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Hetero-Epitaxial Growth of GaN onto SiC-on-SIMOX Substrates

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1.Introduction

A plan to develop electron-photon merged devices has been revealed as one of the next generation, post Si devices [1]. In the devices, electrons undertake the operation or calculation, and light undertakes signal transmission, respectively. In order to realize super high-speed ULSIs applying the synergetic effects, the devices consist of Si LSIs and GaN photo-device arrays. SOI is introduced as a basic technology to fabricate both of these devices monolithically. We had previously developed a 200 mm diameter SiC-on-insulator substrate [2]. The top SiC layer works as a buffer layer for GaN epitaxial growth [3]. In this paper, we report on the hetero-epitaxial growth of GaN onto a 50 mm diameter SiC-on-SIMOX substrate which had been cut out from an 200mm diameter substrate.

2.Experiment

200 mm diameter SIMOX(111) substrates were used as the starting materials. Because SIMOX(111) substrates were not commercially available, our first job was to develop them. The 200mm-SIMOX(111) substrates were formed through oxygen-ion implantation into 200mm-Si(111) substrates with a dose of about 6.0 x $10^{17}/cm^2$ at an acceleration energy of 180 keV, followed by high-temperature anneal including what is known as the “ITOX” process.

The top Si layer of the SIMOX(111) substrate was thinned down to a few nm using a sacrificial oxidation technique. A 3C-SiC seed layer was formed by completely carbonizing the ultra-thin top Si layer of the substrate. Afterward, a single crystalline SiC epitaxial layer approximately 100nm thick was grown on the SiC seed layer using CH_3SiH_3 by means of GS-MBE (Air Water Vacuum-Chemical-Epitaxy (VCE)-system).[2]

After cleaning the surface of the SiC specimen at 1,180 ^{o}C, a 100nm-thick AlN buffer layer and a 2um-thick GaN film were consecutively grown with the MOCVD. The GaN film grown on the SiC-on-SIMOX substrate was evaluated using X-ray diffraction (XRD), a scanning electron microscope (SEM), a cross-sectional transmission electron microscope (XTEM), and selected-area transmission electron diffraction (SA-TED).

3.Results and discussion

Figure 1 shows the XRD result of the specimen. A strong GaN(0002) difraction peak can be seen together with AlN(0002) and Si(111) peaks. Diffraction peaks due to other orientations of GaN are not recognized. This result indicates the GaN film is not polycrystalline but at least oriented on a C-axis. Figure 2 shows SEM images of the film. In the figure, GaN film with hexagonal shapes and a rough surface is observed. In the XTEM images of Fig. 3, the interface of the GaN and AlN can be identified, though that of the AlN and SiC cannot be resolved clearly. On the other hand, the lattice images of the GaN film with hexagonal structure can be distinctly seen. Figure 4 shows SA-TED images of the films. In Fig. 4(c), strong spots corresponding to GaN(0001) surface only are observed. This result indicates that hexagonal GaN(0001) is epitaxially grown on the SiC-on-insulator substrate. In Fig. 4(b), weak SiC (111) spots indicated by circles and strong spots of AlN(0001) hexagonal structure can be found. This result implies that the high temperature AlN buffer layer plays a role in changing the crystal structure from cubic SiC into hexagonal GaN.

4.Conclusion

We succeeded in hetero-epitaxial growth of a 2um-thick GaN film onto a SiC-on- SIMOX(111) substrate with a diameter of 50mm which had been cut out from an originally developed 200mm diameter substrate.

A monocrystalline GaN-on-insulator was obtained judging from the results of XRD, XTEM and SA-TED, although the surface of the film is rough. Improving the rough surface of the GaN film is an issue, but our success indicates a high possibility of developing GaN-on-insulater substrates with 200mm diameter in the near future.

