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Solid phase growth of β-$FeSi_2$ on Si (111) with FeSi source and its application to photonic devices

K. Momiyama, K. Kanomata, S. Kubota, F. Hirose
Graduate school of Sci. & Eng., Yamagata University
4-3-16 Jonan, Yonezawa, 992-8510, JAPAN

β-$FeSi_2$ has been attracting many attention as a Si based material for optoelectronics. This material has been fabricated by various methods, for example, solid phase growth (SPG), reactive deposition epitaxy, molecular beam epitaxy, chemical vapor deposition, ion beam sputtering. However most of methods except for SPG require high cost for the deposition and the low productivity is an issue for mass production.

In SPG, Fe is initially deposited on a Si substrate, followed by annealing the surface in vacuum. Nakano *et al.* [1] reported the solid-phase reaction with initial Fe thicknesses of up to 17 monolayers (ML) and suggested that the grown β-$FeSi_2$ films changed from single crystalline to polycrystalline as the initial Fe thickness was increased. Hattori et al. [2] reported that β-$FeSi_2$ films can be formed on Si(111) with an initial Fe thickness of up to 56 ML, although SPG was not investigated beyond this region because β-$FeSi_2$ growth was believed to be impossible for those thicknesses.

In our previous study, we carefully investigated the solid-phase reaction with initial Fe thicknesses of up to 300 nm by using reflection high-energy electron diffraction (RHEED)[3]. We found that if the substrate temperature was controlled appropriately, single-crystalline β-$FeSi_2$ films were formed on the Si(111) surfaces. However, Fe islands remained on the surface after the SPG. It was suggested that we need to enhance the diffusion of Fe and Si during the growth to increase the thickness of β-$FeSi_2$. Then we examined an FeSi solid source for the initial deposition of FeSi on the Si surface. Since the Si atoms are provided with Fe at the initial deposition, we expected the promotion of the diffusion of Si during the solid phase growth. We found that this method allows a very low-temperature growth of β-$FeSi_2$ at 400 K.

In Fig.1, we summarized results of solid phase growth with the FeSi source. It was found that the crystal phase of FeSi changed from amorphous to the ring-like pattern by way of β-$FeSi_2$ according to the increase of temperature. The β-$FeSi_2$ growth was confirmed even with the initial Fe thickness of in excess of 50 nm. Fig.2 shows a SEM image of β-$FeSi_2$ obtained with the FeSi source. The flat surface was obtained without Fe islands. This is because Fe and Si from the FeSi source diffuse smoothly by providing Si atoms in the deposited film prior to the SPG process. In the conventional process with the Fe source, the Fe islands as the residue of the SPG reaction are unavoidable. We assume that the flat β-$FeSi_2$ film without the Fe islands is applicable for the optoelectronics. We are now examining a solar cell with the β-$FeSi_2$/Si heterostructure as shown in Fig. 3. In the meeting, we are going to discuss the reaction mechanism of β-$FeSi_2$ SPG growth with the FeSi source and demonstrate its application for a photosensing device.

Reference

[1] H. Nakano, K. Maetani, K. Hattori, H. Daimon, Surface Science 601 (2007) 5088.
[2]K. Hattori, K. Kataoka, A. Hattori, H. Daimon, Journal of The Surface Science Society of Japan 29-2 (2008) 120.
[3]K. Momiyama, K. Kanomata, S. Kubota, F. Hirose, to be published in Thin Solid Films.

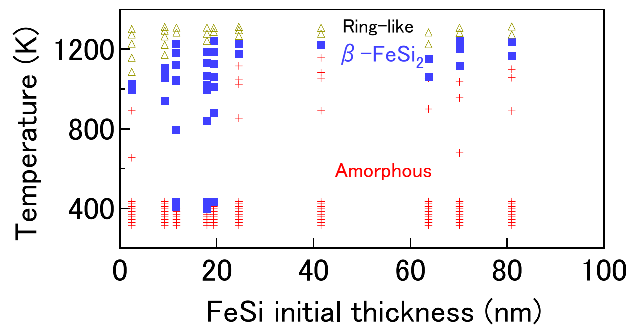

Fig1: Solid phase reaction on FeSi deposited Si(111) surface.

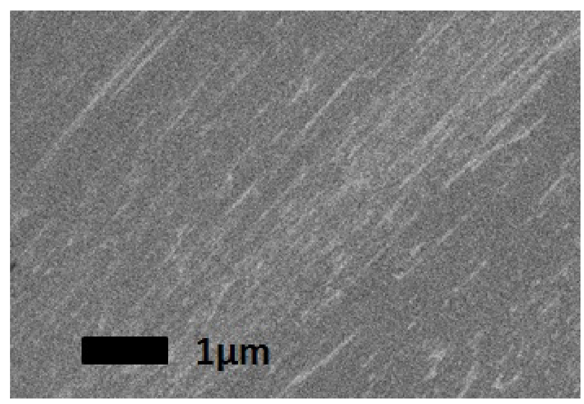

Fig.2: SEM image of β-$FeSi_2$ obtained with FeSisource. The initial deposition thickness of FeSi is 20nm. The SPG temperature was 397 K.

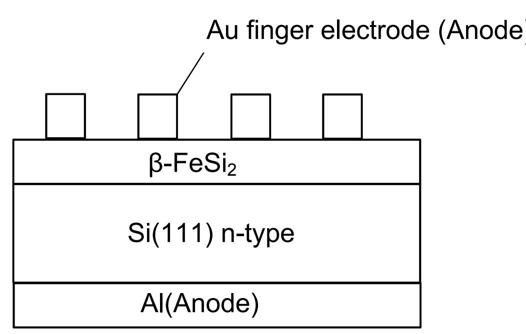

Fig.3: Test device structure for photo sensing.