

Scintillation properties of YPO_4 : RE (RE=Ce³⁺, Pr³⁺ or Nd³⁺)^{*}

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Abstract The spectra of RE-doped YPO_4 (RE=Ce³⁺, Pr³⁺ or Nd³⁺) have been measured. The spectroscopic and decay kinetics properties of pure host YPO_4 were also studied at 8 K and 300 K, which indicated the host had taken part in the luminescent processes of activators. Under the excitation over the bandgap of the host, the electron could relax to the activators. Through the comparison of spectra and decay time, Nd³⁺ doped YPO_4 had better scintillation properties than Ce³⁺ or Pr³⁺ in YPO_4 .

Key words rare earth, spectra, decay time

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1 Introduction

The rare earth (RE) doped YPO_4 have been used as the luminescent phosphor in fluorescent lamps for they were easily synthesized and chemically stable^[1–3]. Recent reports demonstrate that the YPO_4 doped RE could be the promising scintillator materials^[4, 5]. Due to the high energy of YPO_4 bandgap ($E_g = 144$ nm), the research on the scintillation properties about YPO_4 doped RE was scarce because of the difficulties in experiments.

In this paper the spectroscopic properties of pure and RE doped YPO_4 (RE=Ce³⁺, Pr³⁺ or Nd³⁺) have been measured, and decay curves of pure YPO_4 were also monitored. For YPO_4 doped with Nd³⁺ the electron will relax to the Nd³⁺ efficiently under the host excitation, and Nd³⁺ emission has a faster decay time. But for the YPO_4 doped with Ce³⁺ or Pr³⁺ the activators will not be populated efficiently after the host YPO_4 was excited. So YPO_4 doped with Nd³⁺ has the better scintillation properties than those doped with Ce³⁺ or Pr³⁺.

2 Experiment

The pure YPO_4 and YPO_4 : RE (RE=Ce³⁺, Pr³⁺

or Nd³⁺) were synthesized by the coprecipitation method. The excitation and emission spectra of YPO_4 : Ce³⁺ or Pr³⁺ were measured in BRSF. The spectra and decay curves of pure YPO_4 and YPO_4 : Nd³⁺ were measured in DESY.

Figure 1 showed the emission spectra of pure YPO_4 under 120 nm excitation at different temperatures. Fig. 1(a) and Fig. 1(b) display the emission spectra measured at 8 K and 300 K, respectively. The excitation energy (120 nm) was higher than the bandgap energy of undoped YPO_4 ($E_g = 144$ nm)^[6]. The emission bands centered at 245 nm in both Fig. 1(a) and Fig. 1(b) were assigned to the defect emission. There was another defect emission band centered at 425 nm, but the intensity at 8 K (Fig. 1(a)) was stronger than that at 300 K (Fig. 1(b)), indicating that the defect emission peaking at 425 nm quenched at higher temperature. Fig. 2 shows the emission spectra of pure YPO_4 excited by 168 nm, the energy is lower than the bandgap of YPO_4 . There is no obvious difference between the emission spectra at different temperatures (Fig. 2(a) and Fig. 2(b)). It can also be seen that the emission band peaking at 245 nm does not quench at higher temperature.

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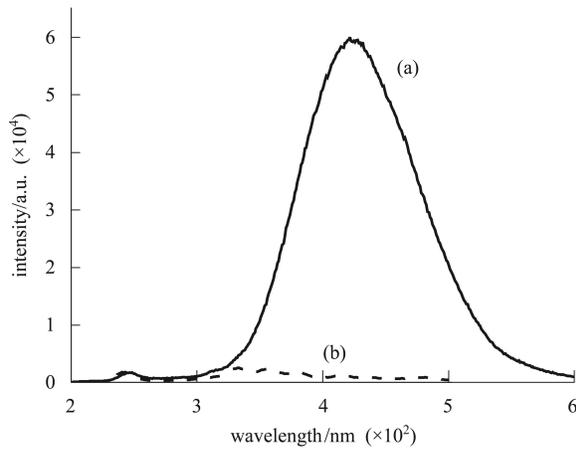


Fig. 1. The emission spectra of pure YPO_4 ($\lambda_{Ex} = 120$ nm) (a) $T = 8$ K, (b) $T = 300$ K.

