Combustion Synthesis of Gadolinium Aluminum Garnet (GAG) Phosphor

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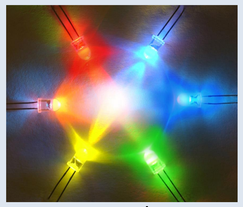
Why GAG?



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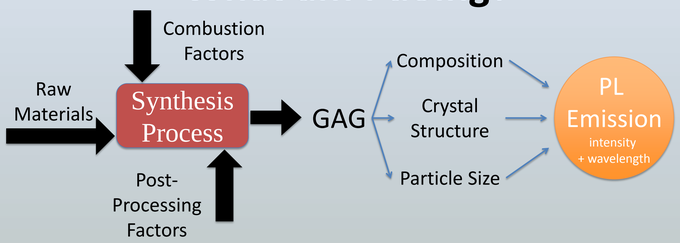
There is still a need for improvement in the quality of white light emissions in solid-state lighting devices.
Yttrium Aluminum Garnet (YAG) is a commonly used and well researched phosphor, but there is a need for a longer wavelength emitting phosphor. GAG is a similar phosphor, but due to differences in atomic size, GAG can emit longer wavelengths of light and theoretically improve white light emissions.

What am I doing?



Objectives

- Maximize photoluminescent (PL) emission intensity
- Synthesize pure garnet phase material
- Define relationships between stoichiometric composition and PL emission (wavelength and intensity)

Combustion Synthesis

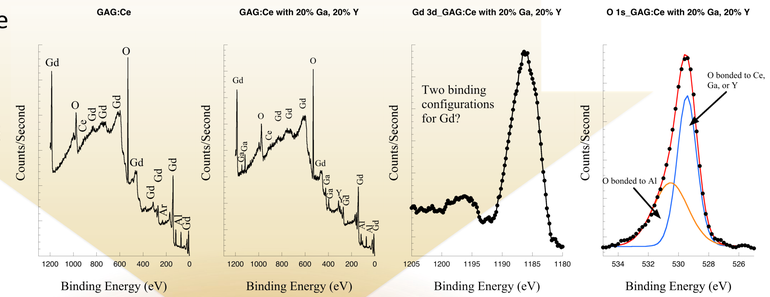
Composition

XPS was used to analyze the elemental composition of the products

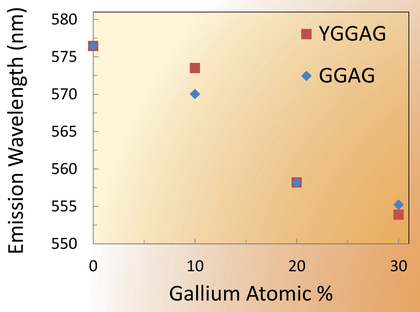
Notations for various materials

YGGAG
YGAG → $[Y_{3x}Gd_{3(1-x)}Ga_{5x}Al_{5(1-x)}O_{12}]$
GGAG → $[Gd_3Ga_{5x}Al_{5(1-x)}O_{12}]$

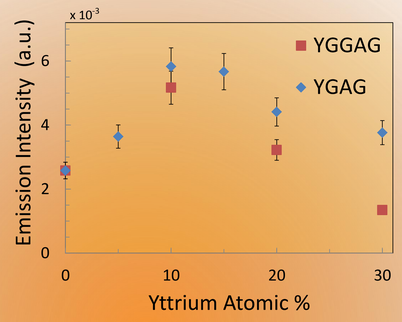
X-ray photoelectron spectroscopy (XPS) spectra



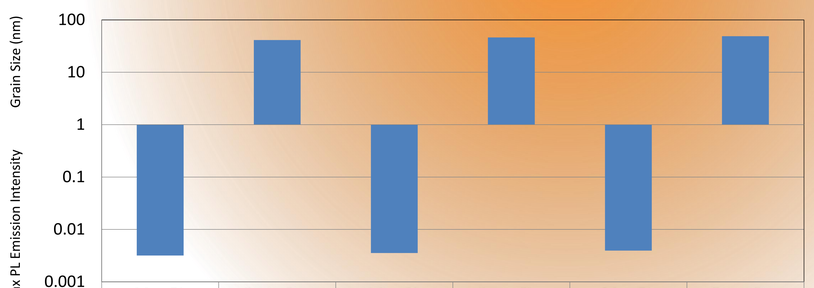
Emission Wavelength Blue Shifts With Increasing Ga^{3+} Concentration



