Enhanced Spontaneous Emission And Light Extraction From Textured Gan Templates Formed During Growth By The Hvpe Method.

J. S. Cabalu[1], C. Thomidis[1], T. D. Moustakas[1] and S. Riyopoulos [2]
[1] Department of Electrical and Computer Engineering, Boston University, 8 Saint Mary's St., Boston, MA 02215
[2] Science Applications International Corporation, 1710 SAIC Dr., MS 2-3-1, McLean, VA 22102

The development of efficient and low-cost GaN-based light emitting diodes (LEDs) for blue/ultraviolet (UV) light sources has been an area of intense research over the past several years, with a goal towards producing light sources for solid-state white lighting. Two of the greatest challenges facing such efforts are (a) the quantum efficiency for light generation and (b) the light extraction efficiency from the LED. Due to these challenges, the current overall power conversion efficiency of nitride LEDs is ~ 21% [1]. In this work, we present a novel approach to the improvement of both internal and external quantum efficiencies through the use of spontaneously formed GaN textured templates as substrates for the growth of nitride-based LED structures. *n*-type GaN textured templates with various degrees of texture (see Figure 1) have been formed spontaneously by the halide vapor-phase epitaxy (HVPE) method and used as substrates for the growth of nitride multiple quantum wells (MQWs) and *p*-*n* junction-based light emitting diodes. In this paper, we focus on the growth, structure and optoelectronic characterization of the textured GaN templates. Both smooth and textured GaN templates were grown employing a GaCl surface pretreatment of the sapphire wafer and a thin low temperature GaN-buffer. These GaN templates were characterized by studying their reflectivity in the UV and visible parts of the spectrum using a 150 W Xenon lamp as well as their photoluminescence (PL) excited with a He-Cd laser. We find that the surface texture is such that the reflectivity is suppressed to approximately 1% to 2% in the entire spectral region as seen in Figure 2. The PL intensity from the textured GaN templates was found to be significantly higher compared to that from identically produced and similarly doped GaN templates having atomically smooth surfaces. As shown in Figure 3, the ratio between the integrated photoluminescence from the GaN textured template and the GaN template with a smooth surface, measured at identical conditions, is approximately 60. We attribute this significant enhancement of the photoluminescence from the randomly textured GaN template partly to enhanced light extraction through the textured surface, which is expected to be only 4% from the smooth surface, and partly to enhanced spontaneous emission rate due to quantum carrier confinement from "wedge" electronic eigen- modes. Similar studies were carried out on GaN/AlGaN and InGaN/GaN MQWs grown on the textured templates. Preliminary results on MQW-type *p*-*n* junction LEDs will be presented. A theoretical model describing the enhancement in the extraction efficiency and the enhancement in the spontaneous emission from these GaN-based textured LED structures will also be presented.

References:

1. OIDA Technology Roadmap Update 2002; see also "The promise of solid state lighting for general illumination", jointly produced report by DOE (BTS) and OIDA.

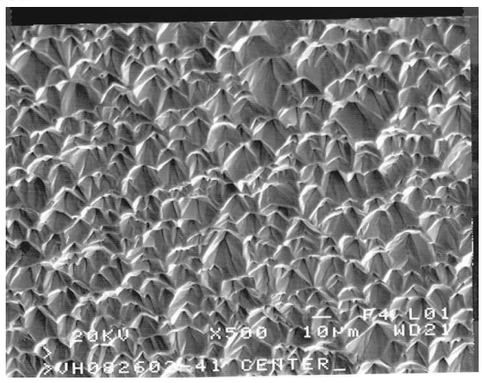

Figure 1. SEM image of a GaN textured template.

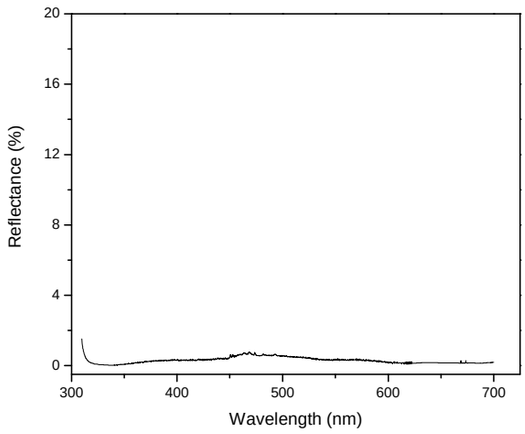

Figure 2. Reflectivity versus wavelength from a spontaneously textured GaN template.

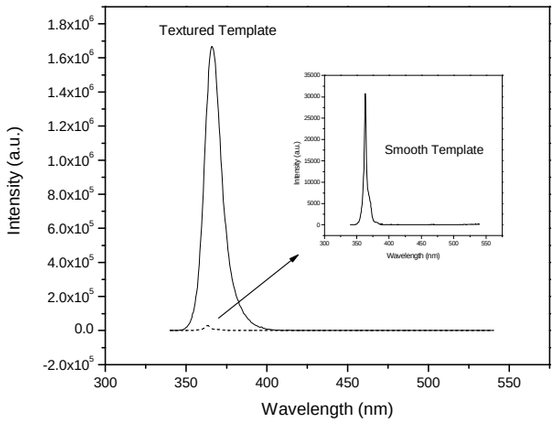

Figure3. Room temperature photoluminescence spectra of a spontaneously textured and smooth GaN templates grown by the HVPE method.