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Reducing the wafer off angle for 4H-SiC homoepitaxy

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Silicon carbide (SiC) is a potentially useful material for high-power, high-frequency, high-temperature, low-power-loss electronic devices. Bulk crystal growth of SiC ingots is usually carried out by sublimation growth method. This method suffers, however, from the problem of a lack of control over doping concentrations. Such control is necessary for the fabrication of electronic devices on semiconductor wafers. It is therefore necessary to use epitaxial growth method, which can give good reproducible control of doping concentration on SiC wafers grown by sublimation method.

During early studies of SiC epitaxial growth, it was difficult to control the polytype. SiC has many polytypes, such as 3C, 6H, 4H, and 15R. These polytypes differ in stacking sequences of three Si-C layers along the *c*-axis. However, the crystal structure on the {0001} plane of α-SiC (as in 6H and 4H polytypes) is identical to that on the (111) plane of the 3C polytype. For this reason, 3C-SiC can easily be made to include α-SiC epitaxial layers grown on (0001) substrates by chemical vapor deposition. However, step-controlled epitaxy, in which the growth is performed on off-axis substrates tilted several degrees toward the [11-20] direction,[1,2] could solve this problem and markedly increases in the stability of the polytype. In addition, a specular surface morphology can also be obtained under various growth conditions. As a result, high-quality SiC epitaxial wafers can be produced reliably. Nowadays, 4 degree off axis substrates was mainly used. However, existence of such off angle makes some problems. Concerning SiC wafer, wafer size have reached to 150mm and existence of large waste due to off cutting of an ingot is required to be reduced. In addition, density of basal plane dislocations propagated from substrate into epitaxial layer can be decreased with lower off angel.[3] For trench MOSFET, existence of wafer off angle makes anisotropy of a MOS channel characteristics.[4,5] Therefore, reducing the wafer off angle is strongly required to solve above problems.

In this study, we have investigated key factor for controlling the polytype and surface morphology of 4H-SiC homoepitaxial growth on lower off angle substrate than 4^{o} off axis.

Epitaxial growth was carried out by using conventional hot wall type chemical vapor deposition with $H_2 – C_3H_8 – SiH_4$ gas system. Typical growth temperature, growth pressure, SiH_4 flow rate and C/Si ratio is 1600 ^{o}C, 250 mbar, 6.67 sccm and 0.6 - 0.9, respectively. Vicinal off angled 2 or 3 inch wafers, theses off angle are lower than 1^{o}, have been used. The wafer off angle was confirmed by XRD measurements. The surface morphology was investigated by Nomarski microscope and atomic force microscope. Polytype stability was investigated by using photoluminescence image system.

As the result, we found that the control of surface energy, control of vicinal off angle itself, and high temperature growth is quite important to control the surface morphology and polytype stability of epitaxial layer grown on vicinal off angled substrate.

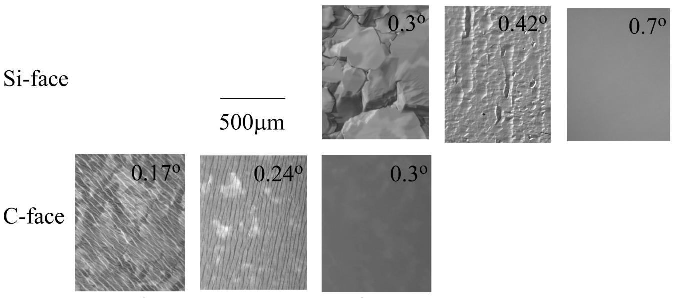

Figure 1 Surface morphologies of grown epitaxial layer with various vicinal off angle and different pace polarity.

Figure 1 shows surface morphologies of grown epitaxial layer with various vicinal off angle and different pace polarity. It is quite clear that surface morphology is strongly depended on vicinal off angle and found to be able to obtain the good surface morphology by controlling vicinal off angle. The critical off angle to obtain the good surface morphology is different with the face polarity. For C-face, more than 0.3^{o} is required to obtain the good surface morphology. However, the critical off angle on Si-face is 2.5 times larger than that on C-face. As well known, the surface energy of C-face is smaller than that of Si-face. Then, the generation of step bunching is well suppressed at very low off angle as shown in this figure. For, Si-face, large step bunching is easily generated due to have bigger surface energy than that of C-face and 2D nucleation is also generated at wider terrace of bunched step. Then, the critical off angle becomes large as shown in this figure.

Si-rich condition, that means low C/Si ratio, also suppress the generation of step bunching (not shown). It is considered that Si-rich condition also reduce the surface energy and enhances the step flow growth.

By using above results, we have successfully grown the epitaxial layer on vicinal off angled 2 or 3 inch substrate with good surface morphology in both faces.

The defect density of 3 inch Si-face epitaxial layer was estimated to be lower than 1 cm^{-2} that was counted in whole wafer. In addition, *I-V* characteristics of Ni SBD fabricated as grown epitaxial layer showed high blocking voltage about 1kV with high yield of about 80%. These results mean that the quality of grown epitaxial layer is quite similar to that of 4 degree off epitaxial layer. Therefore, these results suggest that the wafer off angle for epitaxial growth can be reduced to lower than 4 degree.

Details will be presented in this conference.

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