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C Atomic Order Doping at Si/$Si_{1-x}Ge_x$/Si Heterointerface and Improvement of Thermal Stability

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High performance SiGe-based heterodevices require high Ge fraction and it is essential to suppress the intermixing between Si and Ge at Si/SiGe heterointerface. It was reported that C introduction into SiGe heterostructure is effective to control lattice strain and B diffusion [1]. In our previous work, it was reported that the intermixing between Si and Ge at Si/Ge heterointerface during heat treatment is suppressed by the existence of C atom at the interface [2]. In the present work, C atomic order doping at Si/$Si_{0.5}Ge_{0.5}$/Si heterointerface and the redistribution of Ge fraction during heat treatment is investigated.

The 3nm-thick Si/5nm-thick strained $Si_{0.5}Ge_{0.5}$/Si heterostructure was epitaxially grown at 450-500°C by low pressure chemical vapor deposition using the SiH_4-GeH_4 gas system [3]. The atomic layer order doping of C to the Si/$Si_{0.5}Ge_{0.5}$/Si heterointerface was performed at 400-500°C by SiH_3CH_3 reaction [4]. Some of the samples were heat-treated at 700-750°C for 1hour in H_2 atmosphere. C atom amount at Si/$Si_{0.5}Ge_{0.5}$/Si heterointerface was evaluated by repetition of 0.6-1.3nm-thick wet etching and X-ray photoelectron spectroscopy(XPS) measurement. The distribution of Ge fraction in Si/$Si_{0.5}Ge_{0.5}$/Si heterostructure was also evaluated by the above depth profile measurement method and X-ray diffraction(XRD).

At the Si/$Si_{0.5}Ge_{0.5}$ heterointerface (surface side), the C atom amount is $1.1\text{x}10^{14}\text{cm}^{-2}$ and almost equal to the initial amount ($9.0\text{x}10^{13}\text{cm}^{-2}$) before the Si capping deposition. However, at the $Si_{0.5}Ge_{0.5}$/Si heterointerface (substrate side), the C atom amount is $1.6\text{x}10^{13}\text{cm}^{-2}$ and smaller than the initial amount ($5.8\text{x}10^{13}\text{cm}^{-2}$) before the $Si_{0.5}Ge_{0.5}$ deposition. Depth dependence of Ge 3d XPS intensity of Si/$Si_{0.5}Ge_{0.5}$/Si and Si/$Si_{0.5}Ge_{0.494}C_{0.006}$/Si heterostructures before and after heat treatment at 700°C is shown in **Fig. 1**. The redistribution of Ge fraction due to heat treatment is scarcely influenced by C addition.

XRD rocking curves of Si/$Si_{0.5}Ge_{0.5}$/Si and Si/C/$Si_{0.5}Ge_{0.5}$/C/Si heterostructures are shown in **Fig. 2**. The curve of Si/C/$Si_{0.5}Ge_{0.5}$/C/Si is nearly the same as that of Si/$Si_{0.5}Ge_{0.5}$/Si, in other words, Si/C/$Si_{0.5}Ge_{0.5}$/C/Si heterostructure has similar strain as Si/$Si_{0.5}Ge_{0.5}$/Si. The Ge fraction profile in Si/$Si_{0.5}Ge_{0.5}$/Si and Si/C/$Si_{0.5}Ge_{0.5}$/C/Si are shown in **Fig. 3**. It is found that the redistribution of Ge fraction in Si/$Si_{0.5}Ge_{0.5}$/Si during heat treatment is suppressed by C incorporation. It is considered that this interface strain is dispersed by C incorporation.

References

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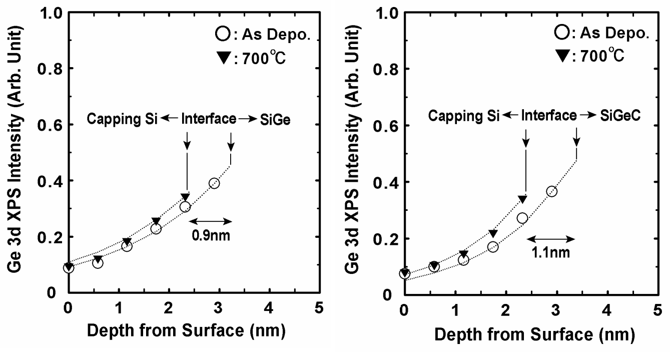


(a) Si/$Si_{0.5}Ge_{0.5}$/Si (b) Si/$Si_{0.5}Ge_{0.494}C_{0.006}$/Si

Fig. 1. Depth dependence of Ge 3d XPS intensity from Si/$Si_{0.5}Ge_{0.5}$/Si and Si/$Si_{0.5}Ge_{0.494}C_{0.006}$/Si heterostructures before and after heat treatment at 700°C for 1hour in H_2 atmosphere. Interface positions shown by arrows are determined by XRD measurement.

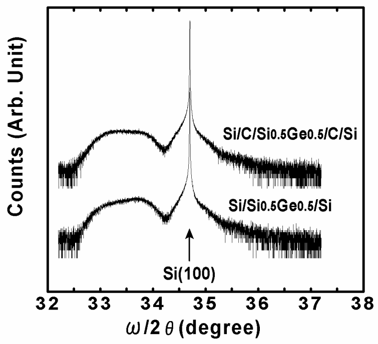
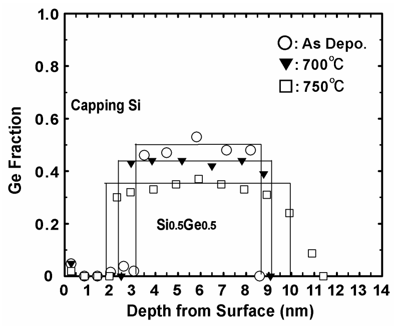
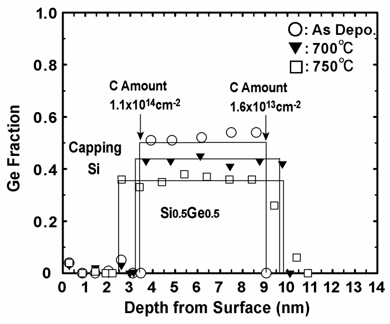


Fig. 2. XRD rocking curves of Si/$Si_{0.5}Ge_{0.5}$/Si and Si/C/$Si_{0.5}Ge_{0.5}$/C/Si heterostructures.



(a) Si/$Si_{0.5}Ge_{0.5}$/Si



(b) Si/C/$Si_{0.5}Ge_{0.5}$/C/Si

Fig. 3. Estimated Ge distribution of Si/$Si_{0.5}Ge_{0.5}$/Si and Si/C/$Si_{0.5}Ge_{0.5}$/C/Si heterostructures before and after heat treatment. Solid lines are determined by XRD measurement.