ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

Synthesis and Luminescence Properties of Yttrium Vanadate based Phosphors

V. B. BHATKAR
Department of Physics, Shri Shivaji College, AKOT (MS) India 444101

Abstract*— Rare earth doped YVO_4 and $YVPO_4$ phosphors find uses in various applications in the fields such as fluorescent lamps, light emitting diodes (LEDs), advanced flat panel display, field emission display devices or biological labelling.. This paper describes a modified combustion synthesis of YVO_4: Eu/Dy and $YVPO_4$: Eu/Dy phosphors. The phosphors were prepared by various other synthesis methods like solid state diffusion, precipitation, etc., and the results are compared. The structure and optical properties of the final products were characterized by X-ray powder diffraction (XRD) and photoluminescence spectroscopy (PL). The characteristic emission of Eu^{3+} and Dy^{3+} was observed in all the samples. It is concluded, that the combustion synthesis using urea and ammonium nitrate provides a rapid and cost effective method for preparing efficient phosphors.

Index Terms— **Combustion Synthesis, Optical Materials, Photoluminescence, Yttrium Vanadate.**

I. INTRODUCTION

The YVO_4 crystal is tetragonal, belonging to space group $^{19}D_{4h}$. The dopant rare earth ion substitutes on Y^{3+} ion sites. The local site symmetry is D_{2d} and it is surrounded by eight O^{2-} ions [1]. Rare earth doped YVO_4 phosphors find many applications. Efficient host sensitized luminescence in YVO_4: Eu was first reported by Van Uitert *et al*. [2]. Levine and Pallila [3] developed YVO_4:Eu as a red component of color television (CTV) phosphor. Later, YVO_4:Eu was also found to be an efficient PL material which can be used in lamps [4]. It was soon replaced by Y_2O_3:Eu. However, it still finds application in high-pressure mercury vapor (HPMV) lamps in which it is used for improving color rendition index (CRI). $Y_{0.95}Eu_{0.05}V_{0.4}P_{0.6}O_4$ phosphor is better for this application [5]. Addition of phosphorus improves the thermal quenching behavior and modifies the excitation spectrum to match with the mercury emission at 253.7 nm [6]. In recent years, YVO_4: Eu phosphor has found applications in medical imaging also [7, 8]. Palilla *et. al.*, [9] reported intense emission in YVO_4:Dy also. Emission in YVO_4: Dy is yellowish. $Y_{0.995}Dy_{0.005}V_{0.4}P_{0.6}O_4$ yields white emission resulting from combination of blue, 484 nm, ($^4F_{9/2} \rightarrow {}^6H_{15/2}$) and yellow, 573 nm, and (4F9/2 → 6 H 13/2) emissions of Dy3 + [10]. Introduction of Bi^{3+} into YVO_4:Eu^{3+} leads to the shift of excitation band to the long-wavelength region, thus the emission intensities of $^5D_0$–$^7F_2$ electric dipole transition of Eu^{3+} at 615 nm upon 365 nm excitation increases sharply [11]–[14], which makes this phosphor a suitable red-emitting material that can be pumped with near-UV light emitting diodes (LEDs). The luminescence property of YVO_4:Eu^{3+} was also investigated as drug delivery system [15] .

In most of the earlier works YVO_4: Eu phosphors have been prepared by solid state reactions. During recent years, YVO_4 based phosphors have been prepared using novel syntheses like hydrolyzed colloidal reaction (HCR) [16], flux technique [17]--[19], solvothermal synthesis [20], combustion synthesis [21–24], sol-gel synthesis [25], Pechini-type sol–gel method [26]--[27], precipitation [28]--[32], urea precipitation [33], hydrothermal synthesis [34]--[38], microwave rapid heating method [39] etc. Various syntheses have been carried out by different workers using starting materials from different sources. The comparison of different methods is therefore difficult. In this paper, we describe synthesis and photoluminescence properties of Eu and Dy doped YVO_4 and $Y(V,P)O_4$ phosphors using different methods.

