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Aldo-Keto Gel Synthesis and Photoluminescence Properties of $YVO_4:Eu^{3+}$ Microsphere

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ABSTRACT

The Eu^{3+} doped YVO_4 phosphor synthesized via simple aldo-keto gel method by using Benzaldehyde and Acetone which then compared with conventional solid state diffusion. Powder X-ray diffraction (XRD) and field emission scanning electron microscopy (FE-SEM) studies indicate that the prepared samples were well crystalline and free from organic impurities. However, the nature of as-prepared phosphor by using aldo-keto gel method does not having any agglomeration. Further photoluminescence (PL), photoluminescence excitation (PLE) spectra and decay curves were superior as compared to solid state diffusion method.

Keywords: Aldo-keto gel method; aldehydes and ketones; spherical particle, PL properties; CIE diagram.

I. INTRODUCTION

Yttrium based materials doped with europium (III) have attracted more attentions among the many researcher group because these are important excellent commercial red-emitting phosphors used in various applications such as color television, the cathode ray tube and plasma display panel [1-3] due to its high quantum efficiency, dip red color purity, and high thermal stability [4]. Among all these yttrium based phosphors, the Eu^{3+} doped YVO_4 is still more demanding in the field of luminescence for the upcoming research because, its wide band gap. Also, absorption spectrum of YVO_4 shows strong and broad bands in the ultraviolet (UV) region [5].

The effect of synthesis method is important in the rare earth doped host lattice because luminescence efficiency is depending on nature of particles (agglomerated or un-agglomerated) [6]. A lot of efforts have been focused on the enhancement in luminescent properties of $YVO_4:Eu^{3+}$ phosphor with non agglomerated and narrow particle size. For the synthesis of phosphors, a variety of conventional and non conventional techniques have been adopted. The conventional method such as solid-state reaction is required lot of time with high temperature for preparation of phosphor [7]. Therefore, there is need to synthesis of such a phosphors at low temperature. The particle size of material prepared by solid state method is in the range of few micrometers and non homogeneous nature of as-prepared phosphor particle size.

All conventional and non conventional synthesis approach is sophisticated synthesis techniques for preparation of $YVO_4:Eu^{3+}$, but suffers with drawback. Because precursor require for synthesis is very costly and other additive chemical required for these methods are very expensive which leads to increase cost of application devices. Therefore in progressive

research we developed a novel synthesis technique for preparation of phosphors.

Inspiring from the above discussions, the present work planned to study the luminescent properties of $YVO_4:Eu^{3+}$ phosphor synthesized by using aldo-keto gel method and compared with very famous method is known as solid state diffusion.

II. METHODS AND MATERIAL

2.1 Solid state diffusion

The phosphor YVO_4: Eu^{3+} was synthesized by solid state methods with Eu concentration 0.01 mole. The precursor Y_2O_3 (99.99%, AR), NH_4VO_3 (AR) and Eu_2O_3 (99.90%, AR) were mixed thoroughly in a mortar with small amount of acetone. The resultant mixture was transferred to an alumina crucible and oven dried at 50°C. The mixture was heated in a resistive furnace at 1100ºC for 10h with intermittent grindings. The white powder of $YVO_4:Eu^{3+}$ so obtained was used for characterization.

2.2 Aldo-keto gel method

Aldo-keto gel method is uses to synthesis of $YVO_4:Eu^{3+}$ phosphor as per the previous work [8]. The precursors used $Y(NO_3)_3$ (99.99%, AR) and $Eu(NO_3)_3$ (99.99%, AR) were mixed together in a china clay basin. In basin $VOSO_4$ (AR) were mixed with some amount of water. On slowly heating to dryness, precipitated changed its color to reddish black. The acidic traces were removed by adding small quantity of deionized water to precipitated and drying 2-3 times; it finally changes to red color.

The red dried compound was finally milled. The benzaldehyde (1M) and acetone (1M) were added to this compound after that NaOH added drop by drop with increasing temperature.

On further slow heating, pyrolysis of foam was started at 450°C and shining black foam was formed at 500°C, which started burning from 700°C. After that one time washing and drying is required for better luminescence properties.

2.3 Material characterization

The phase purities of $YVO_4:Eu^{3+}$ samples were studied using Rigaku miniflex II X-ray diffractometer with scan speed of 2.000°/min and CuK_α (λ = 1.5406 Å) radiation in the range 10° to 90°. The PL and PLE spectra were measured on (Hitachi F-7000) fluorescence spectrophotometer at room temperature. The parameters such as spectral resolution, width of the monochromatic slits (1.0 nm), photomultiplier tube (PMT) detector voltage and scan speed were kept constant throughout the analysis of samples.

