Luminescent Properties of $MPO_4:Eu^{3+}$ (M = Y, Gd, Lu or La) Phosphors Synthesized by Solid-State Reaction for Optical Imaging or FTIR Laser Application

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Introduction

The most intense emission line of Eu^{3+} activated phosphors is often the $^5D_0 \rightarrow {}^7F_2$ transition which occurs at around 610 nm, whereat the human eye sensitivity is very high [1]. Thus, the application of Eu^{3+} doped solid state compounds is state-of-the-art in cathode ray tubes (CRTs), field emission displays (FEDs) electroluminescence displays (ELDs) and plasma display panels (PDPs). [2-4]. However, Eu^{3+} phosphors also show emission lines in the deep red emission range (680 – 720 nm) due to the $^5D_0 \rightarrow {}^7F_4$ transition. The human eye sensitivity in this range is very low, but radiation in this wavelength range has a rather high penetration depth into biological matter [5].

Those phosphor, in which the $^5D_0 \rightarrow {}^7F_4$ transition is dominating are thus potential candidates for optical imaging. Moreover, Eu^{3+} phosphors exhibit line emission with a long decay time, which enables their application as solid state gain media for (NIR) laser based on three or four level approach [6]. Therefore, in the present work the sinterability and luminescence properties of europium-doped yttrium, gadolinium, lanthanum or lutetium orthophosphates $MPO_4:Eu^{3+}$(1%) powders with M = Y, Gd, La, Lu were investigated.

Experiments

All samples were synthesized by solid-state reaction. The powders were prepared using stoichiometric amounts of analytical-grade Y_2O_3, Gd_2O_3, La_2O_3 or Lu_2O_3, Eu_2O_3 and $(NH_4)_2HPO_4$ as starting materials. 1 wt-% of LiF was used as a flux. Reagents were thoroughly mixed in an agate mortar employing acetone as a grinding medium. The mixture of starting materials was dried, transferred to the porcelain crucible and annealed at 1000 °C for 8 h in air. The obtained product was ground, prewashed with 5 M nitric acid solution, dried and ground one more time. X-ray diffraction analysis (XRD) was used for phase identification. The luminescence properties of synthesized samples were characterized by VUV and UV/Vis spectroscopy.

