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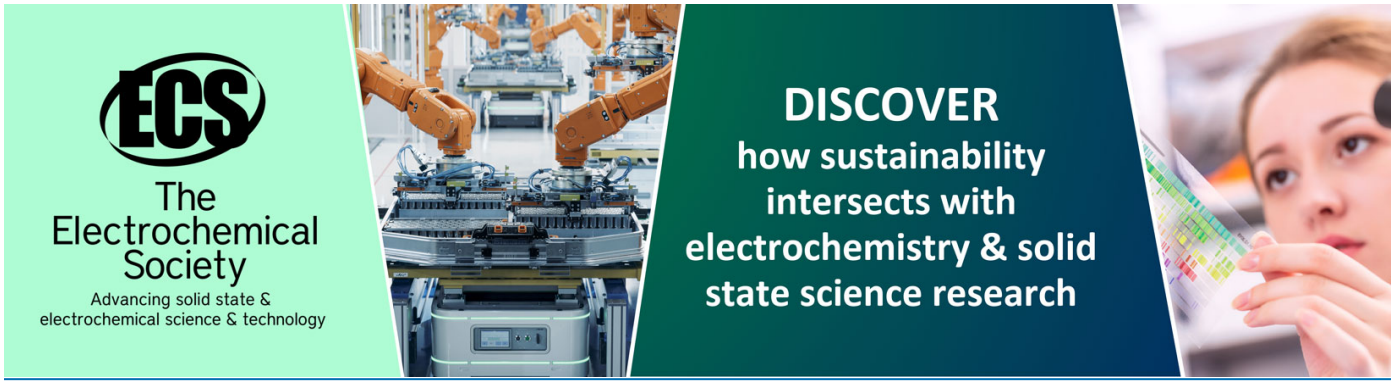

Polymer Based Thin Film Screen Preparation Technique

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Abstract. Phosphor screens, mainly prepared by electrophoresis, demonstrate brightness equal to the standard sedimentation on glass or quartz substrate process and are capable of very high resolution. Nevertheless, they are very fragile, the shape of the screen is limited to the substrate shape and in order to achieve adequate surface density for application in medical imaging, a significant quantity of the phosphor will be lost. Fluorescent films prepared by the dispersion of phosphor particles into a polymer matrix could solve the above disadvantages. The aim of this study is to enhance the stability of phosphor screens via the incorporation of phosphor particles into a PMMA (PolyMethyl MethAcrylate) matrix. PMMA is widely used as a plastic optical fiber, it shows almost nearly no dispersion effects and it is transparent in the whole visible spectral range. Different concentrations of PMMA in MMA (Methyl Methacrylate) were examined and a 37.5 % w /w solution was used for the preparation of the thin polymer film, since optical quality characteristics were found to depend on PMMA in MMA concentration. Scanning Electron Microscopy (SEM) images of the polymer screens demonstrated high packing density and uniform distribution of the phosphor particles. This method could be potentially used for phosphor screen preparation of any size and shape.

Keywords: Polymers; PMMA; film screens

1. Introduction

The last years, research for small-sized sensors, such as nano-phosphors and quantum dots (QDs) is in the spotlight providing noteworthy advances in these fields [1-7]. A challenge in the production processes of these nano-sensors is the aggregation of the nanoparticles in the polymer matrix, which can reduce fluorescence [8]. Therefore, optimum dispersion of the nanoparticles is very important for flexible fluorescent film applications [9, 10]. Fluorescent films can be produced by the dispersion of inorganic nanoparticles into an organic transparent thermoplastic polymer, such as polymethyl methacrylate (PMMA) [11]. Advantages of the PMMA, compared to silica glass, are the higher light transmittance (including UV down to 300 nm), lower weight (1.19 versus 2.20 g cm^{-3} in density, respectively) and higher impact strength, however PMMA cannot be used in high temperature applications [12]. In the above consensus, this paper has focused on the preparation of PMMA/ $ZnSiO_4$:Mn films. The morphology of the samples was investigated by optical and scanning electron microscopy (SEM) while their optical characteristics were evaluated by optical absorption and transmission measurements.

2. Materials and Methods

2.1. Screen sample preparation

$ZnSiO_4$: Mn powder (Lumilux 51140, Derby Luminescents, Ltd.) and a 37.5% w/v PMMA/MMA polymer solution were used for the preparation of the screens samples. PMMA (average Mw=120.000 in micro crystal form) and MMA (99% purity) were supplied by Sigma Aldrich, order code 182230 and Alfa Aesar GmbH, respectively.

