Fabrication of low B-doped p-$BaSi_2$/n$^+$-Si heterojunction solar cells

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[Introduction]

Semiconducting $BaSi_2$ has attracted attention as a future absorber-layer material for thin-film solar cells. It has an indirect band gap of approximately 1.3 eV, matching the solar spectrum, and has large absorption coefficients, reaching 3.0×10^4 cm^{-1} at 1.5 eV [1,2]. We have successfully fabricated n-Si/B-doped p-$BaSi_2$ heterojunction solar cells that achieved a conversion efficiency η of 9.9% [3]. In the work mentioned, B-doped p-$BaSi_2$ (p = 2.2 × 10^{18} cm^{-3}) with an optimum thickness of 20 nm acts as a hole transport layer [3]. The deterioration of η in thicker p-$BaSi_2$ layers is suspected due to the small minority-carrier lifetime τ of p-$BaSi_2$. In previous work, we confirmed that τ strongly depends on the hole concentration p of p-$BaSi_2$. We measured that low doped p-$BaSi_2$ with p=1.4 × 10^{16} cm^{-3} has a τ of 2.0 μs, two orders higher than sample with p=3.9×10^{18} cm^{-3} [4]. In order to utilize B-doped p-$BaSi_2$ as an active layer, we need to employ n-Si with lower resistivity (higher electron concentration n), so that the depletion region stretches toward the p-$BaSi_2$ layer, and that the device has a sufficient built-in potential at the junction.

In this work, we fabricated 300-nm-thick low-doped p-$BaSi_2$ on the Si substrates with various resistivities and examined the electrical properties using J-V characteristics. We then evaluated the result from the crystallinity point of view.

[Experiment]

Briefly, a 5-nm-thick template layer was grown by Ba deposition on a hot n-Si(111) substrates (T_{sub} = 500°C, T_{Ba} = 543°C) with resistivity ρ varied from 0.01–0.1 to 0.1–1.0 and 1.0–4.0 Ωcm. Next, Ba, Si, and B were coevaporated to form approximately 300-nm-thick a-axis-oriented B-doped p-$BaSi_2$ epitaxial films by MBE (T_{sub} = 600°C, T_{Ba} = 569°C, R_{Si} = 2.0 Å/s). The boron k-cell temperature T_B was set to 1000°C which correspond to a p of 1.4 × 10^{16} cm^{-3}. Finally, the samples were capped with a 5 nm-thick a-Si as a passivation layer. The crystallinity of $BaSi_2$ was investigated by RHEED and θ-2θ X-ray diffraction (XRD). The current density versus voltage (J-V) curves were measured under standard AM1.5, 100 mW/cm^2 illumination at 25°C. We also measured the FWHM of the X-ray rocking curve using $BaSi_2$(600) diffraction.

[Results and discussion]

Figure 1 shows the J-V characteristic of sample with different substrate ρ values. In Fig. 1, we see that the rectifying characteristics in the J-V curves gradually disappears as ρ decreases. The J-V characteristic shows a clear ohmic-like behavior when the substrate ρ is less than 0.1 Ωcm even though the depletion region in the p layer are calculated to be less than 200 nm, thinner than the p-$BaSi_2$ layer thickness.

The FWHM values obtained from an ω-scan x-ray rocking curve using a $BaSi_2$(600) diffraction peak of sample with different substrate ρ values are plotted in Fig. 2. In Fig. 2, the degree of preferred a-axis orientation degraded as we decreased the substrate ρ. The decrease of the crystalline quality is probably one possible driving forces behind the degradation of rectifying characteristics in J-V curves. We plan to conduct TEM observations to see what happens around the p-$BaSi_2$/n-Si interfaces to gain further information.

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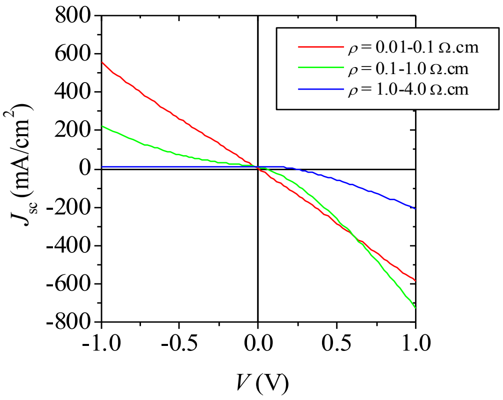

Fig. 1 J-V characteristic of p-$BaSi_2$/n-Si of samples with different Si substrate ρ.

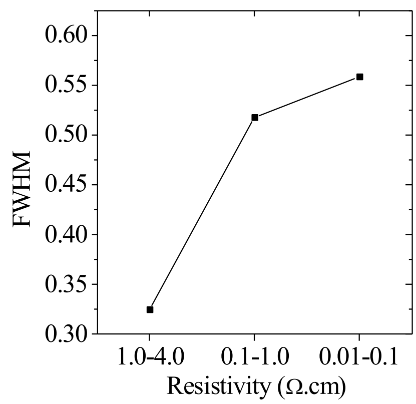

Fig. 2 FWHM values obtained from an ω-scan x-ray rocking curve of $BaSi_2$(600) fabricated on n-Si(111) with different ρ values.

[Reference]

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