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Optical properties of Europium doped GaN nanocrystalline powder

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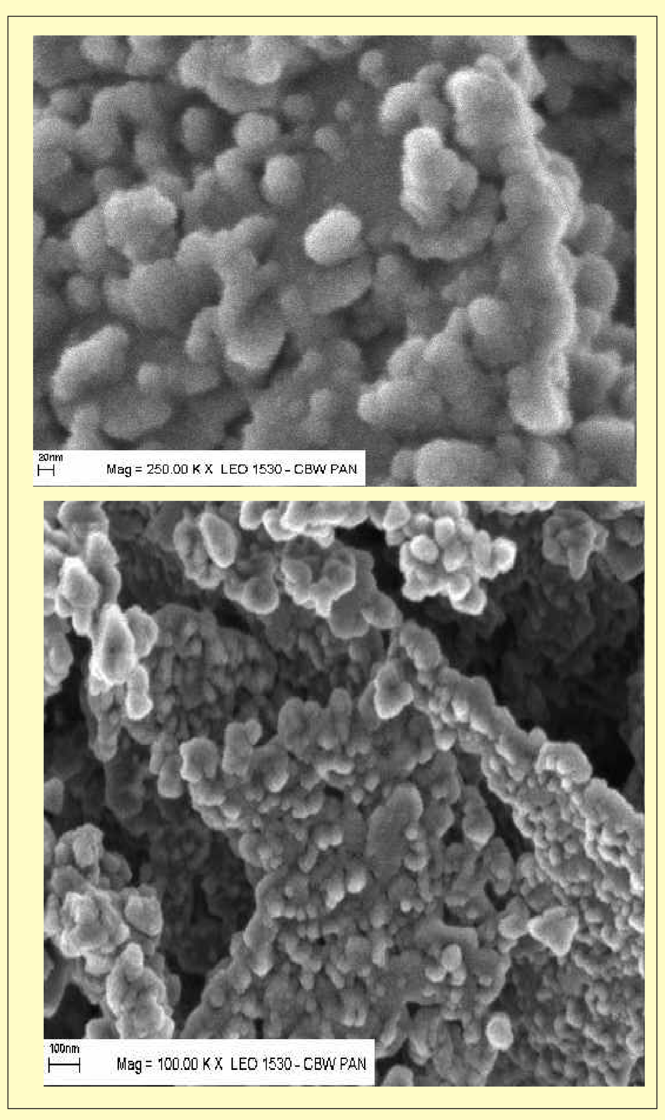
MOTIVATION

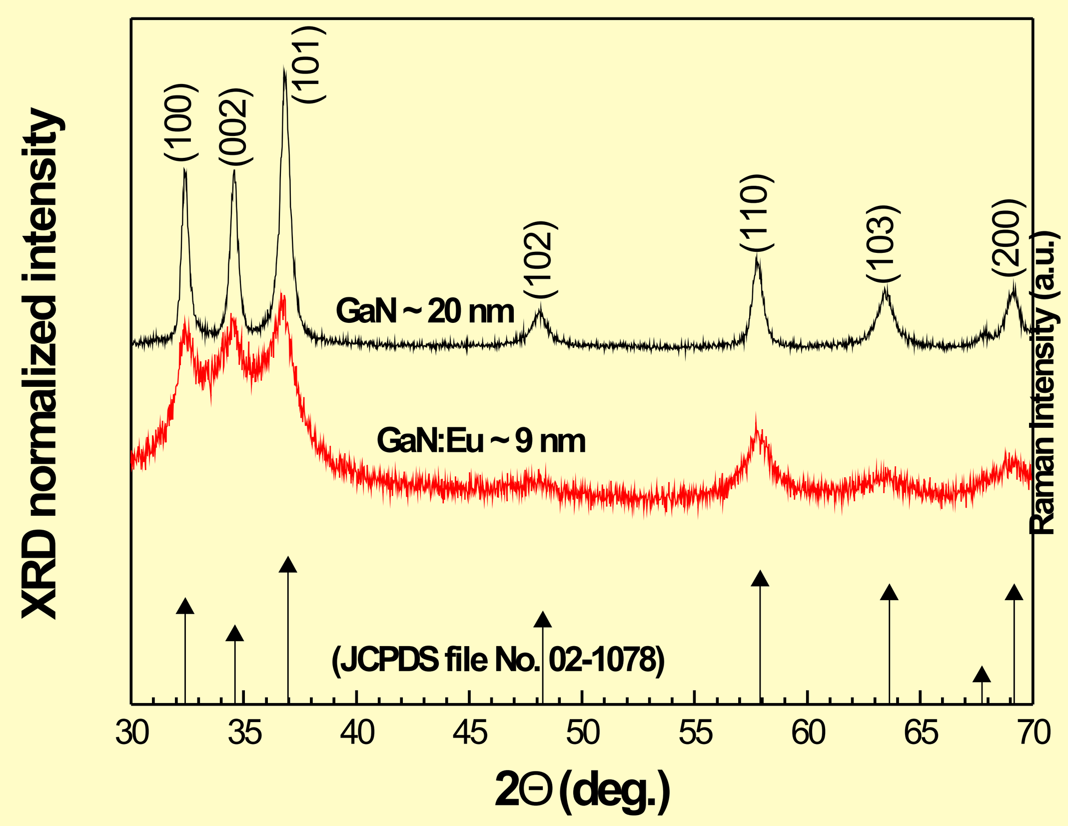
Deeper understanding of the incorporation, excitation, and emission properties of Eu ions in the GaN powder is necessary for its applications in optoelectronic devices
Cheap and relatively simple synthesis procedure of GaN powders compared to MBE and MOCVD grown films makes them attractive for large-area devices
By doping GaN powders with RE ions and utilizing its unique physical properties, it is possible to create alternative materials for some optoelectronic applications. .

