Novel Ce^{3+} Phosphors for Luminescent and Display Applications

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Solid State Lighting and Display Center (SSLDC)

Applications of Phosphors

Solid State Lighting Based on Blue/UV LEDs

- Blue InGaN LED + Yellow Phosphor or
  UV GaN LED + Blue, Green, Red Phosphors

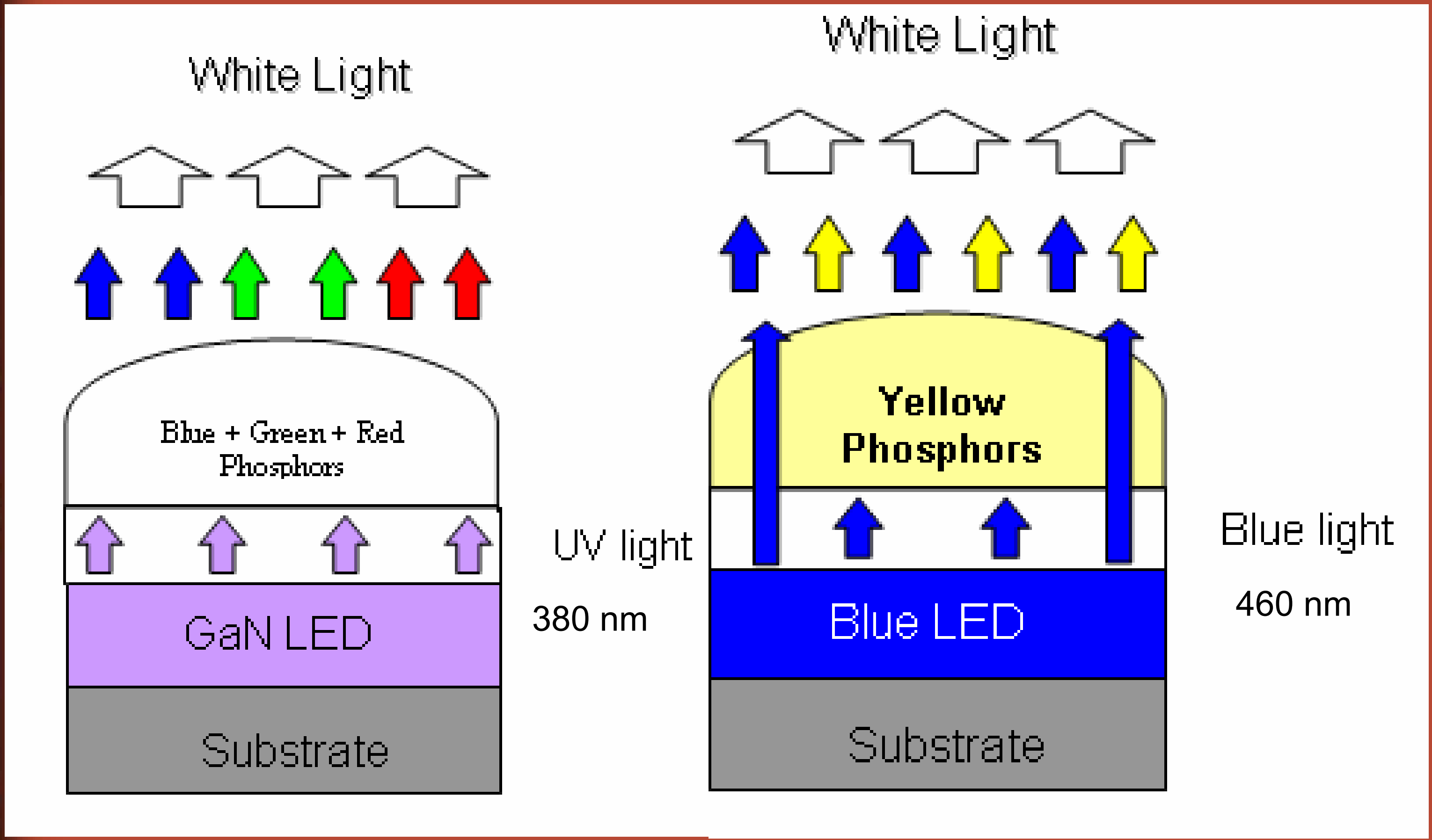
Advantages

- Improve Efficiency
  - Less energy used
  - Reduced cost for light operation
- Color Rendering
  - Better mimics light from Solar output

