Pressure Dependence of Structure and Luminescence Properties in Lanthanide-based Upconverters

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To improve the upconversion efficiency of the NaYF₄:Er³⁺,Yb³⁺ system by tuning the rates of electronic processes through manipulation of the host lattice geometry

Upconversion for PV

Upconversion (UC) is the process of converting multiple low-energy photons into a single high-energy photon; incorporation of an upconverting layer can significantly boost the efficiency of any single-junction cell

UC with NaYF₄:Er³⁺,Yb³⁺

NaYF₄ doped with trivalent erbium and ytterbium is the most efficient NIR-to-visible upconverter to date

Terminology

- Er³⁺, the emitter: chosen for its regularly-spaced energy levels and long-lived excited states
- Yb³⁺, the sensitizer: chosen for its relatively large absorption band and energy resonance with Er³⁺
- NaYF₄, the host: chosen for its chemical stability and low phonon energies

Structural Effects

The UC efficiency in any Er-Yb system is influenced by:

- Intercation separations
- Energy resonance
- Orbital symmetry

All of these factors are structure-dependent!

Experimental Procedure

- Hexagonal and cubic nanoparticles were synthesized
- Size and phase were verified via SEM, TEM and XRD
- Pressure was applied using a diamond anvil cell
- UC luminescence under 980-nm illumination was analyzed
- Pressure-dependent synchrotron XRD was performed

DAC Basics

- Diamond anvil cells (DAC) provide a means to study high-pressure behavior
- Inclusion of a ruby in the sample volume enables pressure calculation

Structure Results

- Hexagonal lattice parameters
- Cubic lattice parameters

Outlook

- UC emission intensities and profiles were observed to be strongly pressure-dependent in both hexagonal- and cubic-phase NaYF₄:Er³⁺,Yb³⁺. Luminescence studies were consistent with XRD patterns and confirmed the phase transformation in the cubic particles. Data suggest lattice expansion may boost UC efficiency

Future Work

- Measure pressure-dependent fluorescence lifetimes
- Use doping to expand the NaYF₄ lattice

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References