II. EXPERIMENTAL

In this study the Eu or Dy activated phosphors were prepared by various methods. The precipitation method [29] consists of mixing ammonium metavanadate (NH_4VO_3) with the nitrate of the selected element at a given concentration and then controlling the pH. Initially a 3M HNO_3 solution was added to lower the pH to a value denoted as 'lower pH'. Then the pH was adjusted to favor the precipitation process. GR grade starting materials, YNO_3, Eu_2O_3 or Dy_2O_3, NH_4VO_3 and/or $(NH_4)_2HPO_4$ were used. Stoichiometric amount of NH_4VO_3 was dissolved in hot water (Soln. A), YNO_3 was dissolved in double distilled water (Soln.B), Eu_2O_3 or Dy_2O_3 was

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

dissolved in 3M HNO_3 (Soln. C). Solutions 'B' and 'C' were mixed and stirred, to this solution, solution 'A' was added. The pH was lowered to 1 to induce complete dissolution, and then raised with the addition of NH_4OH to 4 to obtain pure phase in the form of precipitate. The precipitate so obtained was filtered out, washed with double distilled water and acetone, and dried at 50 ^{O}C. The final product was calcined at 800 ^{O}C.

In the solid state synthesis, the starting materials, YNO_3, dopant oxides (Eu_2O_3 or Dy_2O_3), and V_2O_5 were mixed together in the mortar. It was transferred to the porcelain crucible and heated slowly from 100 ^{O}C to 800 ^{O}C for 12 hours. Slow heating is essential for obtaining 'white' product. During rapid heating if the vanadium compound melts, metal metavandates are formed which impart yellowish body color?

Phosphors were also prepared by combustion synthesis using different fuels like 3-methylpyrazole-5-one (3MP5O Lab. synthesized), Oxalyldihydrazide (ODH, lab. synthesized), glycine, urea, citric acid, etc, and oxidizers like ammonium per chlorate and ammonium nitrate. The oxidizing and reducing valences were calculated as described in our earlier work [21, 22]. Appropriate amount of Y_2O_3 and Eu_2O_3/ Dy_2O_3 were dissolved in 3M HNO_3 to form respective nitrates in the solution. To this solution the stoichiometric amount of fuel and oxidizer were added. Stoichiometric amounts of NH_4VO_3/$(NH_4)_2HPO_4$ in form of aqueous solutions were added to the above solution and stirred to homogenize. The entire solution, in Pyrex dish, was transferred to a furnace pre-heated at 400 ^{O}C. The solution on rapid heating concentrates and ignites at 400C with the evolution of large amount of gases. The voluminous, fine particle product is formed in few minutes. The as formed products were fired in air at the temperatures of the order of 800 ^{O}C for 1 hour. To confirm the structure of the synthesized phosphors, powder photographs were obtained using Philips diffract meter, PW 1710. Photoluminescence spectra were recorded on Hitachi F-4000 spectro-fluorimeter with spectral slit width of 1.5 nm at room temperature.

III. Results and Discussion

The X-diffraction investigations on all the samples proved them to be single phase and crystalline. All the samples can be well indexed to the pure tetragonal phase of YVO_4, indicating that the Eu^{3+} and Dy^{3+} have been effectively doped into the host lattices of YVO_4. The XRD patterns for the prepared samples match well with the JCPDS file 17-341 (Fig. 1).

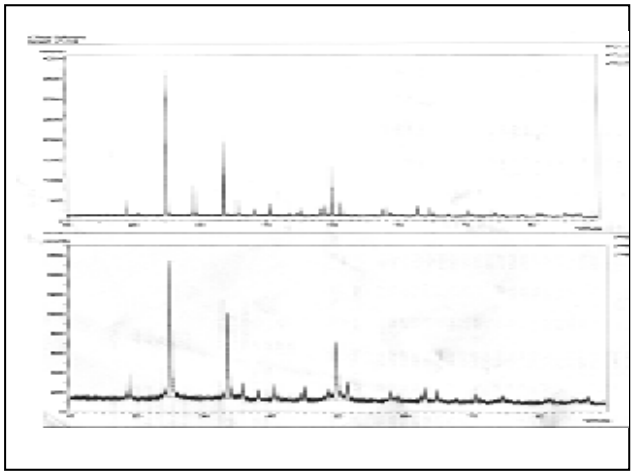


Figure 1. The X-ray diffraction pattern for YVO_4
a) YVO_4 prepared by Urea combustion method
b) YVO_4 prepared by *Chimie douce* method)