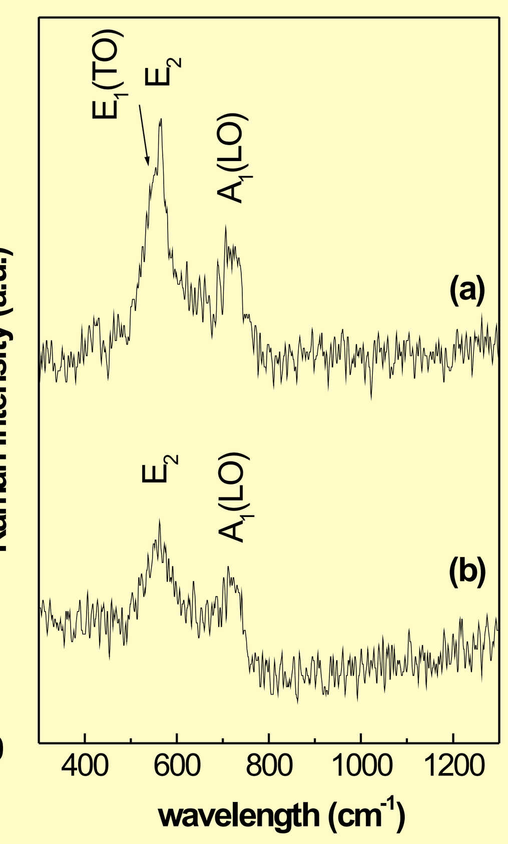
STRUCTURES



SEM micrographs indicates clearly that the sample contains aggregated crystallities with the sizes of 20-100nm.

GaN nanocrystalline powder has been synthesized using a horizontal quartz reactor. [20] The portions of 20.5g Ga_2O_3 (99.999%), 7.2mg EuO_2 (99.99%) and 7.6mg terbium oxide (99.99%) were mixed and solubilized in a hot concentrated nitric acid and evaporated to dryness. Next, the obtained powder was carefully dried in an oven gradually increasing the temperature from 70 to 200C. Then, the powders placed in an alumina crucible into quartz tube (24mm ID) was calcined at 500 C for 4 h in air flow (100 cm^3/min) to convert $Ga(NO_3)_3$ into Ga_2O_3. The crushed powders samples was placed at room temperature into quartz tube in NH_3 flow (120 cm^3/min) and after purging (20 min) the sample was heated (10 C/min) to the required temperature of the 850 C and then was hold in it for 3.5 hours. The NH_3 used for nitridation (99.85 vol.%) was additionally purified by passing it over a zeolite trap. The samples were taken from the furnace after it was cooled to the room temperature under the ammonia flow. The powders were pressed into pellets at power press (80kN) and then the optical measurements were performed. After samples preparation cathodoluminescence (CL) have been used as a post growth treatment.