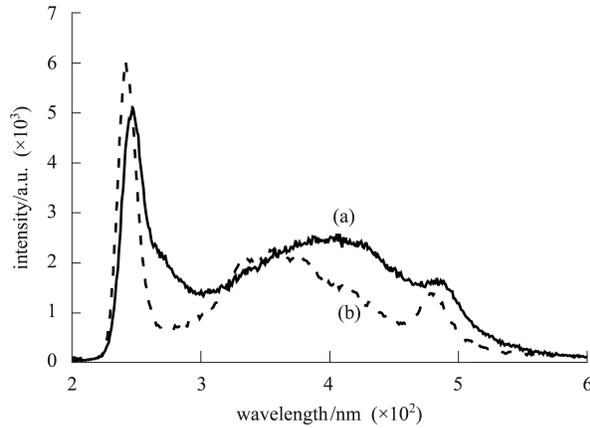


Fig. 2. The emission spectra of pure YPO_4 ($\lambda_{Ex} = 168$ nm) (a) $T = 8$ K, (b) $T = 300$ K.

The excitation spectra of pure YPO_4 monitoring 240 nm and 440 nm are shown in Fig. 3, from which it could be observed that the E_g is the boundary for the excitation spectra shown in Fig.3 (a) and Fig. 3(b). At 8K the defect emission centered at 245 nm is more easily excited by the energy below the E_g , and another defect emission peaking at 425 nm is excited efficiently by the energy over the E_g . Fig. 4 shows the excitation spectra ($T=300$ K) of pure YPO_4 by monitoring 240 nm and 440 nm, respectively. Both Fig. 4(a) and Fig. 4(b) have the same excitation curves over the E_g , but below the E_g the emission band peaking at 245 nm is excited efficiently.

The decay curves of pure YPO_4 ($\lambda_{Ex} = 157$ nm, $\lambda_{Em} = 240$ nm) measured at 8 K and 300 K, respectively, are shown in Fig. 5. At 8 K the decay curve was second-order exponential with faster and slower components, and at 300 K the decay curve was single exponential with only faster decay process. It could be concluded that the emission band centered at

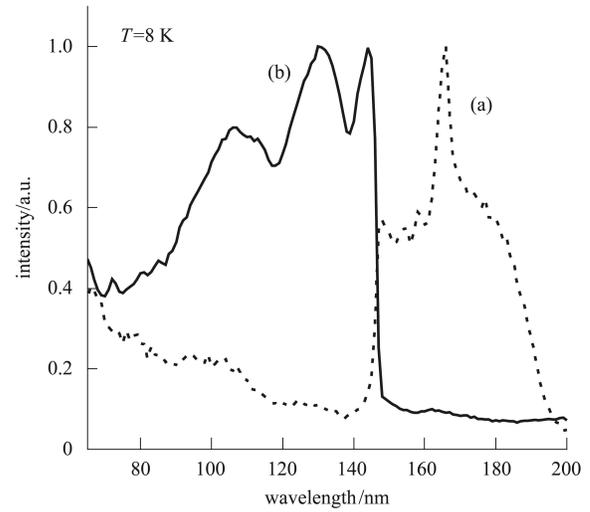


Fig. 3. The excitation spectra of pure YPO_4 at 8 K. (a) $\lambda_{Em} = 240$ nm, (b) $\lambda_{Em} = 440$ nm.

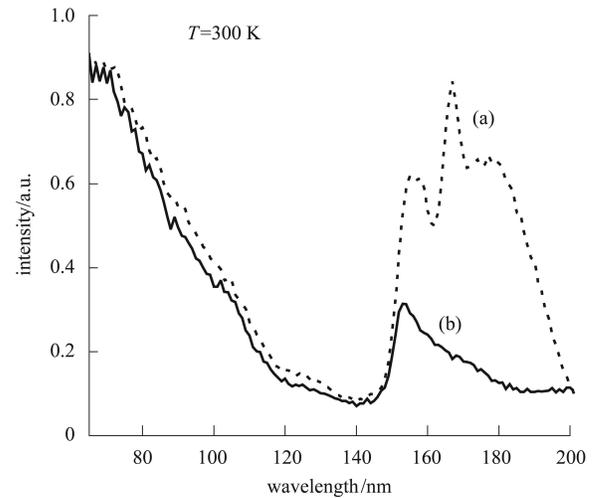


Fig. 4. The excitation spectra of pure YPO_4 at 300 K. (a) $\lambda_{Em} = 240$ nm, (b) $\lambda_{Em} = 440$ nm.