Fig. 2 shows typical emission spectra of YVO_4:Eu phosphors prepared by various methods. The emission is in the form of lines around 585 and 617 nm corresponding to the transitions $^5D_0 \rightarrow {}^7F_1$ and $^5D_0 \rightarrow {}^7F_2$ of Eu^{3+}. YVO_4:Eu phosphor is formed by the precipitation method, but emission is relatively weak. Weak emission is observed in the combustion-synthesized phosphor also when ODH is used as a fuel. Intense emission is observed in the samples prepared by Solid State synthesis as well as the combustion synthesis using 3MP5O, glycine, citric acid or urea as fuels. Similar results were obtained for YVO_4:Dy phosphor also (Fig. 3). Efficient, rare earth doped YVO_4 phosphors can thus be obtained by various syntheses including the conventional solid state synthesis.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

Relative intensities of the phosphors prepared by various methods are compared with the standard phosphor with intensity of 1000 au, in Table 1.

Table: 1, Relative PL intensities of various YVO_4 phosphors

S/N	Name of phosphor	Method of preparation	Relative Intensity
1	YVO_4:Eu	Solid State Diffusion	1000
		Precipitation	390
		Combustion Synthesis……	
		using 3MP5-O	890
		using ODH	160
		using Glycine	845
		using Urea	1000
2	YVO_4:Dy	Solid State Diffusion	975
		Precipitation	68
		Combustion Synthesis	
		using 3MP5-O	1189
		using ODH	270
		using Glycine	285
		using Urea	914

The combustion synthesis appears most suitable, as fine particle phosphors can be prepared in short time. The most convenient fuel for combustion method is urea. It is readily available and economic. Other fuels like 3MP5O are to be synthesized. However, there is no exothermic reaction of RE nitrates/oxides with urea itself. Hence a modified combustion synthesis is used. Heat generated in the exothermic reaction of ammonium nitrate and urea is used to prepare the vanadates. Various ratios of the reactants and ammonium nitrate + urea mixtures were tried. The one giving optimum results is:-

$Y_2O_3 : NH_4VO_3 : NH_4NO_3 :$ Urea 1 : 2 : 18 : 18.

Though YVO_4:Eu and YVO_4:Dy phosphors were discovered earlier $YV_xP_{1-x}O_4$:Eu, and $YV_xP_{1-x}O_4$:Dy phosphors find more wide spread use as lamp phosphors. Efforts were made to synthesize these phosphors using combustion synthesis with exothermic reaction of ammonium nitrate and urea.

The results are presented in Figs. 4 and 5. Efficient red emission was obtained in $YV_{0.4}P_{0.6}O_4$:Eu (Fig.4, curve a) . For the comparison, results on YVO_4:Eu are also included. Addition of phosphorus modifies the excitation spectrum resulting in better overlap with Mercury emission (curves b and c). The emission spectrum remains more or less same. In case of $YV_{0.4}P_{0.6}O_4$:Dy (Fig. 5), addition of Dy modifies the excitation as well as the emission. The emission in $YV_{0.4}P_{0.6}O_4$:Dy (curve a) is white while that in YVO_4:Dy is yellow (curve b).

The absorption and photo luminescent (PL) studies indicated that the energy is absorbed first by the host and then transferred to the emitting level of the Eu^{3+} ions. Excitation at 318 nm in terms of Eu^{3+} concentrations in YVO_4 powders shows that the YVO_4 phosphors display bright red luminescence at about 618 nm belonging to the $^5D_0 \rightarrow {}^7F_2$ electric dipole transition, and a weak band in the orange region of the $^5D_0 \rightarrow {}^7F_1$ transition at 594 nm.

