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ION BEAM INDUCED INTERFACIAL AMORPHIZATION IN SiGe

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Abstract

The surface region of 400 nm thick SiGe/Si containing 10% Ge was amorphized to the depth of 230 nm by Ge ion bomardment to a fluence of 1.0×10^{15} ions/cm^2 at the energy of 200 KeV at room temperature. Some samples were annealed in a N_2 atomosphere at 300℃ for 10 min. Then the samples were bombarded with Ge ions at the energy of 3.9 MeV to fluences of 4×10^{14}, 7×10^{14} and 9×10^{14} ions/cm^2 at room temperature. Rutherford backscattering spectrometry (RBS) measurements revealed that as the fluence increased the a/c interface between amorphous and crystal proceeded toward internal of the sample, indicating a layer-by-layer movement of the interface. The thickness of amorphous layer of the sample without annealing increased as 7.79 nm / 10^{14} ions/cm^2 in contrast to the sample with annealing 4.82 nm / 10^{14} ions/cm^2, representing more rapid interface movement in the sample without annealing.

Ⅰ. Introduction

Ion beam induced epitaxial crystallization (IBIEC) and ion beam induced interfacial amorphization (IBIIA) are well known as the crystallization and amorphization processes using ion beam techniques at low temperatures. IBIEC and IBIIA are widely studied in Si[2,3,6,7)] but there were few studies for SiGe inspite of its usefulness for high frequency devices[1)]. Although IBIEC is extensively studied[2-5)], IBIIA, which is the reverse process of IBIEC, is less studied than IBIEC, where a/c interface moves toward the single crystalline substrate as a result of increase of the amorphous layer. As far as we know, study on IBIEC in SiGe[4,5)] existed but never on IBIIA in SiGe.

In this paper, we investigate IBIIA in SiGe, focusing on the rate of amorphization in the sample with and without annealing before high energy irradiation for IBIIA.

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Ⅱ. Experimental

Samples used were (100) single crystalline SiGe containing 10% Ge with a thickness of 400 nm epitaxially grown on Si substrates. The surface region of SiGe were amorphized by Ge ion bomardment to a fluence of 1×10^{15} ions/cm^2 at the energy of 200 KeV at room temperature. The bombarded sample was divided into two pieces: one was annealed in a N_2 ambient at 300℃ for 10 min and the other was not. Then the both samples were bombarded with Ge ions with the energy of 3.9 MeV at room temperature to fluences of 4×10^{14}, 7×10^{14} and 9×10^{14} ions/cm^2.

The crystallinity was analyzed by 1.5 MeV He^+ Rutherford backscattering spectrometry (RBS) with channeling techniques. In order to detect the slight movement of the a/c interface, the scattering angle was chosen as 120° to increase depth resolution. Transmission electron microscopy (TEM) was used to observe the a/c interface.

Ⅲ. Results & discussion

Figure 1 shows random and aligned RBS spectra from SiGe/Si samples with and without annealing in a N_2 ambient at 300℃ for 10 min after 200 keV Ge irradiation to a fluence of 1×10^{15} ions/cm^2. As shown in Fig. 1 the samples with and without annealing were amorphized to the depth of 230 nm. After annealing the a/c interface becomes sharper than that before annealing. Figures 2 and 3 show RBS spectra from the samples with and without annealing, respectively. These samples were irradiated with Ge ions at the energy at 3.9 MeV to fluences of 4×10^{14}, 7×10^{14} and 9×10^{14} ions/cm^2 at room temperature. As shown in Fig. 2, the a/c interface moved towards lower energies with increasing fluence, indicating that IBIIA occurred. As shown in Fig. 3, although the a/c interface similarly moved towards lower energies, which indicated the occurrence of IBIIA, the movement was small compared with that found in the sample without annealing.

In these figures, aligned spectra do not reach the random yield in the energy range corresponding to the amorphous region. The discrepancy is considered to result from the geometry in the setup of the detector and the sample for the random spectrum measurement. For the random spectrum measurement, the sample was inclined 7° horizontally to avoid channeling. In contrast, aligned spectrum measurement was carried out with almost normal incidence. The difference of the angle of inclination made the increase of outward path of ions. As a result of the energy loss increase at outward path, the spectrum was enlarged along the energy axis according to the increase of the energy loss. Since the total yield from the amorphous layer does not change, the spectrum extended along the energy axis results in the spectrum height decrease.

