Optical characterization of CdS and CdS:Mn nanocrystals fabricated by ion-beam synthesis

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Recently, semiconductor nanocrystals have attracted considerable interest because they exhibit strongly size-dependent optical and electronic properties. One of the most versatile techniques for compound nanocrystal fabrication is high-dose ion implantation followed by thermal annealing, because compound nanocrystals can be simply fabricated by sequential ion implantation of the elements forming the compound. The compound nanocrystals are embedded in the near surface of dielectric matrices. These embedded structures have some advantages for device applications, because of the chemical and mechanical stability and optically transparent matrices. In this work, we have fabricated CdS nanocrystals and Mn doped CdS nanocrystals by means of Cd^+, S^+, and Mn^+ implantation into Al_2O_3 and studied photoluminescence (PL) properties of CdS and CdS:Mn nanocrystals.

The samples were synthesized by equal doses ($2.2x10^{16}$ /cm^2 or $4.3x10^{16}$ /cm^2) of Cd^+ (450 keV) and S^+ (164 keV) into Al_2O_3 at 600 C. Samples annealed at 1000 C show efficient PL. The transmission electron microscopy and x-ray diffraction examinations show that the average diameter of CdS nanocrystals in Al_2O_3 was ~17 nm and the CdS nanocrystals have the wurtzite structure. Mn doped CdS nanocrystals were fabricated by implantation of Mn^+ ($2x10^{15}$ /cm, 250 keV) into CdS nanocrystals at 400 C. The Mn doped samples were annealed at 1000 C for 60 min.

The optical absorption and photoluminescence excitation (PLE) spectra of CdS nanocrystals show two excitonic peaks at 2.62 and 2.68 eV at 5 K. Theses peaks are due to the splitting of the excitonic states in wurtzite CdS nanocrystals. The broad PL band appears near the optical absorption edge. With an increase of the measurement temperature, two peaks are clearly observed in the PL spectrum. This is because excitons trapped at shallow localized states are thermally excited to the free-exciton state. In addition, our scanning near-field optical microscopy study shows that the broad PL is an assembly of sharp PL lines. The observed PL is ascribed to free excitons and excitons bound to impurities in CdS nanocrystals.

CdS:Mn nanocrystals show efficient and broad luminescence around 2.1 eV. This is attributed to the intra-3d transition of Mn^{2+} ions. The PL spectrum of CdS:Mn nanocrystals is completely different from that of CdS nanocrystals, although the PL excitation spectrum of CdS:Mn nanocrystals is similar to the absorption spectrum of CdS nanocrystals. These observations show that efficient energy transfer of carriers occurs from CdS nanocrystals to Mn^{2+} ions. We will discuss radiative recombination processes of excitons in CdS nanocrystals and energy-transfer processes in CdS:Mn nanocrystals.

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