Carrier transport properties of boron-doped p-$BaSi_2$ on Si(111) and Si(001)

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Introduction

Barium disilicide ($BaSi_2$) has attractive features for solar cell application such as a suitable band gap, a large minority-carrier lifetime (τ ~ 10 μs) and a large minority-carrier diffusion length (L ~ 10 μm). In our previous work, we successfully grew boron (B)-doped p-$BaSi_2$ on a flat n-Si(111) substrate to form pn junction solar cells and achieved an efficiency of 9.9%. However, the carrier transport properties of B-doped p-$BaSi_2$ have not been investigated. In this study, we attempted to explore the carrier transport properties of B-doped p-$BaSi_2$ on Si(111) and Si(001). They are both *a*-axis-oriented multi-domain epitaxial layers; there are three and two epitaxial variants rotating by 120 and 90 deg with each other around the surface normal, respectively [1]. Furthermore, the potential profiles across the grain boundaries in undoped n-$BaSi_2$ differ between them [2]. Hence, the scattering mechanisms in those films are of great importance when we apply these materials to solar cells.

Experiment

We used FZ-n-Si(111) and FZ-n-Si(001) substrates with high-resistivity of more than 1000 Ω·cm. B-doped p-$BaSi_2$ epitaxial films exceeding 400 nm in thickness were grown by molecular beam epitaxy (MBE) using reactive deposition epitaxy templates. The temperatures of B K cell (T_B) were set at 1000, 1100, 1170, 1230 and 1300 °C. Then, a 3-nm-thick a-Si layer was prepared over the $BaSi_2$ layers as a capping layer to reduce oxidation of the film. The mobility μ was measured at temperatures between 30 and 300 K using the Van der Pauw method. The applied magnetic field was 0.3T normal to the sample surface.

Results & Discussions

The hole concentration p of the samples at RT are varied from 5.0×10^{16} to 1.1×10^{19} cm^{-3} depending on T_B. The temperature dependences of hole mobility of B-doped p-$BaSi_2$ films on Si(111) and Si(001) are shown in Figs. 1 (a) and 1(b), respectively. We can see from Fig.1 (a) that ionized impurity scattering by which μ is proportional to $T^{1.5}$, determines the μ at low temperatures in highly-doped p-$BaSi_2$ with T_B= 1300°C (p=5.3×10^{18} cm^{-3}). As the doping level decreases with decreasing T_B, grain boundary scattering or other scattering mechanisms play a major role at low temperatures. At high temperatures, acoustic phonon scattering decides μ for low-doped p-$BaSi_2$, while μ is governed by polar optical scattering or grain boundary scattering for highly-doped ones. From Fig. 1 (b), the μ of the films grown on Si(001) shows a similar tendency at high temperatures compared with the films grown on Si(111). However, in a low temperature region, ionized impurity scattering is no longer dominant. To fully reproduce the experimental results, we need to add scattering mechanisms such as intervalley scattering [3], polar optical scattering [4] and so on. Thus, further studies are mandatory to fully understand the scattering mechanisms.

References

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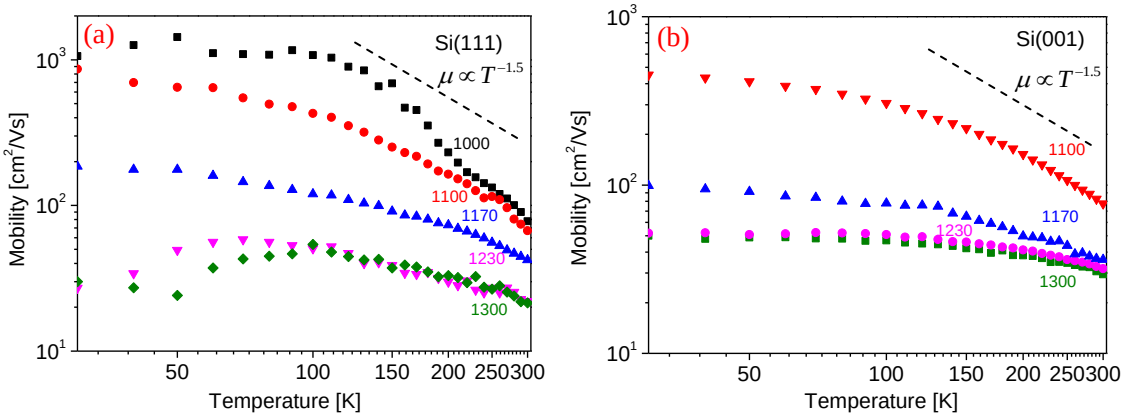

Fig. 1. Temperature dependence of hole mobility for B-doped p-$BaSi_2$ films formed on (a) Si(111) and (b) Si(001) substrates. Dash lines are a guide to the eyes.