Ultraviolet to Near-Infrared Down-Conversion in Bi^{3+} - Yb^{3+} Co-Doped YAM Phosphor

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Recently a number of papers appears showing application potential of Bi^{3+}–Yb^{3+} co-doped materials for solar spectrum modification by means of down-conversion (cutting one high energy photon into two low energy ones) and in such a way for possible enhancement of efficiency of silicon solar cells (see [1] and references here). In particular, down-conversion properties due to cooperative energy transfer (CET) were shown for Bi^{3+}–Yb^{3+} co-doped Y_2O_3, Gd_2O_3, YVO_4, $Y_3Al_5O_{12}$ (YAG), $CaTiO_3$ and other related materials. Here near-infrared emission around 1 μm from Yb^{3+} ($^2F_{5/2}\rightarrow{}^2F_{7/2}$) is observed under ultraviolet excitation of Bi^{3+} ion ($^1S_0\rightarrow{}^3P_1$ transitions).

The down-conversion quantum efficiency of the Bi^{3+}–Yb^{3+} co-doped materials is usually estimated from shortening of luminescence decay time of Bi^{3+} ions. To our best knowledge, there are no reports showing absolute measurements of external quantum efficiency of the down-conversion luminescence for any of Bi^{3+}–Yb^{3+} co-doped phosphor.

To get better insight into the down-conversion mechanisms in Bi^{3+}–Yb^{3+} co-doped phosphors, in the present work, direct measurements of external quantum yield (QY) were applied to a down-converting phosphors combined with measurements of photoluminescence (PL), photoluminescence excitation (PLE) and photoluminescence decay kinetics. The monoclinic yttrium-aluminum oxide (YAM) was chosen for the Bi^{3+}–Yb^{3+} co-doping because it provides additional broadening of absorption of Bi^{3+} ions due to their multisite structure in this host.

It was revealed that the energy transfer occurs mainly from one of four types of Bi^{3+} centers in YAM, namely Bi^{3+}(I), having the excitation maximum at 278 nm and the emission maximum at 360 nm. The absolute measurements of QY shows large discrepancy between the measured quantum efficiencies of the UV to near-IR down-conversion process and the efficiencies estimated from a shortening of the Bi^{3+} luminescence decay time. Obtained results testify the conversion ratio (which should be 2.0 for an ideal quantum cutting mechanism) to be no more than 1.0 for the studied material.

The procedure used in this study can be also applied to the other systems proposed for quantum cutting since it provides a method for checking the real efficiencies of this process instead of estimation derived from the decay kinetics of the energy donor (i.e. Bi^{3+} in this case) alone. Such a procedure is much more reliable.

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[1] Ya. Zhydachevskii et al., *Mat. Chem. Phys.* **143** (2014) 622-628.