Methods to Enhance Upconversion Efficiency from Lanthanide-doped Nanomaterials

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***Abstract*— To improve the upconversion emission efficiency is still a main challenge of all the lanthanide-doped upconversion nanomaterials in order for them to have practical applications such as in data storage, multicolor display, bioimaging, and optoelectronic devices. In this presentation, we explained the possibilities to improve the upconversion emission efficiency of the nanomaterials by more than 10-fold. First, we verify by aberration corrected TEM technique to show that the recovery of surface defects can enhance visible emission efficiency of the upconversion nanomaterials under near-infrared excitation [1]. Furthermore, we show that by using core-shell-shell structure of the upconversion nanomaterials, we can improve the effective energy transfer between core and shells so that the influence of non-radiative recombination and transfer can be significantly suppressed [2]. As a result, deep ultraviolet emission can be obtained under near-infrared excitation. We also demonstrate that the use of optical feedback can control the population inversion at the upper levels of the lanthanide ions so that high emission efficiency can be sustained by laser action [3]. Finally, the use of phonon to assist population inversion in the Tm3+ doped nanomaterials is explained. It can be shown that upconversion emission efficiency at visible regime can be obtained from the upconversion Tm3+ doped nanomaterials under near-infrared excitation at high temperature (473 K) [4].**

Keywords — Upconversion nanoparticles, lanthanide-doped, emission

I. Results

This is a review invited talk on my previous publications in ACS Nano, Advanced Materials and Nature Communication related to the methods to enhance upconversion emission efficiency from lanthanide-doped nanomaterials [1-4]. For more detailed information, please refer to the corresponding journal publications.

Figure 1 shows the HR TEM images of KLu_2F_7:38%Yb^{3+},2%Er^{3+} upconversion nanoparticles before and after thermal annealing treatment [1]. It is shown that the defects can be recovered from the UCNPs. Figure 2 shows the corresponding PL spectra. It is observed that the emission intensity can be enhanced by 10-fold due to the recovery of surface defects.

Figure 3 shows the supreme optical characteristics of our proposed $NaYF_4$@$NaYbF_4$:Tm@$NaYF_4$ core–shell–shell nanoparticle [2].

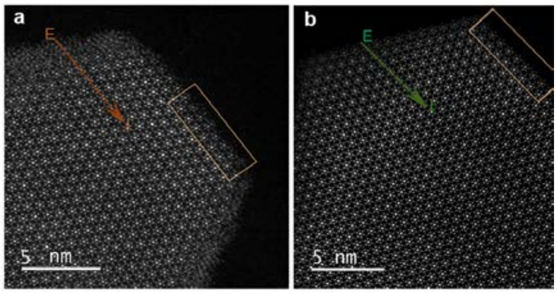

Fig. 1 HAADF-STEM images of KLu_2F_7:38%Yb^{3+},2%Er^{3+} UCNPs (a) before and (b) after annealing at 240ºC.

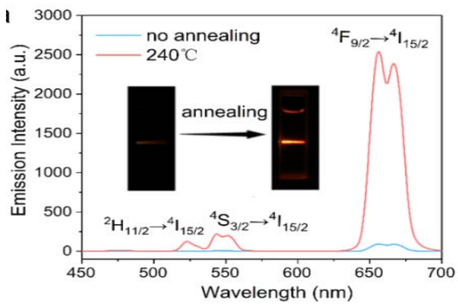

Fig. 2 Upconversion photoluminescence spectra of the KLu2F_7:38%Yb^{3+},2%Er^{3+} UCNPs.

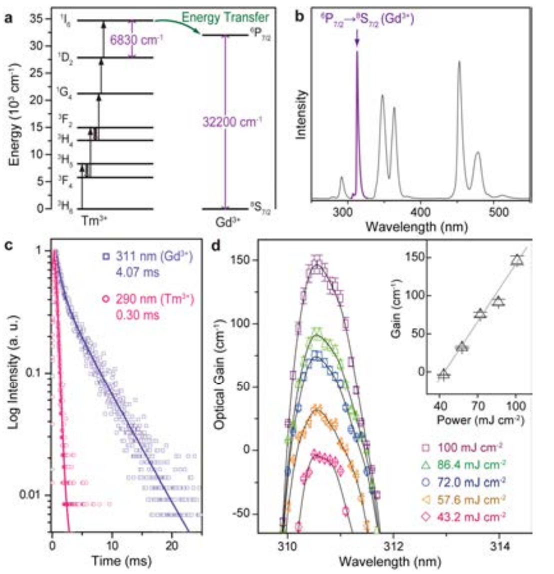

Fig. 3 Optical characteristics of the $NaYF_4$@$NaYbF_4$:Tm@$NaYF_4$ core–shell–shell nanoparticle.

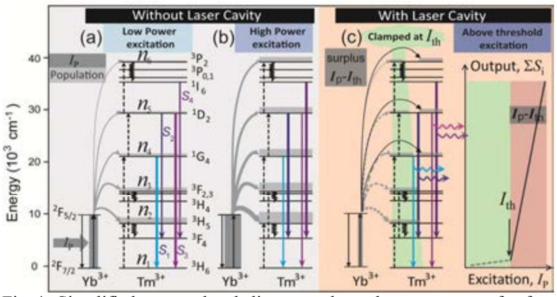

Fig 4. Simplified energy level diagrams show the energy transfer from Yb^{3+} to T m^{3+} in the $NaYF_4$:Yb/Tm@$NaYF_4$ core-shell nanoparticles under (a) low power, (b) high power and (c) above threshold excitations, respectively.

Fig. 4 ex plains the proposed method to enhance upconversion emission from $NaYF_4$:Yb/Tm@$NaYF_4$ core-shell nanoparticles [3]. Fig. 5 s hows how phonon can be u sed to achieve population inversion in lanthanide-doped nanomaterials [4].

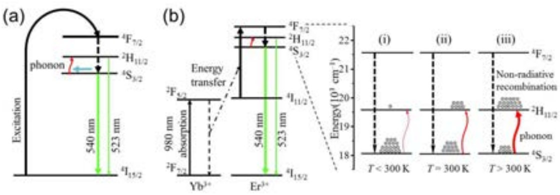

Fig. 5 Energy-level diagrams of Er^{3+}/Yb^{3+} co-doped BLF nanocrystals: (a) Simplified model and (b) population inversion via phonon-assisted process at temperature T (i) < 300 K, (ii) = 300 K and (iii) > 300 K between $^4S_{3/2}$ and $^2H_{11/2}$ states.

References

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Acknowledgement

This work was supported by National Natural Science Foundation of China (grant no. 61775187) and Science and Technology Projects of Shenzhen (grant no. JCYJ20170818105010341).