Efficient Multicolor Light Tuning from Mixing of Fluoride Nanocrystals Powders Co-doped with Yb$^{3+}$/RE (RE = Tm$^{3+}$, Ho$^{3+}$ and Er$^{3+}$)

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The color tuning from upconversion nanoparticles (UCNPs) in the visible and white light generation have been obtained by several ways and they have received lately much scientific and technological interest, owing to their potential applications in color displays technology, assay of biological compounds, remote sensors, optical data storage, and optical printing [1-3]. Crystalline fluoride host matrices LaF$_3$ and CaF$_2$ were chosen for the study due to high resistance to optical damages, low phonon energy (<400 cm$^{-1}$), chemical durability and thermal stability compared to vitreous matrices. The energy transfer competition processes between the dopants ions have been a challenge to obtain a more efficient color tuning and to solve this problem the color tuning was obtained through the mixture of powders of UCNPs LaF$_3$:Yb$^{3+}$/Tm$^{3+}$, LaF$_3$:Yb$^{3+}$/Ho$^{3+}$ and CaF$_2$:Yb$^{3+}$/Er$^{3+}$. In all measurements the ion of Ytterbium (Yb$^{3+}$) was used as a sensitizer and the Tm$^{3+}$, Ho$^{3+}$ or Er$^{3+}$ ions as activators for the generation of colors in the region of blue (Tm$^{3+}$), green (Ho$^{3+}$) and red (Er$^{3+}$). Through the variation of the amount of powder of each sample in the mixture, it was possible to observe the color tuning in the chromaticity diagram CIE-1931 in a direct and efficient way.