Structural and Optical Characterization of Luminescent $(Y_{0.7}Gd_{0.3})_2O_3:Eu^{3+}$ Nanopowder and Translucent Ceramics

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Keywords: ceramics, luminescence, combustion synthesis, electron microscopy

Phosphor nanomaterials are of special interest today due to their broad range of applications from the solid state lightening and novel flat displays to high resolution X-ray detectors and sensors in biomedicine. Among them polycrystalline Eu^{3+} doped mixed oxide $(Y_{1-x}Gd_x)_2O_3$ is a well-known luminescent material widely used to provide red light emission for modern optoelectronic devices [1–3]. Both Y_2O_3 and Gd_2O_3 have the cubic bixbyite structure with space group Ia-3 and can form complete solid solutions. This mixed oxide phosphor is a very good scintillator, as ceramic it is already commercially used for the X-ray computed tomography medical imaging [4]. The transparency and consequently light outputs of sintered ceramics depend on their composition. Gd_2O_3 has a high X-ray absorption coefficient and changing its concentration enables tuning of the X-ray stopping length. Light output of sintered scintillator $(Y_{1-x}Gd_{x)2}O_3$, doped with Eu^{3+} is maximum for pure Y_2O_3, however the optimal composition regarding X-ray stopping length is found for $(Y_{0.7}Gd_{0.3})_2O_3:Eu_{3+}$ solid solution [5].

In this work we report on the successful synthesis of $(Y_{0.7}Gd_{0.3})_2O_3:Eu^{3+}$ luminescent nanopowder and on the processing conditions with which translucent ceramic pellets can be easily obtained.

Nanopowder of $(Y_{0.7}Gd_{0.3})_2O_3$, doped with 3 % at. Eu^{3+} has been prepared with the polymer complex solution method employing polyethylene glycol (PEG). This synthesis method provides powders crystallized in a cubic structure, made of nanoparticles uniform in size, which is a prerequisite for obtaining high quality transparent ceramics. The quality of produced powder is confirmed by XRD and TEM measurements.

Resulting nanopowder was cold-pressed, uniaxially, into pellets of 12 mm in diameter, and then sintered in air for 18 hours, without any additives. Twenty five different ceramic samples were prepared by varying the load from 2 to 10 tones/cm^2 (2, 4, 6, 8 and 10) and sintering temperature up to 1400°C (800, 1000, 1200 and 1400°C). The progressive development in ceramic samples was monitored with SEM and luminescent spectroscopy. Based on acquired results we concluded that in the stimulation of the sintering process the most effective are temperatures above 1200°C and the loads of 8 and 10 tones/cm^2. However, the best results are obtained for the pellet obtained under the maximum load of 10 tones when annealed at 1400°C. These experimental setups led to the finest grains formation and almost complete disappearance of all voids from the ceramic pellet (see Figure 1).

The optical properties remained unchanged for the sintered samples when well developed grains are formed together with a low pore concentration. Luminescence emission of ceramic samples decay faster than for the corresponding nanopowder and this is actually in complete agreement with the grain formation and transformation to the bulk ceramic material. We found out that the asymmetry ratio, obtained from the luminescence emission measurements, may be utilized as an indicator of the structural consolidation of ceramics during thermal treatments.

W. Grogger, F. Hofer, P. Pölt (Eds.): MC2009, Vol. 3: Materials Science,
DOI: 10.3217/978-3-85125-062-6-425 , © Verlag der TU Graz 2009

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6. R. Krsmanović is thankful to the NATO support in the realization of this experiment (grant reference number CBP.EAP.RIG.983373).

