

Study of Photo- Luminescence in Doped Metaphosphate NaCe(PO₃)₄ S.U. Bhonsule ^a, S.P.Wankhede ^b, and S.V.Moharil ^c

a-Department of Physics, P.C.E Nagpur, India

b - Department of Physics, K.D.K.College of Engineering, Nagpur, India

c-Department of Physics, Nagpur University, Nagpur, India,

Corresponding author: subhonsule@gmail.com :

(M): 09011084475

Abstract

Inorganic Phosphor $NaCe(PO_3)_4$: Tb^{3+} was synthesized by solid state diffusion method. The prepared sample was characterized by X-Ray diffraction and photoluminescence. The photoluminescence study shows doped Tb^{3+} leads to a significant increase in the emission intensity in the range of 500-600nm. This is due to the efficient energy transfer from Ce^{3+} to Tb^{3+} under an excitation of 274 nm. Such phosphors can be used for UV lamps application in solid state Lasers and in optical amplifiers. In this paper Photo-luminescence in $NaCe(PO_3)_4$ and $NaCe(PO_3)_4$: Tb^{3+} has been reported. Energy transfer phenomena have lead to the development of new and efficient photoluminescence materials.

Keywords: Cerium metaphosphate; Excitation and emission spectra; solid state synthesi; Energy Transfer.

1.0 INTRODUCTION

Rare Earth doped inorganic phosphors are used extensively in solid state lighting, because they have long life, physical and chemical stability and environment friendly nature. The lanthanide ions like Tb³⁺ and Dy³⁺ in ortho and metaphosphates give a high quantum yield of visible Luminescence. Trivalent lanthanide ions are used extensively for optically-pumped solid-state lasers because they possess suitable absorption bands and numerous fluorescence lines of high quantum efficiency in the visible and near-infrared.[1] Sensitization of characteristic fluorescence is a well known phenomenon on which a large number of experimental studies have been published.[2] Ce³⁺ has a strong absorption in many hosts and emission matching with 4fⁿ levels of other rare earth impurities, and thus it can be used as a sensitizer for Tm³⁺, Sm³⁺, Dy³⁺, Tb³⁺, Nd³⁺, Gd³⁺, and Pr³⁺. In this paper Photoluminescence in NaCe(PO₃)₄:Tb³⁺ has been compared with undoped one. Terbium shows strong excitation corresponding to allowed transition between ${}^{7}F_{6}$ ground state of $4f^8$ configuration to the levels of $4f^75d^1$ configuration. Quite often, this falls in deep UV or VUV region of the spectrum. From the excited state the ion relaxes in several steps to ${}^{5}D_{i}$ levels of $4f^{8}$ configuration. Line emission corresponding to f-f transitions is observed. Commonly observed most intense lines are around 485 nm and 543 nm corresponding to ${}^{5}D_{4} \rightarrow {}^{7}F_{5}$ and ${}^{5}D_{4} \rightarrow {}^{7}F_{6}$ transitions, respectively. At low concentrations blue emission is dominant. Near UV emission around 385 nm corresponding to ${}^{5}D_{3} \rightarrow {}^{7}F_{6}$ transition is also observable. For high concentrations, these emissions are quenched by cross relaxation and the green emission becomes dominant.

1.1 EXPERIMENTAL

The chemicals used for the reaction were of Analytical Reagent grade. Inorganic Phosphor NaCe(PO₃)₄, NaCe(PO₃)₄:Tb³⁺were synthesized by solid state diffusion method with Tb³⁺ concentration varying from 1% to 5%. Method givenby Szczygiel et al and Rzaigui [3,4] were followed for preparation of this compound. 750°C

$$Ce(PO_3)_3 + NaPO_3 \xrightarrow{750} NaCe(PO_3)_4$$

20 hr

For NaCe(PO₃)₄:Tb the constituents Ce(PO₃)₃ and NaPO₃ and sulphate Terbium were were taken in a stoichimetric ratio and crushed in a crucible for 1 h. Then this material was heated at 750°C for 20 hr, resulting in the compound NaCe(PO₃)₄:Tb in powder form. The samples were then slowly cooled at room temperature.



