

# Photoluminescence of Ce<sup>3+</sup> ions doped in LiAl<sub>5</sub>O<sub>8</sub> aluminate systems

G. N. Nikhare\*, S. C. Gedam\*, S. J. Dhoble\*

\*Department of physics, RTM Nagpur University, Nagpur 440033, India

\*Department of physics, K.Z.S. Science College, Kalmeshwar, Nagpur 441501, India

## Abstract

The aluminate phosphors LiAl<sub>5</sub>O<sub>8</sub>: Ce was synthesized by combustion synthesis. Photoluminescence (PL) characterization of the phosphors has been reported in this paper. The Photoluminescence (PL) emission spectra of the LiAl<sub>5</sub>O<sub>8</sub>: Ce phosphors show strong Ce<sup>3+</sup> emission at around 310 nm for the excitation at wavelength of 254 nm wavelength of light due to the 5d→4f transition. These phosphors may be useful in scintillation.

**Keywords:** Combustion synthesis, photoluminescence; aluminates

## INTRODUCTION

The interest in the rare earth doped alkaline earth aluminates has been largely due to their high luminescence efficiency under UV excitation and their ability to maintain their phosphorescence for several hours. Many authors have concentrated to developed aluminates as a lamp, scintillator, flat panel display, X-ray imaging phosphors.

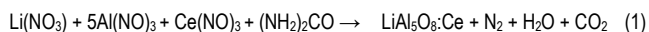
Cerium-doped materials have been the topic of many investigations for their application as tunable- gain media in the ultraviolet (UV) and near UV [1]. The relationship between 4f<sup>n</sup>-5d-level energies and crystalline environment, efforts were concentrated fully on Ce<sup>3+</sup> doped systems. Very recently, D. Jia et-al. [2] developed a persistent phosphor CaAl<sub>2</sub>O<sub>4</sub>: Ce<sup>3+</sup> with violet blue phosphorescence at 400 nm and a persistence time is more than 10 hrs. It is well known that Ce<sup>3+</sup> is an efficient sensitizer, especially for Tb<sup>3+</sup> [3]. The Ce<sup>3+</sup> ion has only one 4f electron in the ground configuration. In excited configuration of Ce<sup>3+</sup> there is one 5d electron with empty 4f shell. So, the structure of the 4f-5d transitions will be dominated by crystal-field splitting of the 5d states of Ce<sup>3+</sup>, since there is no interaction within 4f core and interaction between 4f core and 5d electron for Ce<sup>3+</sup> which strongly influence the energy level structure for excited configuration of RE ions with more than one 4f electron [4,5]. Due to this reason, excitation spectrum of Ce<sup>3+</sup> and emission for aluminate crystals at its lowest-energy edge of 4f-5d absorption should consist of wide absorption band.

For the understanding of the lanthanide f - d structure, knowledge about the excitation spectrum of Ce<sup>3+</sup> in a certain host lattice is very important. The Ce<sup>3+</sup> ion has the 4f<sup>1</sup> configuration and irradiation with UV radiation will excite this 4f<sup>1</sup> electron into a 5d orbital, leaving the 4f shell empty. Therefore, the excitation spectrum of Ce<sup>3+</sup> will give direct information on the crystal-field splitting of the 5d orbitals; similar crystal-field splitting is expected for all rare-earth ions in the same host lattice. In this paper we have reported the PL study of the Ce<sup>3+</sup> ion in aluminates hosts. All the phosphors (LiAl<sub>5</sub>O<sub>8</sub>: Ce and NaAl<sub>11</sub>O<sub>17</sub>: Ce) prepared by single step combustion synthesis [6].

Some authors have studied LiAl<sub>5</sub>O<sub>8</sub> [7-9] for luminescence and phase formation respectively. In the present paper we report cerium activated phosphor prepared by combustion method and characterized photoluminescence (PL) properties.

