

## Research Article

# Synthesis and Downconversion Emission Property of $\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$ Nanosheets and Nanotubes

Chao Qian, Tianmei Zeng, and Hongrong Liu

*College of Physics and Information Science and Key Laboratory of Low-Dimensional Quantum Structures and Quantum Control of the Ministry of Education, Hunan Normal University, Changsha, Hunan 410081, China*

Correspondence should be addressed to Hongrong Liu; [hrlu@hunnu.edu.cn](mailto:hrlu@hunnu.edu.cn)

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Ytterbium oxide ( $\text{Yb}_2\text{O}_3$ ) nanocrystals with different  $\text{Eu}^{3+}$  (1%, 2%, 5%, and 10%) doped concentrations were synthesized by a facile hydrothermal method, subsequently by calcination at  $700^\circ\text{C}$ . The crystal phase, size, and morphology of prepared samples were characterized by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The results show that the as-prepared  $\text{Yb}_2\text{O}_3$  nanocrystals with sheet- and tube-like shape have cubic phase structure. The  $\text{Eu}^{3+}$  doped  $\text{Yb}_2\text{O}_3$  nanocrystals were revealed to have good down conversion (DC) property and intensity of the DC luminescence can be modified by  $\text{Eu}^{3+}$  contents. In our experiment the 1%  $\text{Eu}^{3+}$  doped  $\text{Yb}_2\text{O}_3$  nanocrystals showed the strongest DC luminescence among the obtained  $\text{Yb}_2\text{O}_3$  nanocrystals.

## 1. Introduction

Recently, rare earth (RE) doped luminescence materials have attracted considerable attention owing to their excellent applications in optics, biological labeling and imaging, new light source, catalyst and so on, owing to their unique properties such as narrow band of spectrum, monochromatism and bright of emission light, much stronger light absorb, good thermal and chemical stabilities, and low biotoxicity [1–8]. Much more investigations have focused on fluorides because of their unique advantages such as low phonon energy and high upconversion (UC) and DC luminescence [9, 10]. For example, dual-modal (UC/DC) luminescence has been successfully realized through lanthanide (Ln) ions doped  $\text{NaGdF}_4$  core/shell nanocrystals by Chen's group [11]. In addition to fluorides, RE doped oxides with much better high temperature thermal stability have also attracted much interests and they are applied in thin films, fiber laser, capacitor and precision optical glass, and so forth [12–16]. Chen's group have investigated the phonon confinement effects on the luminescence dynamics in  $\text{Gd}_2\text{O}_3:\text{Eu}^{3+}$  nanotubes and

provided experimental evidence of anomalous thermalization [14]. In addition, the synthesis process of RE oxide doped Ln ions is much more simple and controllable [17]. For example, the  $\text{Tb}_4\text{O}_7$  and  $\text{Y}_2\text{O}_3$  nanotubes with open ends were synthesized by a simple hydrothermal method without adding any template [18]. Via one-step hydrothermal method, the crystal phase, shape, and size controlling of these oxides can be easily obtained by changing the reaction parameters such as pH value of the solution, reaction temperature/time, and. As a result, DC luminescence of various RE oxides like Ln (Eu, Tb, Dy) doped  $\text{Y}_2\text{O}_3$ ,  $\text{Ce}_2\text{O}_3$  and  $\text{Gd}_2\text{O}_3$  has been widely investigated and the important applications of these RE oxides have been reported in recent years [19–22]. Although  $\text{Yb}_2\text{O}_3$  is also a very promising matrix material [23], there is still lack of research about effect of  $\text{Eu}^{3+}$  dopant on the DC luminescence of  $\text{Yb}_2\text{O}_3$ .

In this paper, we reported the controllable synthesis of  $\text{Eu}^{3+}$  doped  $\text{Yb}_2\text{O}_3$  nanosheets and nanotubes with cubic structure by a general and facile hydrothermal method with combination of calcination. The yellow DC luminescence was displayed under ultraviolet (UV) excitation at 395 nm. Furthermore, intensity of DC luminescence can be modified



