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Phosphor Thermometry with Gallium-substituted YAG:Ce

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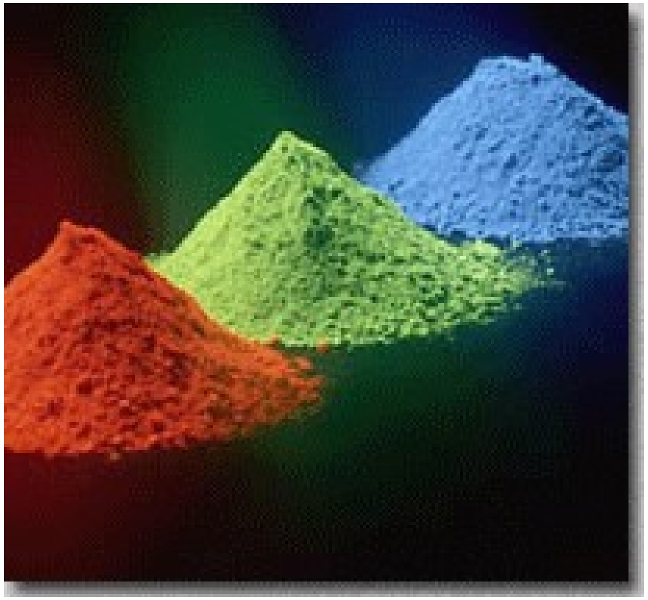
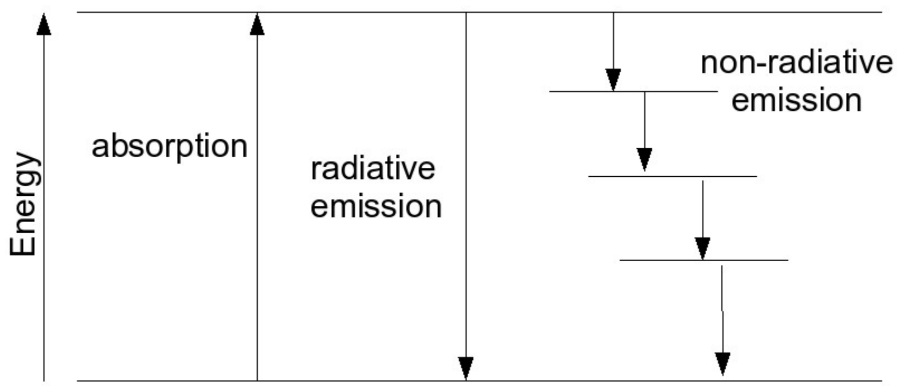
- 2nd year Graduate Student
- Interdisciplinary Materials Science Program
- NSF IGERT Fellow
- Thesis Topics:
  - Materials Properties of Thermographic Phosphors
  - Modeling of electronic transitions in phosphors

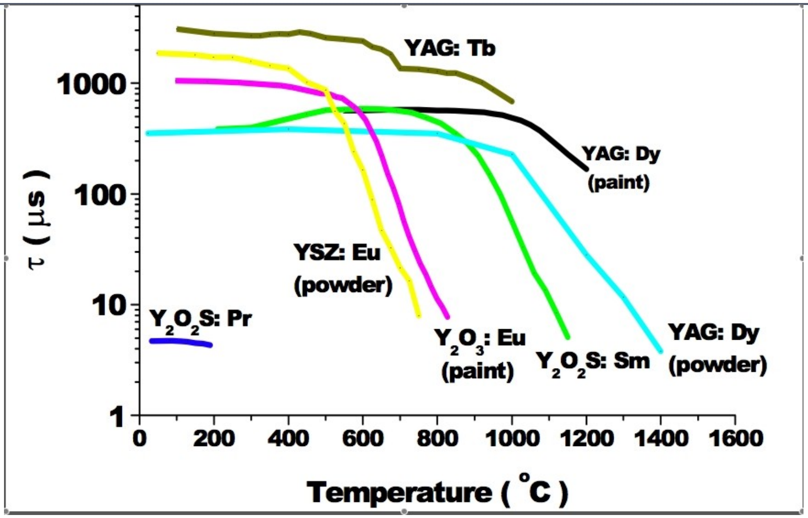
Phosphors



- Emits photons under stimulation of an external energy source (voltage source, photons)
- Crystalline matrix doped with rare-earth of transition metal ion
- Rare-earth dopant introduces new energy state into the band gap of the host lattice
- Solid-state lighting, LEDs, displays, **Thermographic Phosphors**

