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ScienceDirect
Journal of Physics and Chemistry of Solids 69 (2008) 362–365
JOURNAL OF PHYSICS AND CHEMISTRY OF SOLIDS
www.elsevier.com/locate/jpcs

Effect of microwave irradiation on surface characteristics and luminescent properties of $BaMgAl_{10}O_{17}$:Eu blue phosphor

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Abstract

$BaMgAl_{10}O_{17}$:Eu (BAM) has been an excellent blue-emitting phosphor due to its outstanding luminescence efficiency and purity for plasma display panels. An attempt of employing microwave irradiation to modify the surface properties including morphology and crystallinity of BAM powder was performed in this work. X-ray powder diffraction (XRD) analysis and scanning electron microscopy (SEM) images show that the blue-emitting phosphors after microwave irradiation treatment exhibit better crystallinity and smoother surface. Furthermore, the vacuum ultraviolet photoluminescence spectra show that the luminescent intensity of BAM phosphors can be effectively enhanced by a factor of six times under microwave irradiation treatment. The enhanced luminescent properties can be closely related to the surface modification and reduced defects of the BAM blue-emitting phosphors.

Keywords: D. Luminescence

1. Introduction

AC color plasma display panels (PDPs) have been well-recognized as the most promising candidates for large-sized flat panel displays (FPD). However, the performance of phosphor luminance including brightness, color purity, stability and efficiency in PDPs has been still unsatisfactory compared to CRT displays [1]. To overcome this disadvantage, a new generation of large-area display panel with an efficient illuminating technology has been of critical concern. Illuminating phosphors are the key materials to improve the performance of PDPs such as brightness, cost-effectiveness and stability [2,3]. So far, red-emitting $(Y,Gd)BO_3$:Eu (YGB), blue-emitting $BaMgAl_{10}O_{17}$:Eu (BAM), green-emitting Zn_2SiO_4:Mn (ZSM) have been mostly used as illuminating phosphors. However, BAM phosphor has been paid attention because of low brightness (blue), severe degradation of luminescence intensity and a color shift toward longer wavelength [4–6]. Several factors such as crystallinity, particle size and shape, and surface morphology have been considered and adopted to improve the luminance efficiency of BAM and the lifetime of PDPs [7–10]. In addition, microwave irradiation treatment was also developed as a new tool for high-temperature processing of materials because it can give rapid and uniform heating, improved physical and mechanical properties [11]. Even so, microwave irradiation has been little applied to modify the optical behavior of phosphors.

Therefore, in this work, a simple microwave irradiation treatment was used for surface modification of the BAM powder. As surprisingly discovered, a considerable change in the morphological geometry of the phosphor powder was observed. Effect on physical character and resulting illuminant properties of the BAM phosphor will be investigated and discussed.

2. Experiment

To study the effect of microwave irradiation on the luminescent efficiency of PDP phosphor powders, commercial

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0022-3697/$ - see front matter
doi:10.1016/j.jpcs.2007.11.026

blue-emitting $BaMgAl_{10}O_{17}:Eu^{2+}$ (BAM) powder was used as model phosphor which was purchased from Kasei (Serial no. KX-501A; $d = 3.8\,g/cm^3$, $D_{50} = 2.7\,\mu m$, and fabricated by solid-state method). Prior to experiment, the powders were stored in nitrogen environment to prevent influence from mist or hydroxyl. A domestic MW system (2000 W, 2.45 GHz) was modified by installing a condenser through a hole on the ceiling and a magnetic stirrer at the bottom. The microwave irradiation was performed at 100–600 W for various duration times. Temperature under different microwave treatment was measured by infrared telethermometer. The surface morphology of blue phosphors was measured by field-emission scanning electron microscopy (FESEM; JEOL-6700). The crystallinity of BAM was analyzed by X-ray powder diffraction (XRD; MAX SCIENCE M18XHF KXY-8019-1). The photoluminescence (PL) properties of the blue phosphor were analyzed by VUV optical system. The blue phosphors were excited by the VUV light (147 and 173 nm peak wavelength, 25 ns pulse width, and 10 Hz frequency) of synchrotron radiation at room temperature.

