



## Effect of $Y_2O_3:Eu^{3+}$ Particles on Fluorescence, Thermal and Mechanical Properties of Poly(methyl methacrylate) Composite†

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In order to obtain photoluminescence characteristics of poly(methyl methacrylate) (PMMA),  $Y_2O_3:Eu^{3+}$  particles are modified by silane coupling agent (KH-151) and introduced into poly(methyl methacrylate) via the *in situ* polymerization. The  $Y_2O_3:Eu^{3+}$ /PMMA composites exhibit enhanced properties of strength, thermal stability and fluorescence comparing with poly(methyl methacrylate). In particular, the  $Y_2O_3:Eu^{3+}$ /PMMA composite with 0.3 wt % content of  $Y_2O_3:Eu^{3+}$  exhibits the highest tensile strength of 55 MPa, suggesting its potential application in photoluminescence.

**Keywords:**  $Y_2O_3:Eu^{3+}$ , Poly(methyl methacrylate), Particles, Polymerization.

### INTRODUCTION

Metal oxide-polymer composites which combine the desired functionalities of both polymer matrix and metal oxide fillers have attracted much attention in recent years. Europium-doped  $Y_2O_3$  ( $Y_2O_3:Eu^{3+}$ ) is considered as an important fluorescent material owing to its good luminescent property with high chemical stability and acceptable atmospheric stability that give rise to many application areas, such as fluorescent lights, plasma display panel (PDP), cathode ray tubes (CRT) and field emission display (FED)<sup>1,2</sup>. Hence,  $Y_2O_3:Eu^{3+}$  particles are usually introduced into polymer matrix to improve the fluorescent property of polymer.

Poly(methyl methacrylate) (PMMA) is an optically clear amorphous thermoplastic polymer with excellent impact strength and dimensional stability. Due to its favorable properties, PMMA is an excellent substitute for conventional inorganic glass in many applications. Herein, we choose PMMA as polymer base and synthesize  $Y_2O_3:Eu^{3+}$ /PMMA composites by *in situ* bulk polymerization. Their fluorescence, thermal and mechanical properties are investigated in details.

### EXPERIMENTAL

$Y_2O_3:Eu^{3+}$  particles were prepared according to the following procedure. Yttrium oxide and europium oxide were dissolved in dilute hydrochloric acid with constant stirring and then

sodium hydroxide solution was added to adjust the pH value of the system to 13. The mixture was dried at 160 °C in a vacuum oven for 6 h and then calcined at 900 °C for 4 h. The final product was ground into powder and treated with the silane coupling agent (KH-151) under reflux for 4 h at 80 °C.

$Y_2O_3:Eu^{3+}$ /PMMA composites were synthesized as follow: various amounts of  $Y_2O_3:Eu^{3+}$  particles 0, 0.1, 0.3, 0.5, 0.7 and 0.9 % (wt %) were dispersed into methyl methacrylate monomer by sonicating. Polymerization of this mixture was initiated by azodiisobutyronitrile (AIBN) under constant stirring at 80 °C for 0.5 h. Afterwards, the solution in the flask was poured into a glass mould and kept at 50 °C for 5 h and subsequently at 100 °C for 2 h in an electric oven.

### RESULTS AND DISCUSSION

FTIR spectra of modified  $Y_2O_3:Eu^{3+}$  particles (a) and  $Y_2O_3:Eu^{3+}$ /PMMA composite (b) are shown in Fig. 1. The absorption peaks between 3400 and 3450  $cm^{-1}$  are associated with -OH groups, which are bonded onto the surface of  $Y_2O_3:Eu^{3+}$  particles. The characteristic peak of C=C at 1620  $cm^{-1}$  in Fig. 1(b) disappears, suggesting that PMMA chains graft onto *m*- $Y_2O_3:Eu^{3+}$  particles successfully. Additionally, two characteristic bands of acetate groups centered at 1660 and 1260  $cm^{-1}$  are attributed to the stretching vibrations of C=O and C-O in PMMA, respectively.

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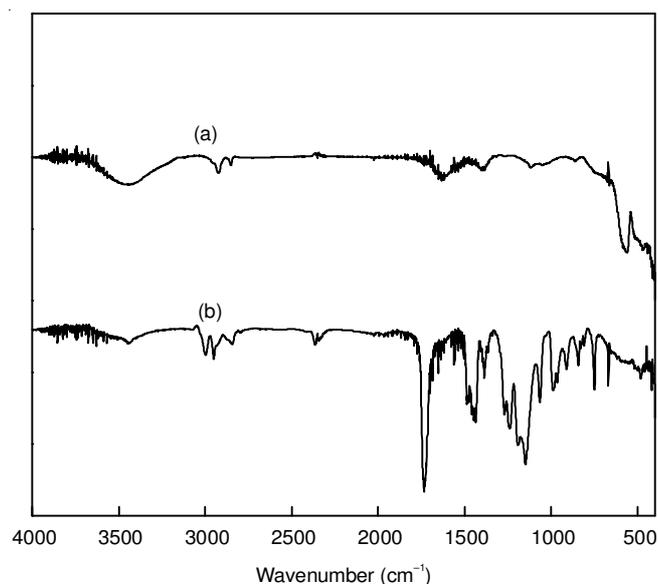


Fig. 1. FTIR spectra of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> particles (a) and Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA (b)

Fig. 2 shows the fluorescence spectra of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites after excitation at 254 nm. All fluorescence spectra of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites show red emission centered at 605–620 nm which is assigned to 4f-electronic transitions of Eu<sup>3+</sup> (<sup>5</sup>D<sub>0</sub>–<sup>7</sup>F<sub>2</sub> electric dipolar transition)<sup>3,4</sup>. Additionally, their fluorescence intensities increase with increasing Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> content.

