On Translucent LuAG:Pr Ceramics

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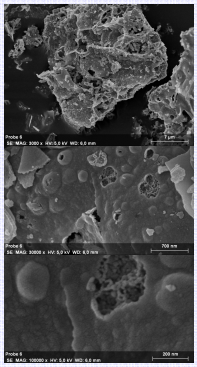
LuAG:Pr is a widely applied luminescent material which can be excited by γ- and x-rays as well as by UV and visible radiation. The short decay time in the nanosecond range of the spin allowed [Xe]4f^{1}5d^1 → [Xe]4f^2 transition of the activator and the high stability of the material are of particular interest for many application areas, e. g. as a scintillator. 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 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 ℃ in air. All ceramics show good translucency, but are not transparent yet. However, excitation the ceramics by a blue LED, yielded a greenish-white spectrum due to the conversion of the blue LED light into a multiline spectrum between 480 and 650 nm.

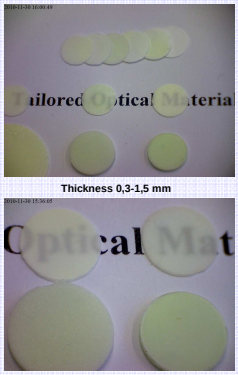
Powder Preparation, Ceramic Fabrication and Light Conversion of LuAG:Pr^{3+}

Dissolving Lu_2O_3, Al_2O_3 and Pr_6O_{11} in nitric acid
↓
Adding fuel – trisamine to the solution
↓
Slow evaporation (80 ℃) and at the end of evaporation combustion process ignites
↓
Ball milled of combustion residue – black precursor
↓
Calcining of black precursor at 800 – 1000 ℃, 1-3 h, air



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

Ball milled of white powder LuAG:Pr
↓
Uniaxial pressing, 30 MPa
↓
Cold isostatic pressing, 300 MPa
↓
Free sintering at 1700 ℃, 4 h, air
↓
Polishing and thermal treatment at 1700 ℃, 1h, air



Thickness 0,3-1,5 mm

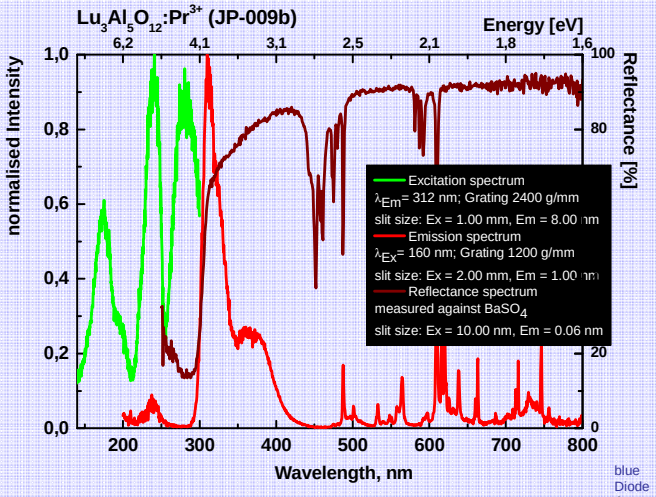
Optical images of sintered ceramics (about 87% of theor. density)

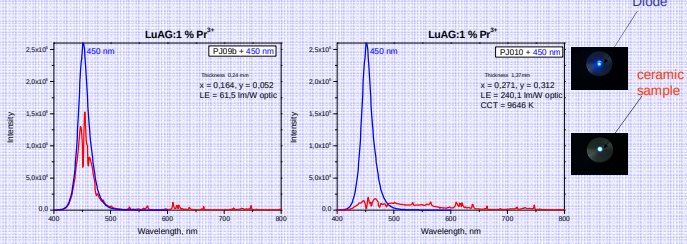
Excitation by blue light, 450 nm
x = 0,271, y = 0,312
LE = 240 lm/W$_{optic}$

Excitation by UV radiation, 350 nm
x = 0,331, y = 0,566
LE = 427 lm/W$_{optic}$

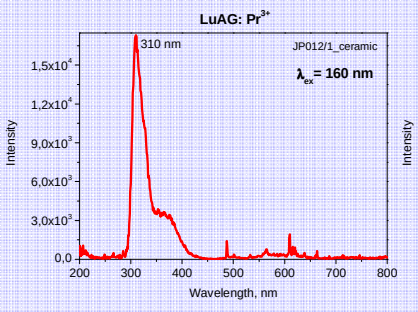
Images of LuAG:Pr ceramics back lit by a blue or UV LED (Thickness 0.98 mm)

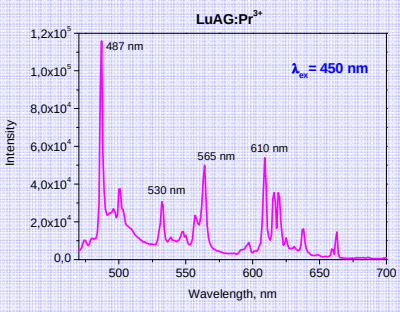
Reflection and Luminescence Spectroscopy of Lutetium Aluminium Garnet Ceramic LuAG:Pr^{3+}



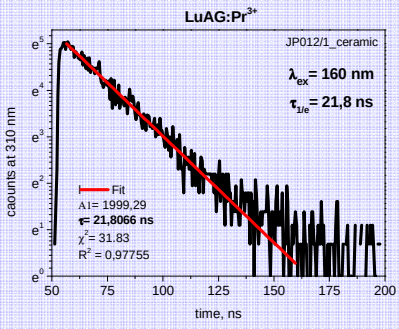


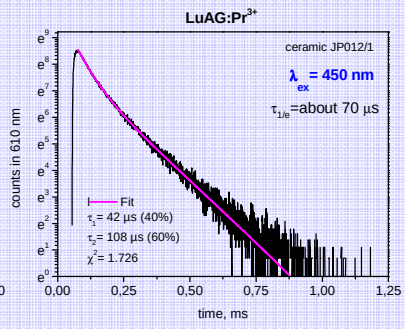
Emission spectra in transmission of LuAG:Pr^{3+} ceramics





Emission spectra for 160 nm and 450 nm excitation





Decay curves upon 160 nm and 450 nm excitation.

Conclusions

Optical transitions between the [Xe]4f^{1}5d^1 configuration and the ground state levels $^3H_4$, $^3H_5$, $^3H_6$, $^3F_2$ and $^3F_3$ of the [Xe]4f^2 configuration of Pr^{3+} results in UV luminescence. In contrast, optical transitions between energy levels of the [Xe]4f^2 configuration of Pr^{3+} are located in the visible range. The absorption lines located at 450 - 480 nm ($^3H_4$ – ^3P_J) and 580 – 610 nm ($^3H_4$ – $^1D_2$) cause the light green body color of LuAG:Pr ceramics. It turned out that excitation by 450 nm radiation results in a whitish spectrum, that consists of a multifold of lines caused by [Xe]4f^2 – [Xe]4f^2 transitions of Pr^{3+}. The rather strong absorption at 450 nm allows the application of such ceramics as colour converters onto LED dies too. The further enhancement of the transparency of garnet type ceramics will be in the focus of our future research.