3. Results and discussion

Fig. 1 shows the particle morphology of the phosphor powder before and after microwave treatment. Without microwave irradiation, the blue-light phosphor presents platelets with particle size ranging from 2 to 5 μm as shown in Fig. 1(a). However, when the phosphors were treated by microwave irradiation, all the morphological changes of blue-light phosphor are at the edges which may be round due to heating or diffusion but their size remained almost unchanged as shown in Fig. 1(b)–(d). The change in particle morphology under microwave irradiation was due to the so-called "thermal-runaway" phenomenon [12,13,15]. Local "hot spots" were induced on the high curvature surface of polygonal particle resulting from tending focusing of electromagnetic field. Rapid absorption of hot spots evolved in a thermal-runaway process could lead to surface melting. The resulting round geometry of the microwave-treated particles strongly substantiated this presumption. However, with such a short time-period of microwave treatment, the crystalline phase of the BAM phosphor remained unchanged, as evidenced in Fig. 2. Furthermore, it is also expected that the surface defects resulting from surface porosity and particle grounding can be eliminated to a certain degree. On this basis, an improved luminescence property can be observed and this is further evidenced in PL measurement. Fig. 3 illustrates the PL properties of blue-emitting phosphors with or without microwave irradiation treatment under VUV excitation (147 nm) at room temperature. It clearly demonstrates that the luminescent efficiency of BAM can be much improved by microwave irradiation treatment, particularly at 300 W/180 s ($T = 900 \pm 50\,^{\circ}C$), which can effectively enhance luminescence by a factor of six times. However, similar outcomes were not detected in other conditions such as 100 W ($T = 150$–$550\,^{\circ}C$) and 600 W ($T = 450$–$1200\,^{\circ}C$) of microwave irradiation (Fig. 4). One hundred watt-treated phosphors showed slightly enhanced luminescence compared to the 600 W-treated and untreated phosphors. This result indicated that if the energy of microwave irradiation transferred to the phosphor particles is not strongly enough to compensate for the surface energy

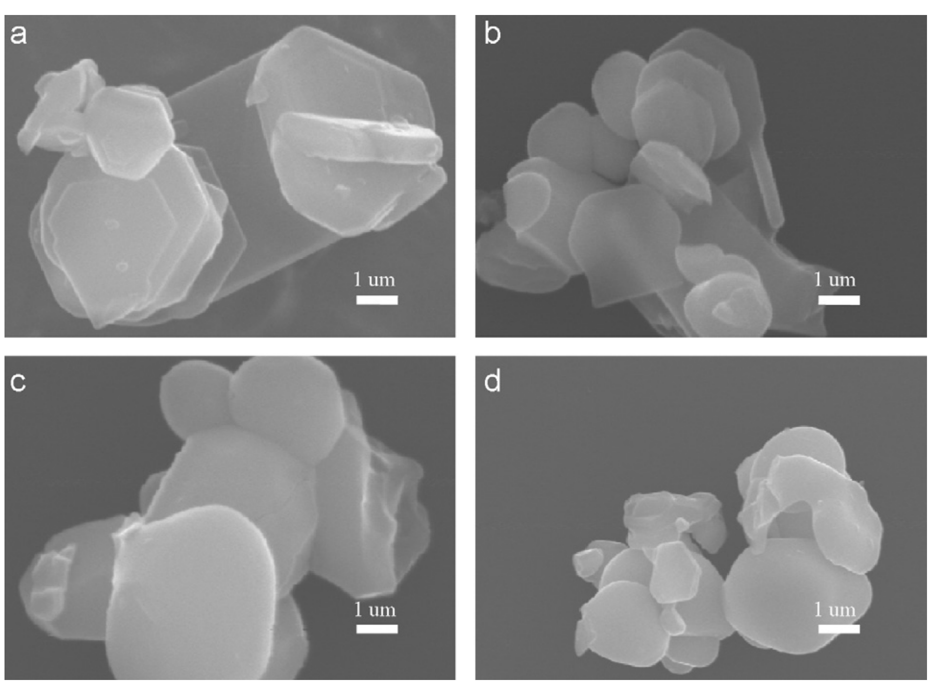

Fig. 1. SEM images of blue-light phosphors (a) without (as-blue phosphor) and with microwave irradiation at (b) 100 W/180 s, (c) 300 W/180 s, and (d) 600 W/180 s.

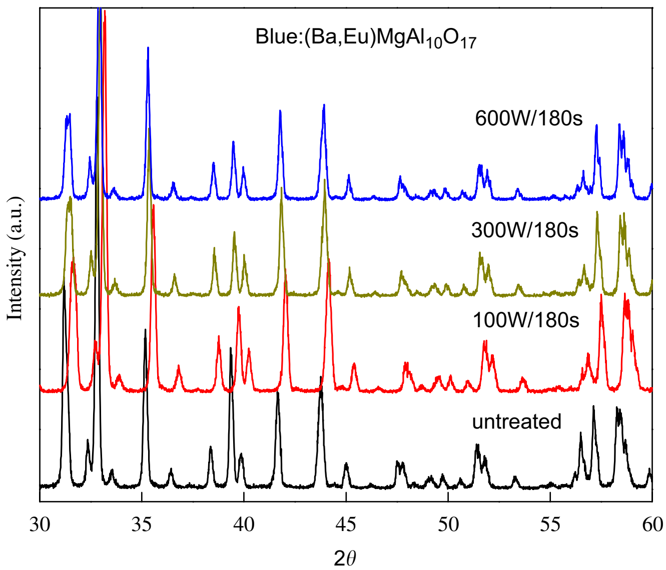

Fig. 2. XRD patterns of blue-light phosphors with and without microwave irradiation.

