International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
© 2021 | IJSRST | Volume 8 - Issue 1

Cr^{3+} Emission in $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$ Phosphors

P. K. Tawalare[1], S. K. Omanwar[2], V. B. Bhatkar[3], S. V. Moharil[4]
[1]Department of Physics,JagadambaMahavidyalaya, Achalpur City, India
[2]Department of Physics, Sant Gadge Baba Amravati University, Amravati, India
[3]Department of Physics, Shri Shivaji Science College, Amravati, India
[4] Department of Physics, RashtrasantTukadoji Maharaj Nagpur University, Nagpur,India

ABSTRACT
Combustion synthesis of Cr^{3+}activated $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$ phosphors was attempted. XRD results indicated formation of alumina, while luminescence results showed profound changes from Al_2O_3:Cr^{3+}. $Al_5SiO_{9.5}$:Cr^{3+}a did not show any photoluminescence, while $Al_5GeO_{9.5}$:Cr^{3+} showed very intense luminescence; almost 150% of that shown by Al_2O_3:Cr^{3+}.

I. INTRODUCTION

alpha Alumina α-Al_2O_3 is a remarkable host material for rare earth ions because it presents excellent mechanical hardness combined with chemical stability and solubility besides a high transparency window from the ultraviolet to the infrared [1]. It plays a major role in many technologies due to its remarkable physical properties, such as a high melting point, hydrophobicity, high elastic modulus, high optical transparency, high refractive index, thermal and chemical stability, low surface acidity, and fine optical and dielectric characteristics [2–4]. The good adhesion to Si surface makes Al_2O_3 attractive in the microelectronics and optoelectronics [5,6]. Owing to some of these properties, it is also an excellent laser host. The ruby (Al_2O_3:Cr^{3+}) is the first crystal found to exhibit a laser emission as demonstrated by Maiman at the Hughes Lab in 1960 [7,8], which marked the beginning of the solid state laser technology. The wide gain and high quantum efficiency of Sapphire (Al_2O_3:Ti) makes this material the optimum ultrafast laser crystal [9].

There are several double oxides involving Al_2O_3which might be easily prepared by combustion synthesis using exothermic reaction between aluminum nitrate and urea. From literature, we found two particular formulae quite attractive; viz. $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$. Both these compounds contain high percentage of alumina. Their structures (orthorhombic) are different from beta alumina (hexagonal) and modification of luminescence properties of Cr^{3+} in these hosts is expected. With these expectations, attempts were made to synthesize Cr^{3+} activated $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$ using combustion synthesis. Results of these experiments are discussed here.

II. METHODS AND MATERIAL

Phosphors were prepared by combustion method using metal nitrates as oxidizer and urea as a fuel [10,11]. Aluminium nitrate, SiO_2/GeO_2 and urea were thoroughly mixed in molar ratio 5:1:15.83. A crucible containing the mixture was inserted at 500 C in a preheated furnace. In few minutes the mixtures swells with evolution of gases and finally a flame appears. The flame lasts for about a minute. The crucible is removed from the furnace after the flame extinguishes. The foamy product is crushed to powder and used for further characterization. For preparing Cr^{3+} doped samples Chromium nitrate in the desired quantity was added to the starting mixture.

The crystalline phases of the synthesized samples were identified by x-ray diffraction (XRD) patterns recorded on XPERT-PRO diffractometer using Cu K_α (λ=1.54059 Å) radiation. The photoluminescence (PL) and photoluminescence excitation (PLE) spectra were measured on Hitachi F-7000 spectrophotometer.

III. RESULTS AND DISCUSSION

Fig.1 shows xrd pattern of the synthesized phosphor.Surprisingly the patterns for $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$ both matched with that of Al_2O_3. It appears that the compounds are not formed by the combustion synthesis. Further experiments proved the contrary. EDAX analysis of $Al_5GeO_{9.5}$ clearly showed presence of Ge (Fig.2). Further, luminescence properties of these compounds were entirely different. Fig.3 shows PL emission spectrum for Cr^{3+} doped $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$ and Al_2O_3 excited by 413 nm.Intense line attributable to ($^2E \rightarrow {}^4A_{2g}$) is seen around 698 nm in the emission spectrum of Al_2O_3:$Cr^{3+}$with several components due to splitting of ^2E levels in crystal field. Similar emission peaking at 699 nm is observed for $Al_5GeO_{9.5}$:$Cr^{3+}$with much higher intensity. On the other hand, emission was totally quenched in $Al_5SiO_{9.5}$:Cr^{3+}.