Display Applications (UV Activated Phosphors)

- Potential for 3X Light Output
- Better Color Saturation of Red, Green, and Blue Output
  - Larger variety of colors represented

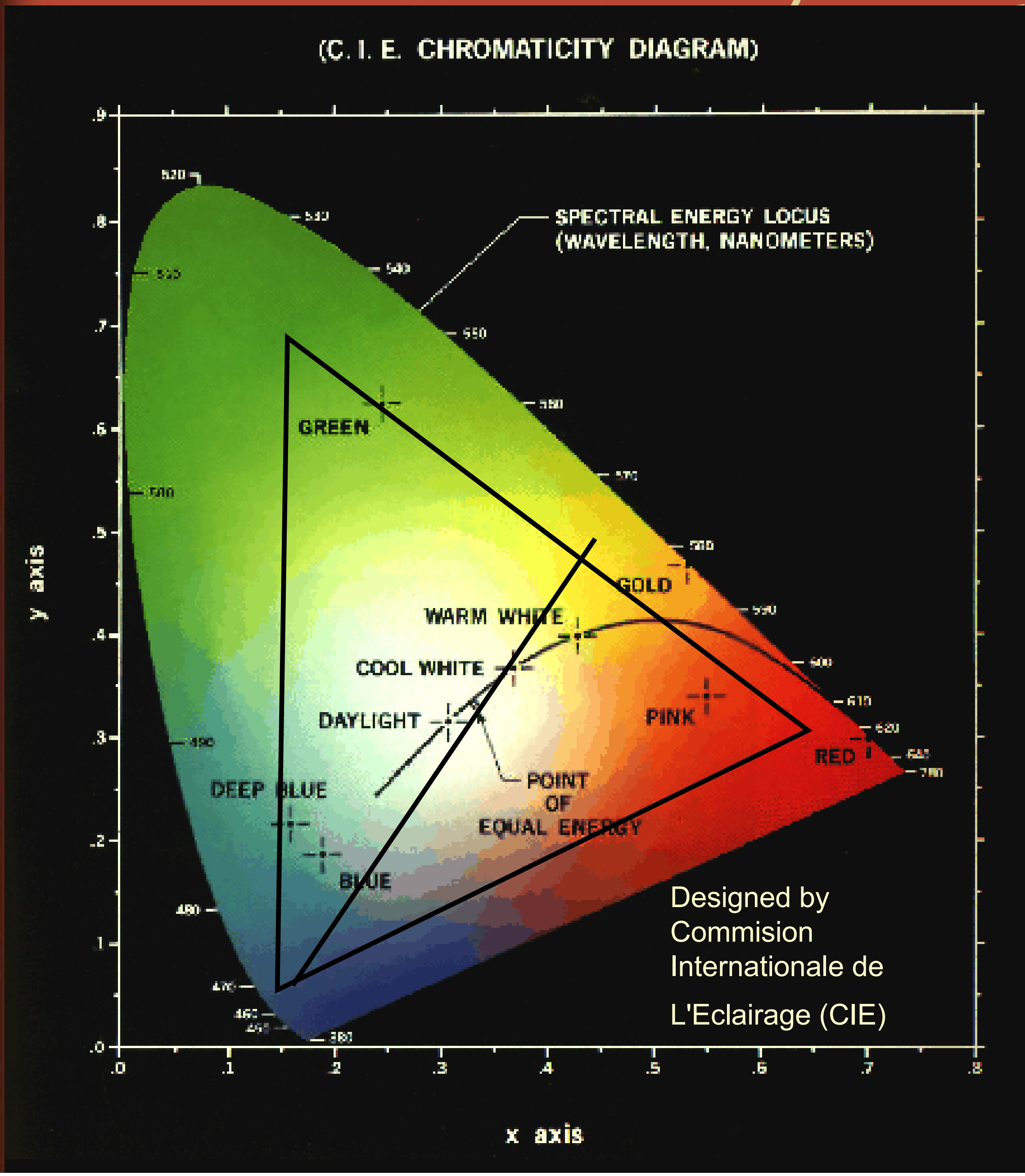
Solid State Applications



UV GaN LED photons get absorbed by the three phosphors and converted into photons with red, green, or blue wavelengths.

