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Luminescent properties of binary $MO\text{-}2SiO_2$ ($M = Ca^{2+}$, Sr^{2+}, Ba^{2+}) glasses doped with Ce^{3+}, Tb^{3+} and Dy^{3+}

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Abstract

Binary alkali-earth silicate glasses doped with Ce^{3+}, Tb^{3+}, and Dy^{3+} were obtained by melt-quenching technique and their photo- and radio-luminescence properties were investigated. The disordered structure of the glass is responsible for an inhomogeneous broadening of the electronic radiative $5d^1$ energy level of Ce^{3+} due to their localization in several positions with different surroundings, possessing a slightly different local ligand field. The influence of glass matrix composition on the Stokes shift as a function of ionic radius of the cation was shown. The radio-luminescence spectral shapes were related to the simultaneous occurrence of emissions from all Ce^{3+} configurations with relative weights proportional to their abundance in the glasses. The possibility of excitation of Ce^{3+} in different localizations was demonstrated and confirmed by the systematic shift of emission from excitation. On the contrary, no shift was observed in the Tb^{3+} and Dy^{3+} doped glasses, thanks to the lower effect of ligand field on their radiative electronic levels.

Introduction

Nowadays, single crystals are the most widely used materials in scintillation detectors [1,2]. However, active research is conducted also on other material forms like glasses, ceramics, or glass ceramics [3–5]. These allow realization of specific compositions and shapes that would be hardly reachable by single crystal growth. When doped with luminescent ions, glasses may display an effective luminescence signal and be promising candidates to substitute single crystals in different fields. In past years the possibility to obtain SiO_2–based fibers [6,7], $BaO\text{-}2SiO_2$:Ce (DSB:Ce) [8,9], $Li_2O\text{-}2SiO_2$:Ce (DSL:Ce) [10,11] and $Li_2O\text{-}2SiO_2$:Tb (DSL:Tb) [12] glasses with high scintillation efficiency was demonstrated. However, a number of problems are limiting the progress especially in the area of silicates [12].

Specific issues are the stabilization of rare-earth ions (REs) in the required valence state and their incorporation in high concentrations, in order to improve the transfer efficiency of excitations from the matrix. This problem may be solved by a few approaches during glasses production: i) to employ of special chemicals (for example SiC[13], $(C_6H_{10}O_5)_n$[14], that work as reducing agents); ii) to modify of the glass composition obtaining multicomponent glasses [15,16]; iii) to control the synthesis conditions (reducing or inert atmosphere)[17–19]. The above listed approaches allow to stabilize the RE predominantly in the required valence state and with