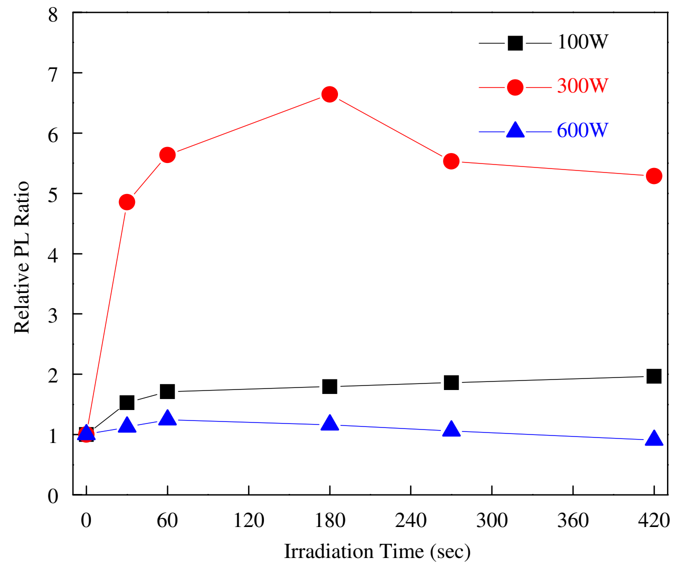

Fig. 4. Emission ratio of blue-light phosphors with and without microwave irradiation.

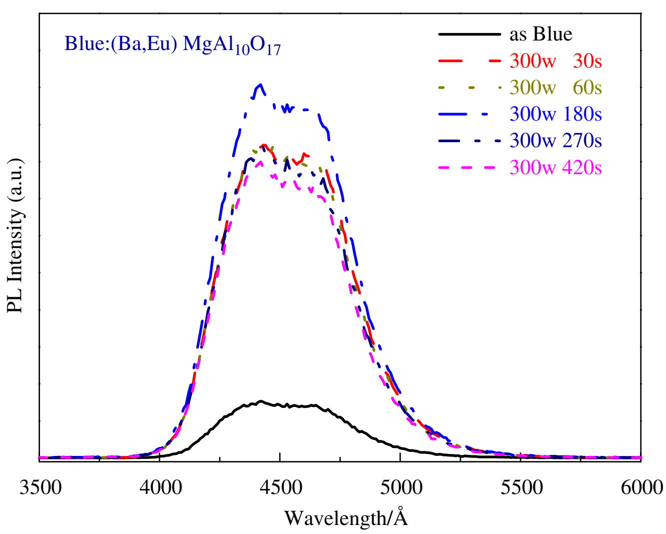

Fig. 3. PL spectra of blue-light phosphors with and without microwave irradiation.

of phosphor particle to cause atomic rearrangement, the improvement of luminescence is not remarkable. Nevertheless, overload energy would aggravate thermal-runaway so that particle surface would be bad. It suggests that a proper microwave irradiation (300 W) would supply the sufficient energy to modify the surface morphologies of BAM phosphor powder. In this condition, both intrinsic and extrinsic defects could be removed and therefore, an enhanced luminescent efficiency of blue-light phosphors can be obtained. The other possible explanation for such a prominent improvement is that temperature of the powder surface increased as a result of absorption of microwave irradiation (300 W), leading to a rapid conduction losses and this would be associated with the thermal activation of the electrons which pass from the valence band to the conduction band. Furthermore, material defects sharply decrease the energy gap between the valence and conduction bands which results in an enhanced electrical conduction [13,14]. Owing to the increase of both electrons in the conduction band and holes in the valence band, the possibility for the excited stated of Eu^{2+} to capture electrons and the ground state to capture the holes increases too, so that the luminescent intensity increases. However, insufficient power (100 W) can hardly provide enough energy to achieve energically enough temperature for electrons transition; overload power (600 W) would raise temperature to a level so that it would aggravate the thermal-runaway effect for phosphors which also procure material melting and slightly thermal degradation.

4. Conclusion

Blue-light phosphors with improved luminescence property can be obtained through microwave irradiation. Surface morphology of the phosphor particles is extensively modified, permitting better crystallinity and particle density to be developed. The PL property shows that the luminescent efficiency of the phosphors can be improved by a factor of six times under microwave irradiation. To the best of our knowledge, this is the first technical report in the community. These results indicate that a cost-efficient operation for mass production of the highly efficient phosphors can be easily developed and encourages a potential development of new-generation back-light devices.

Acknowledgment

The authors gratefully acknowledge the financial support of Central Research Institute, Chungwha Picture Tubes, Ltd., Taoyuan, Taiwan, ROC.

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