Structural and luminescence properties of yellow $Y_3Al_50_{12}:Ce^{3+}$ thin film phosphors prepared by Pulsed Laser Deposition

F.B. Dejene[1], K.T. Roro[2,*], L.F. Koao[1]

[1]Department of Physics University of Free State (Qwaqwa campus), Private Bag X13, Phuthaditjhaba, 9866,South Africa
[2]CSIR National Laser Centre, P. O. Box 395, Pretoria 0001, South Africa
*Author e-mail address: KRoro@csir.co.za

Introduction

Recently, by combining a blue indium gallium nitride (InGaN) light emitting diodes (LED) with yellow Ce-doped $Y_3Al_5O_{12}$ (YAG) phosphore, different groups have successfully demonstrated white LEDs [1-3]. The production of white light was made possible by the phosphore conversion from the LED to emission of a longer wavelength. The yellow emitting phosphore converts a major fraction of the blue excitation light from the LED chip into yellow light, and when both combined white light is produce. Bando *et al.* [4] and Muller-Mach *et el.* [5] have incorporated a phosphore/epoxy hybrid with a reflector cup containing a LED chip for phosphore conversion. The phosphore particles are randomly oriented and interdispersed in the cured epoxy. One of the bottleneck problems of the phosphore/epoxy hybrid system is the difficulty of achieving uniform emission of white light from the LED. In order to overcome the challenges of using mixtures of phosphore powders and epoxies thin film phosphore has been used [6,7]. In this study, YAG phosphore thin films were prepared by pulsed laser deposition (PLD), and the effects of the PLD process parameters on the structural and luminescent properties of YAG thin films were investigated.

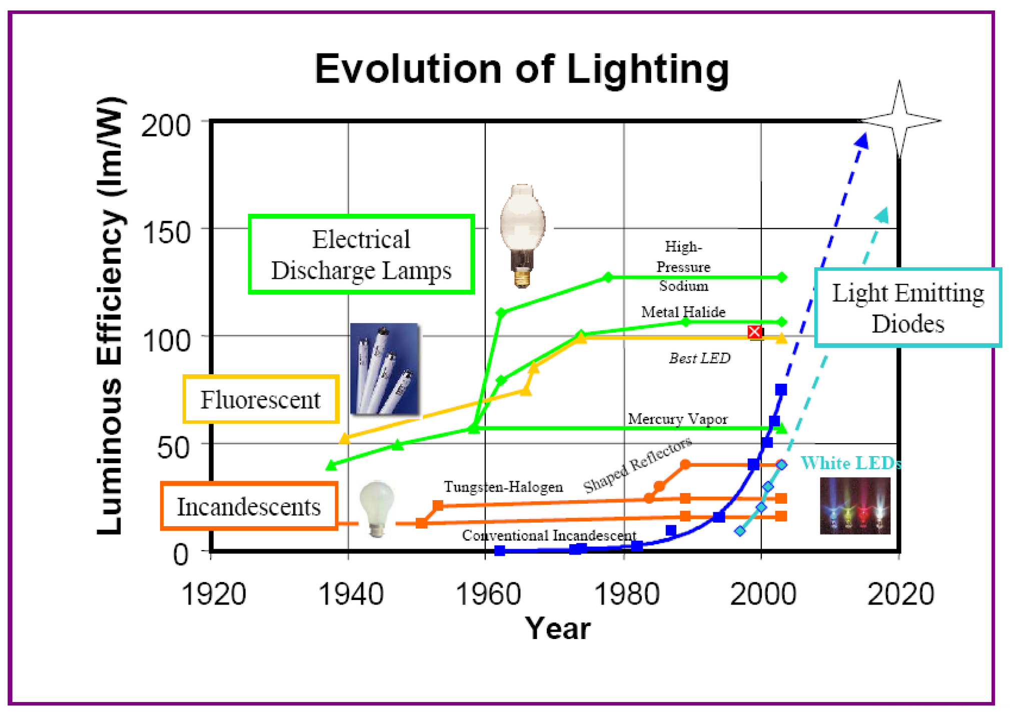
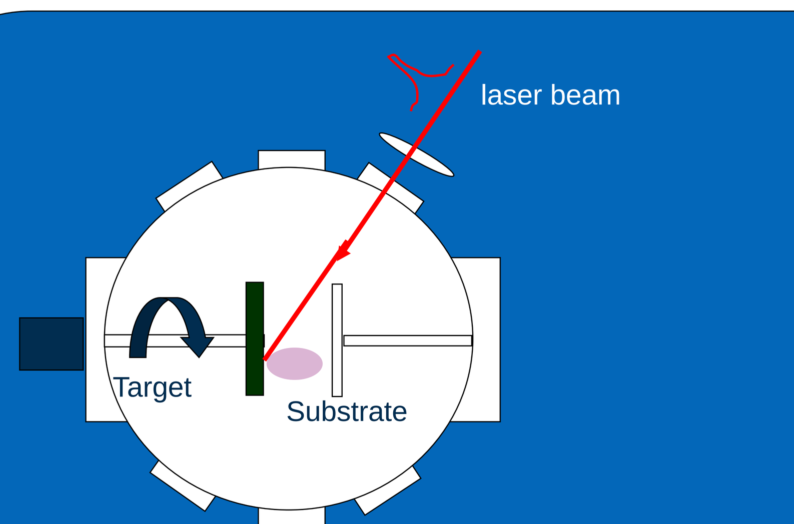