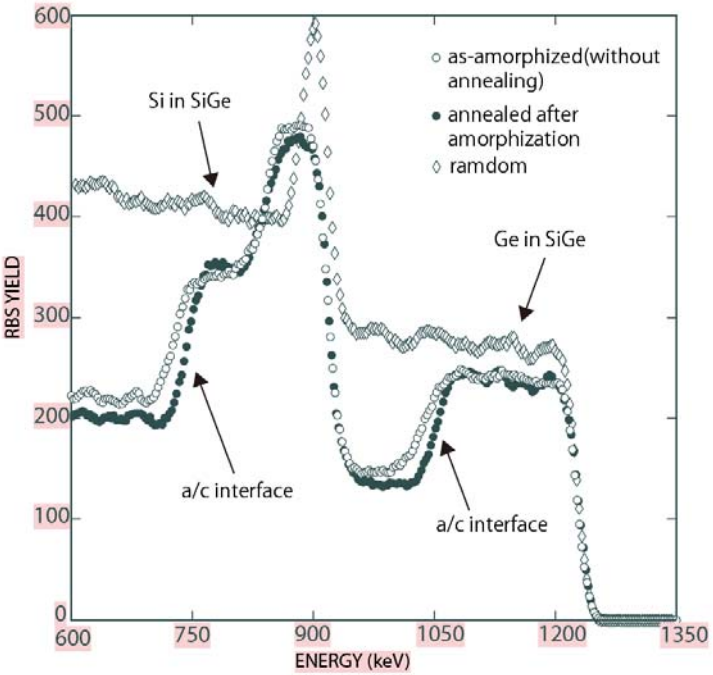


Fig. 1 Random and aligned RBS spectra from SiGe/Si samples amorphized by 200 keV Ge^+ irradiation to a fluence of 1×10^{15} ions/cm^2 at room temperature with and without post-annealing in a N_2 ambient at 300℃ for 10 min.

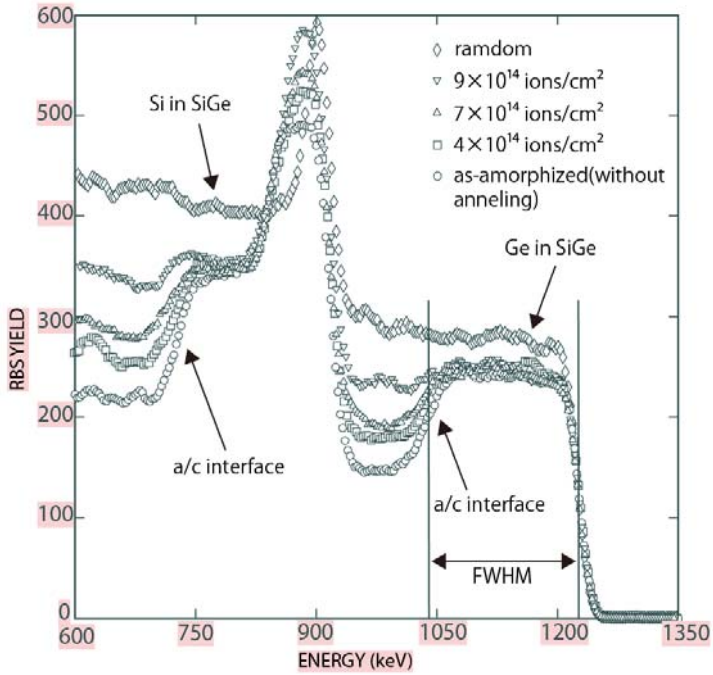


Fig. 2 Random and aligned RBS spectra from SiGe/Si samples without annealing before irradiation with 3.9 MeV Ge ions to fluences of 4×10^{14}, 7×10^{14} and 9×10^{14} ions/cm^2 at room temperature. Amorphous region width is evaluated from FWHM between leading and back edges of the

aligned spectra corresponding to the amorphous region.