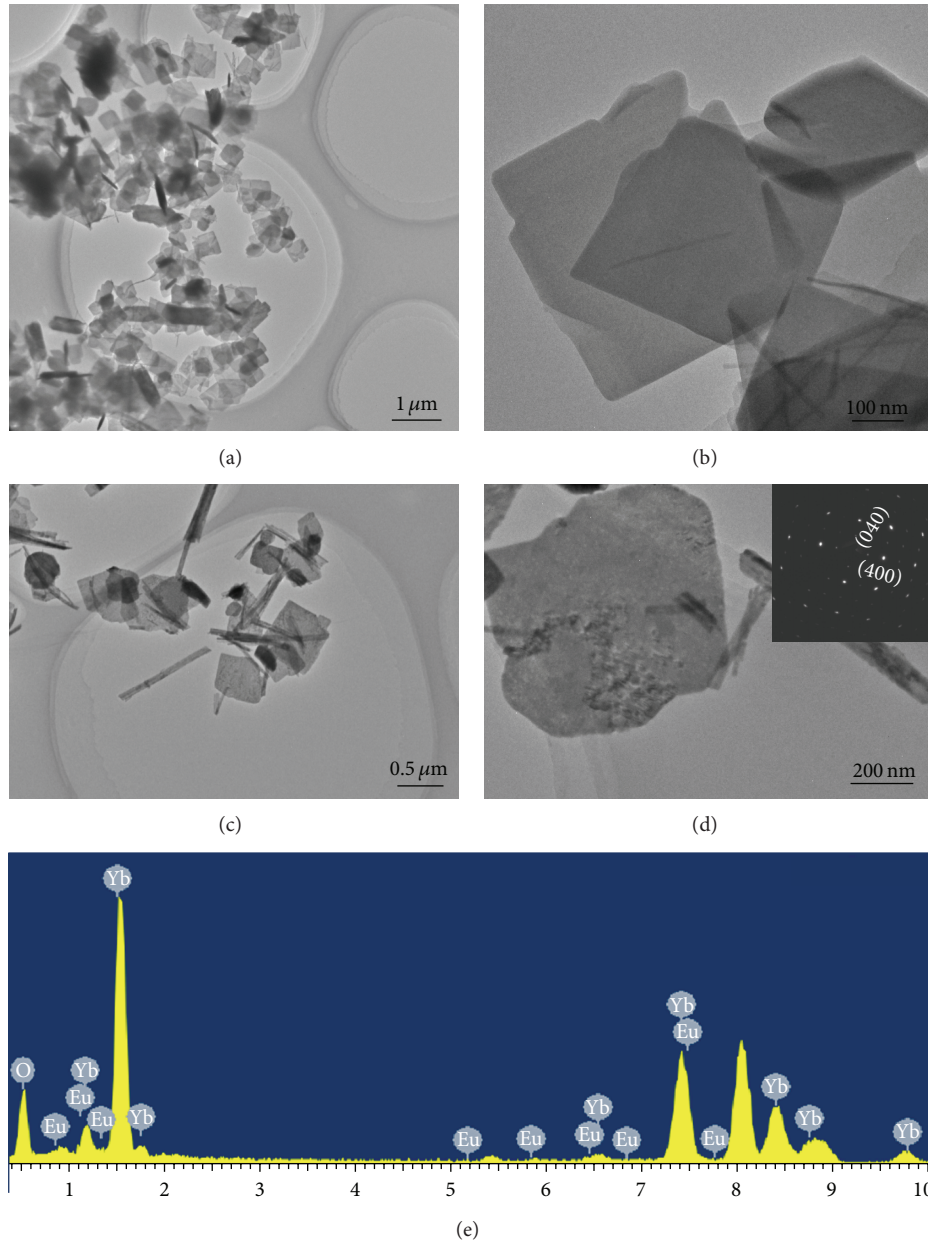


FIGURE 2: (a) TEM image of  $\text{Yb}(\text{OH})_3:\text{Eu}^{3+}$  nanosheets; (b) highly magnified TEM image of individual  $\text{Yb}(\text{OH})_3:\text{Eu}^{3+}$  nanosheets; (c) TEM image of  $\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$  nanosheets and nanotubes; (d) highly magnified TEM image of individual  $\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$  nanosheets and nanotubes; (e) EDS analysis of  $\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$  nanosheets. The inset of Figure 2(d) shows the SAED pattern of  $\text{Yb}_2\text{O}_3$  nanosheets.

574, 593 610, 651, and 660 nm, respectively, were produced by the electron transition from  ${}^5\text{D}_j$  to  ${}^7\text{F}_{j'}$  levels ( $J = 0, 1, 2$ , and  $J' = 1-4$ ) [6, 25]. The strongest DC emission was centered at 593 nm (due to the electron transition from  ${}^5\text{D}_0$  to  ${}^7\text{F}_1$  levels), leading to yellow emission light.

Possible mechanical energy level diagram for  $\text{Eu}^{3+}$  doped  $\text{Yb}_2\text{O}_3$  nanocrystals after pumping at 395 nm is shown in Figure 4 [6, 25]. Under the excitation at 395 nm, the  $\text{Eu}^{3+}$  ion can be excited from the ground state to the excited state. The excited state  $\text{Eu}^{3+}$  ions will decay nonradiatively to the

${}^5\text{D}_2$ ,  ${}^5\text{D}_1$  and  ${}^5\text{D}_0$  levels, resulting in the corresponding blue ( ${}^5\text{D}_2 \rightarrow {}^7\text{F}_0$ ), green ( ${}^5\text{D}_1 \rightarrow {}^7\text{F}_{0,1,3}$ ), yellow ( ${}^5\text{D}_0 \rightarrow {}^7\text{F}_1$ ) and red ( ${}^5\text{D}_0 \rightarrow {}^7\text{F}_{2,3,4}$ ) emissions, respectively.