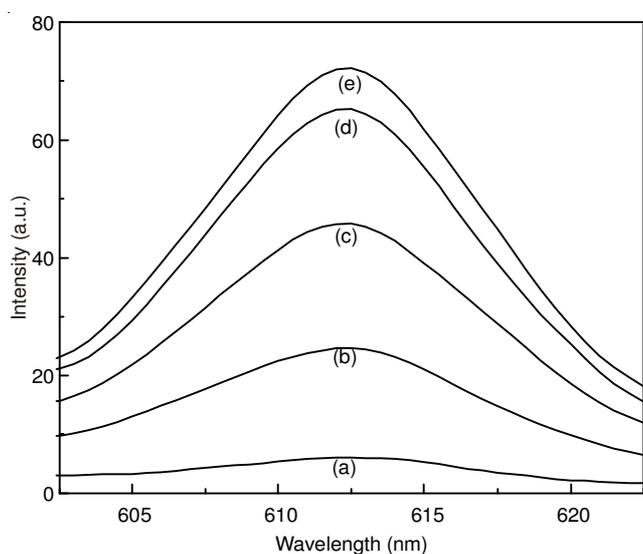


Fig. 2. Fluorescence spectra measured under the 254 nm UV excitation of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA 0.1 % (a), Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA 0.3 % (b), Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA 0.5 % (c), Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA 0.7 % (d) and Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA 0.9 % (e)

Fig. 3 shows the dependence of the tensile strength of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites on Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> contents. The result shows that the tensile strength first increases to a maximum of 55 MPa when Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> content increase to 0.3 %, then it starts to decrease as Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> content increasing. It should be noted that all composites exhibit better mechanical performance than pure PMMA. The highest tensile strength of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites measured in this study are 38 % higher than pure PMMA.

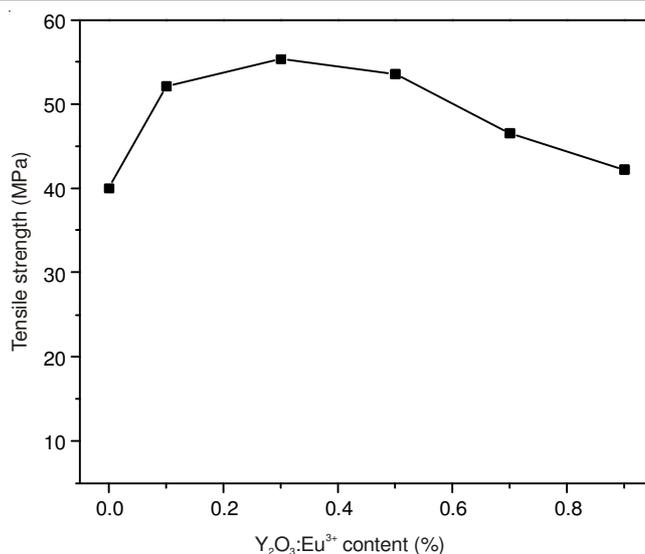


Fig. 3. Effect of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> content on the tensile strength of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites

Thermogravimetric analysis (TGA) of pure PMMA and Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites are shown in Fig. 4. Apparently, thermal stability of the composite is significantly improved by incorporating Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> particles into PMMA matrix. They are thermally stable up to 180 °C and start to degrade in three-steps. The thermal degradation of the Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites shifts to higher temperature comparing with pure PMMA, especially at high content of Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> (0.5 wt %), confirming the enhancement of thermal stability of PMMA by Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> particles.

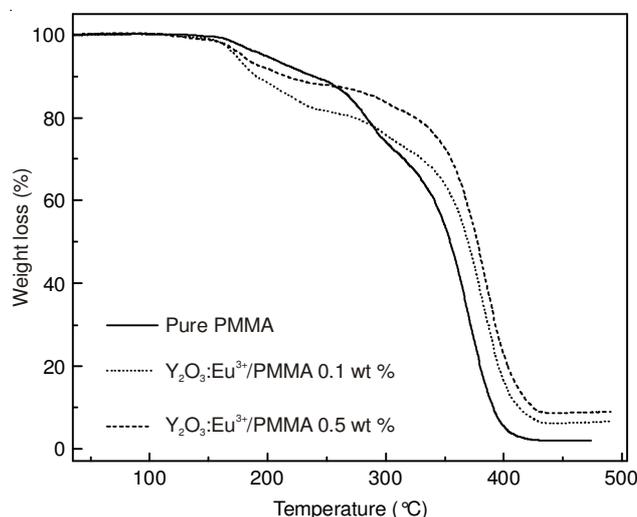


Fig. 4. TGA curves of pure PMMA and Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites

## Conclusion

Red emitting Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites with excellent thermal stability and tensile strength were synthesized by *in situ* bulk polymerization. Tensile strength and TGA data suggest that mechanical and thermal stability are dependent on Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup> content. The optimized Y<sub>2</sub>O<sub>3</sub>:Eu<sup>3+</sup>/PMMA composites with favorable luminescent and mechanical properties holds promising as a new class of fluorescent material.

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