III. RESULTS AND DISCUSSION

3.1 XRD analysis

The formation of the crystalline phase of as-prepared products of solid state diffusion and aldo-keto gel method was confirmed by X-ray diffraction patterns as shown in Fig.1, to verify the phase purity and crystal structure. The X-ray pattern of both method samples indicated a pure phase of the standard YVO_4 and all the peaks are in good agreement with the (ICDD, 01-082-1968). Also the XRD shows that the formed material is completely crystalline and is in single phase, where a = b = 7.11 and c = 6.28 Å. The space group for YVO_4 is a I41/amd(141).

3.2 Morphology of $YVO_4:Eu^{3+}$ phosphors

FE-SEM analysis was done and resulting image displayed in Fig. 2 (A and D). The representative micrograph (A) for solid state diffusion and (D) for aldo-keto gel method shows that synthesized sample comprises regular shape with agglomerated and non agglomeration particles. The $YVO_4:Eu^{3+}$ phosphor prepared by aldo-keto gel method gives the non agglomerated and fine spherical particles. Also the grain boundaries of as-prepared materials were fine and well separated with no organic additives. On the other hand, sample prepared by solid state diffusion method reflects the agglomerated irregular nature of particles.

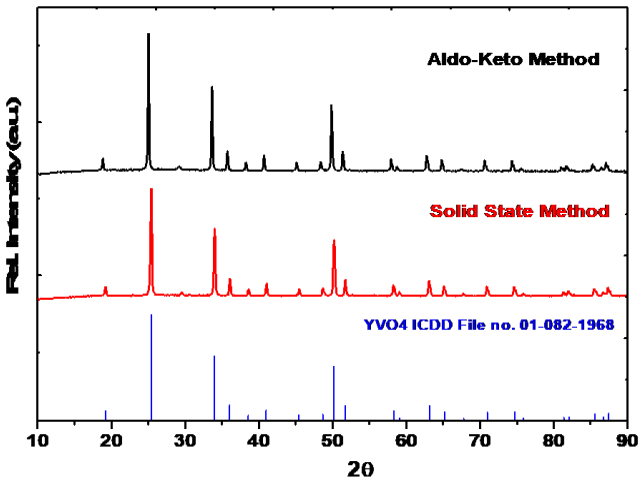

Fig. 1 XRD patterns of the $YVO_4:Eu^{3+}$ nanophosphor synthesized through solid state diffusion and aldo-keto gel method.

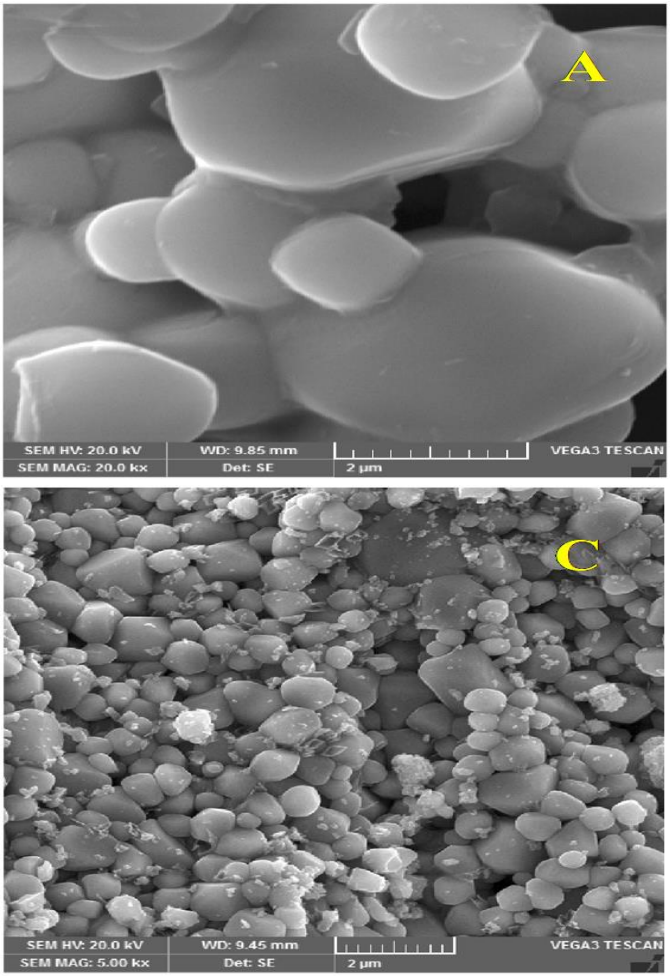

Fig. 2 FE-SEM images of the $YVO_{4:0.01}Eu^{3+}$ phosphor synthesized through solid state diffusion (A) and aldo-keto gel method D).