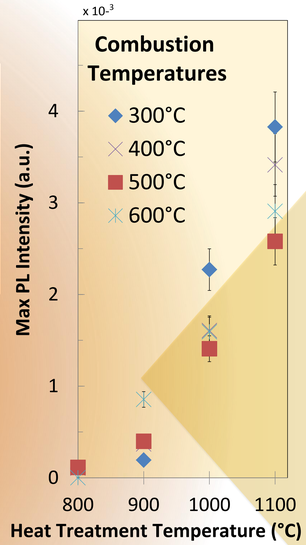
PL Emission Intensity Maximized at 10% Y^{3+} Concentration



Max PL Emission Intensity Increased With Increasing Grain Size

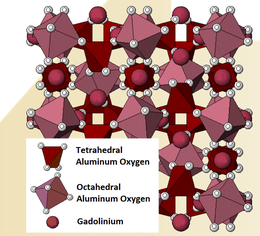


Max PL	Grain Size	Max PL	Grain Size	Max PL	Grain Size
1100 2 hrs		1100 4.5 hrs		1100 14 hrs	
0.003182	41.211384	0.003549	46.274556	0.003938	48.877492



PL emission intensity increases monotonically with increasing heat treatment. However, the maximum intensity does not occur when the most garnet phase material is present. This indicates crystal structure is not the sole determinant in PL emission intensity for samples with consistent composition.

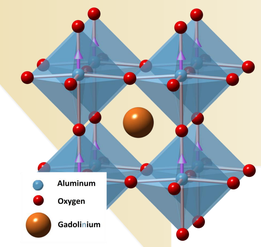
Crystal Structure



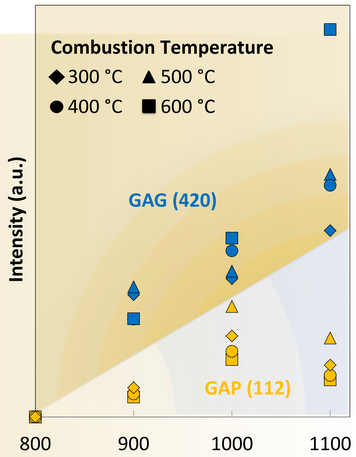
Garnet[1] (GAG) $Gd_3Al_5O_{12}$

Gd-Al-O

Perovskite[2] (GAP) $GdAlO_3$



Crystal structure pictures adapted from
[1] staff.aist.go.jp
[2] www.camsoft.co.kr



Relative intensity of the GAG (420) XRD peak increases with increasing heat treatment temperature and GAP (112) decreases with increasing heat treatment temperature. Thus, the most GAG phase material is synthesized at 1100 °C

Particle Morphology

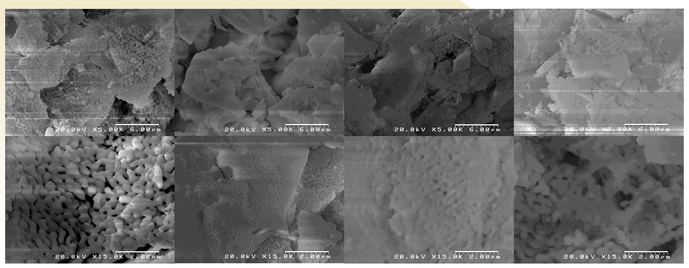
Grain sizes can be estimated using the following:

$$\tau = \frac{K\lambda}{\beta \cos(\theta)}$$

Scherrer's Equation

Scanning electron microscope (SEM) images of material

GAG GGAG YGAG YGGAG



Conclusions

- The most garnet phase material was created when the precursor was combusted at 500°C, then annealed at 1100°C for 4.5 hours
- The most intense PL emission occurred when 10% of the gadolinium was replaced with yttrium; indicating that composition has the greatest effect on PL
- The emission wavelength can be tuned within a 25 nm range by varying the concentration of gallium between 0 and 30 atomic percent
- Gallium and yttrium doping effects are mutually exclusive

Future Work

- Design a system to better utilize the internal energy released by the combustion in order to eliminate the need for annealing
- Develop a method to control particle size
  - Mechanism to crush particles to a desired radius
  - Size-controlled synthesis process
- Investigate the effects that other dopants have on PL
- Complete study on the effects of stoichiometry (varying Y from 0-100% and Ga from 0-100%)

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