AMTC Letters
Vol. 2 (2010)

TEM analysis of SiC crystal grown on (001) 3C-SiC CVD substrate by solution growth

K. Morimoto[1], R.Tanaka[2], K. Seki[2], T. Tokunaga[1], T. Ujihara[2], K. Sasaki[1], Y. Takeda[2], and K. Kuroda[1]

[1] Department of Quantum Engineering, Nagoya University, Nagoya, 464-8603, Japan
[2]Department of Crystalline Materials Science, Nagoya University, Nagoya, 464-8603, Japan

Silicon carbide (SiC) is a wide band gap semiconductor that has been attended as a material for next generation power devices. Considering metal-oxide-semiconductor (MOS) junction based on major polytypes of SiC, i.e., 4H-, 6H-, 3C-SiC, 3C-SiC is expected to show the highest performance because of the lowest interface state density due to the narrower band gap compared to other polytypes [1]. However, large and high quality substrate of 3C-SiC has not been reported. Comparably thicker and higher quality growth of 3C-SiC has been reported by heteroepitaxial growth on Si substrate using improved CVD method [2]. However, some stacking faults have remained in the grown crystal. In the previous study [3], we attempted to grow 3C-SiC single crystal on a CVD (001) 3C-SiC by solution growth, on which plane preferable 3C-SiC growth is expected. In this study, the grown polytype and defects structure were analyzed using transmission electron microscopy (TEM).

Crystal growth was performed on (001) 3C-SiC by solution growth with Si solvent in the carbon crucible at 1700 °C for 3 h 40 min. 3C-SiC wafer which had been prepared by heteroepitaxial growth on Si substrate using CVD method was used as a seed crystal. The TEM samples were prepared by micro sampling method using a focused ion beam (FIB) system JEOL JEM-9320FIB operating at 30 kV. TEM observation with the weak beam method were carried out in JEOL JEM-200CX operating at 200 kV.

Fig. 1 shows a scanning ion microscope (SIM) image of crystal section after solution growth. There are borderlines along (1-11) or (-111) plane between bright and dark contrast area in Fig. 1. In order to investigate the difference of structure between the two areas with different SIM contrast, we prepared TEM samples on the seed crystal and the grown crystal across the borderline, as indicated by a and b in Fig. 1, respectively. Fig. 2 shows the TEM images and selected area diffraction (SAD) patterns of those samples. The SAD patterns identified as 3C-SiC were observed over the whole area of both seed and grown crystal. Thus, it is found that only 3C-SiC has grown during solution growth without polytype transformation. In both Fig.2 (a) and (b), we can see that stacking faults exist much larger in bright SIM contrast area than dark SIM contrast area. Such characteristic SIM contrasts and stacking faults distribution were observed in the samples not only grown crystals but also simply annealed crystals (Fig. 3). It is thought that annealing during solution growth accompanies relaxation of the strain which has been introduced during the CVD growth of seed crystal, as the result of induced high density of stacking faults. Additionally, it is found that, among SAD patterns taken from the areas indicated as point A both in Fig. 2(a) and (b), only the patters with the incident beam direction z along [10-1] showed the streaks along [1-11] direction. Such streaks in the SAD pattern suggest that the existence of high density of stacking faults with the condition of the incident beam direction parallel to the fault plane [4]. The result proves

that the concentrated growth of (1-11) stacking faults in the observed area. Taking into account the above mentioned results, it could be deduced that the expansion of (1-11) and (-111) stacking faults were prevented by (-111) and (1-11) stacking faults grown along the borderline observed left and right hand side of Fig. 1, respectively. Consequently, the defect free region was formed and then, as shown in Fig. 4, the high quality 3C-SiC single crystal which showed dark SIM contrast was grown.

Reference

[1] A. Schöner et al., Chem. Vap. Deposition. 12 (2006) 523
[2] H. Nagasawa et al., J. Crystal Growth. 237 (2002) 1244
[3] R. Tanaka et al., Mater. Sci. Forum 615-617 (2009) 37
[4] H. Yamane et al., J. Alloys Comp. 476 (2009) 282

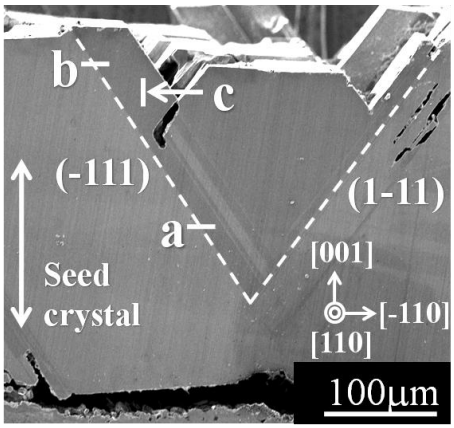

Fig.1. SIM image of (110) section of the sample after solution growth.

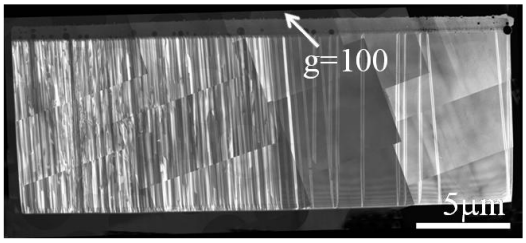

Fig.3. TEM image of the annealed sample.

Fig.4. TEM image of the defect free crystal prepared from ‘c’ in Fig.1.

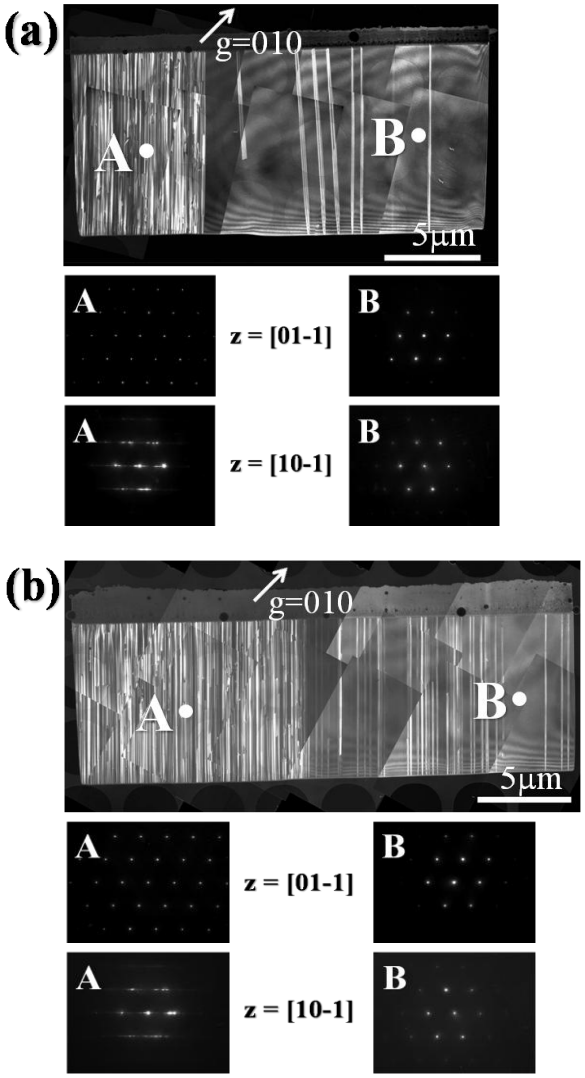

Fig.2. TEM image and SAD patterns (z = [01-1] and [10-1]) from areas indicated as point A and B of (a) seed and (b) grown crystal prepared from ‘a’ and ‘b’ in Fig.1 , respectively.