## Experimental

All the aluminates were produced through the urea combustion technique. For the stoichiometric compositions of the metal nitrates (oxidizers) and urea (fuel) were calculated using the total oxidizing and reducing valencies of the components. For the preparation of LiAl<sub>5</sub>O<sub>8</sub>: Ce, the constituents were Li(NO<sub>3</sub>), 5Al(NO<sub>3</sub>)<sub>3</sub>, (NH<sub>2</sub>)<sub>2</sub>CO and Ce(NO<sub>3</sub>)<sub>3</sub>. The details of the reactions for all compounds are described as follows-



Weighed quantities of each nitrates, urea is added and the mixture is crushed together into mortar for 1/2 hrs to form a thick paste. The resulting paste is transferred into a china crucible and introduced into a vertical cylindrical muffle furnace maintained at 500 °C. The mixture undergoes dehydration and then decomposition with liberation of NH<sub>3</sub> and NO<sub>x</sub>. Large exothermicity results into a flame changing the mixture into gaseous phase. Flame temperature as high as 1600 °C converts the vapour phase oxides into mixed aluminates. The foamy product is crushed into a fine powder and the resultant polycrystalline mass was crushed to fine particle in a crucible. The powder was used in further study. The X- ray diffraction patterns of all samples were matched with standard ICDD data. The photoluminescence (PL) emission spectra of the samples were recorded using Fluorescence spectrometer (Hitachi F-4000). The same amount of sample was used in every case. Emission and excitation spectra were recorded using a spectral slit width of 1.5 nm.

## Results and discussion

### Photoluminescence of LiAl<sub>5</sub>O<sub>8</sub>: Ce

Figure1A shows the PL excitation spectra of Ce<sup>3+</sup> ion in LiAl<sub>5</sub>O<sub>8</sub> lithium aluminate (λ<sub>exc</sub> = 254 nm) monitored at 310 nm emission. Figure1B shows the PL emission spectra of Ce<sup>3+</sup> ion in LiAl<sub>5</sub>O<sub>8</sub>: Ce (where, x = 0.1, 0.2, and 0.5 mole %). The emission peak wavelengths and its relative intensities are shown for different contents of Ce<sup>3+</sup> ion. According to PL spectra, it is seen that the concentrations of Ce<sup>3+</sup> ion not only affects the peak height but also the peak profile. With increase of Ce<sup>3+</sup> concentrations, the emission intensity increases relatively and the emission peak position also

changed. In figure 1B the well known UV emission of  $Ce^{3+}$  ions in these phosphors is around 310-312 nm. This band is due to the allowed transition from 5d to 4f of  $Ce^{3+}$  ions giving maximum intensity for the excitation wavelength of 254 nm with a shoulder at 274 nm. The excitation energy matches with the energy separation between the ground state and lowest state of the 5d level of the ion. This situation populates the lowest 5d level to the maximum, which favors maximum emission intensity. Another characteristic feature of the emission band is the absence of the expected doublet arising due to the transition from 5d  $\rightarrow$   $^2F_{5/2}$  and  $^2F_{7/2}$  levels due to spin orbit splitting of the 4f  $^1$  ground state of  $Ce^{3+}$  ions. Figure 1C shows the energy level diagram for  $Ce^{3+}$  in  $LiAl_5O_8$ .

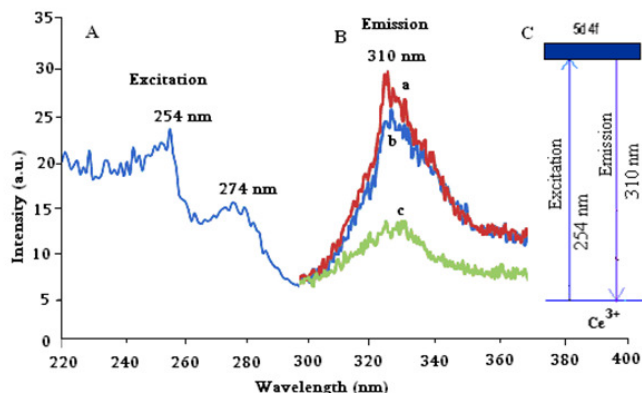


Fig 1. PL (A) excitation and (B) emission spectra of  $LiAl_5O_8: Ce_x$  ( $x = a. 0.5$  mole%,  $b. 0.2$  mole%,  $c. 0.1$  mole %) (C) Schematic energy level diagram of  $Ce^{3+}$  in  $LiAl_5O_8$

## CONCLUSION

Cerium-doped  $LiAl_5O_8$  aluminate phosphor have been prepared by a single-step combustion synthesis in a normal

atmosphere. From the results it is clear that the emission of  $Ce^{3+}$  in  $LiAl_5O_8$  aluminate is at the lower side (310 nm). Hence  $Ce^{3+}$  emission in above phosphors may be useful for scintillation applications.

## ACKNOWLEDGEMENT

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