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Red and green nanocomposite phosphors prepared from porous GaAs templates

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Abstract
Rare-earth-containing oxide nanocomposites are prepared in a controlled fashion from porous GaAs templates. The initial porous GaAs network is replaced by a β-Ga_2O_3 one during annealing at temperatures from 500 to 900 °C. The impregnation of Eu and Er lanthanides from $EuCl_3$:C_2H_5OH and $ErCl_3$:C_2H_5OH solutions results in the formation of xenotime $EuAsO_4$ and $ErAsO_4$ microcrystals finely dispersed into the native oxide matrix. The 4f–4f intrashell transitions in Eu^{3+} and Er^{3+} ions ensure red and green emission from $EuAsO_4$ and $ErAsO_4$ nanophases. These nanocomposites may prove useful in future generations of optoelectronic and photonic devices.

Keywords: porous materials, photoluminescence, x-ray diffraction

Over the last few years, there has been considerable interest in the understanding and control of materials including luminescent materials on a nanometre scale. The control of phosphor structure and morphology at a nanometre level allows one to tailor its macroscopic properties such as emission spectrum and luminous efficiency. Rare-earth-ion-doped nanocrystals dispersed in a transparent medium are of special interest as potential optoelectronic materials. This issue becomes especially important in connection with the growing interest in the development of random lasers (see, e.g., [1] and references therein). Porous semiconductor templates prepared by electrochemical treatment of bulk substrates are ideal matrices for the preparation of a variety of composites including those doped with rare-earth elements as well as media with controlled scattering properties for the development of random lasers. Recently, an attempt was undertaken to dope Eu ions into a porous GaP template [2]. It was supposed that the visible emission comes from the Eu^{3+} ions incorporated into the porous GaP host. Apart from wide-bandgap semiconductors transparent to visible light, porous templates like GaAs and InP are of interest for doping with rare-earth ions exhibiting intrashell transitions in the IR spectral range, for instance, the 1500 nm transition in Er^{3+} ions which is a popular choice in a wide variety of telecommunication applications. Moreover, the easy oxidation of semiconductor templates results in nanostructured oxides which are the most commonly used materials in phosphor technologies. In this paper, we report on the development of technological methods for the preparation of nanocomposites on the basis of porous GaAs templates doped with Eu and Er lanthanides. We identify the nanophases and the electronic transitions responsible for the visible emission from these composites.

(100)-oriented n-GaAs:S wafers cut from Czochralski-grown ingots were used for the fabrication of porous GaAs layers. The free electron concentration in the as-grown substrates was 0.3×10^{18} cm^{-3} at 300 K. The anodic etching was carried out in a double-chamber electrochemical cell. A four-electrode configuration was used: a Pt reference electrode in the electrolyte, a Pt electrode on the sample, a Pt counterelectrode, and a Pt working electrode. The electrodes were connected to a galvanostat/potentiostat. The anodization was carried out in 5% HCl aqueous electrolyte at a constant current density of 100 mA cm^{-2}. The temperature was kept constant at 23 °C. The area of the sample exposed to the electrolyte was 0.2 cm^2.

Eu^{3+} and Er^{3+} ions were incorporated into the por-GaAs layer from $EuCl_3$:C_2H_5OH and $ErCl_3$:C_2H_5OH solutions,