Some Blue InGaN LED photons get absorbed by the yellow phosphor and converted into photons with yellow wavelengths.

CIE Chromaticity Diagram



Research Goals

Synthesize Novel Phosphors (Ce doped)

- Utilize Different Synthesizing Methods
  - Sol-gel
  - Solid State
  - Hydrothermal

Alter Existing Phosphors

- Vary Synthesis Conditions
  - Temperature
  - Host Lattice Structure
    - Varying composition leads to light output shift
  - Particle size

Analysis and Testing

Analyze Resulting Samples

- Powder X-ray Diffraction
- Composition
    - Inductively Coupled Plasma (ICP)
    - Scanning Electron Microscope (EDS SEM)
- Photo Luminescent Input/ Output Measurements (PL)
- Quantum Efficiency Measurement (QE)

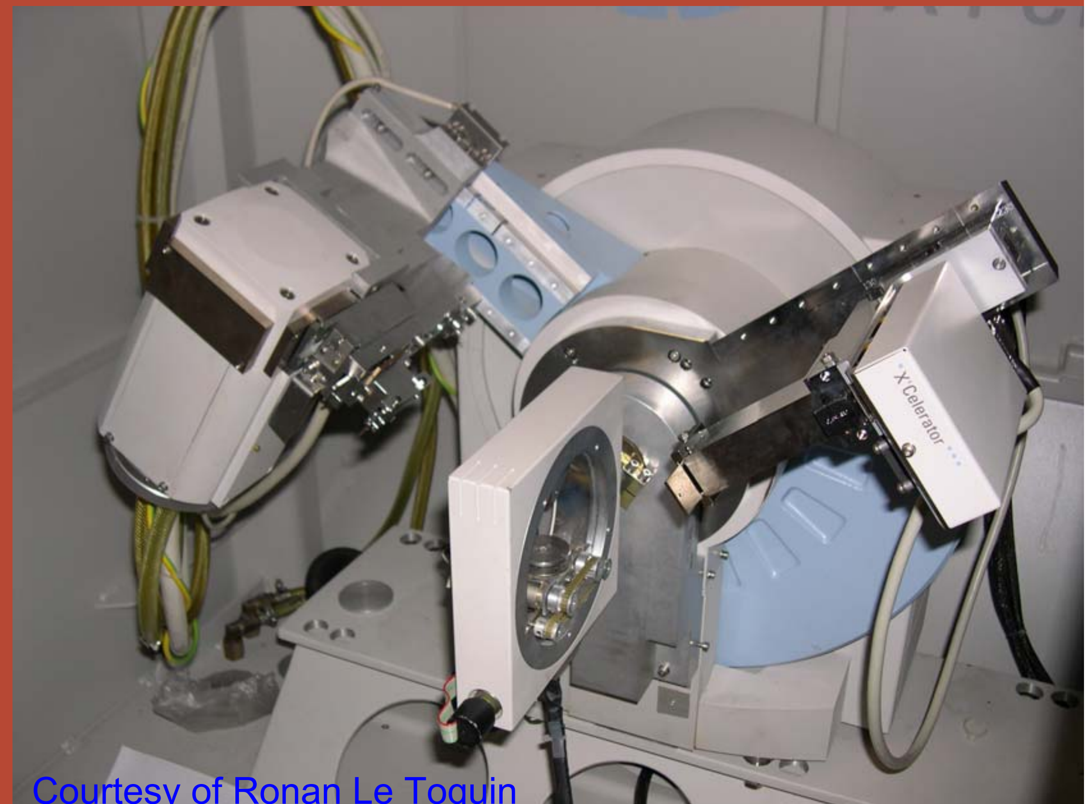
Test Phosphor

- Construct LED for Viable Phosphors

X-Ray Powder Diffraction

Results:

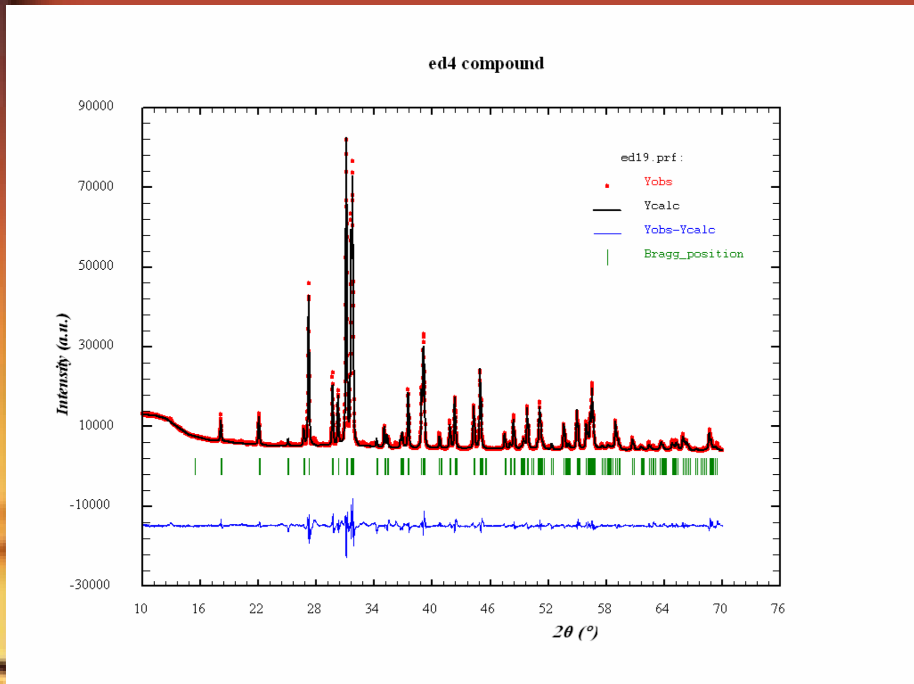
- Plots Diffracted Intensity vs. 2θ
- Determines Lattice Parameters (a,b,c,α,β,γ)

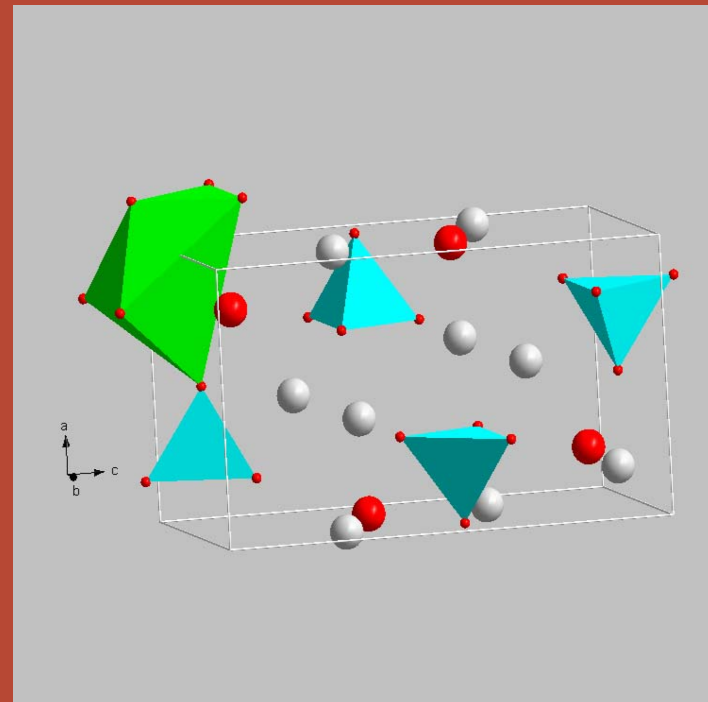


Courtesy of Ronan Le Toquin

Why it is Used:

- Process Determines if Substance is the Desired Phase
  - If not, determines how many phases and the ratio of the phases
- Solve the Structure
- Observe Changes in Lattice Parameters