Further experiments were performed on $Al_5GeO_{9.5}$:Cr^{3+}. Fig.4 shows effect of Cr^{3+}concentration on PL emission intensity. Intensity is maximum for 0.4 mol.% Cr^{3+}. Intensity decreases for higher concentrations due to concentration quenching.From these data critical distance for Cr^{3+} - Cr^{3+} transfer can be calculated using the formula [12].

$R_c = 2\,(3V/4\pi x_c N)^{1/3}$(1)

where x_c is the critical concentration (0.004), N is the number of Al sites in the unit cell (5) and V is the volume of the unit cell (168.034 Å^3). Rc comes out to be 25.22 Å.This is considerably greater than 17 Å observed for Al_2O_3:Cr^{3+}.

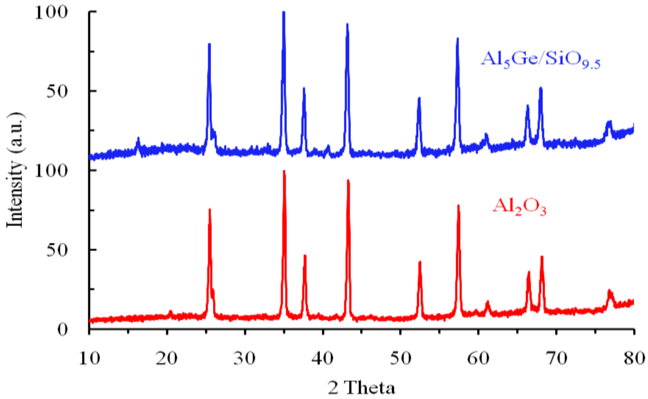

Fig.1 XRD patterns of $Al_5Ge/SiO_{9.5}$ and Al_2O_3

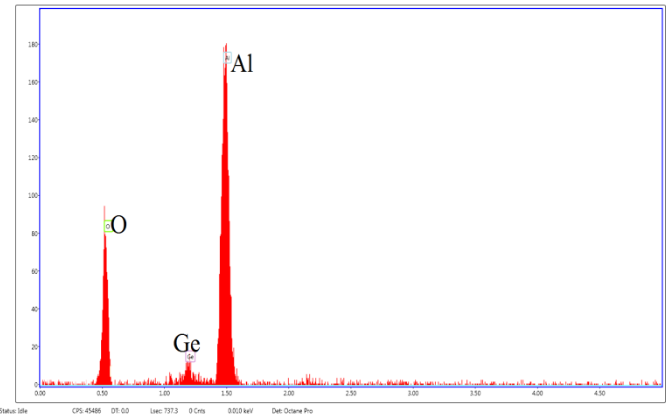

Fig.2 EDAX for Al5GeO9.5

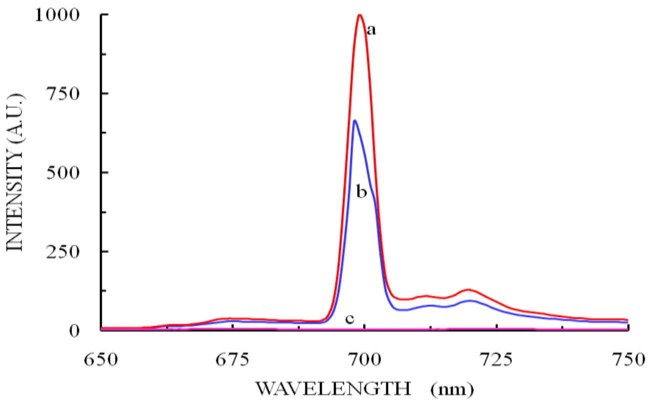

Fig.3 PL emission spectra of a) $Al_5GeO_{9.5}$, b) Al_2O_3 and c) $Al_5SiO_{9.5}$, activated with Cr^{3+}.

Excitation was by 413 nm light.

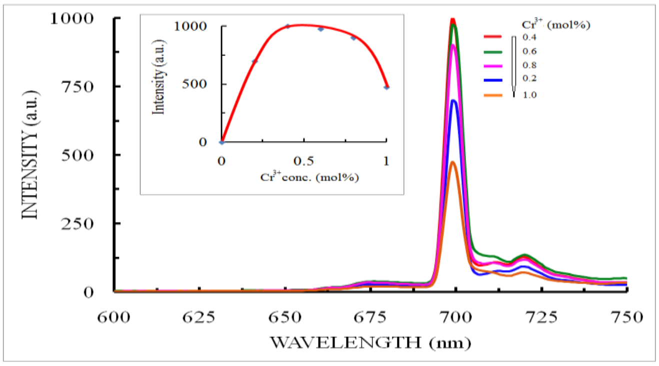

Fig.4 PL emission spectra of a) $Al_5GeO_{9.5}:Cr^{3+}$

Inset shows effect of Cr^{3+}concentration on intensity of 699 nm line.

