Preparation of cubic silicon carbide with smooth surface on carbonized porous silicon

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Silicon carbide (SiC) has been the primary candidate for high temperature operation electronics and low power consumption electronics because of its theoretical properties. Cubic SiC (3C-SiC) has a high electron mobility (1000 $cm^2/V \cdot s$), wide bandgap (2.2 eV) and high saturation electron drift velocity (2.5×10^7 cm/s) .[1, 2] Many researchers aimed to obtain a large area 3C-SiC by heteroepitaxial growth of the 3C-SiC on a large area silicon (Si) substrate.[3, 4] However, the 3C-SiC grown on the Si substrate was of poor quality probably because of defects arising from the strain due to a lattice mismatch and thermal mismatch between SiC and Si.

Porous Si is considered as an effective template for heteroepitaxial growth of lattice mismatched materials. Luryi and Suhir theoretically considered the relaxation of strain in the heteroepitaxial over layer prepared on the seed pads separated by trenches, suggesting the use of porous Si for the heteroepitaxial growth of lattice mismatched materials.[5] Previous work of 3C-SiC growth on porous Si conducted by Purser *et al* has been reported at rather low temperature (1050 °C) for the 3C-SiC growth.[6] It is believed that higher temperature growth of 3C-SiC, above 1150 °C, is required to obtain a device grade crystal.[7] However, porous Si is sensitive to annealing and changes its structure by the annealing (Fig. 1). Thus, to obtain porous Si with smooth surface is difficult at the elevated temperature. The aim of this paper, to describe, for the first time, the preparation of porous Si with smooth surface at the elevated temperature (1150 °C) and growth of 3C-SiC thin film with smooth surface on the porous Si.

3C-SiC thin film with smooth surface was obtained on carbonized porous Si (Fig. 2). Porous Si of porosity ranging 20−60 % was used. Carbonized porous Si was prepared through an annealing of porous Si in propane gas flow at 1150 ºC. 3C-SiC was grown on the carbonized porous Si at 1150 ºC by low-pressure vapor phase epitaxy using silane-propane-hydrogen system. X-ray diffraction revealed existence of 3C-SiC on carbonized porous Si, which is considered playing a major role in maintaining the smooth surface at the elevated temperature (Fig. 3).

Carbonized porous Si is essential, because 3C-SiC with smooth surface was obtained when 3C-SiC was grown on carbonized porous Si, whereas 3C-SiC with rough surface was obtained when 3C-SiC was grown on porous Si without carbonization.

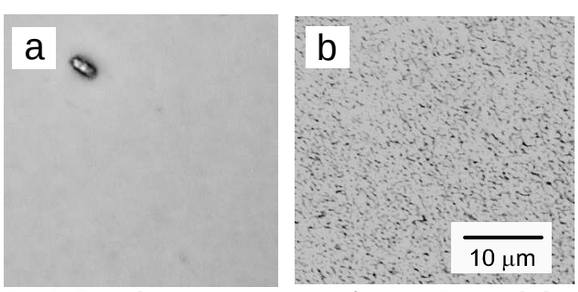

Fig. 1. Optical microscope image of porous Si annealed at 1150 °C, a) in propane gas flow (carbonized) and b) without propane gas flow

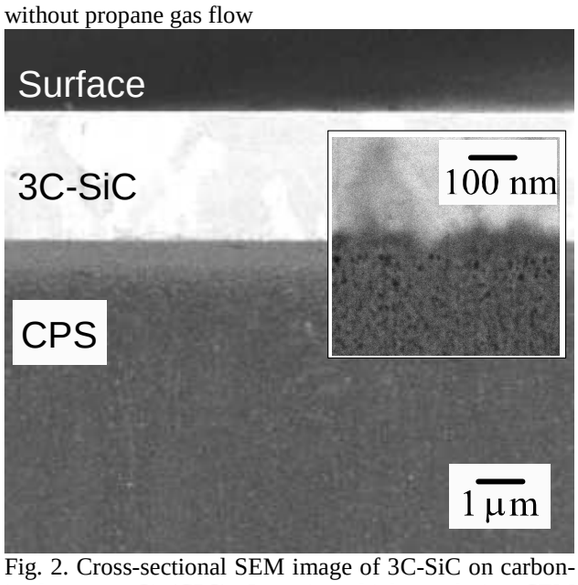

Fig. 2. Cross-sectional SEM image of 3C-SiC on carbonized porous Si (CPS). Inset is a high resolution SEM image of near the interface of 3C-SiC and CPS.

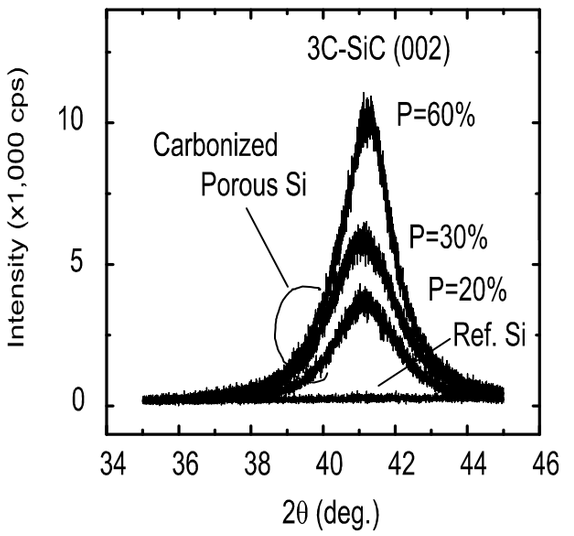

Fig. 3. X-ray diffraction pattern of carbonized porous Si with various porosities (P) ranging from 20 to 60 %. Also standard Si (carbonized) is shown for reference.

Acknowledgements

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References

1. M. Bhatnagar and B. J. Baliga, IEEE Trans. Electron Devices, **40**, 645 (1993).
2. D. K. Ferry, Phys. Rev. B, **12**, 2361 (1975).
3. S. Nishino, J. A. Powell, and H. A. Will, Appl. Phys. Lett., **42**, 460 (1983).
4. S. Nishino, H. Suhara, H. Ono, and H. Matsunami, J. Appl. Phys., **61**, 4889 (1987).
5. S. Luryi and E. Suhir, Appl. Phys. Lett., **49**, 140 (1986).
6. D. Purser *et al*, Mater. Sci. Forum, **338-342**, 313 (2000).
7. Y. Ishida, T. Takahashi, H. Okumura, S. Yoshida, and T. Sekigawa, Jpn. J. Appl. Phys., **36**, 6633 (1997).