Nanoscale physics

Spectroscopy of intra-manifold transitions of Er^{3+} ions in erbium-stabilized nanocrystalline zirconium

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Recently, erbium doped zirconium nanocrystals are recognized to be a very promising material for numerous photonic applications. They combine the advantages of fast oxygen conductor with the rich energy level structure of trivalent erbium ions and the photoluminescence (PL) efficiency enhanced due to small dimensions of nanostructures. It has been shown that the confinement effects can affect the spectroscopic properties of rare earth ions in nanocrystals due to cutting the low-energy phonon modes in the 20-40 nm crystals. As a result the phonon assisted relaxation for electrons can be restricted leading to a rapid increase of the intensity of hot bands that originate from the upper crystal field levels in the $^4I_{15/2}$ ground state of Er^{3+} ions as temperature decreases below 8 K. These factors, together with many others (like pumping regime, excitation wavelength and power density, dopant concentration, temperature and radiative lifetimes of the Er^{3+} excited states) result in the complex up-conversion emissions observed in nanocrystallites doped with Er^{3+}.

We report the near-infrared and visible up-conversion spectra of nanocrystalline $(Er_2O_3)_x(ZrO_2)_{1-x}$ prepared by the sol-gel methods. Here erbium acts both as the stabilizer agent and as the carrier of the Er^{3+} ions. The spectra are studied at various temperatures with purpose to detect the influence of phonon cutting on the intra-*J*-manyfold relaxation in the Er^{3+} ions.

It is shown that for the samples with 0.05 x 0.10 the photoluminescence spectra of Er^{3+} are defined by similar erbium environment in spite of different symmetry of the host ZrO_2 matrix. The low temperature hot band is revealed in the $^4I_{13/2}$ $^4I_{15/2}$ spectrum and interpreted in terms of phonon-assisted process for the intra-manifold $^4I_{13/2}$ relaxation caused by the spatial confinement effects in erbium-stabilized nanocrystalline zirconium.