Eu^{3+}:La_2O_3 nanoparticles dispersed into P3HT as a down converter material for exploiting the solar spectrum

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While down-converter (DC) phosphors have been investigated for decades in the lighting industry, the possibility of down-converting sunlight to enhance performance of solar cells was just been treated recently by Trupke et al. [1].
The concept of wavelength conversion in photovoltaics is to manipulate the incident solar spectrum using appropiate materials in order to convert photons from mismatched portions of the incident solar spectrum into photons within the wavelength range efficiently used by the photovoltaic cell. Many decades of research have gone into optimising silicon devices; however it seems that further advances can be made better by modifying the input spectrum, rather than improving the electronic properties of the device [2]. By placing a luminescent down converter material in contact with the photovoltaic cell, part of the energy in the near-UV region can be reconverted to energy in the visible and near-IR that can be efficiently absorbed by the photovoltaic cell.
We propose to use europium doped lanthanum oxide (Eu^{3+}:La_2O_3) nanoparticles as a down converter material to enhance the efficiency of the P3HT organic solar cells. La_2O_3 nanocrystals doped with 5 mol % of Eu^{3+} were prepared using the modified Pechini method [3]. According to Park et al. [4] due to the concentration quenching effect, the maximum Eu^{3+} concentration for which quenching was not yet observed was determined to be about 5 mol %.
These nanoparticles absorb light in a broad band between 240 and 320 nm, while they emit only in discrete bands located between 580 and 710 nm, presenting a maximum of emission at around 625 nm (see dotted line in Fig.1 and 2).
The motivation for using materials containing rare-earths as DC materials is that this family of elements show luminescent properties over a wide range of wavelengths, extending from the near-infrared (NIR), through the visible (vis) to the ultraviolet (UV).
To study the properties as DCs of these nanoparticles, it was necessary to disperse them into a semiconductor polymeric thin film. This P3HT polymeric matrix possesses good mechanical thoughness, chemical stability, and excellent processability. Besides giving improved properties, this semiconductor polymeric matrix gives the perfect conditions to convert the light emitted from the nanoparticles on energy in the solar cell. We prepared a mixture of P3HT in tetrahydrofuran (TFH) solvent and nanoparticles with a concentration of 15 wt% to respect the polymer. The mixture was stirred during 10 min. A spin coater device was used to make a thin film of this nanocomposite on a piece of quartz under nitrogen atmosphere by adding 1 ml of the mixed solution and then spinned at 500 rpm for 2 min. Figure 3a) shows the film obtained from P3HT and the nanoparticles where it is possible to see the transparent violet colour from the P3HT polymer and it high homogeneity.
The main reason of using this kind of semiconductor polymer, besides its good properties, was due to its absorption region band, as show Fig.3b). Semiconductor P3HT polymer covered partially the range of emission of Eu^{3+}:La_2O_3 nanoparticles, including the most intense emission peak at 626 nm. However, the UV region was not affected for this polymer absorption indicating that the polymer did not absorb efficiently the range of wavelengths covered by the CTS band of the nanoparticles (see not dotted line in Figure 1 and 2). The light emitted from nanoparticles after down-conversion process has to be adsorbed by the polymer extending in this way the spectral range of a hypothetical solar cell based on these materials.

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Figures

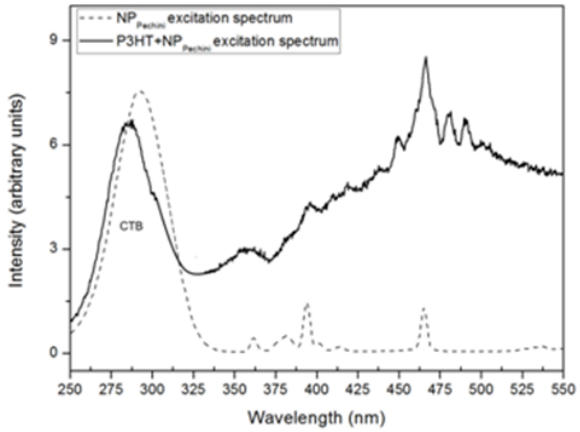

Figure 1. Excitation spectrum of the Eu^{3+}:La_2O_3 nanocrystals (dotted line) with a maximum peak at ~285 nm and excitation spectrum of the nanoparticles dispersed into P3HT polymeric matrix (not dotted line) with maximum at ~280 nm.

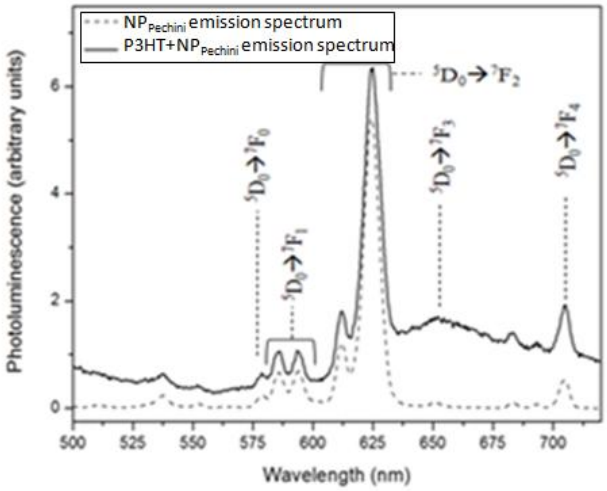

Figure 2. Emission spectrum of the nanoparticles (dotted line) and emission spectra of the nanoparticles dispersed into P3HT polymeric matrix (not dotted line).

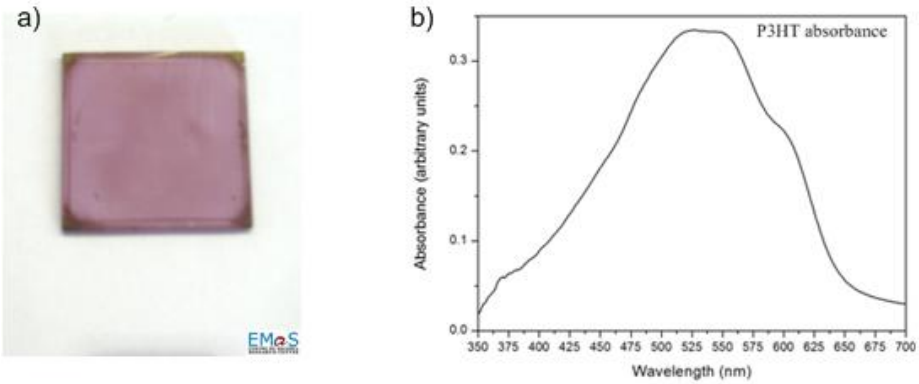

Figure 3a) Photograph of the P3HT polymer with nanoparticles on a piece of quartz; b) absorption spectrum of the P3HT with a wide band from 350 to 650 nm approximately.