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THE FORMATION OF ULTRATHIN SiC LAYER BY OXYGEN AND SILICON IMPLANTATION INTO 4H-SiC(0001) SUBSTRATE

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Abstract

We have studied the formation of ultrathin SiC layer on a thin buried oxide layer embedded in the 4H-SiC(0001) substrate by 50-keV O^+ and 90-keV Si^+ ion implantation followed by annealing at 1100°C for 5 h in Ar ambient. The structures before and after implantations of O and Si were analyzed by Rutherford backscattering spectrometry.

I. Introduction

Si-on-insulator (SOI) structure consists of a surface crystalline Si layer separated from a Si substrate by a buried oxide (BOX) layer. The electronic devices formed on this SOI structure has excellent electric properties of high-performance, low-energy consumption, and high-radiation hardness compared to those formed on the bulk Si substrate. However, the performance of semiconductor devices fabricated on conventional bulk-Si substrates approaches the theoretical limit characterized by the material properties, and thus the effective solutions are strongly demanded. As shown in Fig. 1, laterally confined patterned SOI structure is expected to be one of the candidates for a novel type of high performance and power-saving electronic devices [1-3]. It should be here noted that ion implantation technique is particularly inevitable for synthesizing laterally confined microstructure. In addition, SiC having a wide bandgap of 3.2 eV is widely known as a famous semiconductor material in place of Si-based semiconductor technology.

In this study, we aim at the synthesis of ultrathin SiC layer separated by a BOX layer from SiC substrate, because the electronic properties of SiC with wide bandgap, high drift

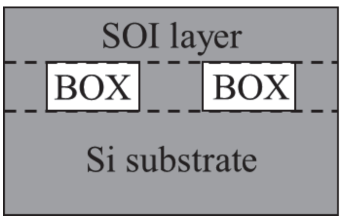

Fig. 1. Schematic image of pattern SOI structure

velocity, and high breakdown electric field are quite excellent compared to those of Si [4]. The BOX layer was first formed by a single O^+ implantation at 800°C followed by 1150°C annealing; however, the single O^+ implantation could not form a stoichiometric SiO_2 BOX layer. So, we performed Si^+ and O^+ co-implantation at 800°C followed by 1100°C annealing to promote the formation of a uniform SiO_2 layer. The elemental compositions and crystallinity were measured by Rutherford backscattering spectrometry (RBS).

II. Experiment

Figure 2 shows the fabrication process of SOI/BOX structure using the separation by implanted oxygen (SIMOX) method [5,6]. We formed two kinds of samples by a single implantation of 50-keV O^+ and co-implantation of 50-keV O^+ and 80-keV Si^+ into 4H-SiC(0001) substrates at the substrate temperature of 800°C. The ion fluences of O and Si ions were 3×10^{17} and 2.0×10^{17} ions cm^{-2}, respectively. The mean projected ranges of O and Si in SiC were estimated to be ~70 nm by TRIM simulation. These samples were then annealed at 1100°C for 5 h in Ar ambient. Finally, we measured the elemental composition and crystallinity by RBS using 2.0 MeV $^6Li^{2+}$ ions.

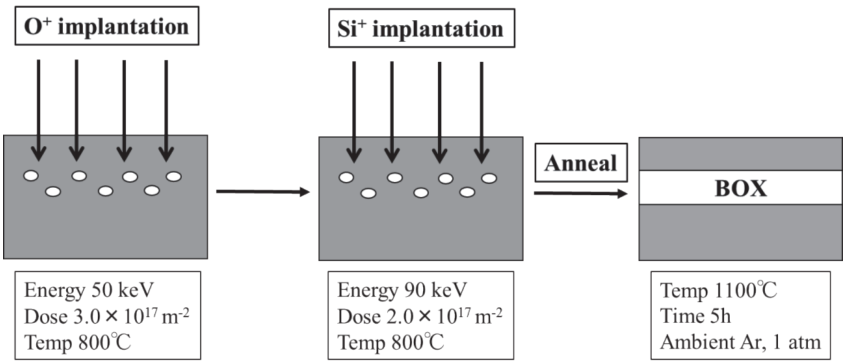

Fig. 2. Fabrication process of SOI/BOX structure by SIMOX method

III. Results and discussion

Figure 3 shows RBS spectra and elemental compositions observed for O^+ implanted (a-d) and Si^+ and O^+ co-implanted (e-h) samples. From the RBS spectra of the single O^+ implantation, the elemental compositions was not significantly changed after high-temperature annealing as shown in Fig. 3(a-d). Regardless of a high fluence of oxygen ion, the crystallinity near the surface region was found to be kept, owing to hot implantation at 800°C. It is suggested that the near surface area consists of the SiC single

