

Luminescent properties of $\text{CaTiO}_3\text{:Pr}$ thin-film phosphor deposited on ZnO/ITO/glass substrate

Sung Mook Chung^a, Sang Hyuk Han^b, Kuk Hyun Song^c, Eung Soo Kim^b,
Young Jin Kim^{b,*}

^a*OEL Device Team, ETRI, Daejeon 305-350, Republic of Korea*

^b*Department of Materials Science and Engineering, Kyonggi University, Suwon 443-760, Republic of Korea*

^c*Digital Technology Standard Division, Korean Agency for Technology and Standard, Gwacheon 427-010, Republic of Korea*

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Abstract

Red-emitting $\text{CaTiO}_3\text{:Pr}$ phosphor thin films were deposited on glass, ZnO/ITO/glass, and ITO/glass substrates by RF magnetron sputtering. The effects of various substrates and heat treatment on the structural and luminous properties were investigated. The films deposited on ZnO/ITO/glass exhibited superior crystallinity and more enhanced PL and CL properties compared with those on ITO/glass. The intermediate ZnO layer between phosphor film and ITO contributed to the growing behaviors and the roughening of $\text{CaTiO}_3\text{:Pr}$ phosphor thin films, and consequently, to the excellent luminescence. The luminescent properties of the films were improved by following heat-treatment due to a combination of factors, namely the transformation from amorphous to poly crystalline phases, the activation of the activators, and the elimination of microdefects.

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1. Introduction

The field emission display (FED) is not only noted as a replacement for the aging cathode ray

tube (CRT), but it also competes with electroluminescence (EL) and the plasma display panel (PDP) in the flat panel display (FPD) market. Its advantage over its competitors is its ease of manufacturing (due to its all solid-state nature), a faster response speed, longer life, excellent screen contrast, high brightness, and a wider viewing angle [1].

*Corresponding author. Tel.: +82 31 249 9766; fax: +82 31 249 9775.

E-mail address: yjkim@kyonggi.ac.kr (Y.J. Kim).

Phosphors used in FED technology are different from CRT phosphors. Oxide phosphors are excellent for FED because they offer advantages over commonly used sulfide phosphors in CRTs [2]. For red emission, $\text{CaTiO}_3\text{:Pr}$ is one of the promising low-voltage luminescent oxide materials for use in FED [3–7], since it exhibits red cathodoluminescence (CL) with CIE coordinates at $x = 0.680$ and $y = 0.311$. These values are very close to the coordinates of “ideal red” [3]. Another important point is the use of thin-film phosphors in FED, since they have many advantages in contrast, chemical stability, and processing regardless of their lower luminescent efficiency. Many researchers have studied the luminescence mechanism in order to enhance the luminous properties of thin-film phosphors by increasing light-scattering centers via surface modification and reducing defects with heat-treatment at high temperatures [8–11]. Similar works were performed for light emitting diodes (LEDs) and thin-film electroluminescence (TFEL) devices. High light extraction efficiency could be obtained by surface texturing [12], surface roughing [13], a two-dimensional surface grating [14], inserting an in situ rough SiN_x [15], and introducing a two-dimensional SiO_2 nanorod pattern into the glass substrate of a TFEL [16].

In this study, the effects of substrate and heat-treatment on the luminous characteristics of $\text{CaTiO}_3\text{:Pr}$ thin-film phosphors were observed. Furthermore, the relationship between the structural properties and luminescent characteristics were determined. One possible method to obtain surface modified thin-film phosphors (with light scattering centers) involves placing a highly crystallized intermediate layer between the amorphous like an indium tin oxide (ITO) substrate and thin-film phosphors. ZnO thin films can be introduced as an intermediate layer because it is relatively easy to obtain a high-quality transparent polycrystalline film.

2. Experiment

$\text{CaTiO}_3\text{:Pr}$ thin-film phosphors were prepared on ZnO/ITO/glass, ITO/glass, and glass substrates

Table 1
Sputtering conditions for ZnO and CaTiO_3 films

Parameters	Conditions	
	ZnO	CaTiO_3
RF power (W)	100	150
Background pressure (Torr)	5×10^{-6}	5×10^{-6}
Working pressure (mTorr)	5	5
$\text{O}_2/(\text{Ar} + \text{O}_2)$ (%)	50	5
Working temperature ($^{\circ}\text{C}$)	300	250–550
Thickness ($\text{\AA}$)	5000	8000

(Corning, USA) by RF magnetron sputtering. Fabrication of the ceramic target was based on a conventional ceramic process. Oxygen and argon were used as an oxidant and sputtering gas, respectively. ZnO thin films were deposited by RF magnetron sputtering on commercialized ITO/glass substrates. The target was cleaned with 10 min of plasma sputtering. After cleaning, a shutter protecting the substrate was removed for the deposition step. The sputtering parameters for $\text{CaTiO}_3\text{:Pr}$ thin films and ZnO are listed in Table 1. $\text{O}_2/(\text{Ar} + \text{O}_2)$ ratio was fixed at 5% according to the results of the preliminary experiment [17]. The thin films were heat-treated in the tube furnace for 3 h at 700°C in vacuum. The structural properties of the films were determined using a thin-film X-ray diffractometer (XRD) with CuK_α radiation. A scanning electron microscope (SEM) with energy-dispersive spectrometer (EDS) was used for analysis of the surface morphology. Surface roughness was observed by atomic force microscope (AFM) with a scan speed of 1 Hz. The photoluminescence (PL) spectra were measured at room temperature using a DASA 5000 monochromator (PSI Inc.) with a xenon light source. The CL was measured with an accelerating voltage from 0.5 to 6.0 kV, and emission current from 0.2 to 1.8 mA.

3. Results and discussion

The Pr content in the CaTiO_3 sputtering target was chosen from the PL spectra of CaTiO_3 powder containing various concentrations of Pr, as shown

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