Multiphase SiO_2-SnO_2-LaF_3 nanostructured glass-ceramics for simultaneous UV and NIR solar spectrum conversion

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In the last few decades, the possibility of increasing of solar efficiency has been extensively investigated. It is well known that the spectral response of commercial silicon solar cells to the solar spectrum constitutes one of the main losses of photovoltaic technology[1]. In order to avoid these losses many efforts have been carried out to enhance the solar cells efficiency by photon conversion from the UV-blue (down-shifting) or NIR (up-conversion) photon to green-red radiation where the Si solar cells response is maximum.

This solar spectrum conversion could be obtained by means of rare earth ions (RE) doped nanostructured glass-ceramics as luminescent layers, without interference with the solar cell active media[2]. These ions show luminescent high quantum efficiencies when they are located in low phonon energy environments related with low non-radiative rates, although with the drawback of low absorption coefficients. This would be resolved by using a “like-antenna” specie which much stronger absorption capacity with subsequent very efficient energy transfer to the emitting RE ions.

In this work we present nanostructured glass-ceramics comprising two nanocrystalline phases, SnO_2 and LaF_3, doped with RE ions and embedded in a silica glass matrix for an efficient photon conversion from UV and NIR into visible. These photon conversion processes would be obtained by means of a strong UV absorption of SnO_2 semiconductor nanocrystals (quantum dots), following with an efficient energy transfer from the host to the Sm^{3+} ions yielding green and red emissions[3]. In particular, as it can bee seen in Fig. 1(a) a broad excitation UV band, correspond to SnO_2 nanocrystals, is observed together with a narrow and weaker peaks, mainly at 401 and 463 nm, related with Sm^{3+} ions. Corresponding emission spectra exciting at the maximum of the SnO_2 broad band give rise to luminescent down-shifting from the UV and blue irradiation into the wanted reddish-orange spectral range, see Fig. 1(b). On the other hand, efficient NIR to visible up-conversion emissions will be obtained by using pairs of RE ions co-doped LaF_3 nanocrystals. These nanocrystals are an exceptional host material for RE ions due to considerable solubility and low phonon energy (300-400 cm^{-1}), which reduces multiphonon relaxation increasing the radiative emissions[4,5]. Particularly, efficient up-conversion processes will be obtained by using the couples Ho^{3+}-Yb^{3+} and Er^{3+}-Yb^{3+} as a co-dopant in LaF_3 nanocrystals, see Fig. 1(c). These materials co-doped with Sm^{3+}-Ho^{3+}-Yb^{3+} and Sm^{3+}-Er^{3+}-Yb^{3+}, present luminescence features that could be used to enhance the efficiency of photovoltaic solar cells.

References

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Figures

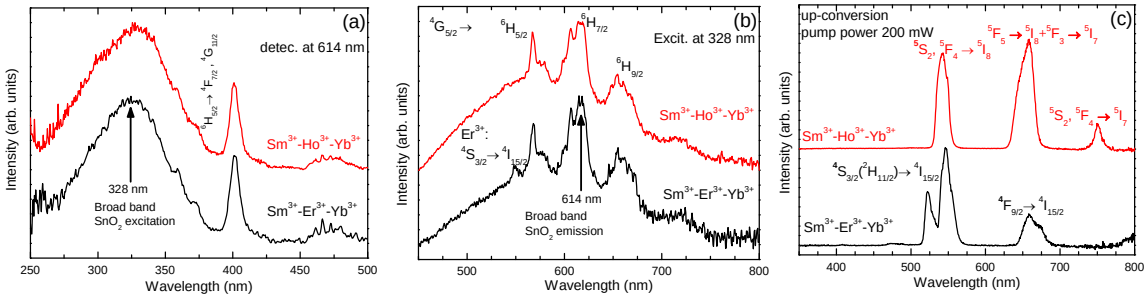

Fig. 1 (a) UV-visible excitation spectra of $90SiO_2$-$5SnO_2$-$5LaF_3$ co-doped with $0.4Sm^{3+}$-$0.1Er^{3+}$-$0.3Yb^{3+}$ (black) and $0.4Sm^{3+}$-$0.1Ho^{3+}$-$0.3Yb^{3+}$ (red), in mol%, heat-treated at 900 ºC during 4 h, detecting at 614 nm and normalized to the maximum of the UV band. (b) Emission spectra under excitation at 328 nm, corresponding to the maximum of the excitation band of SnO_2 nanocrystals and normalized to the maximum of the VIS emission. (c) Up-conversion emission spectra of Sm^{3+}-Er^{3+}-Yb^{3+} and Sm^{3+}-Ho^{3+}-Yb^{3+} samples obtained under 980 nm infrared excitation with 200 mW pump power, both normalized to the maximum of green emission. RE ion transitions are indicated by labels.