Corresponding excitation spectrum is shown in Fig.5. $^4A_{2g}\rightarrow{}^4T_{1g}(^4F)$ and $^4T_{2g}(^4F)$ bands can be clearly seen around 413 and 556 nm. Splitting of $^4T_{1g}(^4F)$, $^4T_{2g}(^4F)$ levels is barely visible in the spectrum recorded at room temperature.

Fig.6 shows luminescence decay curve for $Al_5GeO_{9.5}:Cr^{3+}$ (0.2 mol.%). Single exponential is observed which can be fitted to decay constant $\tau = 3.5$ ms which is almost same as that for $Al_2O_3:Cr^{3+}$ (3.36 ms).

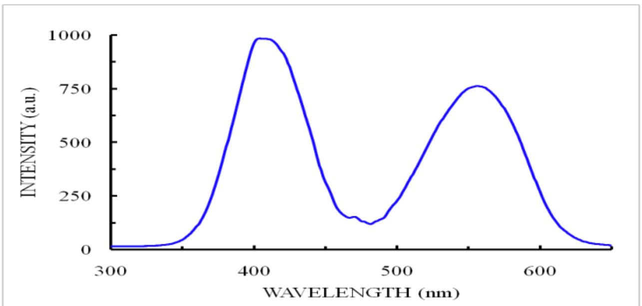

Fig.5 PL excitation spectrum for 699 nm emission of $Al_5GeO_{9.5}:Cr^{3+}$.

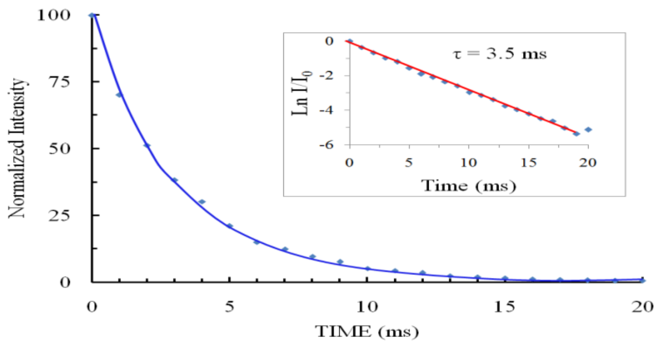

Fig.6 Luminescence decay curve for 699 nm emission of $Al_5GeO_{9.5}:Cr^{3+}$.

IV. CONCLUSION

Attempts were made to synthesize $Al_5GeO_{9.5}$ and $Al_5SiO_{9.5}$compounds by combustion synthesis and obtain modification of luminescence properties of Cr^{3+} activated phosphors. XRD analysis of the combustion synthesized powders showed presence of alpha alumina phase. On the other hand, EDAX indicated presence of Ge. Luminescence properties were also changed a great deal. In $Al_5SiO_{9.5}$, Cr^{3+} emission was totally quenched while luminescence increased by about 50 % in $Al_5GeO_{9.5}$. These inconsistencies need to be investigated further.

V. REFERENCES

[1]. Glauco S. Maciel, NikiforRakov, Michael Fokine, Isabel C. S. Carvalho and Carlos B. Pinheiro , Appl Phys Lett, 89 (2006) 081109-1-3

[2]. Y. Kim, S.M. Lee, C.S. Park, S.L. Lee, M.Y. Lee, Appl. Phys.Lett. 71 (1997) 3604–3606.

[3]. E.P. Gusev, M. Copel, E. Cartier, I.J.R. Baumvol, C. Krug, M.A. Gribelyuk, Appl. Phys. Lett. 76 (2000) 176–178.

[4]. A. Pillonnet-Minardi, O. Marty, C. Bovier, C. Garapon, J. Mugnier, J. Opt. Mater. 16 (2001) 9–13.

[5]. L. Rebohle, M. Braun, R. Wutzler, B. Liu, J.M. Sun, M. Helm, W. Skorupa, Appl. Phys. Lett. 104 (2014) 251113.

[6]. R. Serna, C.N. Afonso, Appl. Phys. Lett. 69 (1996) 1541.

[7]. T. Maiman, Nature 187 (1960) 493.

[8]. G. Boulon, Opt. Mater. 34 (2012) 499–512.

[9]. V.B. Mikhailik, H. Kraus, D. Wahl, Appl. Phys. Lett. 86 (2005) 101909

[10]. J.J. Kingsley, K. Suresh and K.C. Patil, J.Mater. Sci. 25 (1990) 1305

[11]. J.J. Kingsley, N. Manickam and K.C. Patil, Bull. Mater. Sci. 13 (1990) 179

[12]. G. Blasse, Philips Res. Rep. 24 (1969) 131