The characteristics emission peaks of Dy^{3+} due to the transitions of $^4F_{9/2} \rightarrow {}^6H_{15/2}$ at 483 nm and $^4F_{9/2} \rightarrow {}^6H_{13/2}$ at 573 nm were observed in the emission spectra. The characteristic transitions of Dy^{3+} due to $^4F_{9/2} \rightarrow {}^6H_{15/2}$ (blue) and $^4F_{9/2} \rightarrow {}^6H_{13/2}$ (yellow) were detected in the emission spectra and the yellow-to-blue intensity ratio decreased with the increase of *x* value. The morphology and size of the prepared materials were determined from the SEM studies. Fig. 6 shows typical image of the combustion synthesized material. The particles had spherical-like shape and little nanometer size. It also shows agglomerated grains which might be due to the residence time of the powder inside a combustion furnace.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

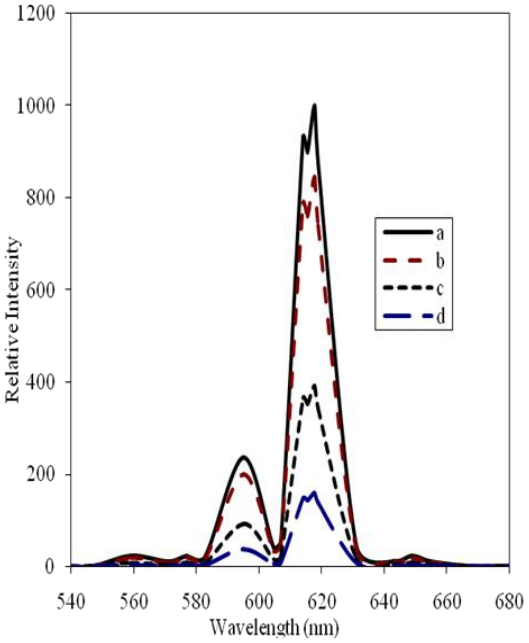
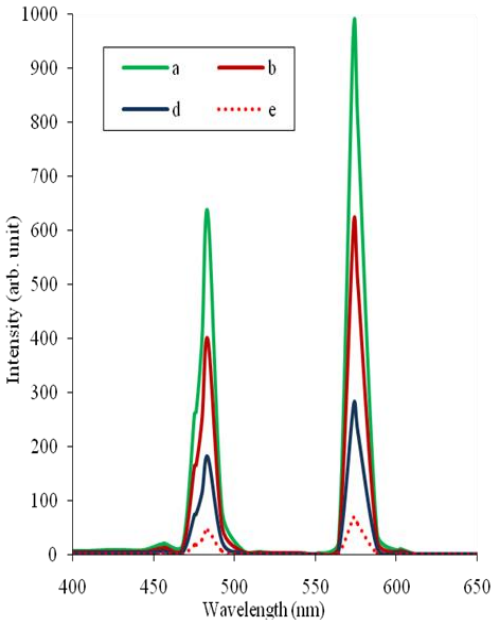


Figure 2. Emission spectra of YVO_4:Eu prepared by different methods.
a) Solid state diffusion or Combustion synthesis using urea as fuel.
b) Combustion synthesis using Glycine as fuel.
c) Combustion synthesis using ODH as fuel.
d) Precipitation



•Fig. 3. Emission spectra of YVO_4:Dy prepared by different methods.
•a) Solid state diffusion
•b) Combustion synthesis using urea as fuel.
•d) Combustion synthesis using Glycine as fuel.
e) Precipitation

