EFFECT OF SIZE CONFINEMENT ON CdSe NANOCRYSTALS IN A GeO_2 GLASS MATRIX CHARACTERIZED BY PHOTOACOUSTIC SPECTROSCOPY

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Semiconductor particles with sizes of a few nanometers in a glass matrix show very attractive properties completely different from those of bulk materials. They have potentials and promises both for basic study of the three-dimensional quantum confinement effect in semiconductors and for applications in the field of optoelectronic devices. Photoacoustic (PA) technique is a photothermal detection techniques and it is proved to be useful for investigating optical absorption characteristics for opaque and optically scattering samples. In the PA method, one can detects an acoustic energy directly proportional to the thermal energy induced by nonradiative relaxation processes. Recently, it was observed that the exitonic transitions of semiconductor nanocrystals were well resolved in PA spectra as compared to the corresponding optical absorption spectra.[1] In the present paper, we report the annealing time and temperature dependence of the PA spectra of CdSe nanocrystals in a GeO_2 glass matrix.

A mixture of GeO_2, Na_2GeO_3, and CdSe powders were melted 1180℃ for 4 hours. Ater that, it was quenched in water. The samples were annealed at 500℃ in a time range of 1 to 16 hours. The other samples were annealed for 30 minutes in a temperature range of 500 to 700℃. PA measurements were carried out by the normal gas-microphone method. Measurements were carried out in the wavelength range of 320 to 800 nm with the modulation frequency of 33 Hz.

Figure 1 shows the PA intensity spectra of the samples with different annealing time (annealing temperature: 500℃). The PA intensity spectra gradually increase from the absorption edges and the absorption peaks can be observed. The absorption edges and peaks in the PA intensity spectra shift to lower energy region with the increase of annealing time. The nanocrystal size can be calculated by the effective mass approximation.[2] The average radius of CdSe nanocrystals are shown in Fig. 2 as a function of cubic root of annealing time, indicating that CdSe nanocrystals in a GeO_2 glass grow by a diffusion processes. The PA intensity spectra of the samples with different annealing temperature shows that the shapes of the PA spectra change with the increase of annealing temperature. The quantum confinement effects become weaker with the increase of nanocrystal radius. From the average radius of CdSe nanocrystals with different annaling temperature, the activation energy of the diffusion processes of CdSe nanocrystals was estimated to be ca. 1.0 eV and it was smaller than that of CdS (~ 0.45 eV).

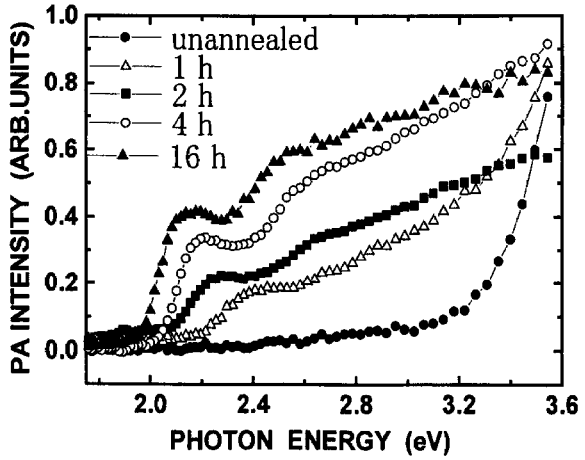

Fig. 1 PA spectra of CdSe nasnocrystals for different annealing time (at 500℃).

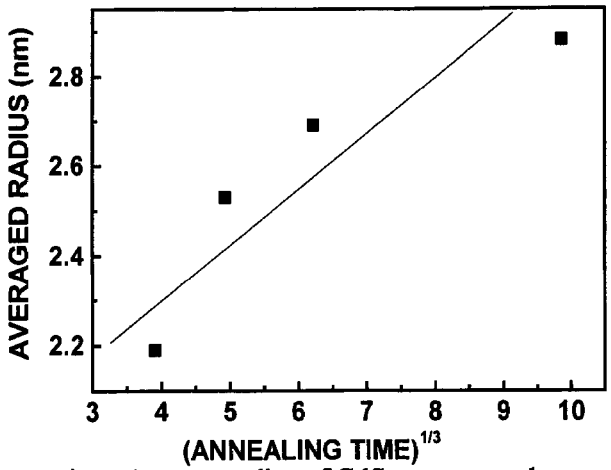

Fig. 2 Average radius of CdSe nanocrystals as a function of (annealing time)$^{1/3}$.

1) P. Nandakumar et al., Solid State Commun. **106**, 193 (1998)., 2) Y.-S. Yuang et al., J. Appl. Phys. **76**, 3041 (1994).