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Fluorescence EXAFS analysis on local structures around Tb ions implanted in SiO_2 on Si

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Introduction

Rare-earth doped semiconductors have been attracting much interest for possible applications in light-emitting devices and for their unique optical properties. Intra-4f-shell luminescence of rare-earth ions doped in semiconductor is sharp and temperature-stable. For example, it is reported that Tb ions implanted in SiO_2:Tb thin film on Si showed strong visible luminescence at room temperature[1]. However, the luminescence intensity in the SiO_2:Tb thin film has been found to depend strongly on growth conditions. Since the electronic states of Tb are perturbed by the crystal field around Tb ions, it is essentially important to study the local structures around Tb ions for understanding and controlling the luminescent properties of Tb ions in semiconductors. In this work, the local structures around the Tb ions implanted in SiO_2 on Si has been investigated by EXAFS measurement in order to find the relationship between the local structures around the Tb ions and the luminescence properties.

Experimental

SiO_2 films of 200 nm thickness, which were formed by dry thermal oxidation, were grown on p-Si(001). Tb ion was introduced into the oxide layer by ion implantation. The implantation were performed at 300keV. Dose density of Tb implanted in SiO_2 was 1×10^{15} Tb ions/cm^2. Annealing of the SiO_2:Tb film was performed in vacuum (~10^{-5} Torr) at 900 ºC for 30min. For comparison, Tb_2O_3 film grown on Si(001) by metalorganic chemical vapor deposition (MOCVD) were also prepared. The EXAFS measurements were performed at the beam line BL12C at KEK-PF.

Results and discussion

Figure 1 shows the Fourier transformed Tb L_{III}-edge $k\chi(k)$ spectra representing radial distribution functions of Tb in the SiO_2:Tb thin films and the Tb_2O_3 film. Main peak in the as-implanted sample shift toward longer radial distance compared with that in the annealed sample. In addition, for the annealed sample a small peak was observed at 2.1 Å. Thus, it is deduced that the local structure between the as-implanted and annealed sample are different.

From the curve fitting, it is found that in the as-implanted sample Tb ions are coordinated by two oxygen (Tb-2O), and Tb-O bond length is 2.09 Å. For the annealed sample, it was found that two types of Tb-O bond length coexisted. Short Tb-O bond lengths were 2.10 Å, and longer ones were 2.27 Å. The longer Tb-O bond lengths were close to that of Tb_2O_3. It is considered that Tb ions coordinate around six atoms with the longer Tb-O bond lengths (Tb-6O). Thus, it is concluded that amount of Tb-6O structure increased by annealing. The PL measurement showed enhancement of luminescence intensity by annealing. Therefore, it is considered that formation of Tb-6O structure is related to the enhancement of luminescence intensity.

References

[1] H. Amekura et al., J. Appl. Phys. 84 (1998) 3867.

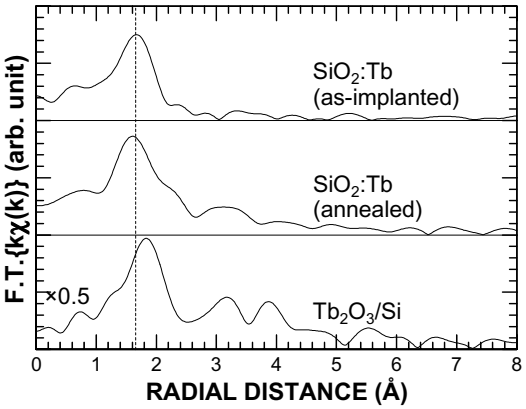

Fig. 1: Fourier transform of Tb LIII-edge EXAFS oscillation function $k\chi(k)$ spectra of the SiO_2:Tb thin films and the Tb_2O_3 film. Dotted lines show position of main peak for the as-implanted SiO_2:Tb film.

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