Results

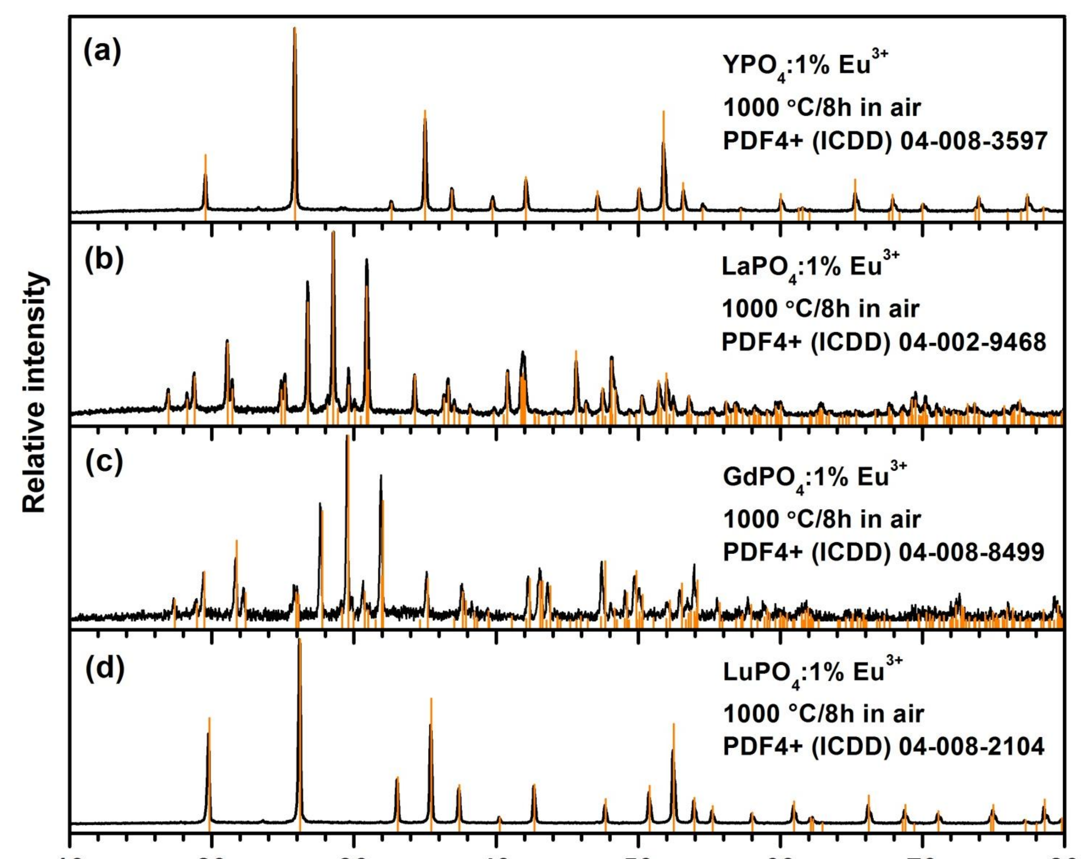

Fig. 1. *XRD patterns of presented $MPO_4:Eu^{3+}$(1%) samples (M = Y, La, Gd, Lu).*

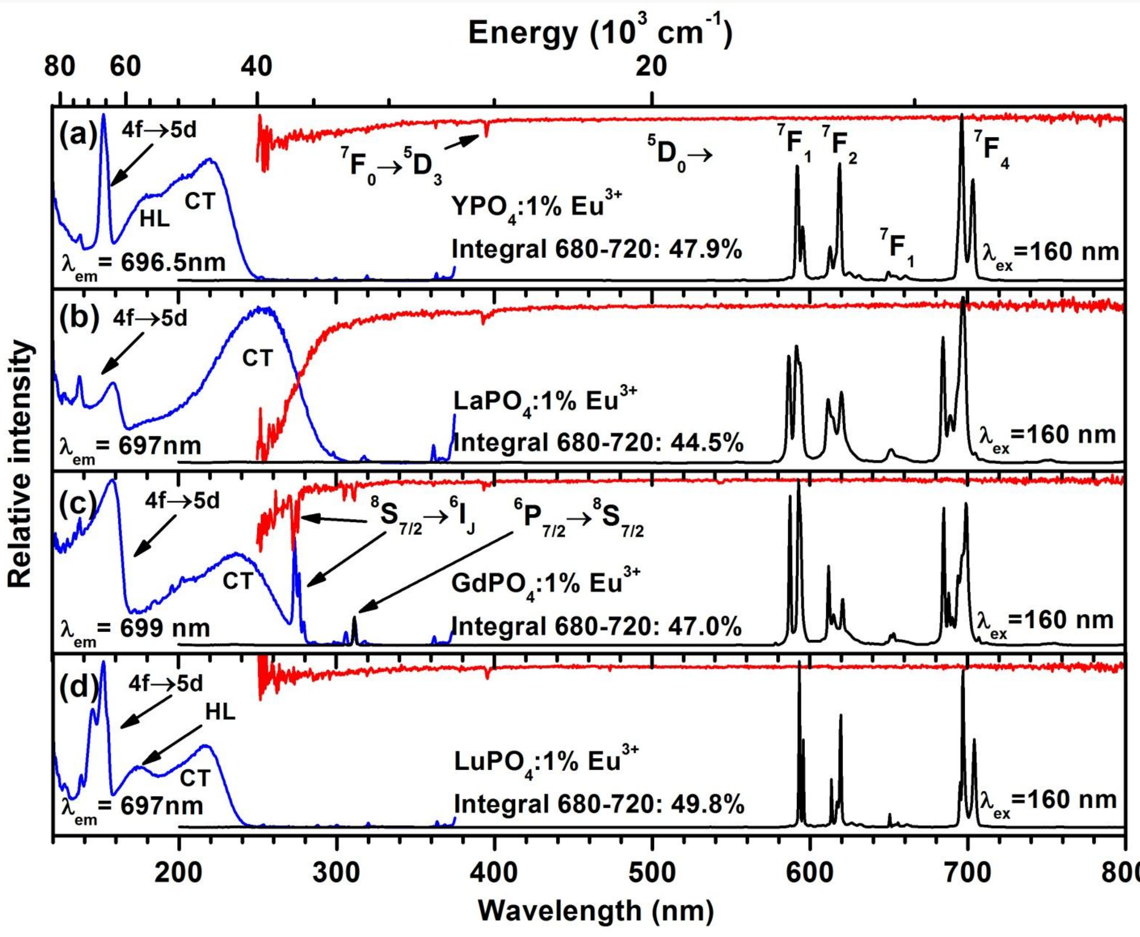

Fig. 2. *Reflection, VUV excitation and emission spectra of presented $MPO_4:Eu^{3+}$(1%) samples (M = Y, La, Gd, Lu).*

