In-situ observations of unidirectional growth processes of SiGe

M. Mokhtari, K. Fujiwara, H. Koizumi, J. Nozawa, S. Uda

Introduction

The expectations for solar cells have been increasing yearly toward solving energy and environmental problems worldwide. The multicrystalline Si (mc-Si) is one of the most important materials along with the Si single crystal (sc-Si) for the substrate of solar cells in the future, although other materials are being developed. It is well known that the inhomogeneous distribution of metallic impurities in mc-Si affects the solar cell efficiency. In this study, we investigated the effect of impurity element on the crystal/melt interface morphology and also investigated the distribution behavior of impurity by in situ observations.

Experimental procedures

We used an *in situ* observation system consisting of a furnace and a microscope for observing Si and SiGe crystal/melt interfaces. To observe the effects of impurity on the crystal growth behavior during unidirectional growth, germanium concentration added in silicon melt was changed.

Results

Fig. 1 shows the morphological transformation of crystal/melt interfaces of Si and SiGe. The flat interfaces (Fig. 1 (a) and (c)) transformed to zigzag-faceted interfaces (Fig. 1 (b) and (d)) when the growth rates increased. As we reported previously [1], the interface instability occurred at much lower growth rate in case of SiGe. We carefully observed the formation processes of zigzag-faceted interfaces of Si and SiGe, and found that those processes were markedly different between Si and SiGe. In case of pure Si, the zigzag-faceted interface was formed by the amplification of sinusoidal perturbations. On the other hand, in case of SiGe, the zigzag faceted interface was formed by encircling a Ge-rich melt. Therefore, the melt drops were remained in the crystal, as shown in Fig. 1(d). We will show that the wavelength of perturbation at the interface instability shortens with increase in Ge concentration

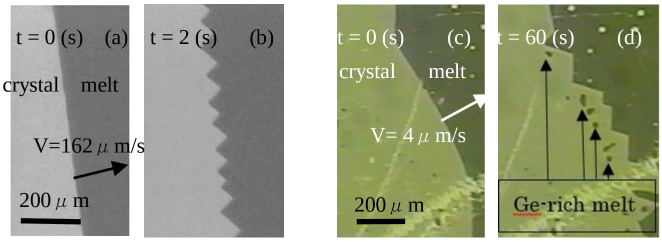

Fig. 1 Evolution of crystal/melt interface morphologies of pure Si ((a) and (b)), and SiGe (Ge=7at%) ((c)and (d)).

Fig. 2 shows the distribution of Ge concentration around 2 types of grain boundaries; random grain boundary and Σ3 grain boundary. It was suggested that the crystal/melt interface morphology is a determinant factor for explaining the distribution of Ge concentration. The crystal/melt interface formed a groove at a random grain boundary and the Ge concentration increased at the grain boundary. On the other hand, the crystal/melt interface was planar at a Σ3 grain boundary, not formed a groove, and the composition of Ge was not increased at the Σ3 grain boundary. These results show that the groove formation at the crystal/melt interface enhances the uptake of impurities.

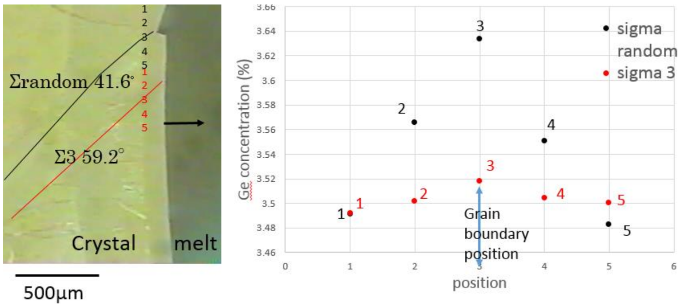

Fig. 2 Dstribution of Ge concentration around a random grain boundary and a Σ3 grain boundary in SiGe (Ge = 8.5at%).

References :[1] R. Gotoh, K. Fujiwara, X. Yang, H. Koizumi, J. Nozawa, and S. Uda, *Appl. Phys. Lett.* **100**, 021903 (2012)