Thermographic Phosphors





Allison et al. Rev. Sci. Instrum. 68(7) 1997

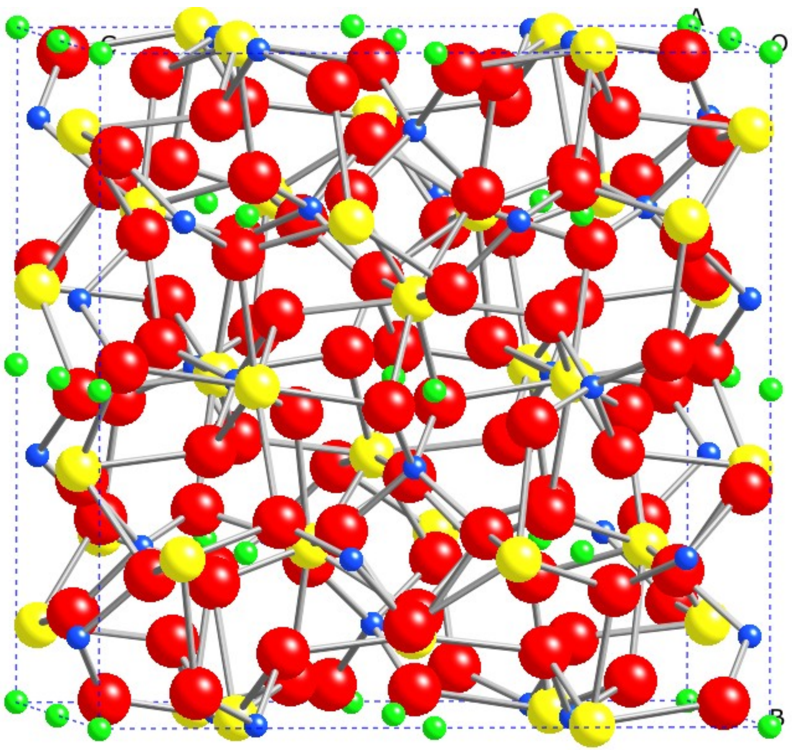
- Special class of phosphors used as non-contact temperature sensors
- Fluorescent lifetime is temperature dependent
- Radiative and non-radiative transitions

$$W_{rad} \quad W_{nr} \quad {}^{1}$$

- Turbine blades, pressure-sensitive paints, biological systems

$Y_3Al_5O_{12}$:Ce, YAG:Ce

- Yellow-green emission
- Nanosecond decay lifetime
- $T_{q,\ \text{bulk YAG:Ce}}$ ~150○C
- $T_{q,\ \text{nanoYAG:Ce}}$ ~7○C
- Gallium-substitution for Al atoms
- Blue-shifts emission spectra
- $T_{q,\ \text{nano Ga-substituted YAG:Ce}}$ =??



TGP Evaluation Criteria

- τ=lifetime of electronic transition
- λ_{exc} = excitation wavelength(s)
- λ_{em} = emission wavelength(s)
- T_q= temperature at which fluorescence begins to decrease due to thermal effects

