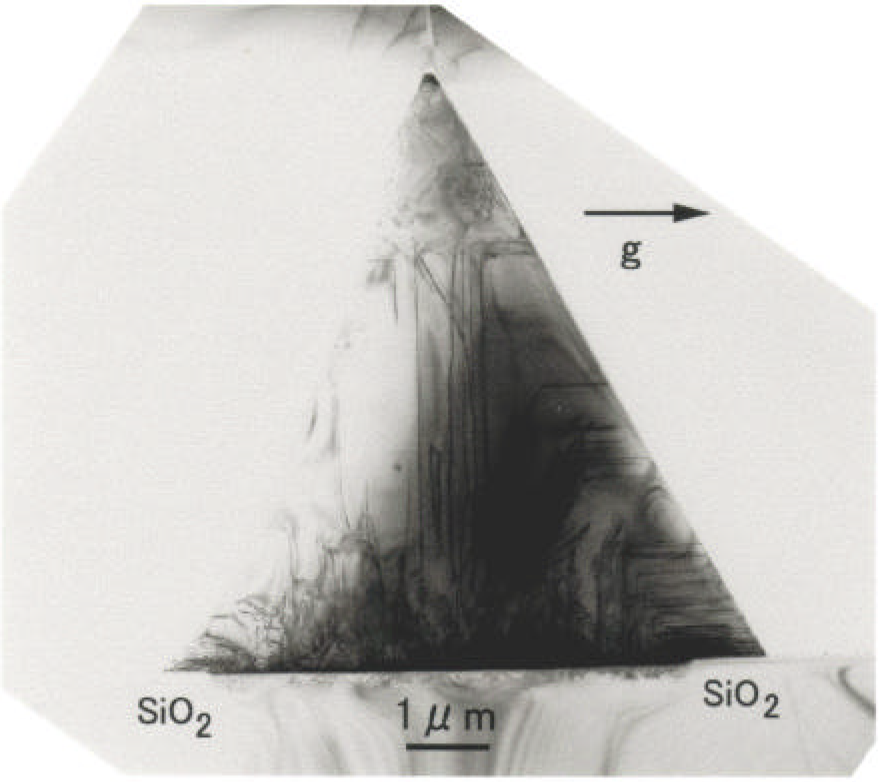

FIG.2 cross-sectional TEM image of GaN stripe