Electronic states of Ce and magneto-transport characteristics in Ce doped Si films

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【Introduction】

We have been interested in the effect of Ce doping on magneto-transport characteristics in Si epitaxial thin films because *p-type* Si:Ce thin films show ferromagnetic behaviors[1]. Although low temperature molecular beam epitaxy (MBE) method enables to control the surface segregation or precipitation of Ce and the compounds, all samples show *n-type* conduction due to high donor density caused by low growth temperature. Therefore, B co-doped Si:Ce thin films have been tried to fabricate. Transport characteristics in B co-doped Si:Ce films with different hole concentration which is obtained by controlling B concentration or growth rate were evaluated. However, the effect of B doping on electronic states of Ce or the origin of anomalous magneto-transport characteristics are still unexplicit. In this paper, the electronic state of Ce measured by X-ray photoelectron spectroscopy (XPS) and the origin of magneto-transport characteristics are discussed.

【Experiments and results】

Si:Ce films were fabricated on (001) silicon on insulator substrate by solid source MBE system. The growth rate, Ce concentration and B concentration were controlled by k-cell temperature. In-situ surface and ex-situ surface morphology were observed by using RHEED and AFM, respectively. 4 terminal Al electrodes were deposited by vacuum evaporation for evaluation of transport characteristics. XPS measurement was carried out using synchrotron radiation at the energy of 2.7 keV in KEK (beam-line 27 A).

Fig. 1 shows Ce 3*d* XPS spectra of Si:Ce (a) and B co-doped Si:Ce thin films. 4 peaks originated in Ce $3d^9 4f^1$ and Ce$3d^9 4f^2$ are obtained by peak deconvolution using Shirley's method with Voigt functional form. On the other hand, there is no peak around 915 eV originated in Ce $3d^9 4f^0$. This result suggests that the Ce ions dissolve in Si exist as Ce^{3+} [4]. As shown in Fig. 1 (b), the spectrum from Si:Ce film is almost identical to that from Si:Ce, B film. Fig. 2 shows the magneto resistance (MR) of B co-doped *p-type* Si:Ce film measured at 10 K. The magnetic field is applied perpendicular to the surface plane. Negative MR component is clearly observed within 3 T. The origin of negative MR is considered as weak localization effect or spin ordering effect. We will discuss the origin of MR observed in B co-doped Si:Ce films using detailed analysis of MR, together with the temperature dependence of MR. The effect of magnetic field direction is also discussed.

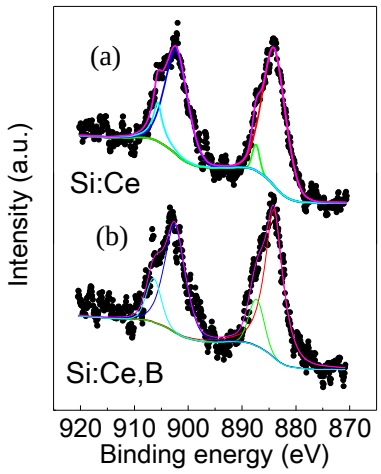

Fig. 1 Ce 3d XPS spectra of Si:Ce (a) and B co-doped Si:Ce (b) films.

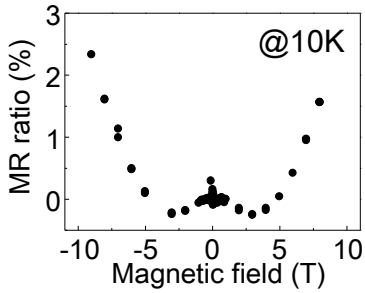

Fig. 2 MR of B co-doped *p-type* Si:Ce film measured at 10 K.

【Reference】

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