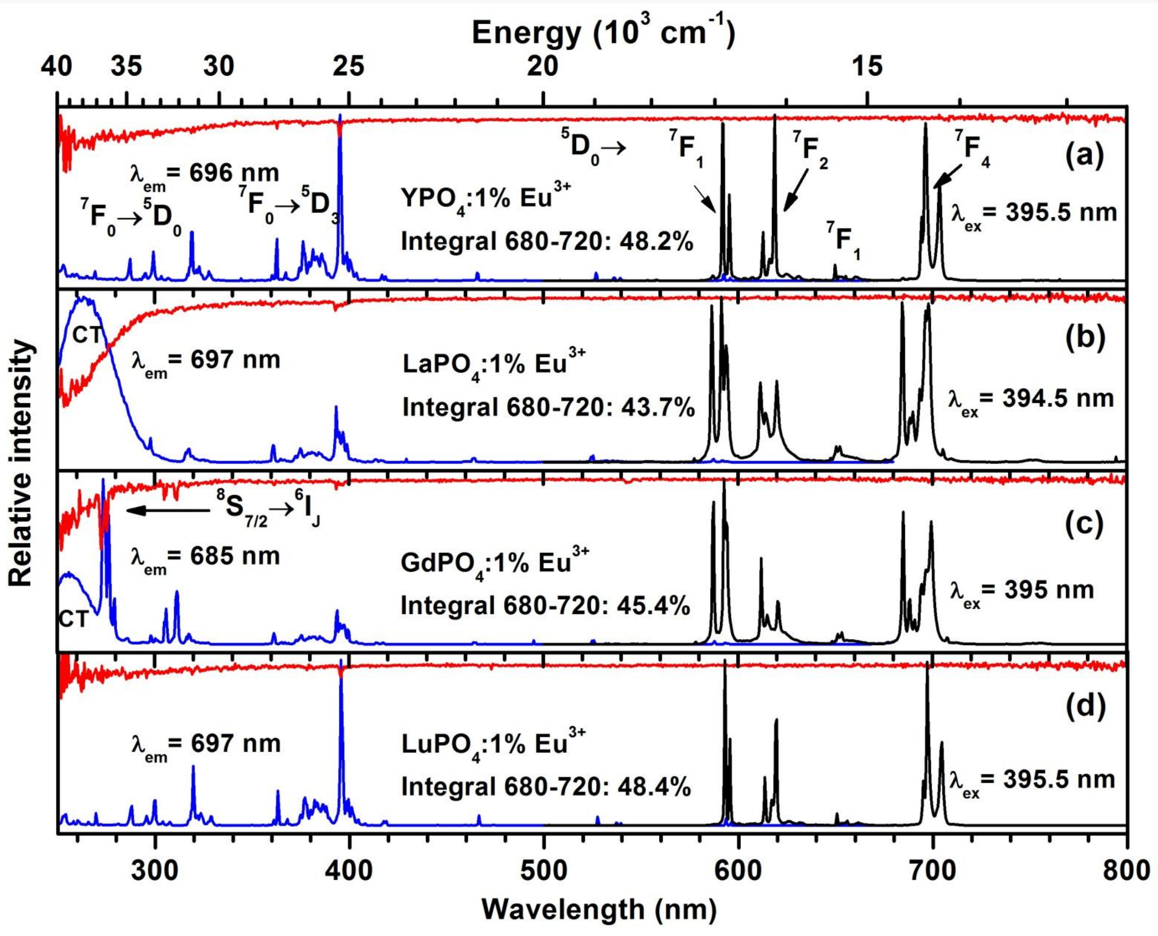

Fig. 3. *Reflection, VU/Vis excitation and emission spectra of presented $MPO_4:Eu^{3+}$(1%) samples (M = Y, La, Gd, Lu).*