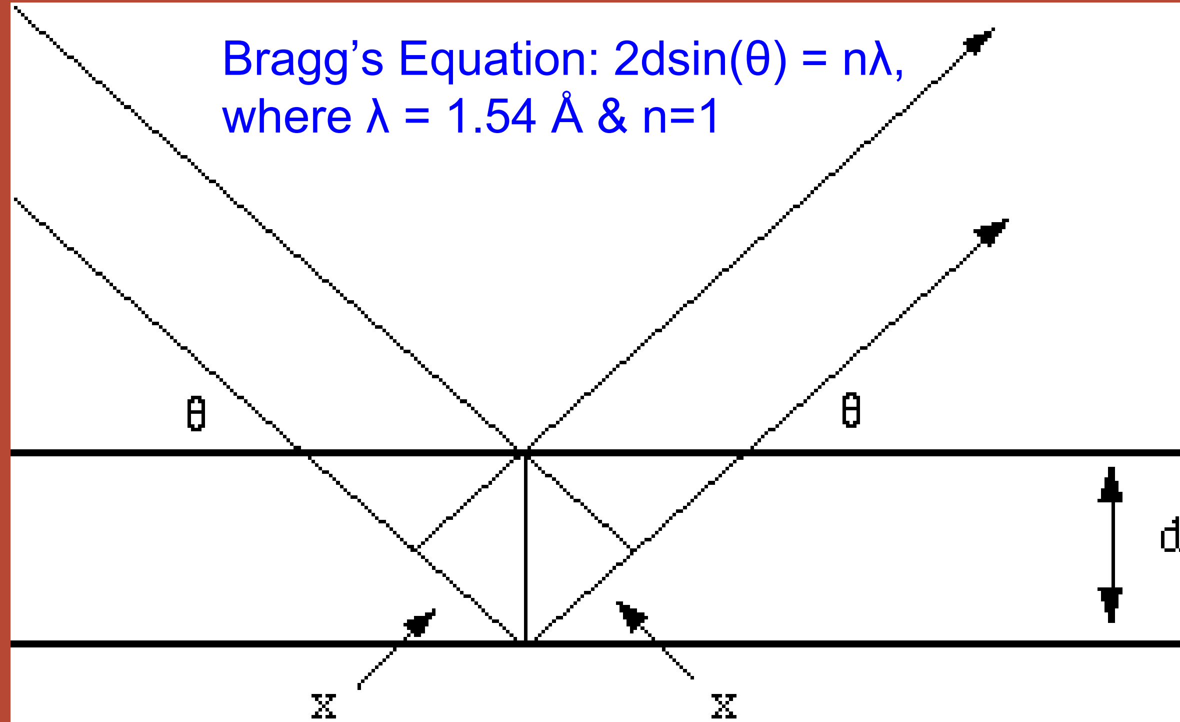
- Peak position (2θ) → Symmetry Lattice parameters (a,b,c,α,β,γ) of the unit cell

- Intensity of the peaks → Position of the atoms in the unit cell

Powder X-Ray Diffraction

How It Works:

Bragg's Equation: $2d\sin(\theta) = n\lambda$,
where λ = 1.54 Å & n=1



Source: http://materials.binghamton.edu/labs/xray/xray.html

Equation for orthorhombic Lattice (a ≠ b≠c α=β=γ=90°):

$$d_{hkl} = \frac{1}{\sqrt{\left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}\right)}}$$

