NIR Photoresponce in New Up-Converting CdSe/NaYF4:Yb,Er Nano-Heterostructures

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Multi-component hetero-nanostructures containing two or more nanosized components arranged in a controlled manner are of fundamental and practical significance for many rapidly developing fields.[1] An interaction between the components of such systems may significantly improve the application performance and even induce new chemical [2] and electronic properties.[3] In this research work, we demonstrate energy up-conversion of near-infrared (NIR) photons, subsequent energy transfer (ET) from lanthanide nanocrystlas to quantum dots (QDs), and the dissociation of thus formed excitons leading to pronounced photoconductivity.[4]

Efficient up-conversion of sub-band-gap energy photons to create a hole-electron pair in a semiconductor would allow breaking a fundamental limitation of single junction photovoltaic devices. We note that energy transfer from $NaYF_4$:Yb,Er onto CdSe has been recently shown for a core-shell structure.[5] However, using silica shell to attach CdSe to the lanthanide nanocrystals precludes electronic interaction between the CdSe and renders its semiconducting properties irrelevant.

Therefore, the aim of this research is to develop a simple method for the synthesis of nano-heterostructures consisting of lanthanide-doped $NaYF_4$ nanocrystals dendritically decorated with CdSe QDs.

To demonstrate feasibility of using CdSe/NaYF4:Yb,Er (CSNY) up-converted energy transfer system in electronic devices, we have studied its photoconductivity upon NIR excitation. The two-contact devices were prepared by spin-coating of solution of studied nanoparticles in toluene on Si/SiO_2 substrates pre-patterned with Au electrodes. These devices showed a reversible and stable NIR photoconductivity switch. To our knowledge, this is the first example of using up-converting nanocrystals in optoelectronic devices and it could have a potential application in photovoltaics to harvest sub-band-gap energy photons.[6]

References

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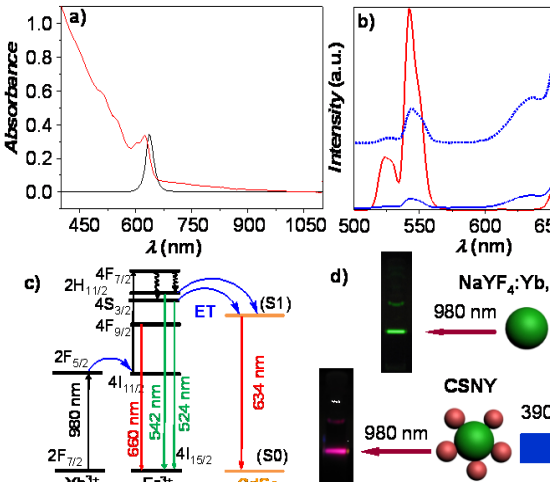

Figure 1. (a) Absorption and emission spectrum of CSNY excited at 390 nm; (b) emission spectra of the seed $NaYF_4$:Yb,Er nanocrystals (red line) and of resulting CSNY (solid blue line; a dotted line shows an expansion of the same) in toluene (both ~1 wt%) excited by NIR laser (λ_{exc} = 980 nm); (c) a simplified schematic of the excitation and ET in CSNY; (d) photographs of the emission from $NaYF_4$:Yb,Er nanocrystals (top) and CSNY heterostructures (bottom) under excitation at 390 nm and 980 nm.

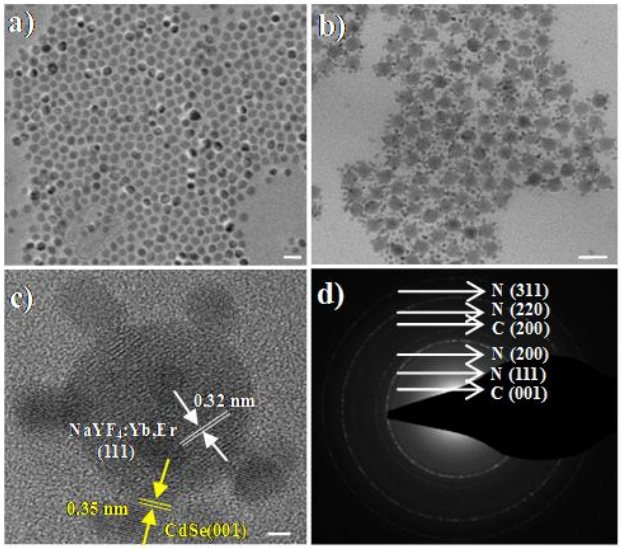

Figure 2. (a) TEM images of original $NaYF_4$:Yb,Er nanocrystals and (b and c) CSNY hetero-nanostructures (d) SAED pattern of a CSNY hetero-nanostructure. Scale bar is: 50 nm (a, b) and 3 nm (c). N represents $NaYF_4$:Yb,Er; and C represents CdSe.

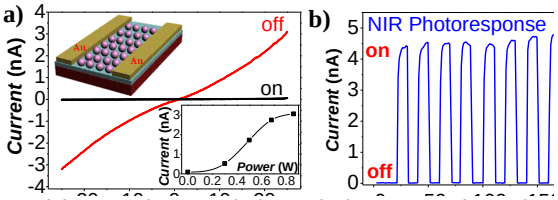

Figure 3. (a) *I-V* characteristics of the CSNY-based device (shown in top inset) in dark (black line) and under 980 nm radiation; bottom inset shows photocurrent-laser power dependence. (b) On-off switching at laser power 0.86 W and bias voltage of 35 V.

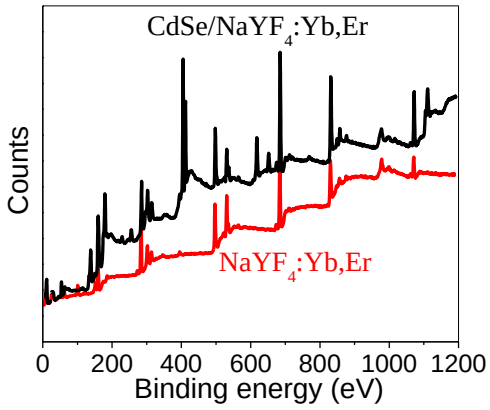

Figure 4. XPS spectra of $NaYF_4$:Yb,Er nanocrystals and CNSY hetero-nanostructures,

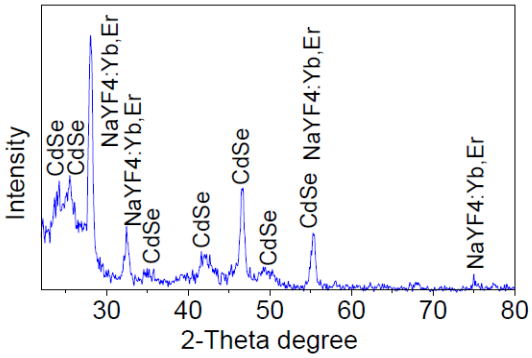

Figure 5. XRD pattern of CNSY hetero-nanostructures, where indexed peaks were assigned to the planes of hexagonal phase CdSe and cubic phase $NaYF_4$:Yb,Er.