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Energy transfer based emission analysis of Eu^{3+} doped Gd_2O_3-CaO-SiO_2-B_2O_3 glasses for laser and X-rays detection material applications

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ABSTRACT

The Eu^{3+}-doped CaO-Gd_2O_3-SiO_2-B_2O_3 glasses were prepared to study photoluminescence, lasing potential and scintillation properties. Glasses absorb photons in ultraviolet, visible light and near infrared regions and are assigned to the energy transitions of Gd^{3+} and Eu^{3+}. Ultraviolet with 275 nm can generate the strong red emission with 614 nm via energy transfer form Gd^{3+} to Eu^{3+}. X-ray scintillation study exhibits strong emission pattern due to Gd-Eu energy transfer. The optimum concentrations of Eu^{3+} ion in this glass is 0.30 mol% as it results maximum emission intensity. The fluorescence lifetime of the $^5D_0$ level decreases from 1.763 to 1.726 ms when concentration increased from 0.05 to 0.40 mol%. From Judd-Ofelt analysis, this glass exhibit high potential for using as laser medium for red laser device with high lasing power and energy extraction ratio. Moreover, this glass performs the integral scintillation efficiency as 13% compared with BGO.

1. Introduction

Rare-earth ion (RE^{3+}) doped glass has been potentially used as the photonic material in recent years. Since low synthesis cost, large-volume production, easy shaping, high optical homogeneity and the possibility of varying luminescence properties within broad limits [1,2]. Also glasses doped with RE^{3+} ions are promising choices to compensate single crystals and ceramics in photonic applications, especially scintillation material and laser medium. Among RE^{3+}, europium (Eu^{3+}) is anion in the class of lanthanide which have the electron configuration $[Xe]-4F^6$. The most intense emission of Eu^{3+} is placed at wavelength around 610 nm which is red color emitting and can be attributed to $^5D_0 \rightarrow {}^7F_2$ hypersensitive transition [3,4]. From this characteristic of Eu^{3+}, it has been doped in many kinds of host to research and develop for using as laser gain medium in red laser device [5,6] and scintillation material in x-ray imaging applications [7,8]. For glass former, silicaborate recombination is an interesting host material because of its thermal, mechanical and chemical resistance. Moreover, it has been used as fiber glass reinforcing organic matrix composites [9]. Adding calcium element can increase intensity of luminescence emission of glass [10]. While, Gd_2O_3 has been a popular oxide for photonic materials due to the efficient energy transfer from Gd^{3+} ions to luminescence activator, high thermal neutron capture cross-section and increase the light yield of emission [11,12]. Glass scintillator with a high Gd_2O_3 content are concentrated in various silicate, borosilicate, phosphate and germinate glasses with fast decay time and/or relative high light yield [13]. The Gd^{3+}-RE^{3+} energy transfer also can enhance the photo emission which improve laser ability. Therefore, it can be said that Eu^{3+}-doped calcium gadolinium silicoborate glass is very interesting for using in photonic application, such as scintillation material and laser medium.

This paper reports about the study of calcium gadolinium silicoborate glasses doped with Eu^{3+}. Physical, optical and luminescence properties were investigated as a function of Eu_2O_3 concentration. The scintillation and laser potential of glass were analyzed by X-ray induced optical luminescence and Judd-Ofelt theory, respectively.

2. Experiment

Eu^{3+} doped calcium gadolinium silicoborate (CaGdSiBEu) glasses with compositions of $10CaO\text{-}25Gd_2O_3\text{-}10SiO_2\text{-}(55\text{-}x)B_2O_3\text{-}xEu_2O_3$ (where x is 0.05, 0.1, 0.2, 0.3 and 0.4 mol%) were prepared by melt

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