Fig.1. Development of luminous efficiency of traditional and LED lamps

Experimental



Synthesis condition

Nd:YAG laser
Freq: 10Hz
Wavelength: 266 nm
Energy: 40 mJ/pulse
Pulse Width ~ 6 ns

Fig.2. Pulsed laser deposition set-up

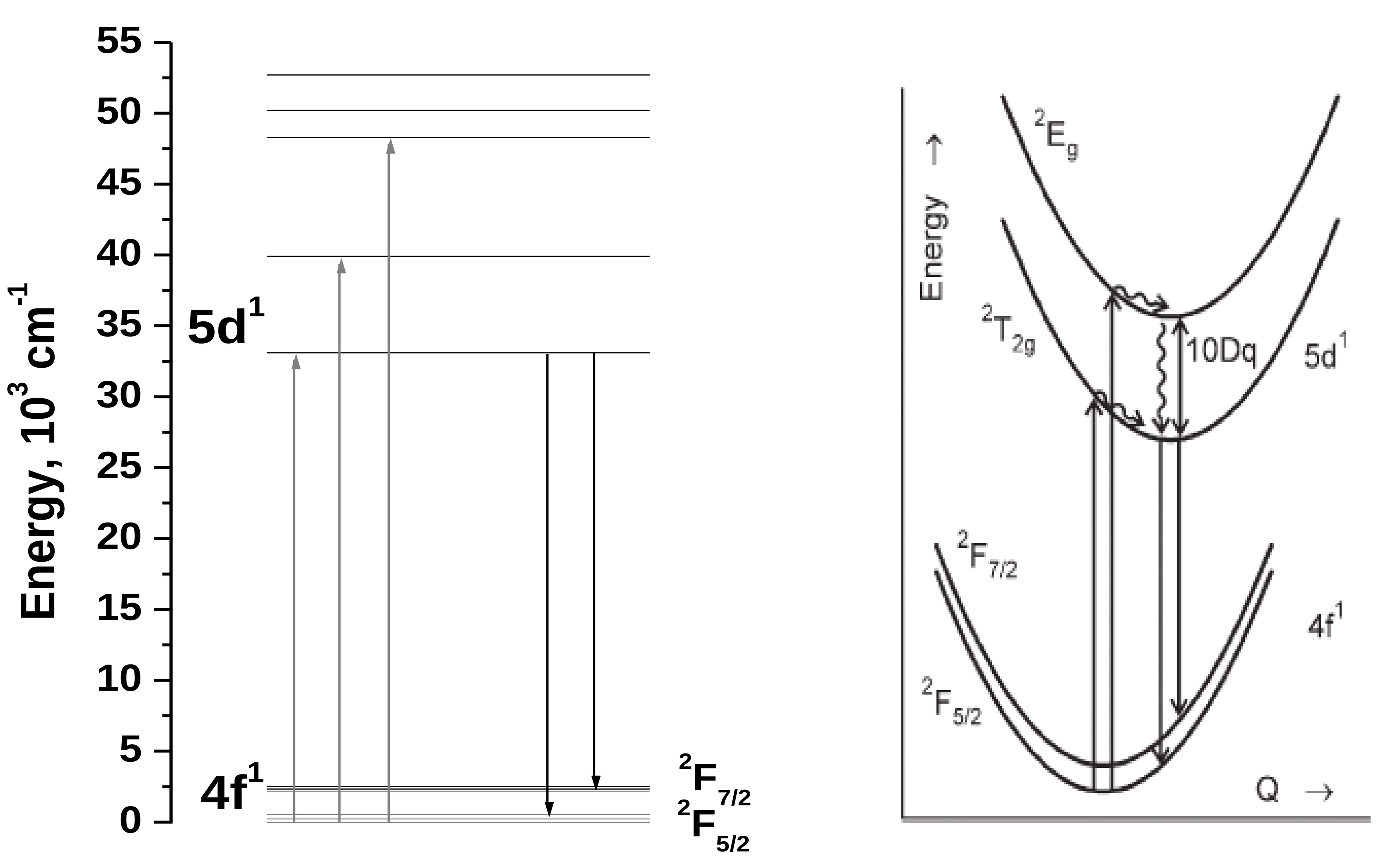


Fig. 3. $4f^1$ and $5d^1$ energy levels of Ce^{3+} in garnets

Results

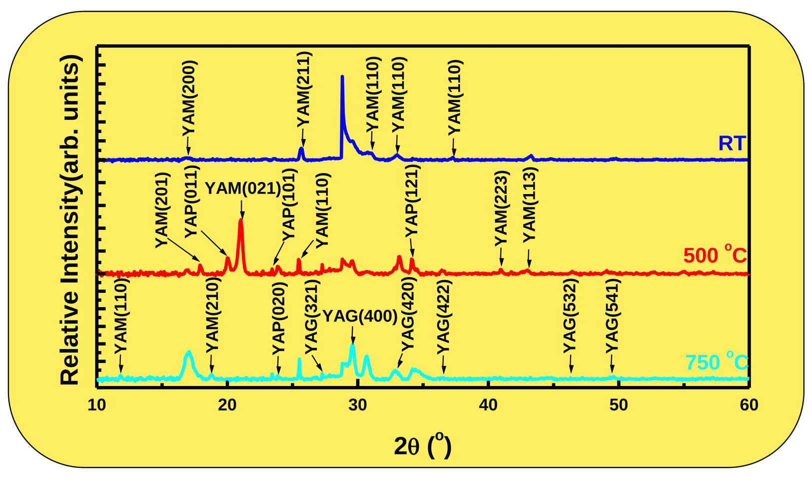


Fig. 4 XRD pattern of $Y_3Al_5O_{12}:Ce^{3+}$ thin films