For the preparation of the screen samples, two different methodologies were followed: In the first one, 100 mg of the $ZnSiO_4$: Mn powder were initially diluted in 1ml MMA in a test tube and the suspension was stirred for 1 min, while in the second, 100 and 200 mg of $ZnSiO_4$: Mn powder were used and in addition to stirring, the test tube was placed in an ultrasound bath for 10 min, in order to achieve maximum homogeneity of the suspension. Afterwards, 1.5 mL of 37.5% w/v PMMA/MMA polymer solution was added and the composite solution was stirred for 4-5 min, using a Vortex stirrer for better mixing. Consequently, it was cast in the polypropylene mounting cup, placed in a vacuum chamber, for entrapped air bubbles removal and left overnight in the closed chamber. The thicknesses of the prepared phosphor screen samples range from 0.4 to 0.6 mm. The prepared PMMA/MMA samples and the phosphor screen samples were examined by a Leica DMLP Polarization Microscope, using Color View III image capture software (Leica Microsystems Wetzlar GmbH).

3. Results and Discussion

A 37.5% w/v PMMA/MMA polymer solution was used for the preparation of the samples, due to its better optical characteristics, mainly the optical translucence, which was found on the results of a previous work [5]. Nevertheless, PMMA/MMA samples were examined by optical microscopy, for air bubbles trapped within the sample that could potentially alter the optical characteristics and the dispersion uniformity of the powder phosphor (Fig. 1).

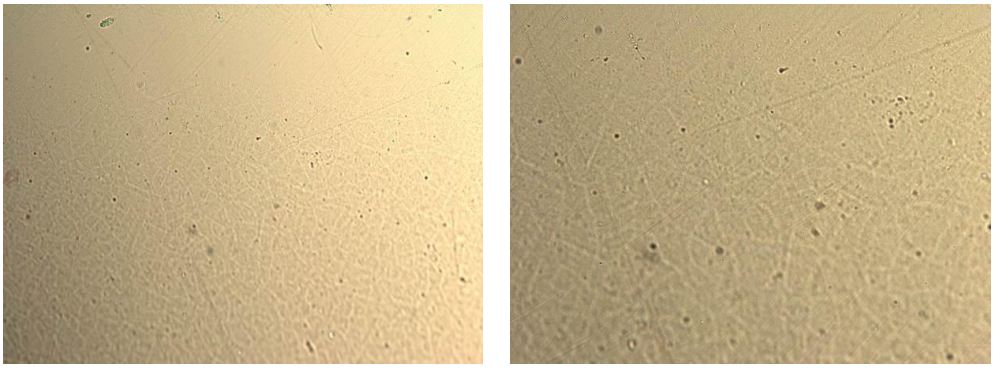

Figure 1. Optical microscopy images of the 37.5 % w/v PMMA/MMA sample, after air bubble removal under vacuum. **Left** image of the PMMA/MMA substrate using magnification 10x/0.30. **Right** image of the PMMA/MMA substrate using magnification 20x/0.5.

Few micro air bubbles (dark spots) were trapped within the polymer matrix with low probability to influence the optical characteristics or the dispersion homogeneity of the final phosphor screens. The morphology of the polymer screens was verified by obtaining SEM micrographs using the Jeol JSM 5310 SEM collaborating with the INCA software (JEOL USA, Inc.). Figure 2 presents SEM images of the produced PMMA/$ZnSiO_4$:Mn composite screen, prepared by the first methodology. Areas of agglomeration are clearly visible, probably due to inefficient dilution of $ZnSiO_4$:Mn powder within the MMA, using the Vortex stirring technique. Figure 3 presents SEM images of the produced PMMA/$ZnSiO_4$:Mn composite screen, using the second methodology, but the same

amount of $ZnSiO_4$:Mn powder (100 mg). Areas of agglomeration are not visible and the powder grains were uniformly sediment in the bottom part of the screen.

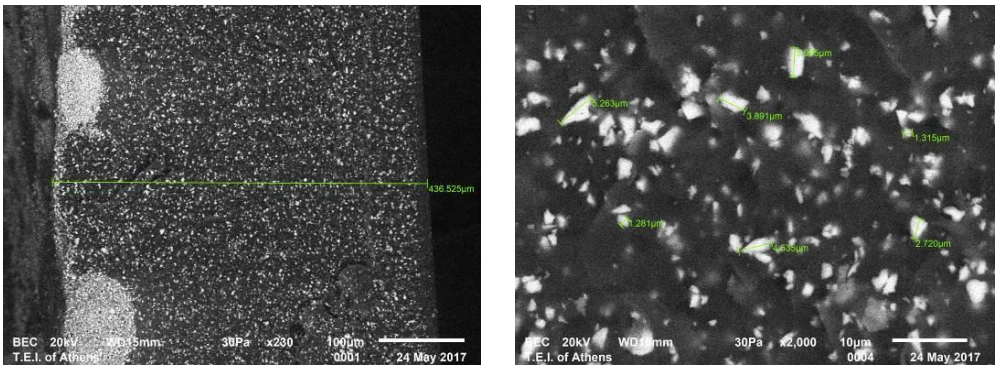

Figure 2. SEM images of the prepared PMMA/ $ZnSiO_4$:Mn composite screen, according to the first methodology. **Left**, areas of agglomeration of $ZnSiO_4$:Mn powder within the MMA, probably due to inefficient dilution (magnification x230). **Right**, area outside the agglomeration section where the ZnSiO4:Mn powder is distributed almost uniformly (magnification x2000).