International Journal of Luminescence and its applications Volume 4(I), 14/02/2014, ISSN 2277 – 6362

 $\begin{array}{c} 750^{\circ}\text{C}\\ \text{Ce}(\text{PO}_{3})_{3} + \text{NaPO}_{3} + \text{Tb}_{2}(\text{SO}_{4})_{3} \rightarrow \\ 20 \text{ hr} \end{array} \text{NaCe}(\text{PO}_{3})_{4}:\text{Tb} \end{array}$

X-ray diffraction patterns were recorded on Philips PANalytical X'pert Pro diffractometer. Photoluminescence (PL) spectra in the spectral range 220-700 nm were recorded at room temperature on Hitachi F-4000 spectro-fluorimeter with spectral slit widths of 1.5 nm.

1.1.1 RESULT AND DISCUSSIONS

Fig.1shows the XRD of prepared $NaCe(PO_3)_4$. X-ray diffraction of prepared $NaCe(PO_3)_4$ is found to match with ICDD file 33-1233 of $NaCe(PO_3)_4$.



FIG1. XRD of NaCe(PO₃)₄

The emission spectra of NaCe(PO₃)₄ shows intense PL emission with peaks at 327.6 nm and 346 nm which are due to transition from the lowest level of 5d configuration to the two ${}^{2}F_{5/2}$, ${}^{2}F_{7/2}$ multiples of the 4f¹ configuration in Ce³⁺ ions and half intensity peaks at 316 nm and 361 nm at λ ext. =254nm(Fig.2).The PL excitation spectrum shows a broad band in the range 220 nm to 320 nm with peak at 298.6 nm, 254.4 nm and 227.6 nm and Half intensity peaks at 310 nm and 282 nm at λ emn. =346nm.



Figure 2: PL spectra of NaCe(PO₃)₄.

Figure 3 shows Emission spectrum of NaCe(PO₃)₄ doped with 1% Tb and 5% Tb.For 5% Tb doping(curve b'),there is significant increase in the emission intensity in the range of 500-600nm showing transfer of energy from Ce³⁺ to Tb³⁺. For 1% doping of Tb³⁺ emission(curve b), it is excited at λ ext. =295nm and for Cerium, it is excited at λ ext. =254nm. For 5% doping of Tb³⁺,Ce³⁺emission and Tb³⁺ emission takes place under an excitation of 274 nm. In emission spectra(curve b') peaks are observed at379.6nm,413.6nm,434.8nm,455.6nm,487.2nm,542.4nm and at 585nm. which correspond to ${}^{5}D_{4} \rightarrow {}^{7}F_{J}$, transitions of Tb³⁺. There is also weak emission in UV region (curve a,a') which is attributable to Ce³⁺ ions.



Figure3:PLspectra of NaCe(PO₃)₄:Tb(1mole%,5 mole %).

2.0 CONCLUSION

The metaphosphates $NaCe(PO_3)_4$ and $NaCe(PO_3)_4$:Tb have been successfully prepared. XRD of the synthesized compound matched excellently with the corresponding ICDD data files. At low concentrations blue emission is dominant. Near UV emission, at around 385 nm corresponding to ${}^5D_3 \rightarrow {}^7F_6$ transition is also observable. For high concentrations, these emissions are quenched by cross relaxation and the green emission becomes dominant. Energy transfer phenomena have lead to the development of new and efficient photoluminescence materials. These phosphors may be applicable in scintillation applications and in the lamp industry.

ACKNOWLEDGEMENT

Work received financial support from the Indian Council for Medical Research (ICMR), New Delhi. We are thankful to Dr. P.L. Muthal and Dr. S.M. Dhopte and his colleagues at National Environmental Engineering Research Institute, Nagpur for making PL measurements.

References:

- 1. M. Srivastava, M.T. Sobieraj, J. Electrochem. Soc. 137. (1990) 2959.
- 2. D. L. Dexter, J. Chem. Phys. 21, (1953) 836.
- 3. Irena Szczgiel and Teresa Znamierowska, J. Solid State Chem. 82 (1989) 181.
- Mohamad Rzaigui and Najia Kbir Ariguib, J. Solid State Chem. 39 (1981) 309