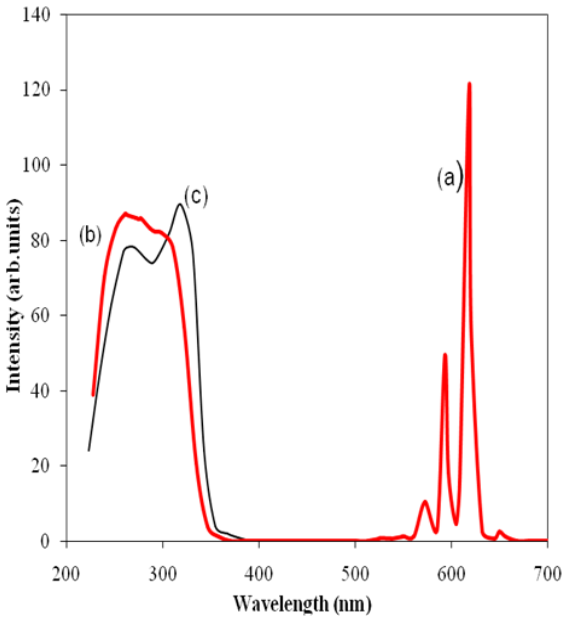


Figure 4. Typical Excitation and Emission spectra of YVO_4:Eu & $YV_{0.4}P_{0.6}O_4$:Eu
a) Emission spectrum of $YV_{0.4}P_{0.6}O_4$:Eu
b) Excitation spectrum of $YV_{0.4}P_{0.6}O_4$:Eu
c) Excitation spectrum of YVO_4:Eu

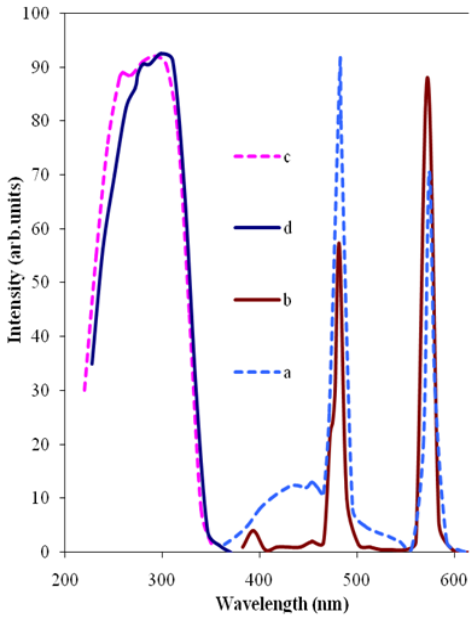


Fig. 4. Typical Excitation and Emission spectra of YVO_4:Dy & $YV_{0.4}P_{0.6}O_4$:Dy
a) Emission spectrum of $YV_{0.4}P_{0.6}O_4$:Dy
b) Emission spectrum of YVO_4:Dy
c) Excitation spectrum of $YV_{0.4}P_{0.6}O_4$:Dy
d) Excitation spectrum of YVO_4:Dy

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

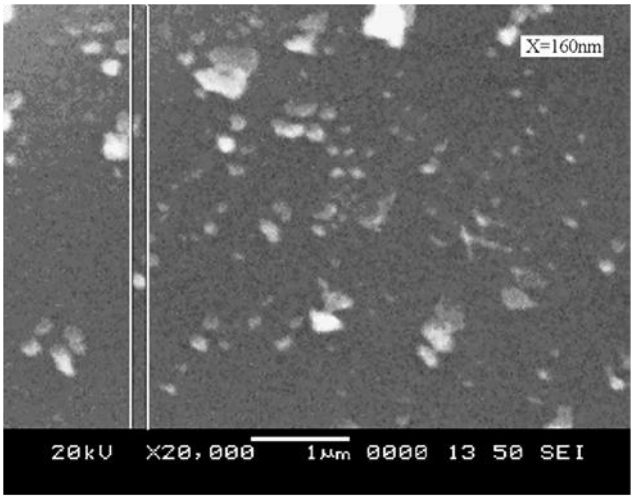


Figure 6, SEM image of YVO_4:Eu

IV. CONCLUSION

YVO_4 based phosphors could be prepared by various methods. The precipitation method is most suitable for preparing large scale batches, but the PL intensities in these phosphors are much lower. Efficient phosphors can be prepared by the conventional solid state synthesis; however, slow heating is essential for obtaining phosphors without body color. The combustion synthesis is the most convenient method for rapid synthesis of efficient phosphors. As result of an efficient energy transfer from vanadate group to dopants, YVO_4: Eu/Dy and $YVPO_4$: Eu/Dy phosphors showed their strong characteristic emission under UV excitation.

ACKNOWLEDGMENT

I acknowledge the facilities provided by Dr. S. V. Moharil, Prof. and Head, Department of Physics; RTM Nagpur university, Nagpur and Dr. S. K. Omanwar, Prof. and Head, Department of Physics, SGB Amravati university, Amravati. I also acknowledge the financial assistance from University Grants Commission, New Delhi, India.