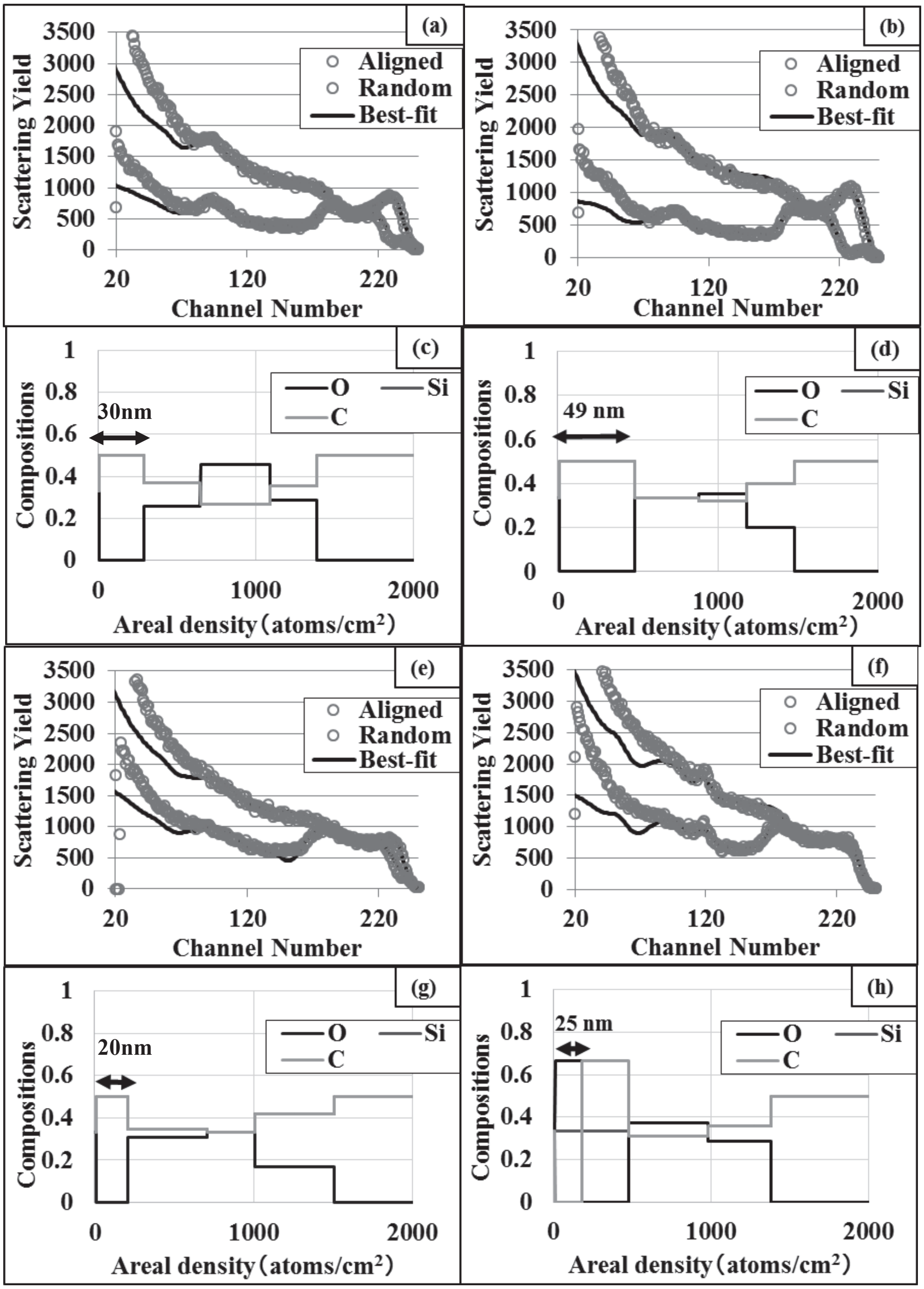

Fig. 3. RBS spectra and elemental compositions observed for O^+ implanted (a-d) and Si^+ and O^+ co-implanted (e-h) samples.

crystal. The thickness of the SiC layer before annealing was approximately estimated to be 30 nm, and that after annealing was remarkably increased to 59 nm. It is indicated that the recrystallization of damaged layers occurred during post-annealing process. Concerning the BOX layer, the thickness was slightly decreased and thus the oxygen concentration was increased. However, this area consists of the mixture of Si, O, and C species, suggesting that the silicon carbonate structure was probably formed as shown in the elemental compositions (Fig. 3 (c) and (d)).

In the case of co-implantation of Si and O, the crystallinity of SiC near the surface was almost lost and the thickness was decreased to about 20 nm for the as-implanted sample. After annealing at 1100°C, a SiO_2 layer of ~25 nm thick was formed on the surface and the surface was changed to amorphous structure.

Consequently, the single oxygen implantation followed by annealing at 1100°C was found to form a thin SiC layer separated by a BOX layer. However, the BOX layer consists of Si carbonate structure rather than a stoichiometric SiO_2 layer, which is different from the case of oxygen implantation into Si substrate. On the other hand, the co-implanted sample showed the significant degradation of the surface SiC layer, indicating that high ion fluence caused the amorphization of surface SiC layer.

IV. Conclusions

In this study, we investigated the formation of buried oxide layer embedded in 4H-SiC(0001) substrate by O and Si ion implantation at 800°C followed by annealing at 1100°C. The single implantation of O in SiC succeeded in the separation of ultrathin SiC crystalline layer by buried silicon carbonate layer.

As for the prospects in the near future, we will perform two kinds of method. One is IBIEC (Ion-beam-induced epitaxial crystallization) method by irradiating Ar^{2+} ions into the samples which were formed for the lower Si and O implantation doses. Another method is performing implantation and post-annealing at higher temperatures.

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