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Down-conversion luminescence of Yb^{3+} in novel $Ba_4Y_3F_{17}$:Yb:Ce solid solution by excitation of Ce^{3+} in UV spectral range

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ABSTRACT

The down-conversion luminescence under UV excitation was demonstrated in single-phase $Ba_4Y_3F_{17}$ solid solution nanoparticles codoped with Ce^{3+}/Yb^{3+}. The complex photodynamic processes occurred in the samples including excited state absorption, excitons and color centers formation. The Yb doping suppressed the solarization effect. The efficiency of down-conversion from UV to near IR luminescence of Yb^{3+} appeared to be high due to Ce^{4+}-Yb^{2+} charge transfer mechanism responsible for energy transfer between Ce^{3+} and Yb^{3+} ions. The direct measurements of down-conversion luminescence quantum yield by means of integrating sphere and calculations of energy transfer efficiency from luminescence spectra data were carried out. The down-conversion luminescence quantum yield reached the maximum value of about 1% for the sample with 0,1 mol.% of Ce^{3+} and 5,0 mol.% of Yb^{3+} ions contents, whereas energy transfer coefficient reached its maximum of about 6,3% for 0,05 mol.% of Ce^{3+} and 5,0 mol.% of Yb^{3+} ions.

1. Introduction

Solar light is the free-available source of energy and may be utilized by different kinds of solar cells. Most of the converters of solar light into electricity are based on silicon solar cells [1] because they are easy to manufacture and recycle. The technology of silicon purification up to solar cell application purity is well developed [2]. The price of silicon solar cell electricity decreased ten times during 2008–2017 years [1], but the conversion efficiency of solar energy to electricity is low (about 25%) [3,4]. One of the promising solutions for increasing the efficiency of solar cells are the up-conversion [5–8] and down-conversion [8–16] luminophores as luminescence coatings. The spectral conversion is achieved in single doped materials [5,8], and systems with pairs of ions such as Er^{3+}/Yb^{3+} used for upconversion [6,7], and Tb^{3+}/Yb^{3+}, Pr^{3+}/Yb^{3+}, Ce^{3+}/Yb^{3+} and even Tm^{3+}/Yb^{3+} used for down-conversion [7–16]. They can provide efficient energy transfer from UV–visible or IR spectral ranges to the range of the highest photoresponse of silicon cells. Down-conversion luminescence process is of special interest here because one high energy photon can be converted into two or even more lower-energy photons due to quantum cutting effect appearing in some compounds.

The quantum efficiency of down-conversion in fluoride luminophores has been repeatedly investigated for various matrices [8,10–16]. In the majority of the papers, quantum efficiency estimations are based on the quenching of the donor ions luminescence due to nonradiative energy transfer to acceptor ions, Ce^{3+} and Yb^{3+} respectively in our case. This luminescence quenching usually appears to be high and expectation that one absorbed photon splits into two due to quantum cutting effect provides efficiency values of up to 190% [1,17]. But it is not of real value for practical application since these photons are not fully converted into useful luminescence of Yb^{3+} in the spectral range of around 1-μm. The cross-relaxation and back-transfer process [18,19], dissipation as heat and non-radiative processes with defects determine pathways for losses of excitation and luminescence energy. Finally, the nature of excitation transfer can be very complicated involving multiphonon processes, charge transfer, or even excitons relaxation [12,20]. In our previous papers and conference talks, we have focused on approach that down-conversion luminescence quantum yield should be estimated using an integrating sphere, since materials with complex but linear processes of energy transfer can provide higher efficiency than materials

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