STRUCTURAL PROPERTIES

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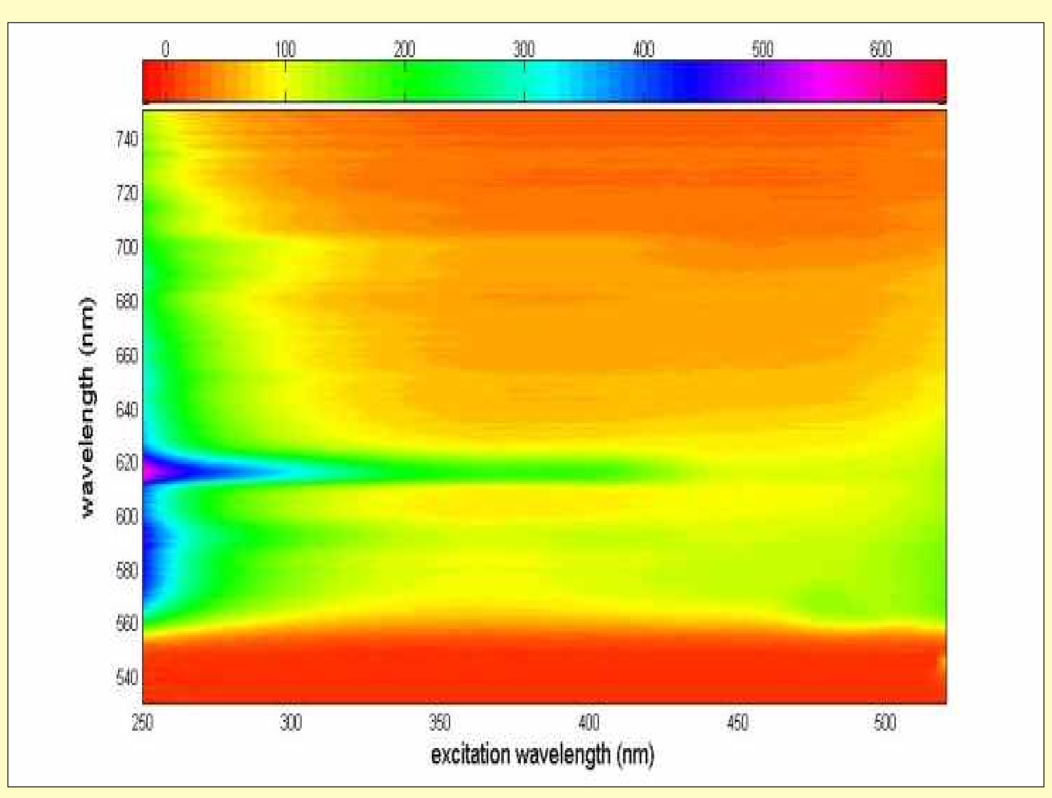
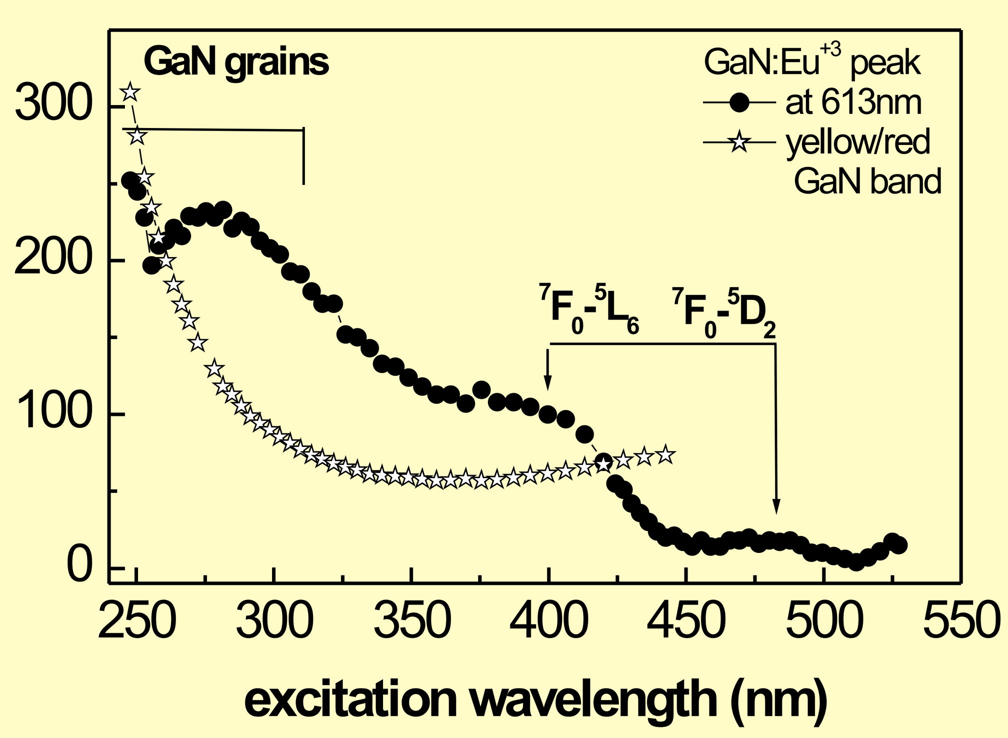
In the hexagonal wurtzite crystalline form of GaN, where atoms mostly occupy the C_{3v} sites, there are five Raman active phonons: A_1 (TO) around 534 cm^{-1}, E_1 (TO) around 556cm^{-1}, E_1(LO) around 740cm^{-1} [21] and usually the most intensive modes, E_2 (high) at 563-567cm^{-1} and A_1 (LO) at 728-735cm^{-1}. In case of GaN nanocrystals (n-GaN) all these modes fall approximately into two bands, one near 550cm^{-1} (E_1 (TO)+ E_2) and one near 750cm^{-1}(A_1 (LO)). In case of GaN:1%Eu^{3+} sample only two modes E_2 and A_1(LO) at 562 and 723 cm^{-1}, respectively have been observed.