REFERENCES

[1] T. Tsuboi, "Up conversion emission in Er^{3+}/Yb^{3+}-codoped YVO_4 crystals", Phys Rev B, 62, 7, 4200, 2000. and Di Paolo R E, Cantelar E, Wang X. M., Tsuboi T. and Cusso F, J "Determination of the Er^{3+} to Yb^{3+} energy transfer efficiency in Er^{3+}/Yb^{3+}-codoped YVO_4 crystals", J. Phys Cond Matter, vol.13, pp. 7999, 2001.

[2] Di Paolo R E, Cantelar E, Wang X. M., Tsuboi T. and Cusso F, J "Determination of the Er^{3+} to Yb^{3+} energy transfer efficiency in Er^{3+}/Yb^{3+}-codoped YVO_4 crystals", J. Phys Cond Matter, vol. 13, pp. 7999, 2001.

[3] A.K. Levine, F.C. Palilla, "A new, highly efficient red-emitting cathodoluminescent phosphor (YVO_4: Eu) for color television", Appl. Phys. Lett. Vol. 5, pp. 118–120, 1964.

[4] F.C. Palilla, A.K. Levine, "YVO_4: Eu: a highly efficient phosphor for high pressure mercury lamps", Appl. Opt. vol. 5, pp. 1467–1468 1966.

[5] M. A. Aia, "Structure and luminescence of the phosphate van dates of yttrium, gadolinium, lutetium, and lanthanum", .J. Electrochem. Soc., vol. 114, pp. 367-370, 1967.

[6] Hoang-Duy Nguyen, Sun-il Mho, In-Hyeong Yeo, "Preparation and characterization of nanosized (Y,Bi)VO_4:Eu3+ and Y(V,P)O_4:Eu^{3+} red phosphors", J. Luminescence., vol. 129 no.12 pp 1754, 2009.

[7] G. Panayiotakis, Cavouras D., Kandarakis I., Nomicos C., Appl. Phys. A, "A study of X-ray luminescence and spectral compatibility of europium-activated yttrium-vanadate (YVO_4: Eu) screens for medical imaging applications ", vol. 62(5) pp 483-486, 1996.

[8] I. Kandarakis, D. Cavouras, E. Kanellopoulos, C.D. Nomicos, G.S. Panayiotakis , "Image quality evaluation of YVO_4:Eu phosphor screens for use in x-ray medical imaging detectors", Rad. Meas., vol. 29 pp 481-486, 1998.

[9] F.C. Palilla., Levine A. K. and Rinkevics M., "Rare earth activated phosphors based on yttrium orthovanadate and related compounds", J. Electrochem. Soc., vol. 112 pp776-779, 1965.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

[10] Chi L. & Chin Q. Su, J. Appl. Chem., vol. 10 pp 27, 1993.

[11] W.J. Park, M.K. Jung and D.H. Yoon,., "Influence of Eu^{3+}, Bi^{3+} co-doping content on photoluminescence of YVO_4 red phosphors induced by ultraviolet excitation", Sensors and Actuators B: Chemical, vol. 126(1) pp 324-327, 2007.

[12] W.J. Park., Jung M.K., Im S.J., Yoon D.H., "Photoluminescence characteristics of energy transfer between Bi^{3+} and Eu^{3+} in $LnVO_4$: Eu, Bi (Ln = Y, La, Gd)", Colloids and Surfaces A: vol. 313-314 pp 373, 2008.

[13] Satoru Takeshita, Tetsuhiko Isobe, Tomohiro Sawayama, Seiji Niikura, "Effects of the homogeneous Bi^{3+} doping process on photoluminescence properties of YVO_4:Bi^{3+}, Eu^{3+}nanophosphor", J. Lum., vol. 129(9), pp 1067-1072, 2009.

[14] Zhiguo Xia, Daimei Chen, Min Yang, Ting Ying., "Synthesis and luminescence properties of YVO_4:Eu^{3+},Bi^{3+} phosphor with enhanced photoluminescence by Bi^{3+} doping", J. Phys. Chem. Solids, vol. 71(3), pp 175-180, 2010.

