

UCRL-PROC-222607



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Structural Properties of Eu-Doped GaN Investigated by Raman Spectroscopy

J. Senawiratne, Y. Xia, T. Detchprohm, J. W.
Tringe, C. G. Stevens, C. Wetzel

July 6, 2006

Fall 2006 Materials Research Society Meeting
Boston, MA, United States
November 27, 2006 through December 1, 2006

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

Structural Properties of Eu-Doped GaN Investigated by Raman Spectroscopy

J. Senawiratne^{1,2}, Y. Xia^{1,2}, T. Detchprohm^{1,2}, J. W. Tringe⁴, C.G. Stevens⁴, and C. Wetzel^{1,2}

¹Future Chips Constellation, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.

²Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.

³Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.

⁴Lawrence Livermore National Laboratory, Livermore, CA 94551-9900, U.S.A.

Rare-earth (RE) impurities doped GaN are highly promising candidates for light emitting device applications due to their efficient electroluminescence properties at room temperature. Among those, Eu doped GaN has been identified as an excellent material for the red spectral region due to its strong emission at 620 nm. As a transition internal to the Eu doping atom (4f-4f), light emission originates in a much smaller complex than the more flexibly controllable quantum structures of wells, wires, and dots. This is thought to make the center less susceptible to structural defects and in particular radiation damage in the lattice host. Nevertheless, the lattice host is crucial for providing the excitation in from of free electrons and holes. In this respect, the actual lattice site Eu occupies in the host lattice, i.e. in GaN, is important. A large fraction of Eu atoms are typically inactive which must be attributed to their lattice site and local environment.

GaN films implanted with Eu to concentrations of $\sim 10^{18} \text{ cm}^{-3}$ were subjected to a highly directed beam of 500 keV He⁺ at a dose of $5 \times 10^{14} \text{ cm}^{-2}$. By means of a shadow mask, irradiated and unexposed regions lie very close to each other on the same sample. We used optical and structural analysis to identify the exerted radiation damage.

At the full radiation dose, photoluminescence intensity has decayed to ~ 0.01 of its initial value. From the dose dependence of the radiation decay we previously concluded, that this decay is in part due to the destruction of radiative Eu sites [J.W. Tringe, unpublished (2006)]. Along the transition from virgin to irradiated material we analyze the accumulated damage in terms of surface morphology (atomic force microscopy), crystallinity (x-ray diffraction), and phonon dispersion using micro-Raman spectroscopy. In addition to the well-studied E₂(high) mode, two new vibrational modes at 659 cm^{-1} and 201 cm^{-1} were observed in the Eu implanted and annealed sample, prior to He⁺ irradiation. These modes are either remnants of the implantation damage or related to the Eu impurity. As such they can be indicative of the actual lattice site the Eu atom resides on. After irradiation, broad Raman modes at 300 cm^{-1} are being observed. This band indicates disorder activated Raman scattering (DARS) due to the radiation damage. An additional narrow mode appears at 672 cm^{-1} , which can possibly be due to a nitrogen vacancy related vibrational mode.

The continuous transition from irradiated to un-irradiated sample allows the direct evolution of radiation damage and its coordinated effects in structural, optical and vibrational properties. By its systematic correlation we anticipate to be able to elucidate the Eu lattice interaction and the processes of radiation damage.

This work was performed under the auspices of the US Dept. of Energy by the Univ. of California Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.