Minority-carrier lifetime in B-doped $BaSi_2$ epitaxial films

°M. Emha Bayu[1], Cham Thi Trinh[2], R. Takabe[1], S. Yachi[1], K. Toko[1], N. Usami[2], T. Suemasu[1]
[1]Univ. of Tsukuba, [2]Nagoya Univ.
E-mail: s1620378@u.tsukuba.ac.jp

[Introduction]

$BaSi_2$ is attracting attention as a future absorber-layer material for earth abundant thin film solar cell. It has an indirect band gap of approximately 1.3 eV, matching the solar spectrum, and has large absorption coefficients, which is 30 times larger than that of crystalline silicon [1,2]. Recently we have fabricated n-Si/B-doped p-$BaSi_2$ heterojunction solar cell that achieved a conversion efficiency η of 9.0% [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. The deterioration of η in thicker p-$BaSi_2$ layer are suspected due to the small minority-carrier diffusion length of p-$BaSi_2$ layer. In order to leverage p-$BaSi_2$'s potential as absorption layer, we need to increase the thickness of p-$BaSi_2$ layer by employing those with excellent minority-carrier lifetime. In this work we performed minority-carrier lifetime measurement by microwave-detected photoconductivity decay (μ-PCD), of B-doped p-$BaSi_2$ with various hole concentrations in the pursuit of p-$BaSi_2$ with the most excellent minority carrier lifetime.

[Experiment]

A 5 nm-thick template layer was grown by Ba deposition on a hot FZ n-Si(111) substrate (T_{sub} = 500°C, T_{Ba} = 540°C). Next, Ba, Si, and B were co-evaporated to form approximately 600 nm-thick *a*-axis-oriented B-doped $BaSi_2$ epitaxial films by MBE (T_{sub} = 600°C, T_{Ba} = 573°C, R_{Si} = 2.0 Å/s). The Boron k-cell temperature T_B was varied to 1000°C, 1100 ° C, 1230 ° C, and 1350 ° C. The hole concentration p measured by Hall measurement was changed from 1.4 × 10^{16} cm^{-3} to 3.9 × 10^{18} cm^{-3} accordingly. 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 X-ray diffraction (XRD). Excess-carrier recombination kinetics was then investigated by the microwave-detected photoconductivity decay (μ-PCD) method. The excess carriers were generated by a 5 ns laser pulse with a wavelength of 349 nm and photoconductivity decay was measured by the reflectivity of microwave with the frequency of 26 GHz. The photon flux density was 1.1×10^{15} $cm^{-2}\cdot s^{-1}$.

[Results and discussion]

Figure 1 shows the μ-PCD decay curves of B-doped p-$BaSi_2$ with different p. It represents the decay of excess-carriers generated by pulse laser beam. From fig.1 it is clearly seen that the excess-carriers were decayed quickly at higher p, meaning that the minority-carrier lifetime τ is higher in lower p. From this decay curve, we than extract the effective τ of each sample.

Next, we plot the correlation between p and the extracted effective τ in Fig. 2. In Fig. 2, τ are decreased by the increase of p. τ is about 0.05 μs for p=5 × 10^{18} cm^{-3}. In contrast, we achieved the highest τ of 2.0 μs in the sample with lowest p =1.4 × 10^{16} cm^{-3}. This means that the minority-carrier diffusion length for p-$BaSi_2$ with p~10^{16} cm^{-3} is approximately 10 times larger than that with p~10^{18} cm^{-3}. From this result, p-$BaSi_2$ with small p is considered a potential absorber layer in solar cells.

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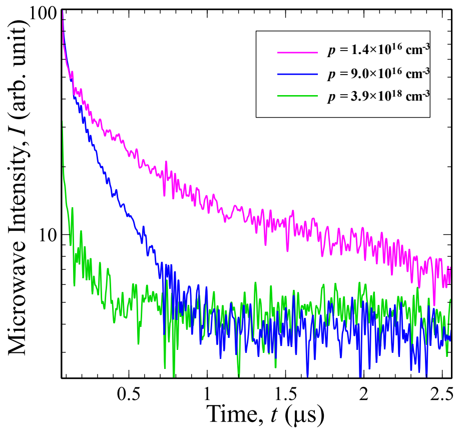

Fig. 1 Photoconductivity decay curves of B-doped $BaSi_2$ with different hole concentrations.

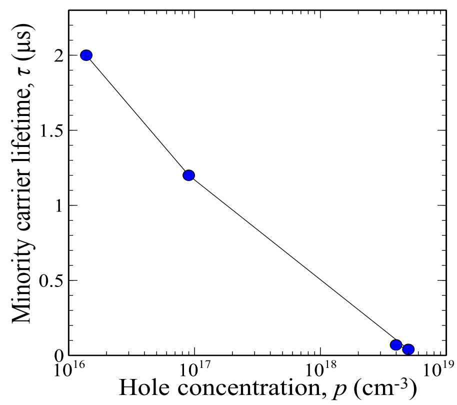

Fig. 2 Dependence of minority-carrier lifetime on hole concentration.

[Reference]

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