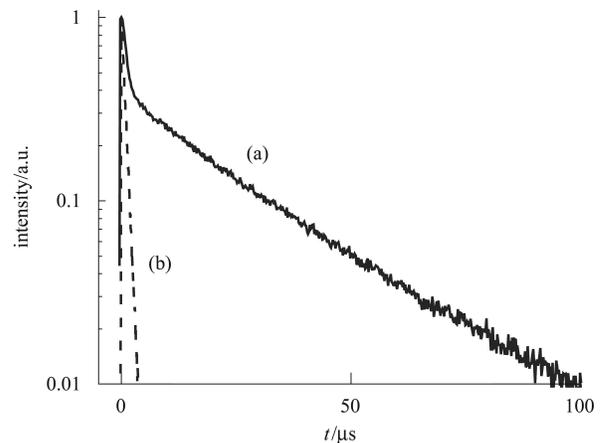


Fig. 5. The decay curves of pure YPO_4 ($\lambda_{Ex} = 157$ nm, $\lambda_{Em} = 245$ nm) (a) $T=8$ K, (b) $T=300$ K.

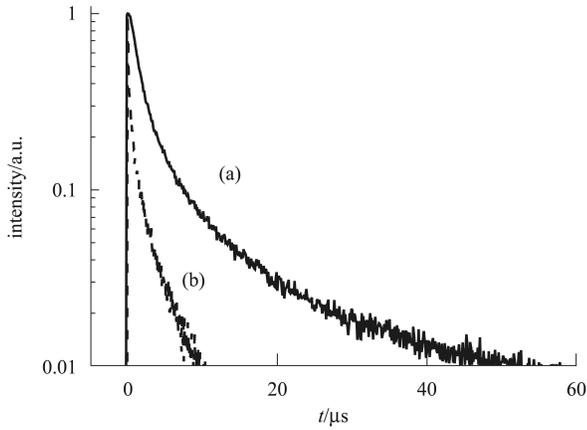


Fig. 6. The decay curves of pure YPO_4 ($\lambda_{Ex} = 157$ nm, $\lambda_{Em} = 425$ nm) (a) $T=8$ K, (b) $T=300$ K.

245 nm had shorter lifetime at 300 K. It was also observed that the emission band peaking at 440 nm had faster decay time at 300 K comparing with that at $T=8$ K, but the decay curves shown in Fig. 6 were non-exponential for the complicated relaxation processes.

The excitation and emission spectra of YPO_4 : Ce³⁺ measured at 77 K are shown in Fig. 7, and for the excitation spectrum Fig. 7(a) the excitation peaks from 335 nm to 120 nm were assigned into Ce³⁺ $4f \rightarrow 5d$ excitation bands^[7]. The emission bands in Fig. 7(b) from 300 nm to 400 nm were Ce³⁺ $5d \rightarrow 4f$ emission. The drop around 322 nm in Fig. 7(b) could be caused by the reabsorption of electrons in Ce³⁺ ground states.

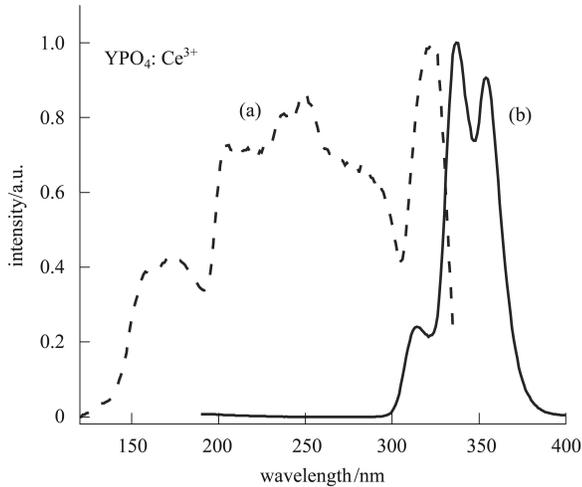


Fig. 7. The excitation and emission spectra of YPO_4 : Ce³⁺ at 77 K. (a) $\lambda_{Em} = 330$ nm, (b) $\lambda_{Ex} = 160$ nm.

Figure 8(a) and Fig. 8(b) show the excitation and emission spectra of YPO_4 : Pr³⁺, respectively, and the excitation peaks from 230 nm to 120 nm were

assigned into the Pr³⁺ $4f^2 \rightarrow 4f5d$ excitation^[7]. The emission peaks from 200 nm to 280 nm were assigned into Pr³⁺ $4f5d \rightarrow 4f^2$ emission.