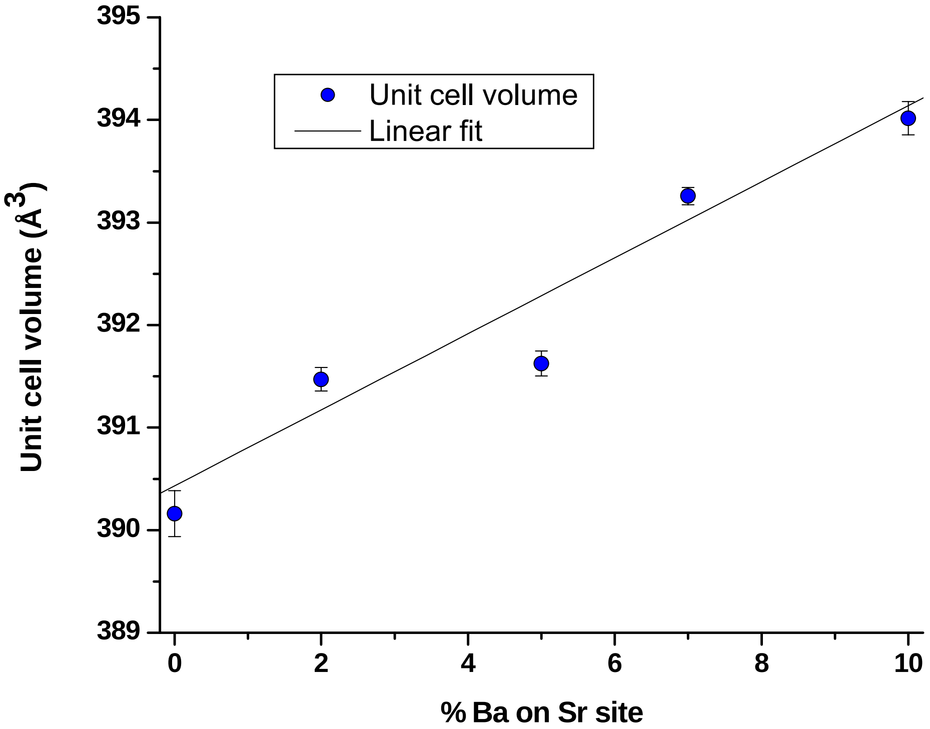
Results

Comparison Between ED-3, ED-19, ED-44, ED-50, and ED-51:

Each sample had different amounts of Sr replaced with Ba

$r_{Sr^{2+}}$ --> 1.26 Å

$r_{Ba^{2+}}$ --> 1.42 Å

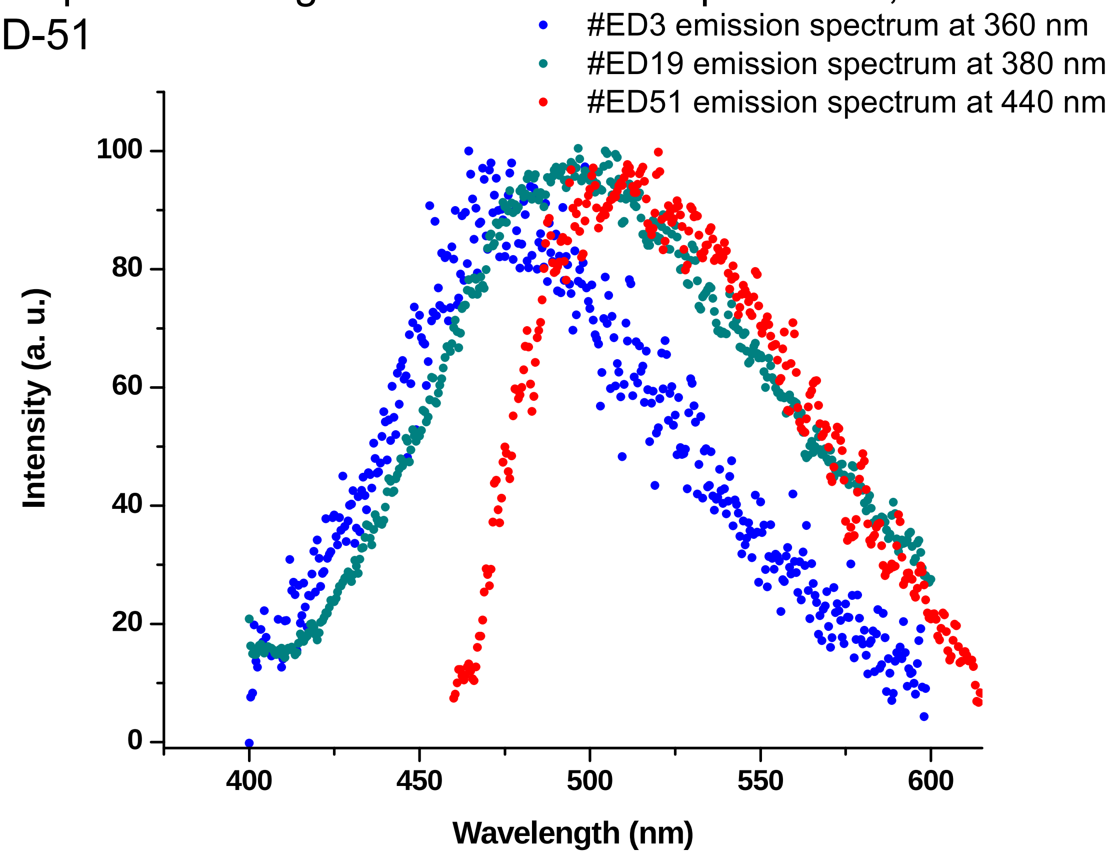


Difference of Cell Parameters:

	A (Å)	B (Å)	C (Å)	V (Å^3)
ED-3 (no Ba)	5.6594(11)	7.0801(14)	9.7372(18)	390.16
ED-50 (2% Ba)	5.6647(05)	7.089(08)	9.7485(09)	391.47
ED-19 (5% Ba)	5.6610(6)	7.1021(9)	9.7406(9)	391.62
ED-44 (7% Ba)	5.6646(4)	7.1203(6)	9.7501(6)	393.26
ED-51 (10% Ba)	5.6684(8)	7.127(1)	9.7532(13)	394.02

