Selective growth of GaN microstructures on (111) facets of a (001)Si substrate by MOVPE

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Selective area growth(SAG) of semiconductors on a patterned substrate has enabled us to fabricate microstructures as quantum wires and dots. In case of GaAs/AlGaAs quantum structures, various methods have been adopted; wires in grooves or on mesas, dots in pits or on pyramids, etc[1-3]. These methods are expected to be superior to other methods because of the controllability of the size and position of the objects on the wafer. Recently use of Si as the substrate for the growth of GaN has attracted much attention because of the possible application to opto-electronic devices[4]. In this paper, we will demonstrate the selective growth of microstructures of wurtzite GaN on (111) facets on a (001) silicon substrate.

On a (001) silicon substrate, an SiO2 mask film (thickness 70 nm) was deposited and a stripe pattern of which period is 6 - 20 μm was developed by conventional photolithography. The stripe was along (0-11) direction. The sample was then immersed in a KOH solution to etch the silicon surface. Because of the anisotropy of the etching speed, we get trench structure as shown in Fig.1. The sidewall of the trench is of (111) facet. On the patterned substrate, the growth of GaN was performed by atmospheric pressure metalorganic vapor phase epitaxy(MOVPE). Following heat treatment, an $Al_xGa_{1-x}N$ intermediate layer was deposited at 1200℃. Then the SAG-GaN was grown at 1060℃. We used TMA, TMG and NH_3 as the source gases.

Figure 2 shows SEM images of a SAG-GaN obtained after 10 min growth. Obviously the growth is achieved on the (111) facets. On the bottom of the trench, on the other hand, only a small amount of polycrystalline is obtained. We observe no growth on the SiO2 mask (top of the mesa). We achieved single-crystal GaN triangular bars of as long as 1mm. The GaN is of wurtzite and the C-axis is along the (111) axis of the silicon. In Fig.2 (b), we can see that the GaN grew higher than the mesa, but the overgrowth is not much. This suggests that the depth of the trench could determine the size of the GaN triangular bar. In order to study this point further, we tested 30 min growth on substrates with different stripe widths. The results are shown in Fig. 3. Obviously, three different stripe widths give nearly the same size of the triangular bar. It is notable that the size is not so different from that shown in Fig.2. This confirms that we can define the size by the depth of the trench.

In case of 10 μm stripe, Fig.3(a), polycrystalline are observed on the bottom. This might be attributed to the un-desired nucleation of GaN due to the roughness of the bottom surface. In order to get a mirror surface, following the etching by KOH, we cleaned the surface by a nitric acid solution. By this surface treatment, we found that the anomalous deposition of polycrystalline on the (001) bottom is completely avoided as shown in Fig.4. The detail mechanism of the stable facet formation will be discussed in relation to the growth conditions.

[1] T. Fukui, K. Kumakura, K. Nakakoshi, and J. Motohisa, Solid. State Electronics, **40**(1996) 799.
[2] M. Kawabe, J. Cryst. Growth, **150**(1995) 370.
[3] Y. Sugiyama, Y. Sakuma, S. Muto, Appl. Phys. Lett. **67**(1995) 256.
[4] Y. Kawaguchi, Y. Honda, H. Matsushima, M. Yamaguchi, K. Hiramatsu, and N. Sawaki, Jpn. J. Appl. Phys. **37**(1998) L966.

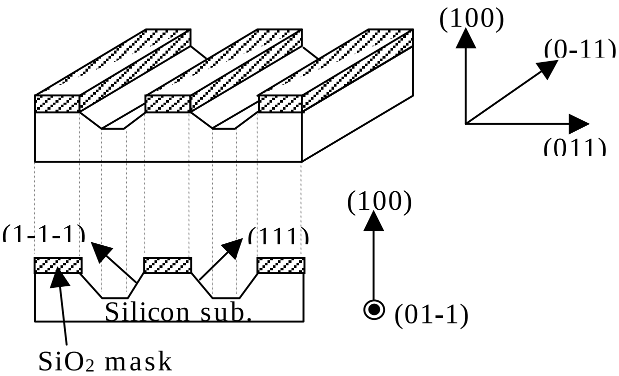

Fig. 1 Schematic trench structure on (001) silicon surface prepared by KOH etching.