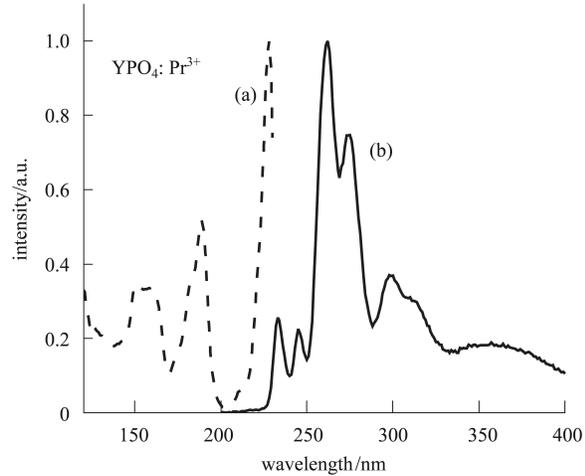


Fig. 8. The excitation and emission spectra of YPO_4 : Pr³⁺ at 77 K. (a) $\lambda_{Em} = 260$ nm, (b) $\lambda_{Ex} = 160$ nm.

The excitation and emission spectra of YPO_4 : Nd³⁺ are displayed in Fig. 9(a) and Fig. 9(b), respectively. Because the 120 nm excitation is over the E_g of YPO_4 , the emission spectrum is predominant by the defect emission around 425 nm at 8 K. The decay curve is displayed in Fig. 10, and the fitted lifetime is about 6 ns.

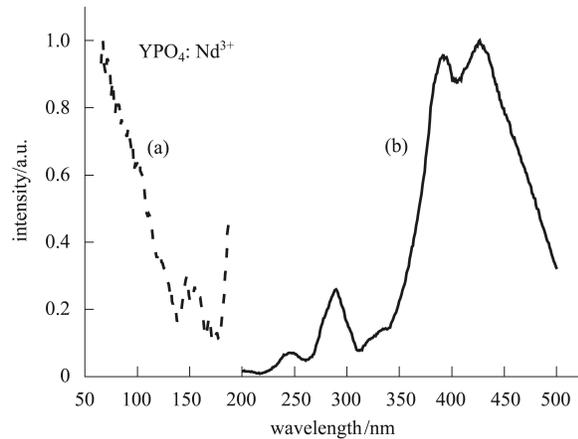


Fig. 9. The excitation and emission spectra of YPO_4 : Nd³⁺ at 100 K. (a) $\lambda_{Em} = 195$ nm, (b) $\lambda_{Ex} = 120$ nm.

The decay curves for the YPO_4 : Ce³⁺, Pr³⁺ or Nd³⁺ have been reported in Ref. [8], and the decay time for Ce³⁺ and Pr³⁺ is about 23 ns and 17 ns, respectively. In our work the measured decay time for Nd³⁺ doped in YPO_4 is about 6 ns. From the aspect of lifetime, Nd³⁺ has less response time than Pr³⁺ and Ce³⁺. Furthermore, the spectra of YPO_4 :RE indicate that Pr³⁺ or Nd³⁺ could be excited efficiently by the energy over the bandgap.

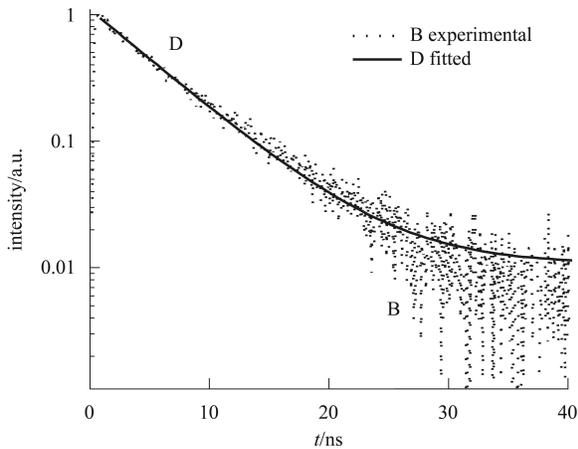


Fig. 10. The decay curve of $\text{YPO}_4:\text{Nd}^{3+}$ at 300 K. $\lambda_{Ex} = 120$ nm, $\lambda_{Em} = 280$ nm.

3 Conclusion

The spectra and decay properties of YPO_4 undoped and doped with Ce^{3+} , Pr^{3+} or Nd^{3+} are analyzed. The Nd^{3+} doped YPO_4 has faster response time than $\text{YPO}_4:\text{Ce}^{3+}$ or $\text{YPO}_4:\text{Pr}^{3+}$, and Nd^{3+} could get efficiently the energy under the host excitation. In conclusion, the host YPO_4 , Nd^{3+} is a more promising activator in the scintillator materials than Ce^{3+} or Pr^{3+} .

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