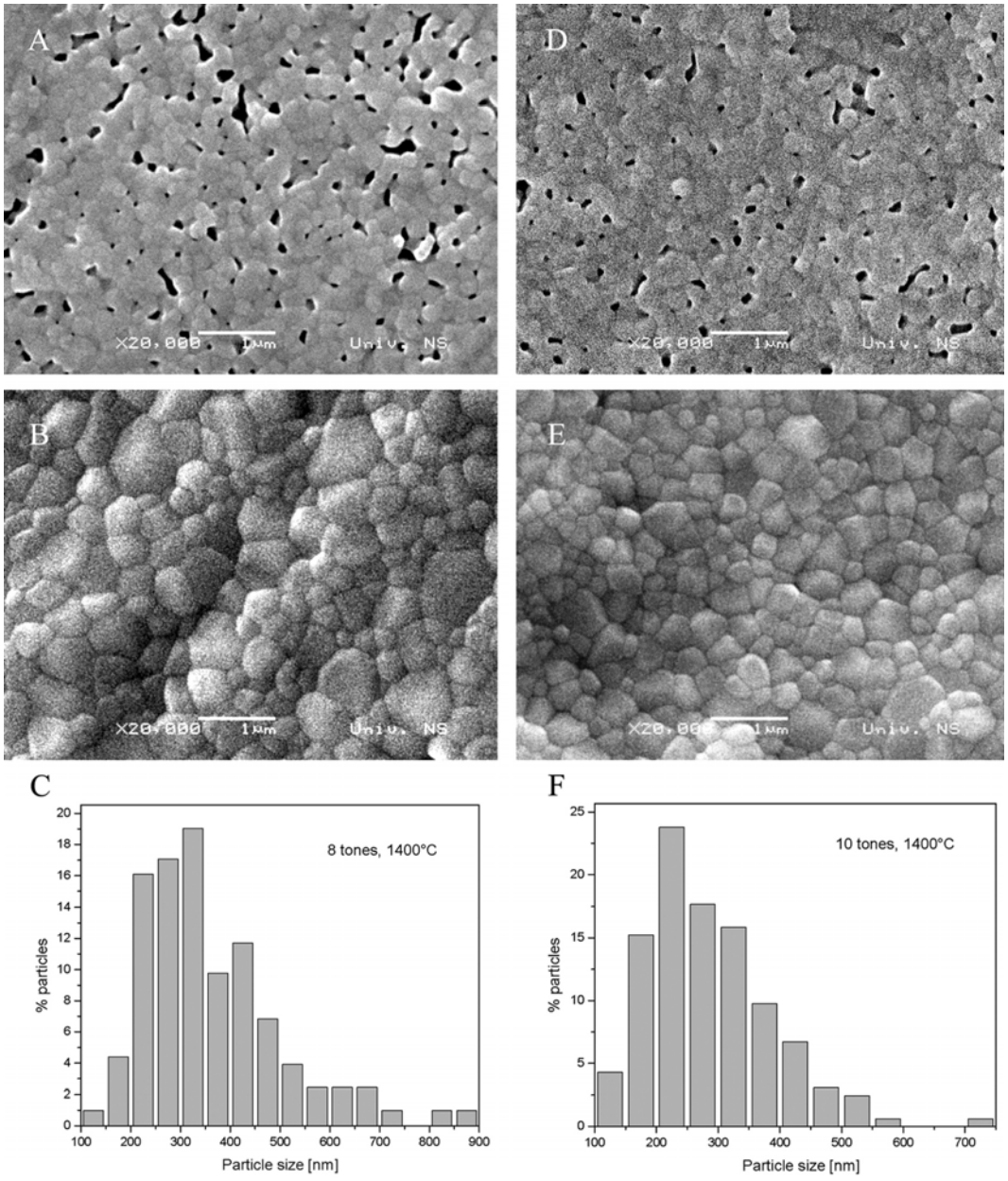

Figure 1. SEM images taken from the two series of ceramic pellets: first obtained under the load of 8 tones and annealed at 1200°C (A) and 1400°C (B), and second obtained under the load of 10 tones and annealed at 1200°C (D) and 1400°C (E). Note the absence of voids in samples annealed at 1400°C. Scale bars are 1μm. The size distribution of observed grains from the samples in (B) and (E) are given with the histograms in (C) and (F), respectively.

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