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Photoluminescence enhancement from β-$FeSi_2$ on Ag-coated Si

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1. Introduction

Semiconducting β-$FeSi_2$ shows photoluminescence (PL) and photoresponse near 1.54 μm, which is a wavelength for fiber optics communications. This material has been regarded as a candidate for application to monolithic integrated circuits of optoelectronics devices because of the compatibility with the Si-process technology [1]. It is able to epitaxially grow on Si substrates [2]. Light-emitting diodes using β-$FeSi_2$ active-layer showed the emission efficiency of about 0.1% [3]. It is pointed out that non-radiative recombination centers at hetero-interfaces affect the light emission efficiency.

On the other hand, it has been reported that the PL intensities were enhanced by coating copper (Cu) or gold (Au) layer on Si(100) wafers and the crystallinity of those β-$FeSi_2$ films was improved as well as β-$FeSi_2$/Si hetero-interface [4, 5]. In this study, we report the enhancement of PL intensities from β-$FeSi_2$ films by coating silver (Ag) layer on Si(100) wafers by using metal-organic chemical vapor deposition (MOCVD).

2. Experiments

85-nm-thick Ag layer was deposited on n-type czochralski (CZ) Si(100) wafers at room temperature in vacuum ($<5\times10^{-6}$ Torr) atmosphere. As a reference, 40-nm-thick Au and 20-nm-thick Cu layers were also deposited on Si(100) wafers. 200-nm-thick β-$FeSi_2$ films were deposited on the Au-coated Si, Cu-coated Si and Ag-coated Si wafers by MOCVD using iron pentacarbonyl [$Fe(CO)_5$] and monosilane (SiH_4). The deposition temperature and rate were 1023K and 1.6 nm/min, respectively.

Crystallographic structure of the films was characterized by x-ray diffraction (XRD, Philips MRD) using a Cu Kα radiation. The surface morphologies of the films were observed by scanning electron microscopy (SEM, FEI Shirion). The PL spectrum was measured using the 514.5 nm line of an argon-ion laser. The average excitation power and the spot diameter of the laser beam were 50 mW and 0.5 mm, respectively. The PL spectrum was collected by aspheric lens group with three groups and three elements (F/1.25) and analyzed with a 1 m focal length single monochromator (Jobin Yvon THR-1000) and detected with a liquid nitrogen-cooled Ge p-i-n photodiode (Edingburg Instruments) and amplified by the lock-in technique.

3. Results and Discussion

Figure 1 shows the XRD θ-2θ scan profiles for the deposits on (a) Au-coated, (b) Cu-coated and (c) Ag-coated Si(100) wafers. A mixture phase of α-$FeSi_2$ and β-$FeSi_2$ and polycrystalline β-$FeSi_2$ phase preferred to (100)-orientation and were observed on Au-coated Si and on Cu-coated Si(100) wafers, respectively, as shown in Fig. 1(a) and 1(b). It must be mentioned that the diffraction peaks originated from η-Cu_3Si was slightly observed for the films on Cu-coated Si(100) wafers. On the other hand, (100)-orientated β-$FeSi_2$ single phase was observed on Ag-coated Si(100) wafers.

Bird's-eye view SEM images of the iron disilicide grains are shown in Figures 2. As shown in Fig. 2(a), square, trapezoid, and rod-like crystal grains with sizes of several micrometres were observed on the Si substrate surface, for the Au-coated Si(100) wafers. The film on the Cu-coated Si(100) wafers contained of small crystalline grains with several hundred nm sizes. On the other hand, a continuous film formed on the Ag-coated Si(100) wafers.

Figure 3 shows PL spectrum for the β-$FeSi_2$ on Ag-coated Si(100) wafers, together with the spectra for the β-$FeSi_2$ on Cu-coated and Au-coated Si(100) wafers, which were not post-anneal treated. The PL spectra for any samples showed clear peaks at 0.806 eV. While the apparent shapes of the PL spectra appear to be structured with few luminescence bands, the peak energy corresponded to that of β-$FeSi_2$, reported by Hunt *et al.* [6] and Martinelli *et al.* [7]. The PL peak intensities for the β-$FeSi_2$ on Au- and Ag-coated Si(100) were approximately one-fifth and twice as large as that for the epitaxial β-$FeSi_2$ film on Cu-coated Si(100), respectively.

Taking the results of XRD analysis and SEM observation into account, these PL intensities were considered to be affected by the β-$FeSi_2$ volume amount in excited area by Ar-ion laser. Thus, the film of β-$FeSi_2$ single phase with flat surface on the Ag-coated Si(100) exhibited the maximum PL intensity.

4. Summary

A clear PL spectrum for β-$FeSi_2$ films was observed by Ag coating on Si(100) without post annealing. The control of the crystal structure and surface morphology led to the enhancement of PL intensity.

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References

[1] V. Borisenko (Ed.), *Semiconducting Silicides.* pringer-Verlag, Berlin, (2000).

[2] N.Cherief, C.D'Anterroches, R.Cinti, T.Tan and J.Derrien, Appl. Phys. Lett. **55** (1989) 1671.

[3] T. Suemasu, K. Takakura, C. Li, Y. Ozawa, Y. Kumagai, and F. Hasegawa, Thin Solid Films **461** (2004) 209.

[4] K. Akiyama, S. Kaneko, H. Funakubo and M. Itakura, Appl. Phys. Lett. **91** (2007) 071903.

[5] K. Akiyama, H. Funakubo and M. Itakura, Proceedings of Mater. Res. Soc. Symp. **1396** (2012) DOI: 0.1557/opl.2012.85.

