National Center for Solid-State Lighting

by **M. E. Coltrin and J. A. Simmons**

Motivation—Solid-State Lighting (SSL) uses semiconductor-based inorganic or organic light-emitting diodes (LEDs) to produce white light for general illumination. The Center for Integrated Nanotechnologies (CINT), jointly operated by Sandia National Laboratories and Los Alamos National Laboratory, has been selected as headquarters for the National Center for Solid-State Lighting (NCSSL), with Sandia as lead Lab. The NCSSL is a virtual, multi-lab center which incorporates multiple R&D projects from the five DOE Nanoscale Science Research Centers (NSRCs).

Accomplishment—The purpose of the NCSSL is to stimulate and enable the rapid transition of fundamental nanoscience discoveries into energy efficient SSL technologies. Technical projects for the NCSSL were selected by a competitive proposal process, with Sandia capturing 4 of the 7 (and CINT 5 of the 7) projects awarded in FY07, consisting of:
"Investigation of Surface Plasmon Mediated Emission from InGaN LEDs using Nano-patterned Metal Films," (PI: A. Fischer) to develop a high efficiency LED structure taking advantage of surface plasmons, which are electromagnetic waves at the interface between a metal and dielectric which have demonstrated improve light emission by as much as 90 times in specialized, optically pumped LED structures.

"Nanostructural Engineering of Nitride Nucleation Layers for GaN Substrate Dislocation Reduction," (PI: D. Koleske) to develop growth methods to reduce GaN dislocation densities on sapphire that inhibit device efficiencies. This study will establish the correlation between the nucleus density and dislocation density, then develop methods to reduce the nucleus density — while maintaining the ability to fully coalesce the GaN films.

"Nanowire Templated Lateral Epitaxial Growth of Low Dislocation Density GaN," (PI: G. Wang) to develop decreased defect density GaN substrates enabling higher efficiency LEDs. We will develop growth techniques for GaN nanowires that are then induced to grow laterally and coalesce into a high quality planar film.

"Development of White LEDs using Nanophosphor InP Blends," (PI: L. Rohwer) to develop oxide nanophosphors and semi-conductor quantum dots (QDs) in encapsulants to produce high conversion efficiency white-emission. The ultimate goal of this research is to produce white LEDs containing nanophosphor-QD blends that are superior to LEDs made with QDs or traditional phosphors alone.

Significance—In the next decade or two, solid-state lighting promises to reach energy efficiencies that are ten times as high as incandescent bulbs and twice as high as fluorescent lamps. If SSL at that efficiency were to replace all the incandescent and fluorescent lamps in the nation, the nation's electrical energy use would fall by 10%. Reaching the ultimate efficiency and cost targets of SSL requires breakthroughs in understanding the nanoscale science of LED materials that the NCSSL seeks to provide.

Sponsors for various phases of this work include: DOE Office of Energy Efficiency & Renewable Energy (EERE) and DOE Office of Basic Energy Sciences

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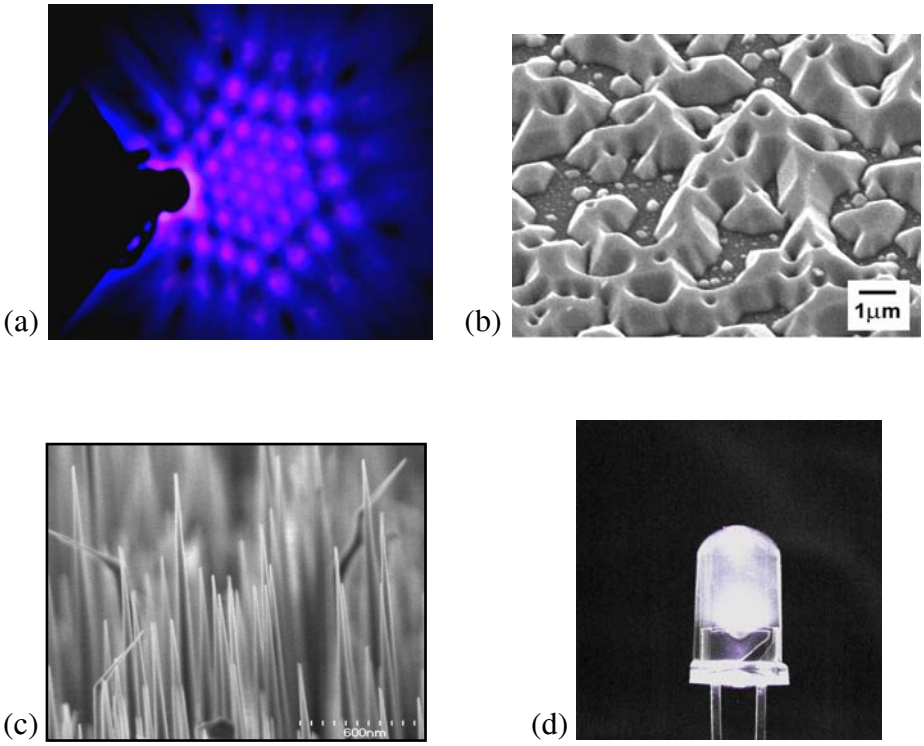

Figure 1. Sandia is working on four projects as part of the NCSSL to enhance materials performance at the nanoscale: (a) improving light-extraction efficiencies through surface plasmon creation, (b) improvement of GaN material quality through manipulation of the growth process of the initial nucleation layer, (c) development of arrays of highly aligned GaN nanowires and subsequent coalescence into low defect-density substrates for LEDs, and (d) production of high conversion efficiency white-emission from blends of special nanophosphors.