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Epitaxial Growth of β-$FeSi_2$ on Single Crystal Insulator

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1. Introduction

β-$FeSi_2$ thin film is able to epitaxially grow on Si substrate [1], and has large hall mobility of 400 cm^2/Vs [2]. It has ability to control the electrical conduction type by doping transitional-metal, such as Mn and Co [3]. It is expected that the electrical conductive property could apply for electronic device. However, fabrication of epitaxial β-$FeSi_2$ thin film was reported only on Si substrate. If the growth technique of epitaxial β-$FeSi_2$ thin film would be established on various substrates such as insulator, larger ability to the fabrication and application of this material extends to various devices such as FET.

In this paper, we report on succeeding of epitaxial β-$FeSi_2$ film growth on insulator.

2. Experiments

Iron silicide films were prepared on MgO(001), $MgAl_2O_4$(001), $SrTiO_3$(001), $(Y_{0.1}Zr_{0.9})O_2$(001) and Al_2O_3(001) substrates at 735°C by RF magnetron sputtering method under Ar atmosphere. These oxides were reported to be epitaxially grown on Si(001) substrate [4]. The chamber pressure and deposition rate of the films were $3x10^{-1}$ Pa and 0.8 nm/min, respectively. Both of X-ray fluoroecence (XRF) and Rutherford backscattering spectroscopy (RBS) were employed to measure the Si/Fe atomic ratio of the films, and it was verified to be 2. Crystallographic structure of the films was characterized by X-ray diffraction (XRD, Philips MRD) using CuK_α radiation, and the pole figure measurement was used to determinate the epitaxial relationship between the film and substrate.

3. Results and Discussion

Figure 1 shows XRD patterns of the films deposited on (a) MgO(001), (b) $MgAl_2O_4$(001), (c) $SrTiO_3$(001), (d) $(Y_{0.1}Zr_{0.9})O_2$(001) and (e) Al_2O_3(001) substrates. As a reference, the pattern of the epitaxail β-$FeSi_2$ film on Si(001) substrate is showed in Figure 1(f). On MgO(001) and $SrTiO_3$(001) substrates, the films were consisted of amorphous, and polycrystalline β-$FeSi_2$ phase was formed on $MgAl_2O_4$(001) substrate. On the other hand, β-$FeSi_2$ phase having (100)-preferred orientation was formed on $(Y_{0.1}Zr_{0.9})O_2$ and Al_2O_3(001) substrates as shown in Fig. 1(d) and (e). These (100)β-$FeSi_2$ films were verified to be epitaxially grown from XRD pole figure measurement. The threefold symmetry of epitaxial β-$FeSi_2$ variants was observed on Al_2O_3(001) substrates, while the twofold symmetry which is the same as the epitaxial film on Si(001) substrate was observed on $(Y_{0.1}Zr_{0.9})O_2$(001) substrate.

Lattice matching is important factor for hetero epitaxial growth of the film. Figure 2 shows the relationship between lattice mismatch along b- and c-axes of β-$FeSi_2$ on each substrate. As a result, compressive lattice strain was preferred to (100) oriented epitaxial growth. However, on Al_2O_3(001) substrate, epitaxial growth of (100)β-$FeSi_2$ film was observed in spite of large lattice strain of even 12%. This fact suggests that epitaxial growth of β-$FeSi_2$ film is affected by not only lattice matching but also by other factors such as arrangement of anion and cation.

4. Conclusions

We succeeded in preparation of epitaxial β-$FeSi_2$ film on insulator. This result suggested larger ability to the fabrication and application of this film to various devices such as FET.

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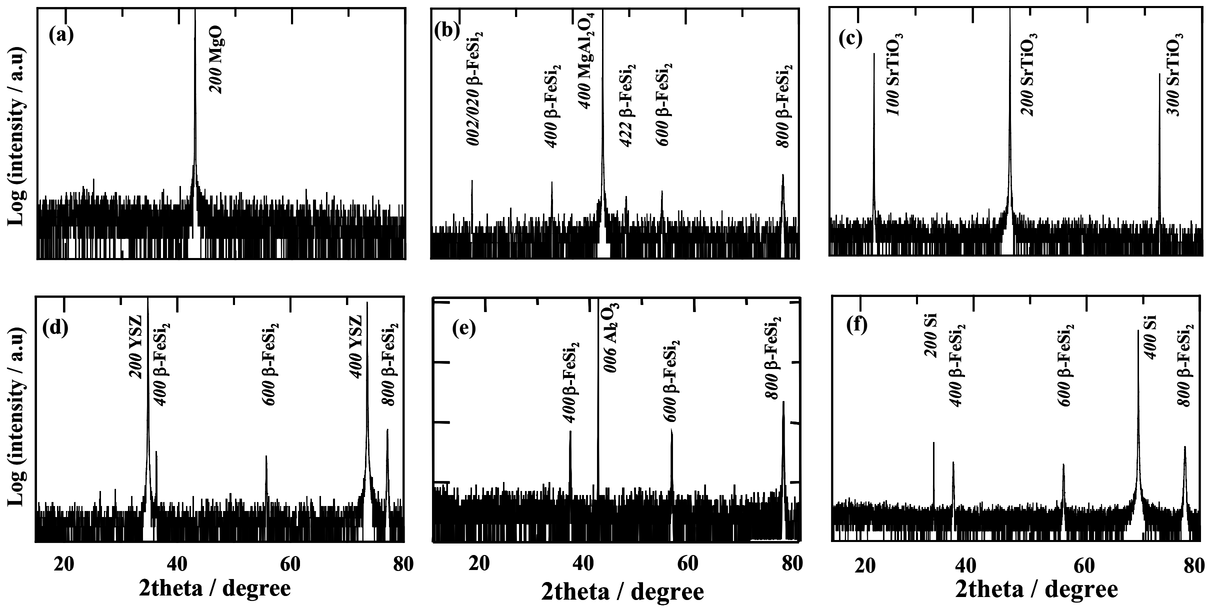

Figure 1. XRD patterns of the films deposited on (a) MgO(001), (b) $MgAl_2O_4$(001), (c) $SrTiO_3$(001), (d) $(Y_{0.1}Zr_{0.9})O_2$(001) and (e) Al_2O_3(001) substrates. These films were prepared by RF magnetron sputtering method. And XRD patterns of epitaxial β-$FeSi_2$ film on (f) Si(001) substrate [5].

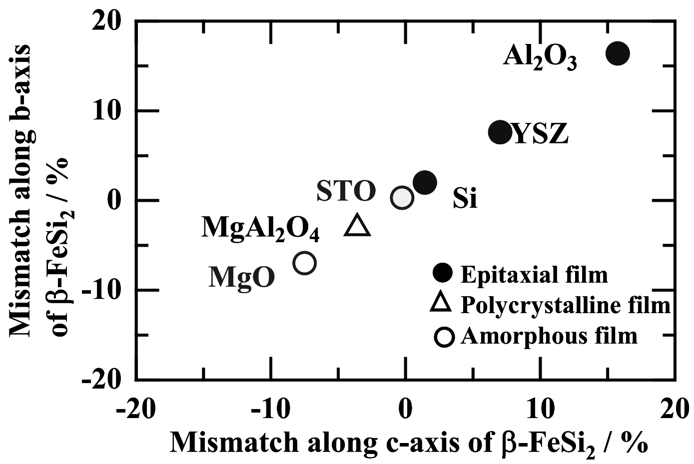

Figure 2. Relationship between lattice mismatch along b- and c-axes of (100)-oriented β-$FeSi_2$ grown on various substrates.