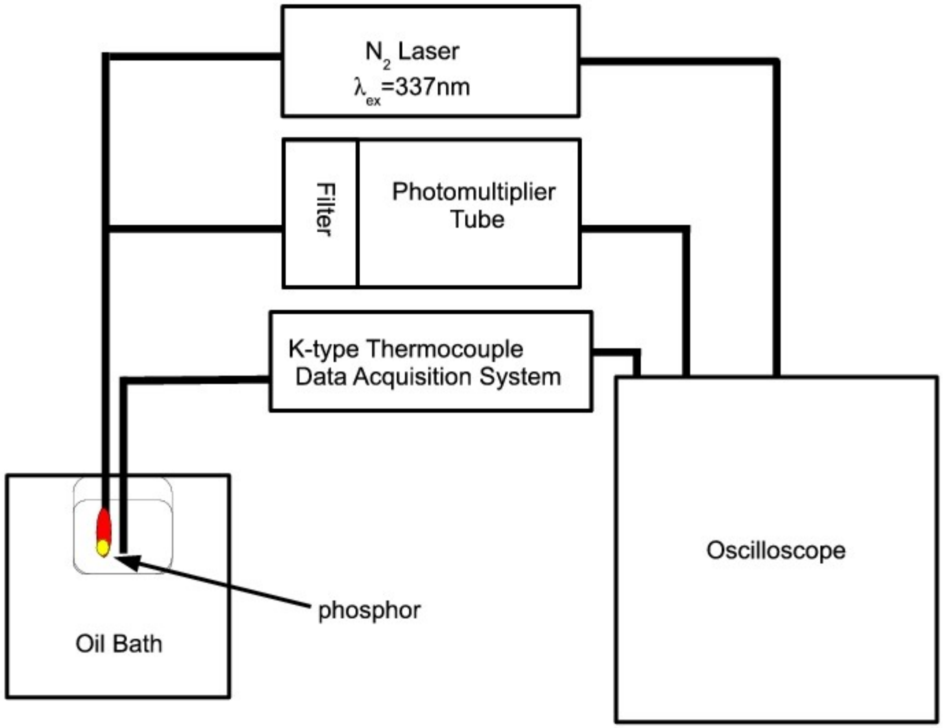
Factors which influence TGP criteria

- Rare-earth dopant
- Host Lattice
- Crystal Size (bulk or nano)
- Fabrication Method

Changing T_q

- 4 samples of nanocrystalline YAG:Ce were made via a combustion reaction
- Two of the samples had Ga^{3+} atom substituted for Al^{3+} atoms in the host lattice
- particle size
  - Ga-substituted samples ~27nm
  - no Ga-substituted samples ~32nm
- Lifetime measurements were determined as a function of temperature used laser-induced fluorescence
- T_q can be lowered by changing the host lattice and particle size