- RT: intermediate phase of $Y_4Al_2O_9$(YAM)
- 500 ºC: Pattern for YAM, $YAlO_3$(YAP) & YAG
- 700 ºC: additional peaks related to YAG

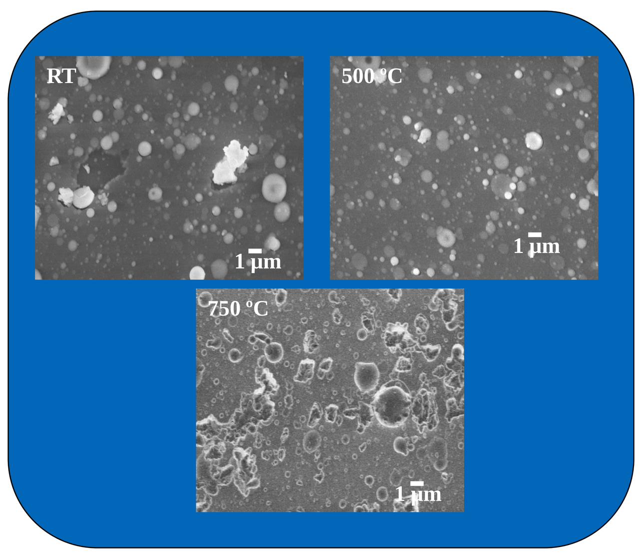


Fig.5. SEM images of $Y_3Al_5O_{12}:Ce^{3+}$ thin films

- RT: Rough, large spherical particles
- 500 ºC: size of the particles decreased
- 700 ºC: particles irregular in shape & larger in size → partial crystallization of YAG

