

NEW SPECTROSCOPIC DATA OF ERBIUM IONS IN GaN THIN FILMS

F. Pellé^(a), F. Auzel^(a), J.M. Zavada^(b), A.J. Steckl^(c)

^(a)UMR7574-CNRS 1, Place Aristide Briand, F-92195
Meudon cedex

^(b)US Army Research Office, Electronics Division,
Durham, NC 27709, USA

^(c)University of Cincinnati, Nanoelectronics Laboratory,
Cincinnati, OH 45221, USA

Wide gap semiconductors (WBS) doped with rare earth (RE) atoms appear as an especially promising class of materials with potential applications in the field of displays and as infrared light sources. Among the WBS, the III-N material system has special advantages. These materials are chemically and thermally stable and have been used to realize full-color electroluminescent devices (1). While there have been many studies of the spectroscopic properties of different RE ions in GaN thin films, no clear correlation between the efficiency of the visible RE³⁺ luminescence and the interaction of the RE ion with the semiconductor host has been established. In particular, the RE excitation and de-activation pathways have not been determined. Here we will present new results on the spectroscopic analysis of Er³⁺ ions in GaN thin films. Use of solid source molecular beam epitaxy for thin-film deposition has led to very high levels of Er concentration, $\sim 10^{21}$ ions/cm³ in the GaN host (2).

Based on site-selective excitation spectroscopy, three kinds of sites have been identified for the Er³⁺ ions. The majority of the Er³⁺ ions, which is considered as the main center, was determined to be substituted on the Ga sub-lattice. The two other sites were ascribed to Er³⁺ complexes in interstitial positions and assigned to Er-related defects.

The lifetime of the ⁴S_{3/2} visible fluorescence of the main center was strongly quenched with increasing Er concentration. A non-exponential time behavior for the decay profile was observed for the ⁴S_{3/2} fluorescence of the main center. The complex decay profile and its concentration dependence indicate that the optical relaxation involves energy transfer processes between adjacent Er³⁺ ions (Figure 1). The fluorescent transients were modeled and interpreted using a diffusion-limited migration of the optical interaction (3). All the microscopic parameters of the characterizing the interaction were determined and compared to the experimental data. Further spectroscopic studies of the de-excitation schemes and the luminescence efficiency will be discussed.

The energies of the Stark components of the ⁴I_{15/2} multiplet were deduced from emission spectra recorded at low temperature for several excited states of the main center. From the overall splitting of the ⁴I_{15/2} multiplet, it has been possible to deduce the crystal field strength using a scalar field parameter N_v (4). The scalar crystal field parameter allows a simple comparison between different host materials.

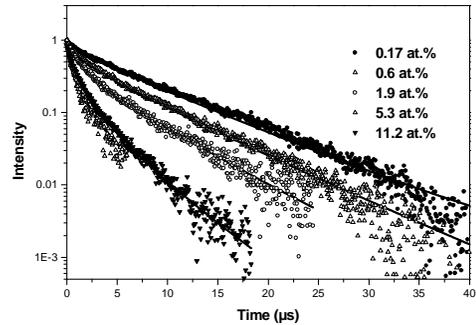


Figure 1 : ⁴S_{3/2} decay profile as a function of Er³⁺ concentration (T=300K) (Symbols : experimental data ; full lines : theoretical curves).

C

Obtained for other inorganic materials, the crystal field strength was found much weaker in GaN than in oxides. This result should indicate that the rare earth is well embedded in the semiconductor host and not in a parasitic oxide phase.

ACKNOWLEDGMENTS

This work has been partially supported by the US Army (Contract number N62558-02-M-5113).

REFERENCES

1. D.S. Lee, J. Heikenfeld, R. Birkhahn, M. Garter, B.K. Lee and A.J. Steckl, *Appl. Phys. Lett.*, **76**, 1525 (2000).
2. D.S. Lee, J. Heikenfeld, A.J. Steckl, U. Hömmerich, J.T. Seo, A. Braud and J. Zavada, *Appl. Phys. Lett.*, **79**, 719 (2001).
3. M. Yokota and O. Tanimoto, *J. Phys. Soc. Japan*, **22**, 779 (1967).
4. F. Auzel and O. Malta, *J. Physique*, **44**, 201 (1983).