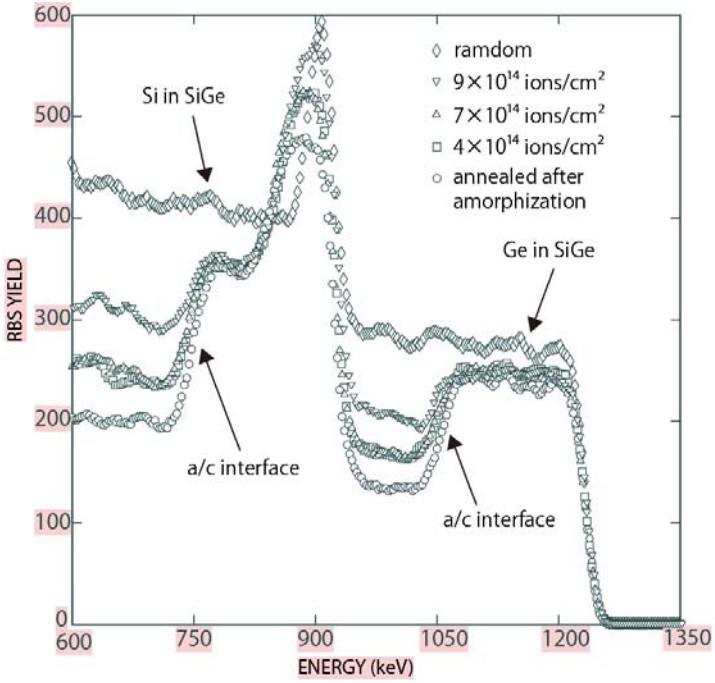


Fig. 3 Random and aligned RBS spectra from SiGe/Si samples with annealing before irradiation with 3.9 MeV Ge ions to fluences of 4×10^{14}, 7×10^{14} and 9×10^{14} ions/cm^2 at room temperature.

Fig. 4 represents increment of the energy width of amorphous region for the fluence. The amorphous layer increased linearly in the both samples with and without annealing. The deviation found in the sample without annealing at a fluence of 4×10^{14} ions/cm^2 was considered to be within the statistical fluctuation. The energy width of the amorphous region of the sample with and without annealing increased as 3.9 keV / 10^{14} ions/cm^2 and 6.3 keV / 10^{14} ions/cm^2, which corresponded to 4.82 nm and 7.79 nm, respectively.

Fig. 5 (a) and (b) are XTEM images from the a/c interface of the sample with and without annealing. The a/c interface transient region of the sample without annealing is broader than that with annealing, indicating that the transient region became narrow after anneling. This result is well agree with that shown in Fig. 1, which represented sharp transition at a/c interface. It is considered that the atoms in the transient region in the sample without annealing is more mobile than those in the sample with annealing because the incomplete tetrahedral covalent bonding increased due to by a lot of displacement atoms in the transient region. The increase of the mobile atoms consequently leads to enhance the amorphiztion.

