Optical Transitions of Eu Ions in GaN: The Puzzle of the 634 nm Peak

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Funding provided by National Science Foundation’s Research Experience for Undergraduates under grants PHY 0849416 and PHY 1359195

EXPERIMENTAL SET UP

Diagram below of the free-beam set up.

BACKGROUND AND MOTIVATION

GaN doped with Eu is an important material for future use as the active layer of red LEDs. After excitation, the major emission, in the spectra takes the form of 3 peaks centered on 621 nm. These peaks are assigned to the \( ^5D_0 \) to \( ^7F_j \) transitions of the majority defect center, Eu1. However, the spectra also shows a much smaller peak at 634 nm. This peak is roughly 20 times smaller than the ones at 621 nm (as seen below), but becomes comparable in strength in the emission of the most efficient LEDs. While this observation underscores the relevance of this emission peak for application, its origin remains unclear.

In literature, the 634 nm peak is often assigned to the \( ^5D_0 \) to \( ^7F_2 \) energy level transition. However, the peak is present with the same strength under resonant excitation conditions for which only the \( ^5D_0 \) state is excited. Excitation of the \( ^5D_0 \) would require additional energy and the questions arises where the additional energy comes from. Diagram of the energy level transitions is shown below.

ELECTRON PHONON COUPLING

We were able to exclude the possibility that the 634 nm peak is a phonon-assisted transition. Such transition would be shifted by the phonon energy (11 meV and 66 meV) from the 621 nm lines. In fact, we see such a replica (see figure below) shifted by 11 meV. The 634 nm peak on the other hand does not show any signs of splitting into the 3 peaks, and is only 40 meV from Eu1 instead of 66 meV.

TEMPERATURE DEPENDENCE

Temperature dependent measurements using confocal spectroscopy were performed. While we find a significant reduction of intensity for all peaks and a broadening of the 621 nm peaks, the relative ratio of the integrated emission strengths at 621 nm and 634 nm is barely changed. This excludes thermal activation as the main process of exciting to the \( ^5D_0 \) energy level. Below are spectra displaying the decrease in intensity as well as spectra scaled to each other to display the broadening that occurs.

SAMPLE DEPENDENCE

Data recently collected, as well as old data, was further analyzed to determine if the strength of the 634 nm peak is dependent on sample growth conditions (GaN 262 versus GaN 264) and annealing. For both cases, we were able to exclude an effect (shown in graphs below).

CONCLUSIONS

Through our research we have ruled out that the 634 nm peak affected through sample dependence or phonon coupling. Although the 634 nm peak could still be an energy transition from \( ^5D_0 \) to \( ^7F_2 \) we have ruled out that this excitation would occur thermally.

At this point, the origin of the 634 nm peak is still open but we speculate that it might be related to a different Eu sites and/or a center reconfiguration during the optical excitation process. Further investigation needs to be done to determine what affects the 634 nm peak and what causes the high intensity found in the most efficient red LEDs.