Characterizations of crystalline quality and electrical properties of nitrogen-doped $BaSi_2$ films on Si(111)

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Introduction $BaSi_2$ has many advantages such as a band gap of 1.3 eV, matching the solar spectrum, a large absorption coefficient of 3×10^4 cm^{-1} at 1.5 eV, exceeding those of CIGS [1], and a minority-carrier diffusion length of ca. 10 μm [2]. Because of these excellent properties, $BaSi_2$ is considered to be a good material for pn junction solar cells. $BaSi_2$ doped with group 15 element such as P, As, and Sb shows n-type conductivity. However, there has been no report on N-doped $BaSi_2$. Thereby, we have attempted to dope nitrogen into $BaSi_2$ (N-doped $BaSi_2$) using radio-frequency (RF) plasma N source. Previously we reported that the hole concentration was not determined by a beam equivalent pressure of N_2 but plasma intensity of N atom. We can control its carrier type (p or n) by plasma intensity. However, the carrier concentration seems not to depend on the plasma intensity. This phenomenon may be caused by crystal quality. Thus, in this study, we attempted to evaluate the crystal quality of N-doped $BaSi_2$ by various methods.

Experiment We grew N-doped $BaSi_2$ thin films on high resistivity n-Si (111) (ρ>1000Ω·cm) with different N plasma intensities. First, we deposited Ba on a Si (111) substrate by reactive deposition epitaxy. Second, we co-deposited Ba, Si and N on the template at 580 ℃ to grow approximate 190 nm thick N-doped $BaSi_2$ to examine its crystal quality. The reflection high energy electron diffraction patterns were observed during the growth. The RF plasma power for nitrogen was set to 70 W. The plasma intensity with a wavelength of 747 nm indicates the amount of N atom [3]. To change the amount of N, we varied the plasma intensity from 560 to 1100 arbitrary unit (a.u.). X-ray diffraction (XRD) and secondary ion mass spectrometry (SIMS) measurement were carried out to characterize their crystalline quality and N concentrations.

Results & Discussions Figures 1 shows an example of N SIMS profile in N-doped $BaSi_2$. This sample was fabricated under the intensity of 655[a.u.]. The hole concentration was approximate 10^{17} cm^{-3} at room temperature. It was found from the SIMS result that the N was uniformly distributed and its concentration is around 10^{20} cm^{-3}. Similar results were obtained for other samples. Figure 2 shows the dependence of carrier type on plasma intensity. As reported previously, the carrier type was changed from p to n when the intensity is large (over 750). Figure 3 shows the dependence of plasma intensity and the XRD FWHM of $BaSi_2$(600). The FWHM increased with increasing the N plasma intensity. This means that the more nitrogen doped in $BaSi_2$, the poorer crystal quality becomes.

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Reference [1] K. Toh, *et al.*, Jpn. J. Appl. Phys. **50** **(**2011) 068001. [2] M. Baba, *et al.*, J. Cryst. Growth **348** (2012) 75. [3] H. Okumura, *et al.*, J. Cryst. Growth **198** (1998) 390.

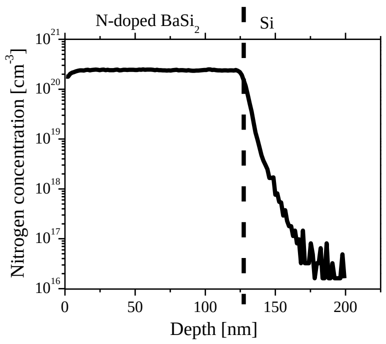

Fig 1 Example of N SIMS profile in N-doped $BaSi_2$.

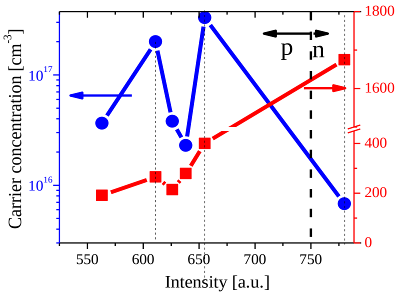

Fig 2 Dependence of N-plasma intensity (λ=747nm) and carrier con. and mobility of N-doped $BaSi_2$.

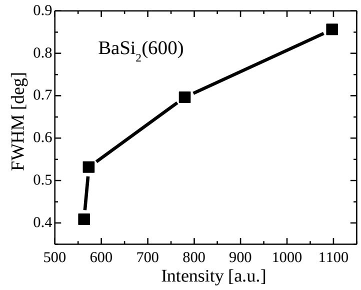

Fig 3 Dependence of N-plasma intensity (λ=747nm) and XRD FWHM of $BaSi_2$(600) peak in N-doped $BaSi_2$.