The influence of  $\text{Eu}^{3+}$  concentration on the DC luminescence was investigated by comparison of the emission spectra (Figure 5) of the synthesized  $\text{Yb}_2\text{O}_3:\text{X}\% \text{Eu}$  ( $X = 1, 2, 5, 10$ ) samples. It can be seen that the strongest DC luminescence was achieved in 1% Eu doped sample. With further increasing the  $\text{Eu}^{3+}$  content, the DC luminescent intensity was decreased, which was mainly ascribed to the concentration quenching effect [26].

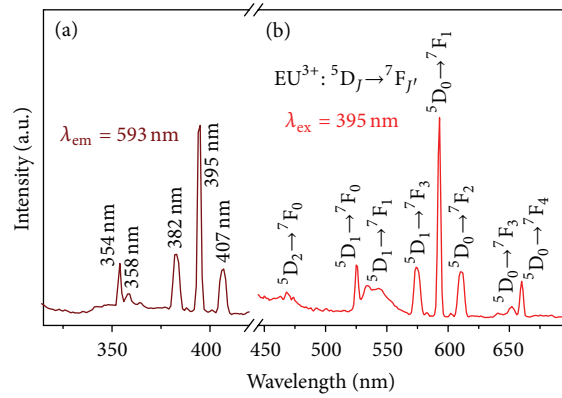


FIGURE 3: (a) Photoluminescence excitation spectrum of  $\text{Yb}_2\text{O}_3: 1\% \text{Eu}^{3+}$  nanocrystals by detecting the emission at 593 nm and (b) emission spectrum under the excitation at 395 nm.

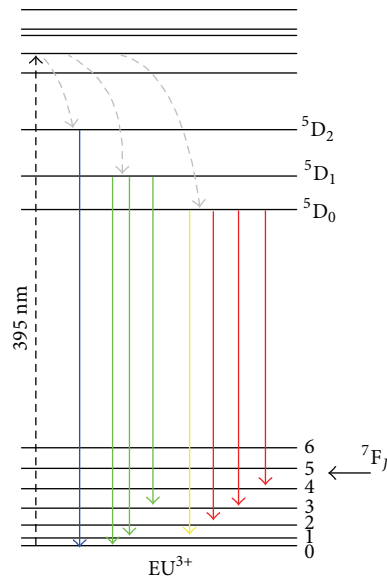


FIGURE 4: Scheme of energy levels of  $\text{Eu}^{3+}$  in  $\text{Yb}_2\text{O}_3$  and possible mechanical energy level diagram for  $\text{Eu}^{3+}$  after pumping excitation at 395 nm.

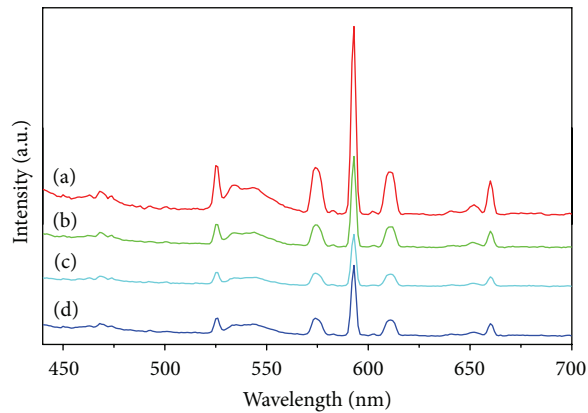


FIGURE 5: Photoluminescence emission spectra of different concentrations of  $\text{Eu}^{3+}$  doped  $\text{Yb}_2\text{O}_3$ : (a) 1%  $\text{Eu}^{3+}$ , (b) 2%  $\text{Eu}^{3+}$ , (c) 5%  $\text{Eu}^{3+}$ , and (d) 10%  $\text{Eu}^{3+}$  by excitation at 395 nm.



## 4. Conclusions

$\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$  nanosheets and nanotubes doped with different concentrations of  $\text{Eu}^{3+}$  were successfully synthesized by a facile controllable hydrothermal process followed by calcination at  $700^\circ\text{C}$ . The XRD confirms the synthesized  $\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$  with cubic structure. The TEM images revealed  $\text{Yb}(\text{OH})_3:\text{Eu}^{3+}$  with sheet- and tube-like morphology, respectively. The DC emissions of the synthesized  $\text{Yb}_2\text{O}_3:\text{Eu}^{3+}$  centered at 470, 525, 530, 574, 593, 610, 651 and 660 nm were observed under the strongest excitation at 395 nm. The intensity of DC emission can be tuned by adjusting the concentration of  $\text{Eu}^{3+}$ , while the strongest intensity yellow DC luminescence was obtained at 1%  $\text{Eu}^{3+}$ .

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