Control of hole density in acceptor co-doped Si:Ce films

°Yusuke Miyata, Kazuya Ueno, Takeshi Yoshimura, Atsushi Ashida and Norifumi Fujimura,

(Grauate School of Eng., Osaka Pref. Univ.)

E-mail: fujim@pe.osakafu-u.ac.jp

【Introduction】

We have been interested in the effect of Ce doping on magneto-transport characteristics in single crystalline Si films because *p*-type Si:Ce films show ferromagnetic behavior. Although low temperature molecular beam epitaxy system enable to control surface segregation of Ce, all samples show *n*-type conduction due to high donor density caused by low growth temperature. In the case of acceptor co-doping, it is difficult to obtain shallow *p*-type conduction because of high donor density of Si:Ce films. Only degenerated *p*-type conduction by heavy acceptor doing is obtained. In order to evaluate Ce^{3+} ion, which has a *4f* spin, related transport characteristics, control of fermi energy near the valence band is necessary. Thus, it is essential to decrease donor density in Si:Ce films. In this paper, we report the decrease of donor density by change of growth temperature or rate in order to control of hole concentration in B co-doped Si:Ce films.

【Experiments and results】

Si:Ce films were fabricated on (001) silicon on insulator substrate by solid source MBE system. Growth rate, Ce concentration and B concentration were controlled by k-cell temperature. In-situ and ex-situ surface structure and morphology were observed by RHEED or AFM, respectively. Four terminal Al electrodes were deposited by vacuum evaporation for evaluation of transport characteristics.

Fig. 1 shows change in the growth rate and Ce concentration as a function of k-cell temperature of Si or Ce. The experimental result of growth rate and Ce concentration (●) are fitted with the exponential function (broken line) suggesting that these two parameters can be controlled independently. By using these results, Si:Ce films with identical Ce concentration (0.5 at.%) were able to be fabricated by using different growth rate. Fig. 2 shows carrier density and mobility of these samples. Carrier densities of all samples are much lower than that of Si homoepitaxial thin film (10^{18} cm^{-3}). However, clear change of carrier density and mobility by control of growth rate is not recognized by changing the growth rate. We will discuss the control of donor density in Si:Ce films and the correlation between hole density and magneto-transport characteristics in B co-doped Si:Ce films including the Si:Ce films with higher Ce concentration.

【References】

[1]T. Yokota *et. al.*, J. Appl. Phys., **93**(2003)219. [2]Y. Miyata *et. al.*, Journal of Smart Processing, **2**(2013)219.

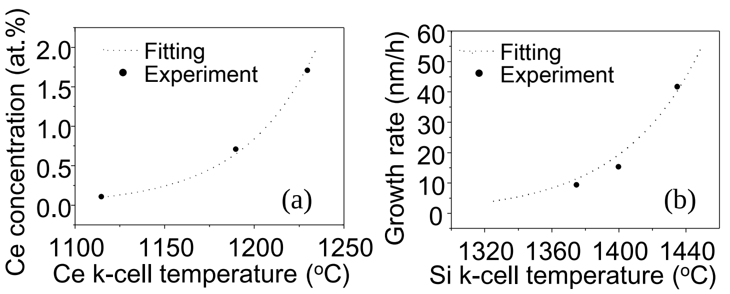

Fig. 1 Fitting (broken line) and experimental (●) growth rates (a) and Ce concentrations (b) as a function of k-cell temperature.

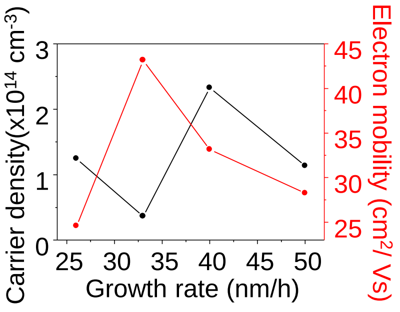

Fig. 2 Carrier density (black) and electron mobility (red) as a function of growth rate.