

Low-temperature epitaxial growth of β -SiC by multiple-energy ion implantation

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A cubic silicon carbide (β -SiC) buried layer was synthesized in Si(111) using a combination of multienergy carbon ion implantation at room temperature and post-thermal annealing. The crystal structure and the crystalline quality of the β -SiC layer was identified by x-ray diffraction in the θ - 2θ mode and was examined by pole figure measurement of x-ray diffraction. Interestingly, by using the multienergy implantation technique, the β -SiC buried layer showed epitaxial growth at annealing temperatures as low as 400 °C. At an annealing temperature of 800 °C, the x-ray pole figures show that the β -SiC buried layer has a near-perfect epitaxial relationship with the silicon substrate. [S0163-1829(98)02843-4]

Silicon carbide is a promising candidate material for device applications due to its outstanding properties such as wide band gap, high-temperature stability and high thermal conductivity, radiation hardness and chemical inertness, etc.^{1,2} Considerable effort has been devoted to developing and improving methods to produce silicon carbide with high purity and good crystalline quality. Among these methods, high-dose carbon implantation into silicon in combination with subsequent or *in situ* thermal annealing, namely, ion beam synthesis (IBS), has been proven a powerful means of synthesizing polycrystalline or epitaxial β -SiC in silicon.^{3,4} In accordance with the previous studies, the key factor that determines the crystalline quality of the β -SiC layer by IBS is the annealing temperature.⁵ It seems to be clear from the published results to date that annealing temperatures between $\sim$ 850 and 900 °C are needed to crystallize the implanted Si-C layer and transform the disordered Si-C bonds into the ordered β -SiC structure.^{6,7} However, other authors demonstrate that much higher annealing temperatures, e.g., 1000,⁸ 1250,⁹ and 1405 °C (Ref. 10) are demanded to achieve crystalline silicon carbide layer in silicon. It has been reported also that other conditions like the implantation temperature¹¹ and the implanted carbon dose⁹ might have some influence on the growth of the buried silicon carbide layer. Therefore, more systematic work is required for successful application of IBS to synthesize SiC.⁵

Recently, a multienergy ion implantation approach has been proposed to produce thick silicon carbide layer in silicon, and to modify its composition profile.¹² By selecting carefully the implantation energy and dose of carbon ions, a rectangular carbon concentration profile can be achieved for the buried β -SiC layer using this approach.¹² It is therefore applicable in device fabrications now that the β -SiC layer is able to grow epitaxially at low annealing temperatures.

We report, in this paper, the epitaxial growth of the β -SiC buried layer in silicon at low annealing temperatures by using this multienergy ion implantation technique.

A silicon wafer of (111) orientation was used as a substrate for multienergy carbon ion implantation. Using TRIM simulation, three different energies, i.e., 160, 100, and 60 keV, and three corresponding doses, i.e., 1×10^{18} , 9×10^{17} , and 5.3×10^{17} C⁺/cm², were selected for the implantation. The beam current density of the carbon ions was controlled in the range of 9–12 μ A/cm², which results in a target temperature of about 335–365 °C due to the beam heating effect. The implanted samples were then annealed in argon flux at temperatures from 400–1200 °C for 10 h to allow the growth of crystalline silicon carbide. After annealing, all samples were analyzed by x-ray diffraction in the θ - 2θ mode to identify the structure and by the pole figure measurement of the x-ray diffraction to examine the crystalline quality of the SiC buried layer.

X-ray diffraction analysis in the θ - 2θ configuration was carried out using a precise x-ray diffractometer with a resolution of 0.002°. The x-ray-diffraction pattern was obtained using a step of 0.02° with Cu K α 1. The Cu K α 2 was filtered by a monochromator. Figure 1 shows the diffraction pattern

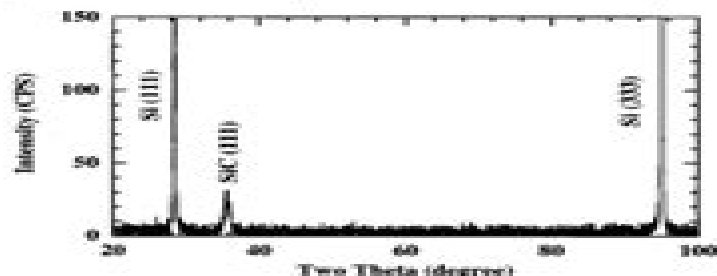


FIG. 1. The x-ray-diffraction pattern of the β -SiC buried layer formed after 10 h annealing at 800 °C, showing clearly the β -SiC (111) peak.

Low Temperature Epitaxial Growth Of Semiconductors

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