On Translucent LuAG:Pr and LuAG:Pr,Ce Ceramics

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12th International Conference and Exhibition of the European Ceramic Society
Stockholm Sweden | June 19-23.2011

LuAG:Pr and LuAG:Pr,Ce are well known luminescent materials which can be excited by γ- and x-rays as well as parts of the UV and the visible spectrum. The short decay time in the nanosecond range due to the spin allowed 5d → 4f transition of the activator and the high stability of the material are of particular interest for many application areas, e. g. scintillators. Single crystalline LuAG:Pr has been intensively studied. Even though there is a great demand for rare earth doped LuAG single crystals as scintillators and solid state laser materials they lack in utilization of their capacity due to the high costs for these crystals. Additionally, polycrystalline transparent ceramics of rare earth doped LuAG have been prepared and investigated in order to obtain a new optical material for various applications.

In this work, translucent ceramics of LuAG:Pr and LuAG:Pr,Ce have been prepared and characterized. To this end, a nanoscale powder obtained by a combustion method with trisamine as fuel was mechanically compacted and sintered. The powder comprising soft agglomerates of about 10 -20 µm in size (primary crystals of about 100 nm was densified in two steps by uniaxial and subsequently by isostatic cold pressing without any additives. The obtained green bodies with a theoretical density of more than 50% were sintered at 1700 °C in air. The ceramics show good translucency, but are not transparent yet. Spectroscopic measurements revealed strong absorption in the VUV range and a broad emission band peaking at around 310 nm (LuAG:Pr) and 504 nm (LuAG:Pr,Ce). The decay time of the 5d → 4f emission after excitation at 160 nm has been determined to about 20 ns (LuAG:Pr) and 60 ns (LuAG:Pr,Ce). The rather strong absorption at 450 nm allows the application of such ceramics as colour converters onto LED dies too.

Powder Preparation, Ceramic Fabrication and Light Conversion of LuAG:Pr^{3+} and LuAG:Pr^{3+},Ce^{3+}

Dissolving Lu_2O_3, Al_2O_3 and $Pr(NO_3)_3$*$6H_2O$ and CeO_2 in nitric acid

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Adding fuel – trisamine to the solution

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Slow evaporation (80 °C) and at the end of evaporation combustion process ignites

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Ball milled of combustion residue – black precursor

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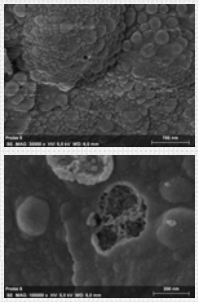
Calcining of black precursor at 800 – 1000 °C, 2 h, air



SEM images of calcined agglomerated precursor (LuAG doped by 1% Pr)*

Ball milling of white powder* LuAG:Pr in ethanol

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Uniaxial pressing at30 MPa without additives

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Cold isostatic pressing at 300 MPa

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Free sintering at 1700 °C, 4 h, air on Al_2O_3 substrate

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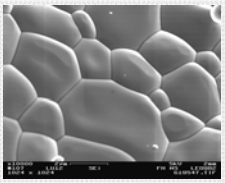
Polishing and thermal treatment at 1700 °C, 1h, air



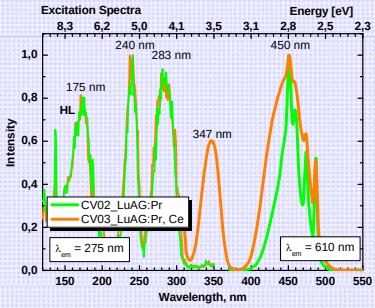
SEM image of sintered ceramics (about 92% t.D.)