[15] Yang P, Huang S, Kong D, Lin J, Fu H, "Luminescence functionalization of SBA-15 by YVO4:Eu^{3+} as a novel drug delivery system", Inorg Chem., vol. 46(8), pp 3203-11, 2007.

[16] S. Erdei, R. Schlecht and D. Ravichandran, "Hydrolyzed colloid reaction (HCR) technique for phosphor powder preparation", Displays, vol. 19, pp 173-178, 1999.

[17] Ermeneux F. S., Moncorge R., Kabro P., Copobianco J. A., Bettinelli M. and Cavalli E., Opt. Soc. Am., Proc. Adv. Solid-State Lasers, vol.1, pp 498, 1996.

[18] S. Erdei, N. M. Rodriguez, F. W. Ainger, W. B. White, D. Ravich, N. M. Rodriguez, F. W. Ainger, W. B. White, D. Ravich, ran, L. E. Cross and L. E. Cross, Luminescent characteristics and morphology of Eu^{3+}:YVO_4 phosphor powders prepared by HCR and flux techniques, J. Mater. Chem., vol. 8, pp 99-103, 1998.

[19] Lianhua Tian, and Sun-il Mho, "Enhanced photoluminescence of YVO_4:Eu3+ by co doping the Sr^{2+}, Ba^{2+} or Pb^{2+}ion" Journal of Luminescence, vol. 122-123 pp 99-103, 2007.

[20] G. Jia,; Song, Y.; Yang, M.; Huang, Y.; Zhang, L.; You, H.., "Uniform YVO_4:Ln^{3+} (Ln=Eu, Dy, and Sm) nanocrystals: Solvothermal synthesis and luminescence properties Optical Materials, vol. 31(6), pp 1032, 2009.

[21] V. B. Bhatkar, S.K.Omanwar and S.V.Moharil "Combustion synthesis of the Zn2SiO4:Mn Phosphor", Phys. Stat. Sol. (a) vol. 191, No.1, pp 272-276, 2002.

[22] V. B. Bhatkar, S.K.Omanwar and S.V.Moharil, "Combustion synthesis of silicate phosphors", Optical Materials, vol. 29 , pp 1066–1070, 2007.

[23] Sang Do Han, S.P. Khatkar, V.B. Taxak, Gaytri Sharma, Dinesh Kumar, "Synthesis, luminescence and effect of heat treatment on the properties of Dy3+-doped YVO_4 phosphor", Materials Science and Engineering, B, vol. 129(1-3) pp 126-130, 2006.

[24] Haiping Zhang, Mengkai Lü, Zhiliang Xiu, Guangjun Zhou, Shufen Wang, Yuanyuan Zhou, Shumei Wang , "Influence of processing conditions on the luminescence of YVO_4:Eu^{3+} nanoparticles", Materials Science and Engineering, B, vol. 130, no. (1-3), pp 151-157, 2006.

[25] Arnaud Huignard, Thierry Gacoin, and Jean-Pierre Boilot, "Synthesis and Luminescence Properties of Colloidal YVO_4:Eu Phosphors", Chem. Mater., , vol. 12 (4) pp 1090–1094, 2000.

[26] Yee-Shin Chang, Feng-Ming Huang, Yeou-Yih Tsai, Lay-Gaik Teoh, "Synthesis and photo luminescent properties of YVO_4:Eu^{3+} nano-crystal phosphor prepared by Pechini process", Journal of Luminescence, vol. 129(10) pp 1181-1185, 2009.

[27] Zhiguo Xia, Daimei Chen, Min Yang, Ting Ying., "Synthesis and luminescence properties of YV_{O4}:Eu^{3+}, Bi^{3+} phosphor with enhanced photoluminescence by Bi^{3+} doping", Journal of Physics and Chemistry of Solids, vol. 71(3) pp 175-180, 2010.

[28] Bing Yan, Xue-Qing Su, "In situ chemical co precipitation composition of hybrid precursors to synthesize $YP_xV_{1-x}O_4$:Eu^{3+} micron crystalline phosphors", Materials Science and Engineering B, vol. 116(2) pp 196-201, 2005.