Results

Comparison of Light Emission for Samples ED-3, ED-19 and ED-51



Larger host lattice structure parameters

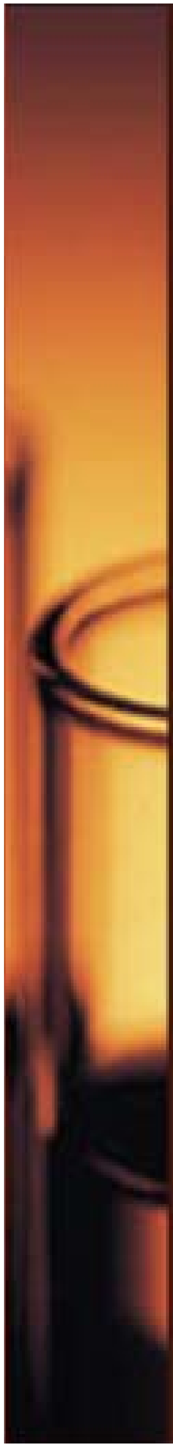
|

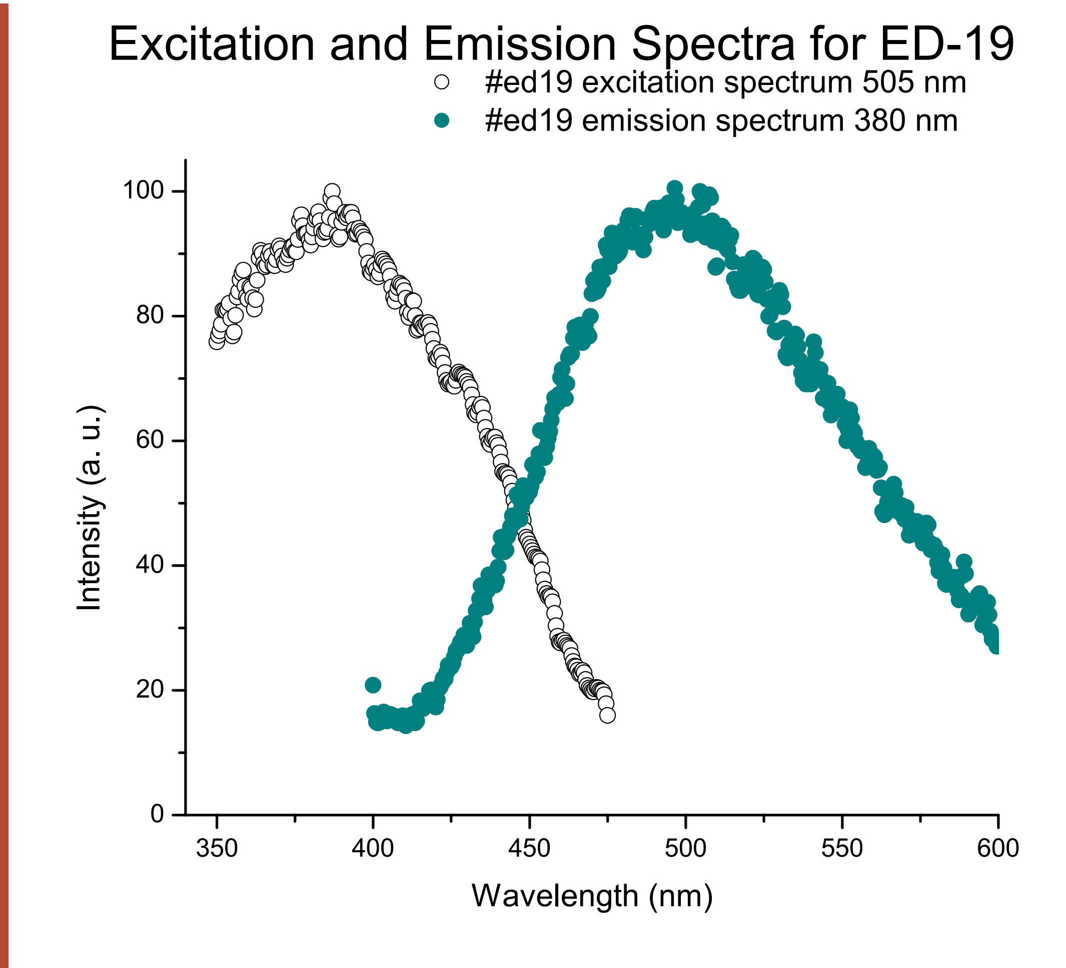
V

Red shift in emitted light

(higher wavelengths)

	Emission λ (nm)
ED-3 (no Ba)	482
ED-19 (5% Ba)	505
ED- 51 (10% Ba)	522

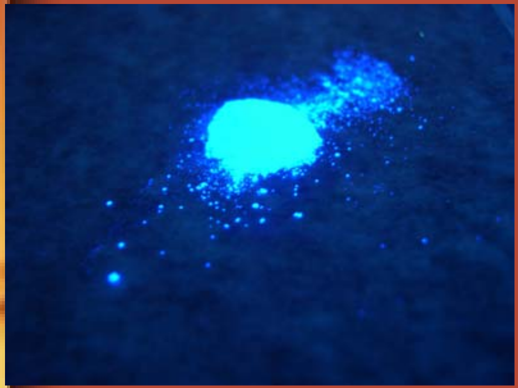




	Excitation λ (nm)	Emission λ (nm)
Acquired Results	380	505
Desired Results	380	530

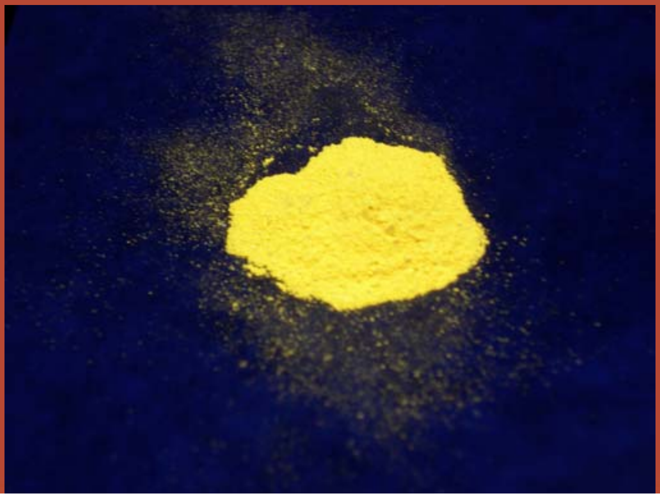
Results

Phosphors for GaN LED (380nm):



Blue **Green** **Red**

Yellow Phosphor for InGaN LED (460 nm):



Future Research

- Continue to explore new phosphors, especially green and red phosphors, excited in UV (380 nm) light
- Find very efficient yellow phosphors, excited in blue (460 nm) light
- Push the barium doped compound even more into the emission wavelength of the green and increase its efficiency

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