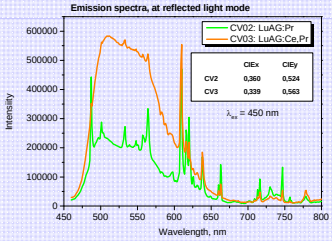
Ceramics LuAG:Pr;Ce and LuAG:Pr, Thickness 0,25 mm

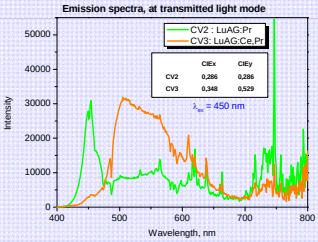
LuAG:Pr und LuAG:Pr,Ce ceramics and back lit by a blue LED

Excitation by UV radiation, 160 nm (300-800 nm)	Excitation by blue light, 450 nm (460-800nm)
LuAG:1%Pr	LuAG:1%Pr
CIEx = 0,238, CIEy = 0,534	CIEx = 0,359, CIEy = 0,525
LuAG:1%Pr,0,1%Ce	LuAG:1%Pr,0,1%Ce
CIEx = 0,386, CIEy = 0,517	CIEx = 0,339, CIEy = 0,563

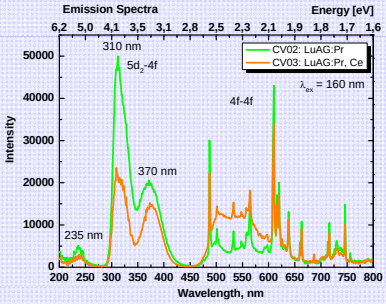
Luminescence Spectroscopy of Lutetium Aluminium Garnet Ceramic LuAG:1% Pr^{3+} and LuAG:1% Pr^{3+}, 0,1% Ce^{3+}

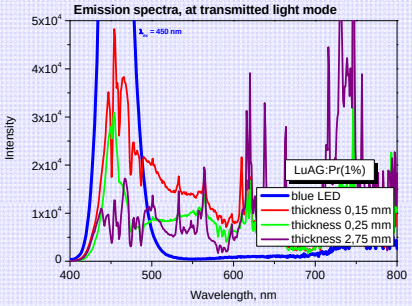


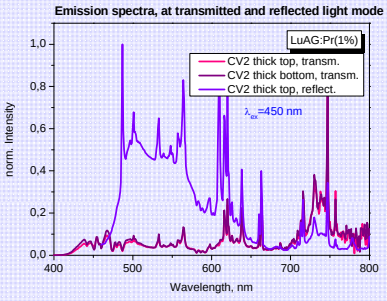




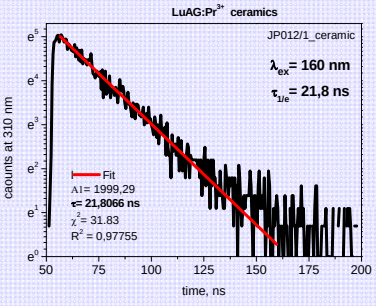
Emission spectra for 450 nm and 160 nm excitation







Images of LuAG:Pr^{3+} ceramics and their emission spectra in transmission excited by blue light



Decay curves upon 160 nm excitation.

Conclusions

The optical properties of LuAG:Pr and LuAG:Pr,Ce ceramics were recorded. Fluorescence spectra show excitation bands at 240 nm, 284 nm, 347 nm and 450 nm due to 4f-5d transition of the trivalent lanthanides. In the visible range transitions at 450-480 nm ($^3H_4$-^3P_J) and 580-610 nm ($^3H_4$-$^1D_2$) were observed.
The excitation spectra were mainly dominated by the Pr^{3+} ion and the influence of the Ce^{3+} ions was relatively weak. The emission spectra show very strong transitions at 310 nm and 370 nm (UV) due to the 5d-4f transitions of the Pr^{3+} ions and a series of weak transitions above 450 nm (4f-4f transitions).
The Ce^{3+} ion (0,1% Ce) significantly influenced the emission of the Pr^{3+} ions (1% Pr) by quenching the UV emission and strengthening the VIS emission. A further material optimisation of LuAG:Pr,Ce should offer transparent ceramic phosphors as converter for a wide range of application areas.