5.Acknowledgment

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6.Reference

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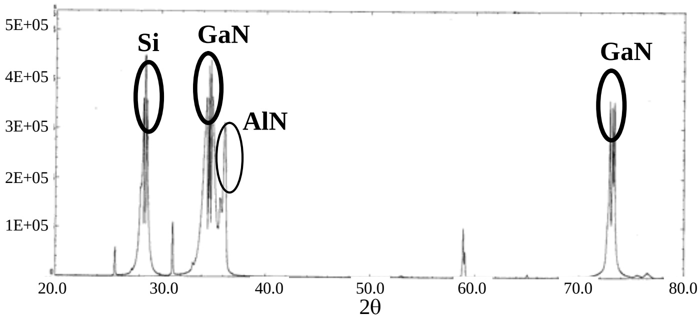

Fig. 1 XRD result of the specimen

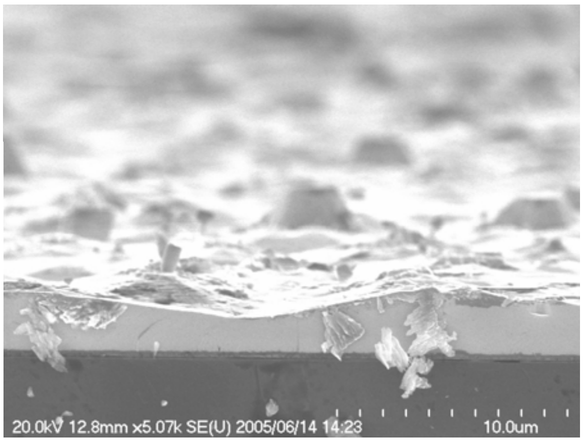

Fig. 2 SEM image of the films

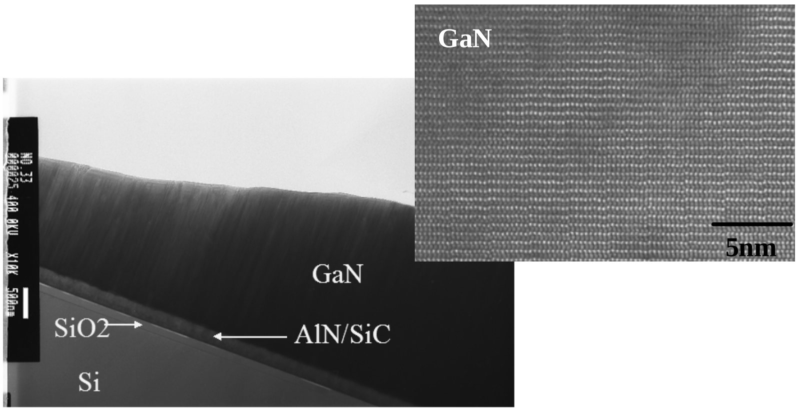

Fig. 3 XTEM image of the specimen

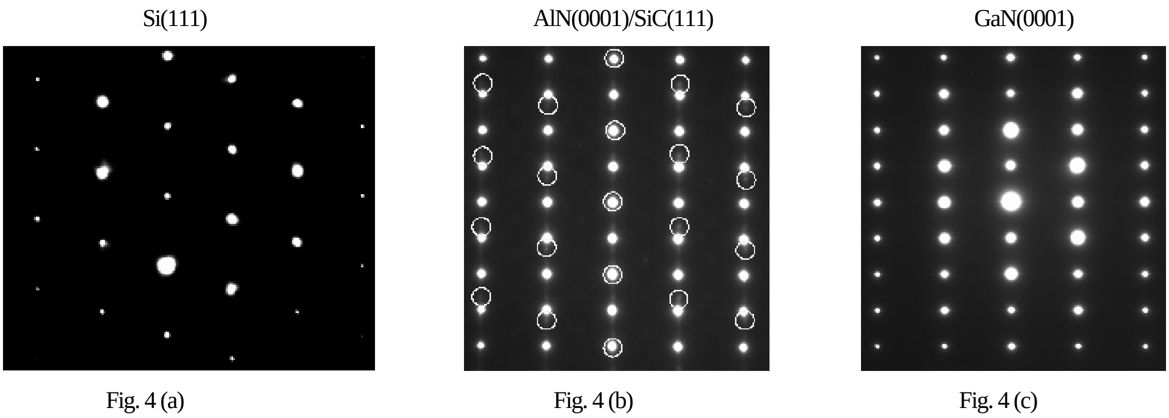

Fig. 4 SA-TED images of the films