EXCITATION SPECTRA

Excitation curve for 613 nm emission line shows two well resolved bands. The most intense band around 275nm is attributed to excitation throught GaN grains. The second band near 395nm results from electron transitions that correspond to direct excitation of Eu3+ ions.

EMISSION SPECTRA

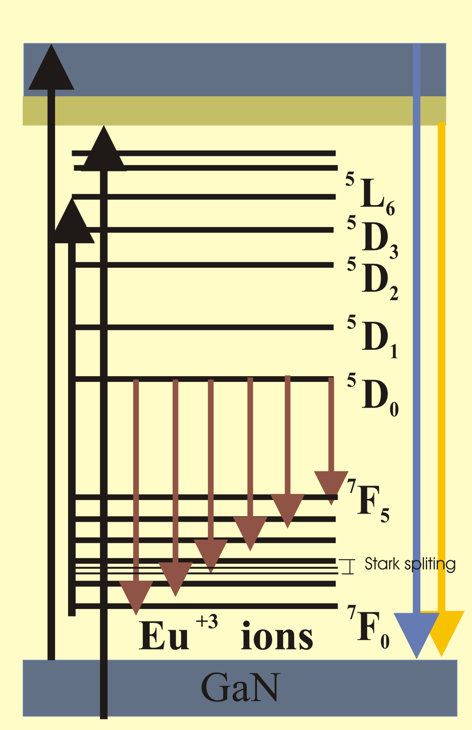
PL spectra exhibit two groups of emission lines associated with the GaN host-matrix and Eu3+ ions. Due to the post growth treatment (CL) three different emission spectra have been observed due to the different structural domains:

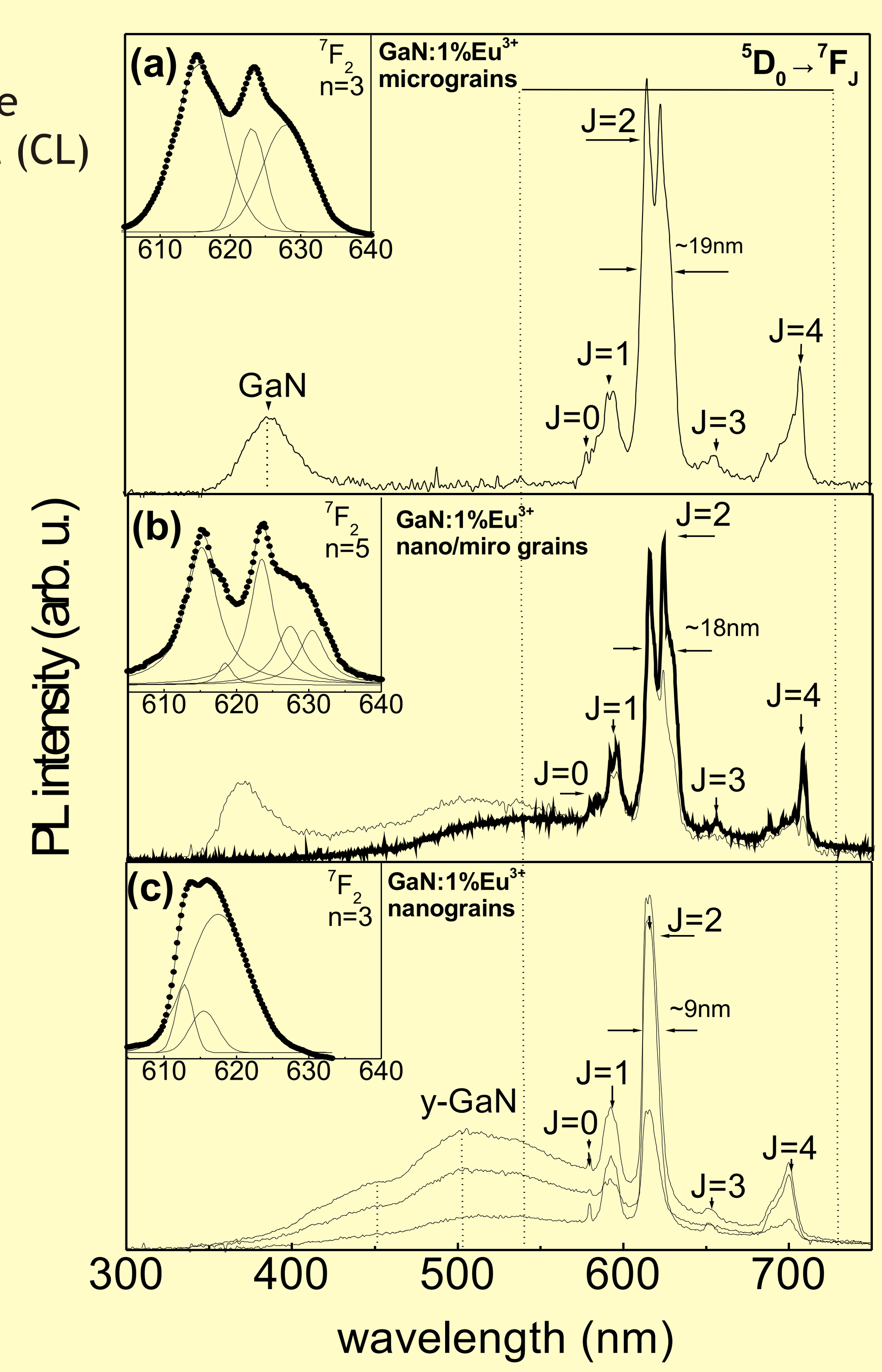
For the domain with the nano grains, PL spectrum exhibits:

1. A broad yellow/red emission typical for poor quality GaN layer
2. No emission related to GaN bandgap
3. Narrow PL lines associated with Eu3+ ions are clearly observed

For the domain with micro grains PL spectrum exhibits:

1. No yellow/red emission defect related
2. Emiission related to GaN bandgap has been observed
3. Narrow PL lines associated with Eu3+ ions are clearly observed





CONCLUSIONS:

It has been shown that the aggregetion of nanocrystalline GaN:Eu grains to micrometer conglomerates leads to significiant changes in emission spectra. The energy transfer from GaN grains (and related defect states) to Eu ions has been shown. Also direct excitation of Eu ions has been observed.