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Characterization of Y_2SiO_5:Ce thin films

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Abstract

Uncoated and SnO_2-coated Y_2SiO_5:Ce thin film phosphors grown on Si (1 0 0) substrates by a pulsed laser deposition technique were characterized with scanning electron microscopy (SEM), atomic force microscopy (AFM), energy dispersive X-Ray analysis (EDS) and X-Ray diffraction (XRD). Cathodoluminescence (CL) of both the uncoated and SnO_2-coated thin film phosphors was investigated for possible application in low voltage field emission displays (FEDs). Blue emission with peak values at 440 and 500 nm was from spherically shaped particles distributed unevenly on the surfaces of both the uncoated and coated thin film phosphors.

Keywords: Y_2SiO_5:Ce; Thin films; Cathodoluminescence; SEM; AFM; EDS; XRD; PLD

1. Introduction

The latest research studies on flat panel display (FPD) technology are aiming at improving luminescent efficiency of the phosphors used in field emission displays (FEDs) [1–3]. FEDs require higher efficiency at lower voltages (lower as 5 kV, in comparison with CRTs that require voltages between 20 and 30 kV). The lower voltages means FEDs operate with low energy electrons which have a shallower penetration depth for cathodoluminescence (CL).

Higher current densities are required to maintain brightness and constant power, in the FEDs. However, the current density has been found to influence the degradation rate of CL intensity of traditional sulphide-based phosphors used in FEDs [4]. Compared to sulphide-based phosphors, oxide phosphors have been found to be more stable in high temperature, high pressure and high current densities needed for the FED environment [5,6].

Thin film phosphors have some advantages over powders in the FED environment, such as a reduction of light scattering and a good thermal contact between the screen and the faceplate [4,7]. Pulsed laser deposition (PLD) is a technique used to grow thin films with an important feature of maintaining the stoichiometry of the target material [4,7]. Surface morphology and thickness can be controlled by varying some of the growth parameters, such as the ambient gas pressure and the amount of pulses [7,8].

Shin et al. [9] investigated degradation of the CL intensity of ZnS:Mn phosphor coated with SnO_2. Although the photo-luminescence (PL) emission intensities showed little change when SnO_2 was coated on the surface, the CL emission intensity depends on the excitation energies. The degradation of the CL intensity of ZnS:Mn is consistent with a well known electron stimulated surface chemical reaction (ESSCR) [10]. Coating the surface of the phosphors is one possibility of decreasing the degradation rate. The coating should be thin enough to be transparent at low energies and it should not influence the chromaticity and brightness of the phosphor [11].

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Y_2SiO_5:Ce, is a blue emitting (double shoulder peak between 400 and 500 nm) rare earth phosphor. Light emission in rare earth phosphors is due to characteristic luminescence where electron hole pairs get created in the atom itself, emitting photons as they recombine. Ce^{3+} (trivalent cerium) has only one electron in the 4f shell. The 4f energy level splits into the $^2F_{5/2}$ levels due to the electron having the ability to exhibit $a + 1/2$ or $-1/2$ spin [12]. Coetsee et al. [13] and Bosze et al. [12] reported on the cathodoluminescence of Y_2SiO_5:Ce powder phosphors and Zhang et. al. [5] reported on the photo-luminescence of Y_2SiO_5:Ce thin film phosphors with a light emission mechanism, due to the 5d → 4f transition, resulting in the double shoulder peak between 400 nm and 550 nm.

In this study, we report on the characterization of blue emitting Y_2SiO_5:Ce phosphor thin films prepared by the PLD technique. Results were compared with the same thin films coated with SnO_2 through consecutive pulsed laser deposition method. Scanning electron microscopy (SEM), atomic force microscopy (AFM), energy dispersive X-ray analysis (EDS) and X-ray diffraction (XRD) were used to determine the surface morphology. Cathodoluminescence (CL) was used to investigate light emission from the thin films.