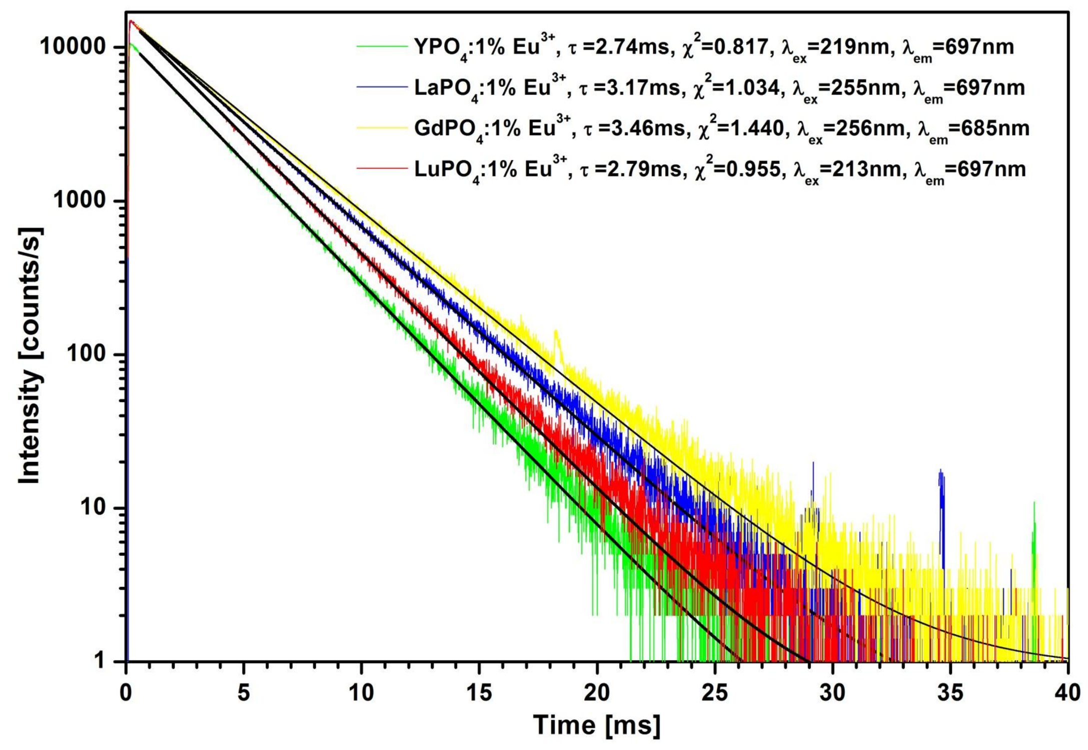

Fig. 4. *Decay curves of presented $MPO_4:Eu^{3+}$(1%) samples (M = Y, La, Gd, Lu).*

Conclusions

In this work, we demonstrated that we were able to obtain single phase samples of lanthanide-substituted orthophosphates (XRD patterns of synthesized samples matched well with the corresponding reference pattern (**Fig. 1.**)). Under 160 nm wavelength excitation the emission of $^5D_0 \rightarrow {}^7F_4$ transition was dominant (680 – 720 nm wavelength range) (**Fig. 2.**). It was slightly dependent on the chemical composition of the matrix. The increase of the radius of ion M^{3+} caused the decrease of the emission of $^5D_0 \rightarrow {}^7F_4$ transition. The percentage fraction of the emission of $^5D_0 \rightarrow {}^7F_4$ transition (integral of 680 - 720 nm range) according the whole Eu^{3+} emission spectra (integral of 570 – 720 nm range) was respectively 49.8% (R(Lu^{3+})=0.085 nm), 47.9% (R(Y^{3+})=0.093 nm), 47.0% (R(Gd^{3+})=0.094 nm) and 44.5% (R(La^{3+})=0.106 nm). To our knowledge, for the first time it was demonstrated, that up to 50% of emission is attributed to the $^5D_0 \rightarrow {}^7F_4$ transitions. Thus, ortho-phosphates doped with Eu^{3+} can be regarded as alternative materials for optical imaging purposes, which could be effectively excited by UV and near UV light (**Fig. 2-3.**). Moreover, Eu^{3+} doped ortho-phosphates phosphors exhibit line emission with 2.7 - 3.5 ms decay time, (**Fig. 4.**) which enables their application as solid state gain media for NIR lasers, too.

References

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