[29] Emmanuel Baudrin, Sophie Denis, François Orsini, Laurent Seguin, Marcel Touboul and Jean-Marie Tarascon, "On the synthesis of monovalent, divalent and trivalent element vanadates", J. Mater. Chem., vol. 9 pp 101, 1999.

[30] Oka Y., Yao T. and Yamamoto N., "Hydrothermal Synthesis of Lanthanum Vanadates: Synthesis and Crystal Structures of Zircon-Type $LaVO_4$ and a New Compound LaV_3O_9", Journal of Solid State Chemistry, vol. 152 pp 486, 2000.

[31] Su XQ, and Yan B., "The synthesis and luminescence of YPxV1-xO4: Dy^{3+} microcrystalline phosphors by in situ co-precipitation composition of hybrid precursors", Materials Chemistry and Physics, vol. 93(2-3) pp 552-556, 2005.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

[32] Bing Yan, Xueqing Su, Kun Zhou, "In situ chemical coprecipatation composition of hybrid precursors to red $YVO_4:Eu^{3+}$ and green $LaPO_4:Tb^{3+}$ phosphors", Mater. Res. Bull., vol. 41(1) pp 134-143, 2006.

[33] A. Newport, J. Silver, and A. Vecht., the Synthesis of Fine Particle Yttrium Vanadate Phosphors from Spherical Powder Precursors Using Urea Precipitation, J. Electrochem. Soc., vol. 147 no. 10 pp 3944-3947, 2000.

[34] Limiao Chen, Guocong Liu, Younian Liu and Kelong Huang, .Synthesis and luminescence properties of $YVO_4:Dy^{3+}$ nanorods, Journal of Materials Processing Technology, vol. 198 (1-3) pp 129-133, 2008.

[35] S. Ray, A. Banerjee, P. Pramanik , "Shape controlled synthesis, characterization and photoluminescence properties of $YVO4:Dy^{3+/}Eu^{3+}$ phosphors , Materials Science and Engineering: B, vol. 156(1-3) pp 10-17, 2009.

[36] Juan Wang, Yunhua Xu, Mirabbos Hojamberdiev and Gangqiang Zhu, "Influence of sodium dodecyl sulfonate (SDS) on the hydrothermal synthesis of $YVO_4:Eu^{3+}$ crystals in a wide pH range", J. Alloys and Comps, vol. 487(1-2) pp 358, 2009.

[37] Fei He, Piaoping Yang, Na Niu, Wenxin Wang, Shili Gai, Dong Wang, Jun Lin, " Hydrothermal synthesis and luminescent properties of $YVO_4:Ln^{3+}$ (Ln = Eu, Dy, and Sm) microspheres", J. Colloid and Interface Science, vol. 343(1) pp 71-78, 2010.

[38] Sungho Choi, Young-Min Moon and Ha-Kyun Jung, "Luminescent properties of PEG-added nanocrystalline $YVO_4:Eu^{3+}$ phosphor prepared by a hydrothermal method", Journal of Luminescence, vol. 30(4) pp 549-553, 2010.

[39] WJ Park, MK Jung, T. Masaki, SJ Im and DH Yoon, "Characterization of YVO_4: Eu^{3+}, Sm^{3+} red phosphor quick synthesized by microwave rapid heating method," Mater. Sci. Eng. B, vol. 146, pp 95 – 98, 2008.

AUTHOR BIOGRAPHY

VINOD BABARAO BHATKAR.
M.Sc. (Physics), M. Phil., Ph. D.
Associate Professor and Head
Department of Physics
Shri Shivaji College, Akot (MS) 444101

Research area: Material science, Luminescence, Biomaterials.

Teaching Experience:	30 years
Research Experience:	15 years
Minor research Projects	02
Major Research Project	01

Research Papers

International Journals	Published	**17**
	Communicated	05
International Conferences		06
National Conferences		26

1. Life member of Instrument society of India.
2. Life member of Luminescence society of India.
3. Life member Indian science congress Association.
4. Life member Society for Biomaterials and artificial organs, India.