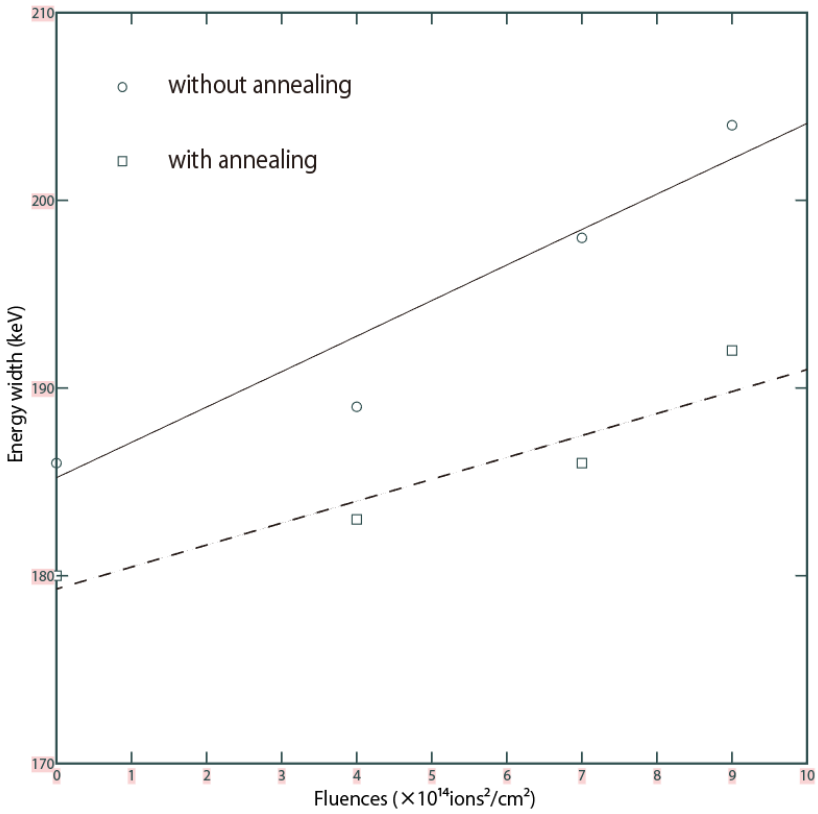
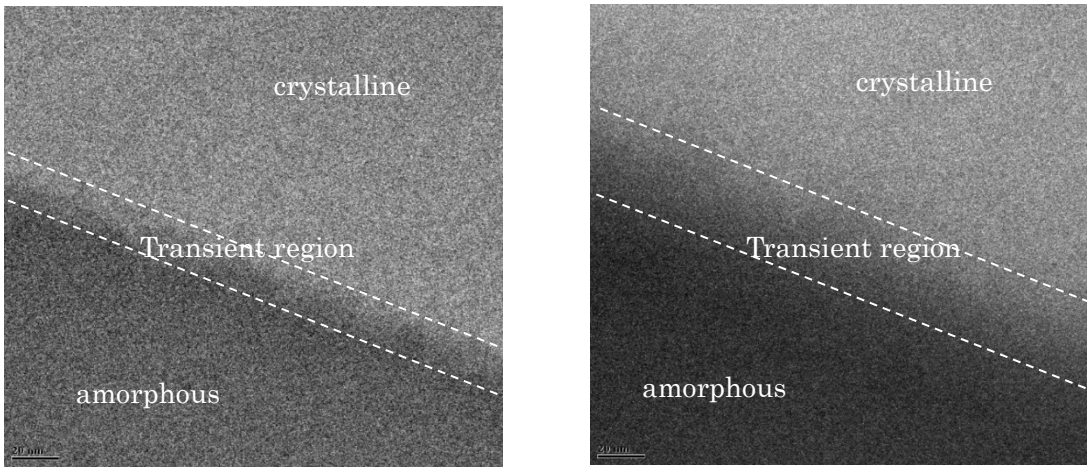


Fig. 4 The energy width of amorphous region evaluated from FWHM between edges corresponding to the surface and a/c interface as a function of Ge fluence. The solid line indicates the regression line of plots in the sample without annealing. The dashed line indicates the regression line of plots in the sample with annealing



(a) (b)

Fig. 5 XTEM images of the a/c interface of the sample amorphized by Ge irradiation with 200 keV to a fluence of 1×10^{15} ions/cm^2 at room temperature (a) with and (b) without post-annealing in a N_2 ambient at

300℃ for 10 min respectively.

Ⅳ Conclusion

The surface region of 400 nm thick SiGe/Si containing 10% Ge was amorphized to the depth of 230 nm by Ge ion bomardment to a fluence of 1×10^{15} ions/cm^2 at the energy of 200 KeV at room temperature. Some samples were annealed in a N_2 ambient at 300℃ for 10 min. The samples were bombarded with Ge ions to fluences of 4×10^{14}, 7×10^{14} and 9×10^{14} ions/cm^2 at the energy of 3.9 MeV at room temperature. RBS with channeling technique revealed that ion beam induced interfacial amorphization (IBIIA) occurred in these samples and the a/c interface became sharp after annealing. In addition, the measurement revealed that the movement of the interface of the sample without annealing was faster than that of sample with annealing. The thickness of amorphous layer of the sample without annealing increased as 7.79 nm / 10^{14} ions/cm^2 in contrast to the sample with annealing 4.82 nm / 10^{14} ions/cm^2. From the TEM observation the a/c interface region of the sample without annealing is broader than that with annealing before IBIIA. That is to say, increase of the incomplete tetrahedral covalent bonding in the transient region of the sample without annealing enhanced IBIIA.

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