Spectroscopic Properties of $Y_4Al_2O_9$:Ce Crystals under High Pressure

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$Y_4Al_2O_9$ crystals, abbreviated here as YAM (monoclinic yttrium aluminate), are difficult to grow in a bulk form by the Czochralski method since they undergo structural phase transition under cooling. However they may be manufactured by the micro-down pulling method. YAM:Ce crystals with various concentrations up to 1% of Ce, grown by this technique were studied in this work.

The crystal structure has been accurately determined by XRD on single crystal samples. The obtained crystals were characterized by various spectroscopic techniques, such as FT-IR, absorption, Raman, luminescence, luminescence decay kinetics, and photoluminescence excitation. FT-IR absorption in the spectral region of 4f→4f transitions of Ce^{3+} ions reveals existence of several Ce^{3+}-related centres in this compound, in agreement with its crystallographic structure. Absorption spectra consist of several bands in the UV region associated with optical transition between 4f and 5d states of Ce^{3+} ions. Luminescence of this material, which appears in a blue spectral region between 430 and 540 nm, undergoes strong temperature quenching, which begins already at temperature of about 20 K. The luminescence quenching is thermally activated with activation energy equal to about 21 meV.

We associate this quenching with position of the 5d state of Ce^{3+} close to the bottom of the conduction band [1]. High pressure luminescence experiments, performed in diamond anvil cell confirm this hypothesis. Due to pressure induced increase of the separation energy between the 5d states of Ce^{3+} ions and a bottom of the conduction band the temperature of the luminescence quenching is increased. Meanwhile the increase of pressure causes the red shift of luminescence spectra. Furthermore, pressure induces large red shift of the luminescence at pressure of above 70 kbar - at lower energies, which might be a fingerprint of phase transition. To verify our hypothesis about pressure-induced phase transition, Raman spectra of the YAM have been measured under high pressure up to 172 kbar.

For better understanding of the nature of processes associated with Ce^{3+} luminescence quenching in YAM we investigated Ce^{3+} luminescence kinetics as function of pressure and temperature. It was found that for all considered pressures and temperatures the luminescence decays exhibit two-exponential behaviour. The PL lifetime decreases with the increase of temperature , whereas it increases with increasing pressure for pressure range up to 120 kbar.

[1] G. Cunningham, Y. R. Shen, K. L. Bray, *Phys. Rev. B* **65** (2001) 024112.