2. Experimental

Silicon (Si) (1 0 0) substrates were cleaned in Acetone for 5 min, in an ultrasonic water bath and then for another 5 min in methanol. The substrates were blown dry with nitrogen (N_2) gas. Commercially available Y_2SiO_5:Ce standard phosphor powders from phosphor technology (UK) were pressed into a pellet and annealed at 600 °C for about 16 h in air. The powder was heated to remove any water vapour and other gases that might be trapped in the pellet.

The Lambda Physic 308 nm excimer XeCl laser was used to ablate the thin films. The laser energy was 81.81 mJ, repetition rate of 10 Hz, 6600 laser pulses were used to ablate the phosphor layer and 1200 pulses were used to ablate the SnO_2 layer. The vacuum base pressure was 3×10^{-5} Torr before the system was backfilled with oxygen ambient gas to a pressure of 7.5×10^{-4} Torr, the substrate temperature was 400 °C and the target to substrate distance was 3.7 cm.

Rutherford backscattering (RBS) was used to measure the thickness of the thin films by using a 3.1 MeV $4He^+$ beam. SEM, AFM and EDS were used to monitor surface morphology and topography. SEM images were taken with the Gemini LEO 1525 Model at the CSIR – NML (Council for Scientific and Industrial Research – National Metrology Laboratory), Pretoria. AFM was done with the Digital Instruments Multi Mode with Nano Scope IV Controller and JV Scanner model and EDS was done with the Oxford 1525 model. The crystal structure of the thin films was determined with XRD by using a Siemens D5000 equipped with a Cu source.

CL spectroscopy, excited by an electron beam with 2 keV energy electrons and a beam current density of 26 mA/cm^2, was used to investigate the luminescence of the thin films. The CL measurements were made in an ultrahigh vacuum (UHV) chamber (base pressure of 4×10^{-9} Torr and backfilled with oxygen to a pressure of 1×10^{-6} Torr), with a PHI Model 549 system. Data were collected with a PC2000-UV Spectrometer using OOI Base32 computer software.

3. Results and discussion

RBS results indicated that the coated thin films have a 58 nm thick SnO_2 layer on the surface. It also reported a non-uniform layer which was shown by SEM, AFM and EDS to be the Y_2SiO_5:Ce phosphor layer consisting of spherical shaped particles not uniformly distributed. Fig. 1 shows the SEM images of the surface morphology for the uncoated (a) and coated (b) thin films.

The surface is very rough with the particles not uniformly distributed that varied in micron sizes. Fig. 2 shows the AFM results done in contact mode. AFM results as shown in Fig. 2, (a three-dimensional image in which the colour intensity represents the altitude with dark for low and white for high.) indicated that the particle size distribution varies between 10 nm to micron size particles. The surface is not smooth, but covered with spherical particles. The 3D data or Z measurements provided by the AFM

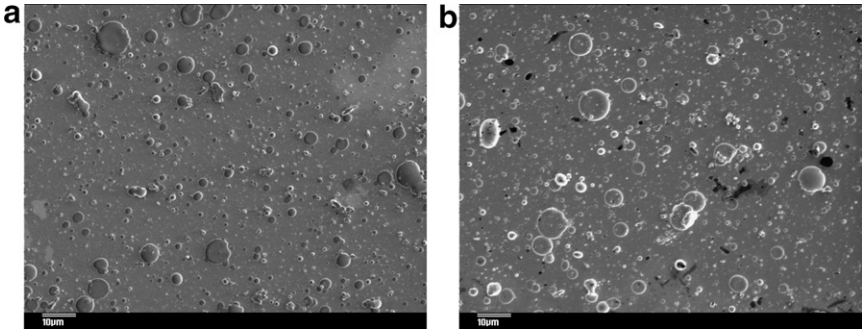

Fig. 1. SEM images of the (a) uncoated and (b) coated phosphor thin films with a magnification of 1000×, 10 kV electrons, scale – 10 µm.