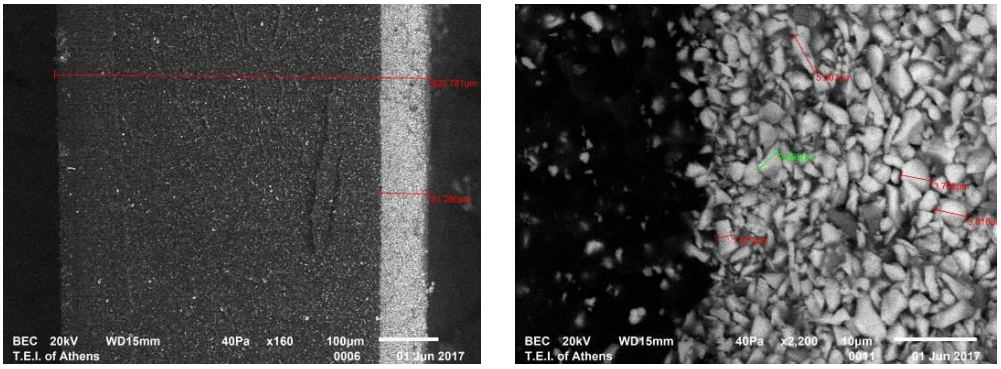

Figure 3. SEM images of the prepared PMMA/ $ZnSiO_4$:Mn composite screen, according to the second methodology and 100 mg $ZnSiO_4$:Mn powder. **Left**, distribution of $ZnSiO_4$:Mn powder within the MMA, forming a thick uniform sedimentation area (magnification x160). **Right**, distribution of $ZnSiO_4$:Mn grains forming a uniform layer of about 80µm (magnification x2200).

The last preparation method was used to achieve higher surface density scintillation screens of about 70 mg/cm^2 [13], using 200 mg of $ZnSiO_4$:Mn powder. SEM images of the prepared PMMA/ $ZnSiO_4$:Mn composite are presented in Figure 4. By comparing the sets of these images it appears that in the last screen, although it had twice as much phosphor powder concentration, the deposition of the phosphor powder grains was equally uniform, as in the previous screen. The thicknesses of the prepared phosphor screen samples range from 0.4 to 0.6 mm. This variation in thickness may be due to fluctuation of the composite volume that remained on the walls of the polypropylene mounting-cup during the vacuum process. Screen powder packing density appears to be better in this case. Although the powder quantity was twice as much, the phosphor layer thickness remained almost the same as previously.

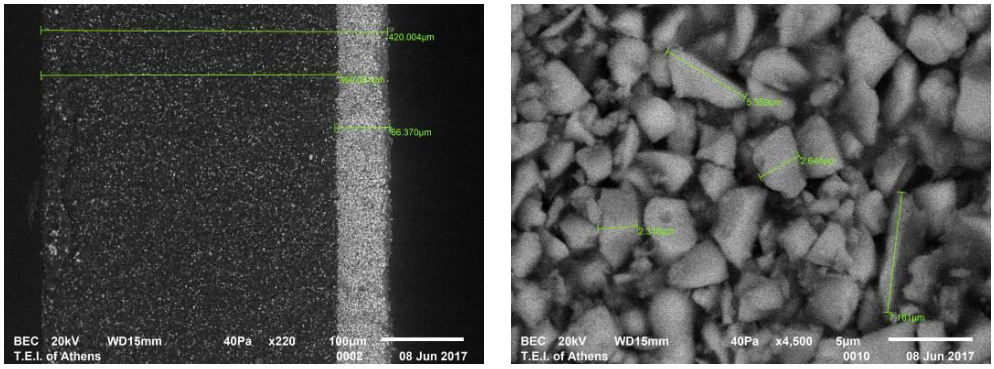

Figure 4. SEM images of the prepared PMMA/ $ZnSiO_4$:Mn composite screen, according to the second methodology and 200 mg $ZnSiO_4$:Mn powder. **Left**, distribution of $ZnSiO_4$:Mn powder within the MMA (magnification x220). **Right**, distribution of $ZnSiO_4$:Mn grains forming the a uniform layer (magnification x4500).

4. Conclusions

In the present work, we attempt to enhance the stability of phosphor screens, used in medical imaging via their preparation method. The concept was the incorporation of phosphor particles into a polymer matrix, which could potentially decrease the disadvantages of fragility and shape of the screens, as well as the material loss. Thus, we prepared composite fluorescent films by the dispersion of inorganic phosphor into an organic transparent PMMA. Scanning electron microscopy images of the polymer screens demonstrated uniform distribution and high packing density of the phosphor particles. This method could be potentially used for phosphor screen preparation of any size and shape.

5. References

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