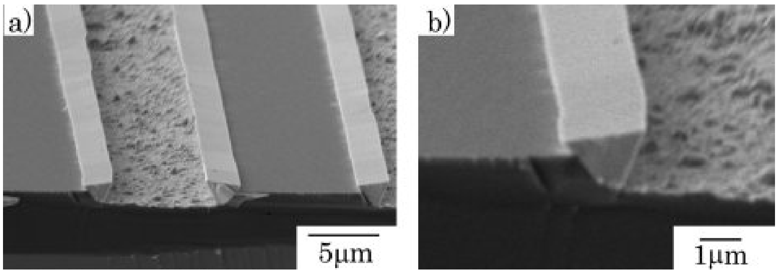

Fig. 2 SEM images of GaN grown on (111) facets.

The growth time is 10min. The stripe period is 20μm and the etching depth is 1μm. The right hand side image shows that the growth of GaN exceeds the mesa of silicon substrate. Note that the growth of GaN on the bottom of the trench is scarce but small amount of polycrystalline.

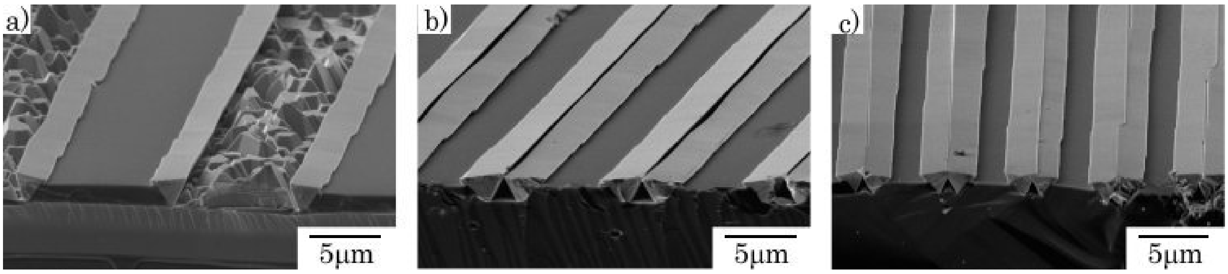

Fig. 3 SEM images of GaN grown for 30min.

The etching depth is the same as in Fig.1. The stripe period is a)20μm, b)10μm, and c)6μm. The size of the GaN triangular bar is nearly the same as shown in Fig.1. In case of a), additional supply of the source material resulted in the abnormal growth on the bottom of the trench. In case of c), adjacent bars have coalesced each other.

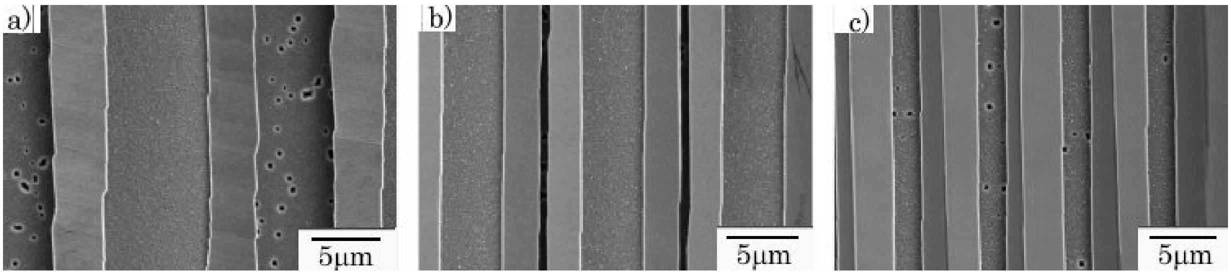

Fig. 4. SEM images of GaN grown for 30min after the surface treatment(see text.)

The etching depth and stripe periods are same as Fig.3. The selectivity is much improved and no abnormal growth is observed on the bottom of the trench. The slight irregularity in a) is due to the misalignment of the stripe direction.