[6] T. D. Hunt, K. J. Reeson, R. M. Gwilliam, K. P. Homewood, R. J. Wilson and B. J. Sealy, J. Lumin. **57** (1993) 25.

[7] L. Martinelli, E. Grilli, D. B. Migas, L. Miglio, F. Marabelli, C. Soci, M. Geddo, M. G. Grimaldi and C. Spinella, Phys. Rev. B **66** (2002) 085320.

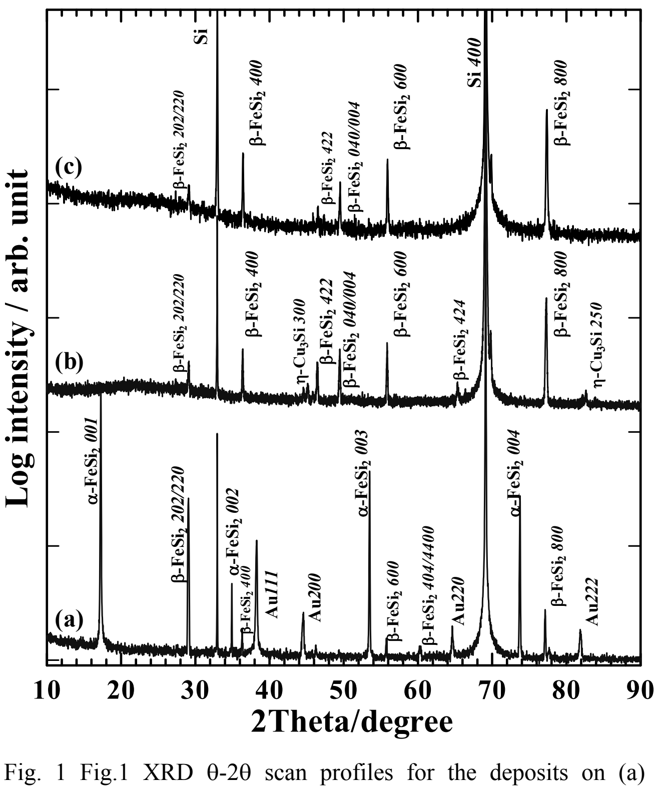

Fig. 1 Fig.1 XRD θ-2θ scan profiles for the deposits on (a) 40nm-thick Au-coated Si(100), (b) 20nm-thick Cu coated Si(100), and (c) 85nm-thick Ag-coated Si(100) wafers.

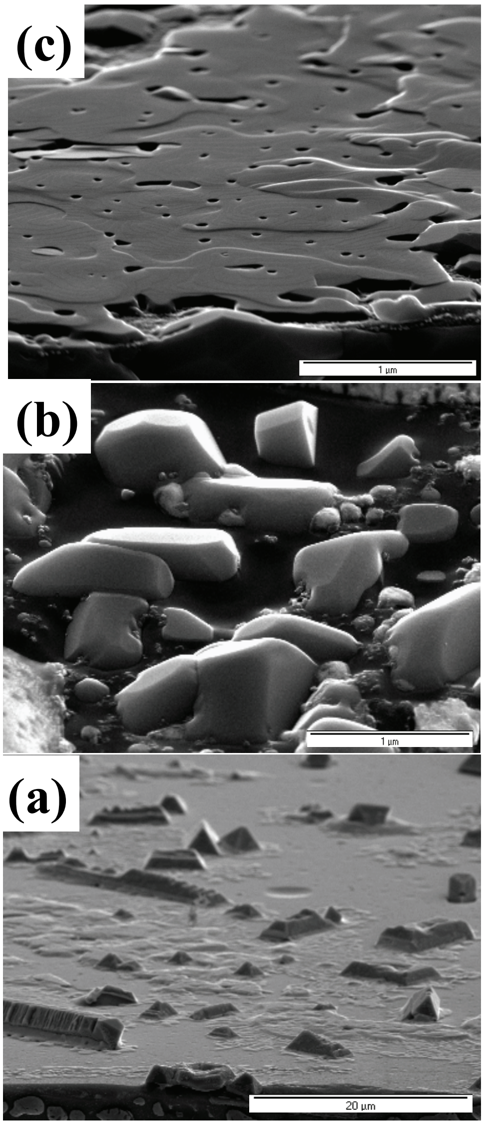

Fig. 3 Bird's-eye view SEM images for the iron disilicide on (a) 40nm-thick Au-coated Si(100), (b) 20nm-thick Cu coated Si(100), and (c) 85nm-thick Ag-coated Si(100) wafers.

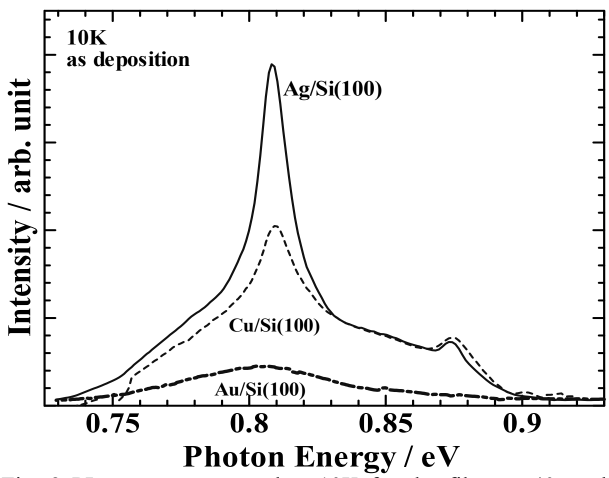

Fig. 2 PL spectra measured at 10K for the film on 40nm-thick Au-coated Si(100), 20nm-thick Cu coated Si(100), and 85nm-thick Ag-coated Si(100) wafers.