Devitrification behavior of sol-gel derived ZrO2-SiO2 rare-earth doped glass: correlation between structural and optical properties.

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Abstract

Efficiency of the most common single-junction Si solar cells is limited to 30% because of the mismatch between the incident solar spectrum and the spectral absorption properties of the material. The photon down-conversion phenomenon is considered as an effective approach for improving of the solar cells performance. Particularly cooperative energy transfer from single Tb3+ to two Yb3+ ions, with quantum efficiency up to 196% has been observed. In present study rare-earth doped ZrO2-SiO2 glass is considered as a potential down-converter for solar energy applications. The base glass has high thermal stability and chemical durability, whereas crystalline products formed during devitrification, in particular ZrO2, can improve its optical properties. 30 ZrO2-70 SiO2 glasses doped with 1 mol % Tb3+ or 1 mol % Tb3+ and 10 mol % Yb3+ were synthetized by sol-gel method. The obtained gels were heated at different temperatures and times (1000∘C : 2h, 5h, 10h, 30h; 1100∘C : 2h, 5h, 10h, 30h).

By means of fluorescence spectroscopy it was found that efficiency of the down-conversion photoluminescence depends on the gel heat-treatment procedure. At the same time alteration of Tb3+ and Yb3+ emission spectra were observed, evidencing about changes in local environment of the rare-earth ions. Raman spectroscopy investigation revealed possible formation of up to 3 different crystalline phases in the samples, including monoclinic and tetragonal ZrO2. According to the XRD analysis, the latter phase found to be dominant in the samples.
To understand influence of these crystalline phases on the luminescence properties several micro-2D maps under 488, 532 and 780 nm laser excitation were collected, allowing to correlate emission of the rare-earth ions with the host matrix structural changes. It was demonstrated that the observed alteration of the emission spectra is largely related to the incorporation of Tb3+ and Yb3+ into the crystalline phases. It is shown that the final performance of the down-conversion is determined by efficiency of Tb-Yb energy transfer as well as the ions emission itself in the different phases formed and redistribution of the rare-earth elements during devitrification of the glass.

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