3.3 Photoluminescence properties

Fig. 3 demonstrates excitation and emission spectra of $YVO_4:Eu^{3+}$ phosphor synthesized by using solid state method and aldo-keto method with same concentration of Eu^{3+} ions (0.01 mole). The excitation and emission spectrum reflects that the phosphor prepared by aldo-keto gel method gives highest PL emission intensity as compared to solid state diffusion. The excitation attributed at 615 nm and emission monitored at 621 nm wavelength. The excitation spectrum shows similar nature except for a difference in intensity. It consists of a broad band with high intensity from 200 to 350 nm centered at 315 nm due to a charge-transfer transition from the oxygen ligands to the central vanadium atom inside the VO^{3-}_4 ion. Also, several narrow bands with low intensity in the range of 350–500 nm are due to the f–f transitions within Eu^{3+} 4f6 electron configuration [9].

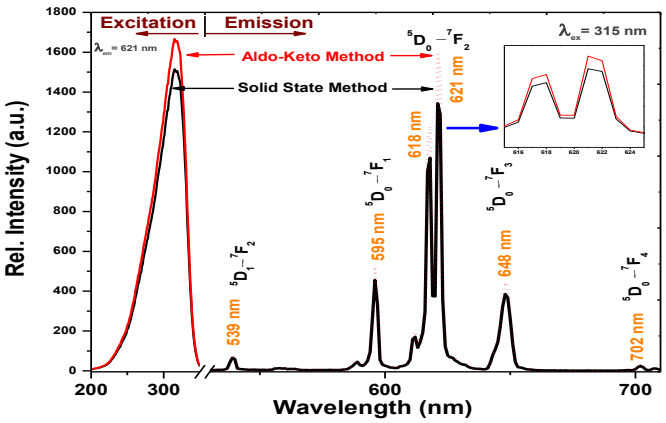

Fig. 3 PL excitation and emission spectra of $YVO_{4:0.01}Eu^{3+}$ phosphor synthesized via solid state diffusion (Black lines) and aldo-keto gel method (Red lines) (Inset of emission at 618 nm and 621 nm.

The emission spectra of $YVO_4:Eu^{3+}$ is as shown in Fig. 3. It consist of number of emission peaks in the ranging 550 to 710 nm corresponding to of $^5D_0 \rightarrow {}^7F_J$ (J = 1, 2, 3, 4) transitions of Eu^{3+} ions. The peak at 595 nm is corresponding to $^5D_0 \rightarrow {}^7F_1$ transition in the orange region due to magnetic dipole interaction and peaks at 618 and 621 nm are corresponding to $^5D_0 \rightarrow {}^7F_2$ transition in the red region due to electric dipole transition. The electric dipole transition is sensitive to

chemical bonds in the vicinity of the Eu^{3+} ion. On the other hand, the magnetic dipole transition is changes with the crystal field strength around the Eu^{3+} ion. Therefore, the PL intensity ratio of $^5D_0 \rightarrow {}^7F_2$ (Red) to $^5D_0 \rightarrow {}^7F_1$ (Orange) transitions is depend on the Eu^{3+} ions local surrounding environment. Generally, Eu^{3+} ions occupies an inversion symmetry site in the host matrix, then the orange emission ($^5D_0 \rightarrow {}^7F_1$) could be a dominant emission. Moreover, The peaks at 648 and 702 are corresponding to $^5D_0 \rightarrow {}^7F_3$ and $^5D_0 \rightarrow {}^7F_4$ transition respectively. In $YVO_4:Eu^{3+}$ phosphor the electric dipole transition ($^5D_0 \rightarrow {}^7F_1$) shows superior PL intensity than magnetic dipole transition ($^5D_0 \rightarrow {}^7F_2$). The small peak at 539 nm is attributed to $^5D_1 \rightarrow {}^7F_2$ transition. [10].

IV. CONCLUSION

The inorganic intense red emitting $YVO_4:Eu^{3+}$ phosphor was first time successfully prepared by aldo-keto gel method and compared with solid state diffusion method. The experimental results indicate that aldo-keto gel method requires low temperature than that of solid state reaction and also reaction complete in less time.

The aldo-keto gel method does not need expensive equipment and result in good PL intensity. The aldo-keto gel method is based on molecular synthesis of particles so that agglomeration of phosphor particle can be avoided.

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