The effect of B co-doping on the surface morphology and transport characteristics of Si:Ce films

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【Introduction】

Diluted magnetic semiconductors (DMSs), based on Si, continue to attract much interest. We have been interested in Ce doped Si (Si:Ce) films because *p*-type Si:Ce films show ferromagnetic behavior. Although low temperature growth enables to obtain uniform distribution of Ce in Si without any silicidation reactions, all the LT-grown samples exhibited *n*-type conduction and paramagnetism even after Ce^{3+} doping due to extremely low solid solubility of Ce in Si at substitutional site. An increase of the strain energy due to an increase of substitutionaly dissolved Ce, which has larger covalent radius (163 pm)[4] than that of Si (116 pm)[4] prevent Ce from highly doping into Si. Here, we discuss the effect of B co-doping, which has smaller covalent radius (85 pm)[4] than that of Si on surface morphology and transport characteristics.

【Experiment】

Si:Ce films were deposited on SOI(001) substrates by solid-source molecular beam epitaxy (MBE) system. The growth rate and thickness were fixed as 40 nm/h and 20 nm, respectively. The growth rate, Ce concentration and B concentration were controlled by the temperature of each k-cell. *In-situ* and *ex-situ* surface morphology were evaluated by RHEED and DFM. Magneto-transport characteristics were measured at the temperature ranging from 5 to 300K.

【Results and discussion】

Fig. 1 shows the change in the root mean square of the roughness (Rrms) of Si:Ce films without B co-doping measured by DFM. Although the surface becomes rough with increasing the Ce concentration, the value stays within 1 nm. The decrease of Rrms value at the sample at 1190 °C is seems to be originated in the strain relaxation by the formation of 3-folded re-constructed periodic surface structure. Fig. 2 shows the co-doping effect of B for the samples with the Ce k-cell temperature of 1190 °C and 1230 °C. Although little effect is recognized for the samples, which have surface reconstructed structure (Ce k-cell temperature of 1190 °C), the surface of the samples deposited with the k-cell temperature of Ce at 1230 °C becomes smooth with increasing B concentration. We will discuss the effect of B co-doping on stress relaxation, the formation of acceptor level and transport characteristics as well.

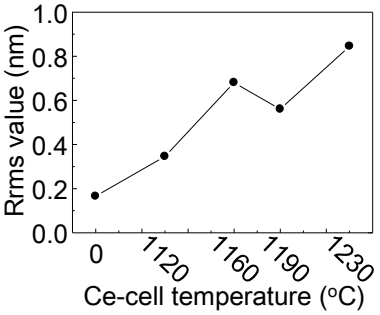

Fig. 1 Change in the Rrms value as a function of k-cell temperature for Ce.

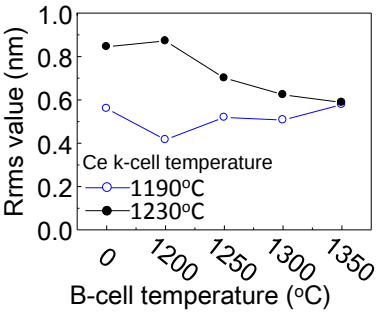

Fig. 2 Effect of B doping on the Rrms value.

【Reference】

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