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Scanning and Transmission Electron Microscopy Investigation of $SrGd_2O_4$: Yb,Tm Up-conversion Luminescent Material

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In recent decades, inorganic luminescent materials have gathered significant attention due to their great potential for various applications [1-4]. The rare-earth (RE)-based UC luminescent materials are particularly interesting for their exceptional optical, electronic, and magnetic properties. These materials have distinct intra-4f electronic transitions and existence of plenty long-living electronic excited states at different energies, all of which makes electron promotion to high-energy states possible [5, 6].

RE-based UC luminescent materials are composed of a host material (matrix), a sensitizer (absorbs the IC radiation), and an activator (provides emission in the visible and UV part of the spectrum) [7]. So far, the best results have been gained by co-doping the matrix using Yb^{3+} as sensitizer and Er^{3+}, Ho^{3+}, Tm^{3+}, etc. as activators [8-10]. As for the hosts, rare-earth oxides (ARE_2O_4; A = Ca, Sr, Ba and RE = trivalent rare-earth ions) have great perspective for producing highly efficient luminescent materials. To the best of our knowledge, $SrGd_2O_4$ has been poorly investigated so far, although it has an enormous potential for variety of applications since it is environmentally friendly, has high thermal stability and good chemical durability [11]. In this work, we will present new UC luminescent material composed of $SrGd_2O_4$ (host) doped with Yb^{3+} (sensitizer) and Tm^{3+} (activator).

Control of particle morphology has attracted a great deal of attention from researchers, so efforts for finding appropriate synthesis method are still very current issue. The morphology of the obtained particles is mostly influenced by the synthesis methods used for preparing the material. Luminescent properties mainly interested for us, are in very close connection with the morphology. Here, samples were synthesized using glycine-assisted combustion method, with constant concentration of Tm^{3+} (1 at%) and different concentration of Yb^{3+} (2, 4, 6 at%). All samples were heated in the furnace at 500 °C for 1.5h and then thermally treated for 2.5 h at 1000 °C. X-ray diffraction (XRD) was used to see phase crystallinity and purity, and revealed that all peaks are assigned to the pure orthorhombic lattice of $SrGd_2O_4$ with space group *Pnma* (JCPDS Card No.:01-072-6387). Luminescent properties were investigated after recording UC luminescence spectra at room temperature under 980 nm excitation for all samples. The spectra revealed strong blue emission bands which originates from Tm^{3+} ions $^1D_2 \rightarrow {}^3F_4$ and $^1G_4 \rightarrow {}^3H_6$ and weak red emission $^1G_4 \rightarrow {}^3F_4$ transitions. Morphology and structure were thoroughly studied by field emission scanning electron microscopy (FE-SEM) and transmission electron microscopy (TEM), whilst energy dispersive spectroscopy (EDS) was used to provide additional information about constituting elements and their distribution. FE-SEM analysis revealed irregular spherical-like morphology with all samples, and particle size of around 100 nm. TEM examination showed nanostructures organized as a group of agglomerated nanoparticles. EDS verified uniform distribution of all composing elements through every sample [12].

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