Temperature-Dependent Fluorescent Experiement

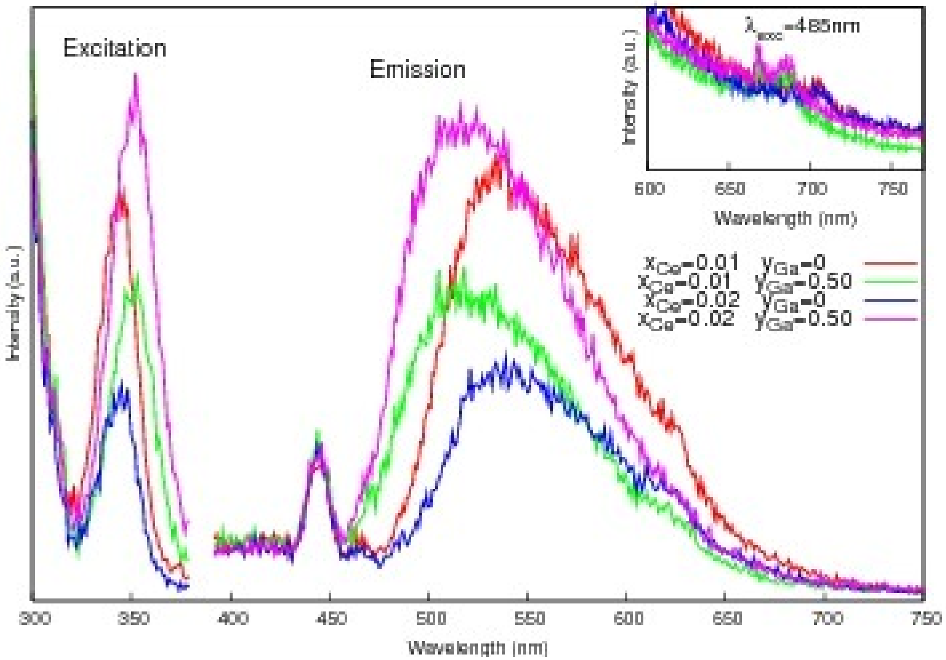


- N_2 excitation source
- λ_{exc} =337nm
- 540 nm emission filter

Photoluminescence

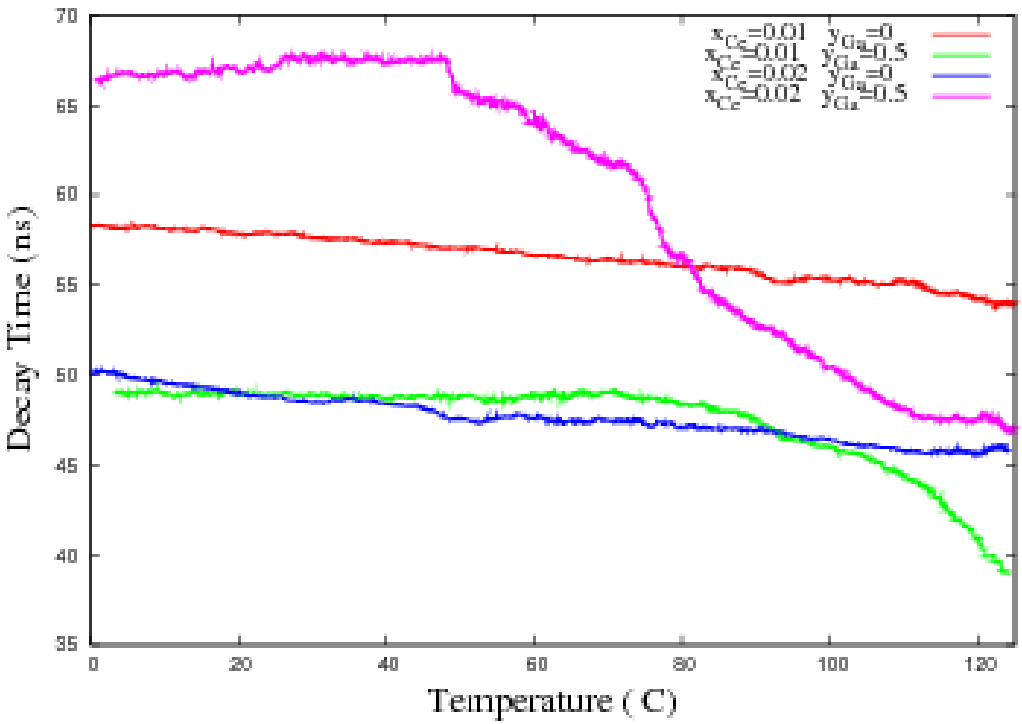
- Intense, broad-band emission, yellow-green emission
- Ga blue shifts emission
- distortion in host lattice

X (%Ce)	Y (%Ga)	λexc (nm)	λem (nm)
0.01	0	343	537
0.01	0.5	351	514
0.02	0	343	539
0.02	0.5	351	517



Results

- Ga-substitution:
  - Ga^{3+} increases covalency between Ce-O bond
  - non-emitting electronic states are lower in energy
  - non-emitting states become energetically favorable at lower temperatures
- Size effects:
  - Ga-substituted samples are smaller
  - surface defects introduce energy traps
  - trapped energy released thermally (non-radiatively)



Conclusions and Future Work

- Ga-substituted YAG:Ce is a good TGP with short decay time for low-temperature applications
- Ga-substitution in YAG lattice lowers quenching temperature because of the decrease in particle size and the change in the host lattice

Future Work:

- Development of high-temperature phosphors, such as YSZ:Dy, for use in turbine engines
- Optimal fabrication method
- DFT modeling of doped/substituted YAG lattice to determine electronic structure

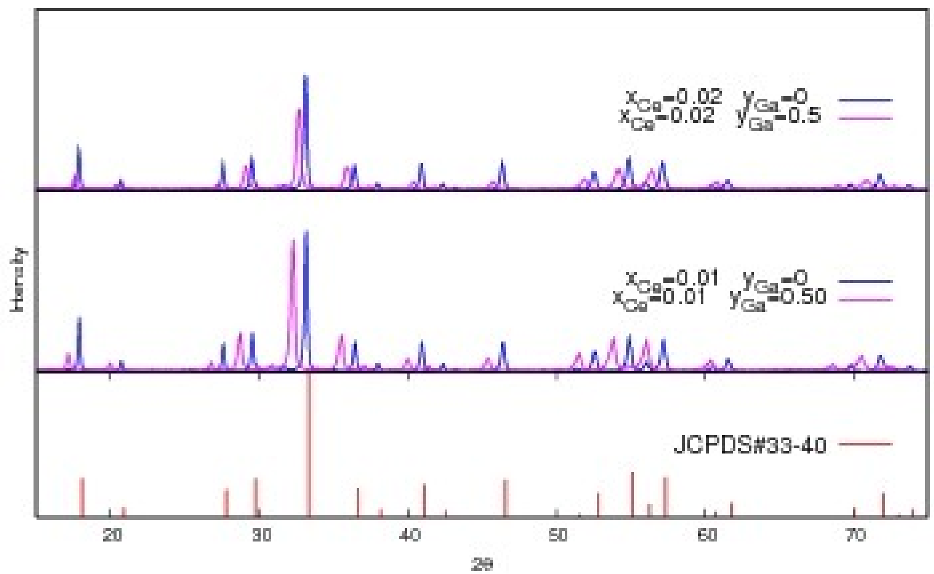
Supplementary Information

- More Data!!!

X-ray Diffration (XRD)

- Diffracted X-rays reveal information about crystallographic sturcture
- Ga increases lattice constant and reduces particle size

X (%Ce)	Y (%Ga)	a (nm)	ACS (nm)
0.01	0	1.21	37.1
0.01	0.5	1.22	27.1
0.02	0	1.21	32.4
0.02	0.5	1.23	27.3



Transmission Electron Microscopy (TEM)