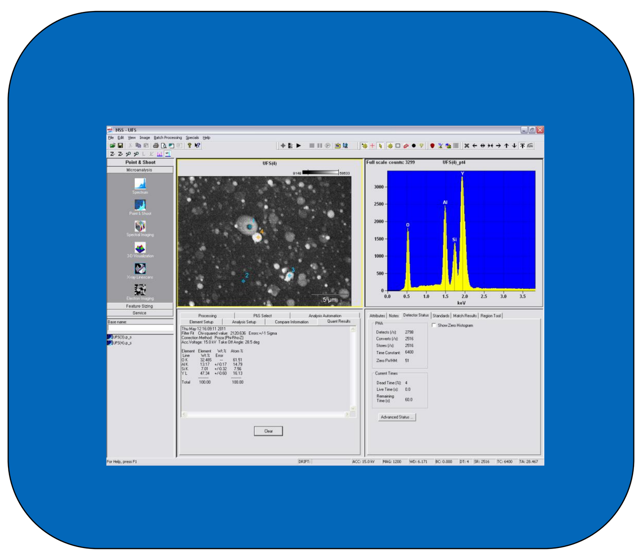


Fig. 6. Typical EDS spectra of $Y_3Al_5O_{12}:Ce^{3+}$ thin films

- Peaks related to Y, O, Al, Si are observed
- No Ce peak is observed
  → Ce is very little in quantity

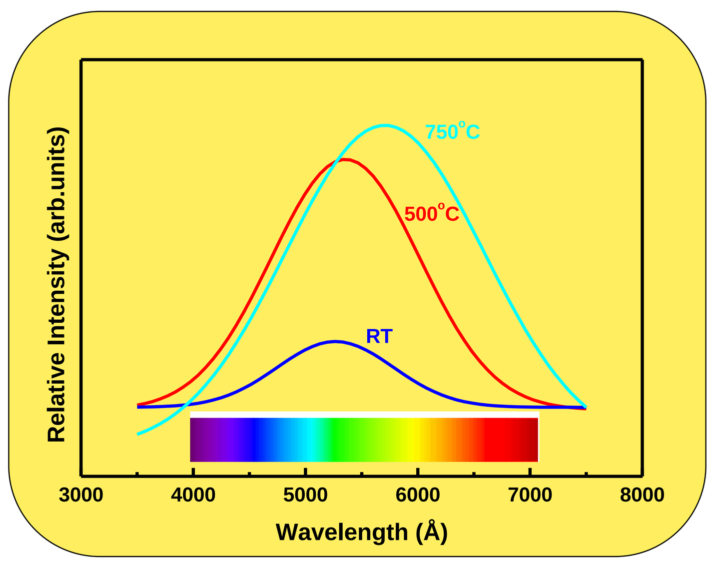


Fig.7. PL spectra of $Y_3Al_5O_{12}:Ce^{3+}$ thin films

- ↑ $T_{substrate}$ ↑ in intensity
  - → increase in crystallinity
- PL is due to $4d^1 \rightarrow 4f^1$ of Ce^{3+}[8-10]
- PL band is red shifted

Conclusions

- The pulsed laser deposition technique is used to deposit $Y_3Al_5O_{12}:Ce^{3+}$ thin films
- It is found that as substrate temperature increases from room temperature to 750 ºC the degree of YAG phase increased
- The intensity and maximum of the Ce^{3+} emission were found to change with increase in substrate temperature

References

[1] Lee S, Seo SY 2002 *J. Electrochem. Soc.* **149** *J85–J88*
[2] Yum JH, Seo SY, Lee S, Sung YE 2003 *J. Electrochem. Soc.* **150** *H47–H52*
[3] Yum JH, Kim SS, Sung YE 2004 *Colloid Surf. A: Physicochem. Eng. Aspects* **251** *203–207*
[4] Bando K, Sakano K, Noguchi Y, Shimizu Y 1998 *J. Light Vis. Environ.* **22** *2–5*
[5] Mueller-Mach R, Mueller GO, Krames MR, Trottier T 2000 IEEE *J. Sel. Top. Quantum Electron.* **8** *339–345*
[6] Choe JY 2002 *Mater. Res. Innov.* **6** *238–241*
[7] Mueller-Mach RB, Mueller GO 2007 U.S. Patent 7183577 B2
[8] Patra A, Ganguli D 1992 *J. Non-Cryst. Solids* **144** *111*
[9] Turos-Matysiak R, Gryk W, Grinberg M, Lin YS, Liu RS 2006 *J. Phys. Condens. Matter.* **18** *10531*
[10] Reisfeld R, Patra A, Panczer G, Graft M (1999) *Opt Mater* **13** *81*