Digital alloys: short period superlattices of AlN/AlGaN for ultraviolet device applications

Sergey A. Nikishin\textsuperscript{1}, Boris A. Borisov\textsuperscript{1}, Vladimir V. Kuryatkov\textsuperscript{1}, Jayant Saxena\textsuperscript{1}, Gela D. Kipshidze\textsuperscript{1}, K. A. Bulashevich\textsuperscript{2}, I. A. Zhmakin\textsuperscript{2}, Sergey Yu. Karpov\textsuperscript{2}, Yuri N. Makarov\textsuperscript{2}, Mark Holtz\textsuperscript{3}, and Henryk Temkin\textsuperscript{1}

\textsuperscript{1}Texas Tech University, Nano Tech Center/Department of Electrical and Computer Engineering, Box 43102, Lubbock, Texas 79409 USA
\textsuperscript{2}STR, Inc., P.O. Box 70604, Richmond, VA, 23255-0604 USA
\textsuperscript{3}Texas Tech University, Nano Tech Center/Department of Physics, Lubbock, Texas 79409 USA

We describe electrical and optical properties and computer simulations of deep ultraviolet light emitting diodes (LEDs) and photodetectors (PDs) based on AlGaN digital alloys: short period superlattices of AlN/Al\textsubscript{x}Ga\textsubscript{1-x}N (x = 0.04 – 0.08) with periods in the range of 1.00 – 2.25 nm. Digital alloys of AlGaN were grown on (0001) sapphire substrates using gas source molecular beam epitaxy with ammonia. Silicon, derived from silane, and Mg, evaporated from effusion cell, were used for n-type and p-type doping, respectively. Details of growth procedure and device fabrication have been described previously [1-4]. The effective bandgaps of digital alloys were obtained from optical reflectance and room temperature cathodoluminescence measurements. Effective bandgaps between ~ 4.3 eV (288 nm) and ~ 5.3 eV (234 nm), as determined by optical reflectivity measurements, were obtained by monolayer (ML) variations in the AlN and Al\textsubscript{x}Ga\textsubscript{1-x}N thickness. The control of Al\textsubscript{x}Ga\textsubscript{1-x}N and AlN thickness provides “coarse” and “fine” adjustment of the effective bandgap. Keeping the AlN thickness constant and changing the Al\textsubscript{x}Ga\textsubscript{1-x}N thickness provides the coarse control of 400 ± 30 meV/ML. Keeping the Al\textsubscript{x}Ga\textsubscript{1-x}N thickness constant and growing with different AlN widths provides the fine control of 100 ± 20 meV/ML. For n-type digital alloys with edge luminescence at 240 - 260 nm we obtain electron concentrations in the range of $1 \times 10^{18} - 2 \times 10^{19}$ cm$^{-3}$ with mobility of 30 - 10 cm$^2$/Vs. For analogous p-type alloys hole concentration of $2 \times 10^{17} - 1 \times 10^{18}$ cm$^{-3}$ with mobilities of 7 - 4 cm$^2$/Vs are obtained. LEDs operating in the range of 260 – 290 nm exhibit turn-on voltages in the range of 4.5 – 6.5 V and support dc current densities in excess of 500 A/cm$^2$ at room temperature. The cutoff wavelength of PDs based on AlGaN digital alloys can be adjusted in the range of (247 – 280) nm by changing the AlN/Al\textsubscript{x}Ga\textsubscript{1-x}N thickness ratio.

This work is supported by DARPA-SUVOS (Dr. J. Carrano), NSF (ECS-00700240, 0321186, 0304224, and 0323640), NATO SfP 974505, SBCCOM, and the J. F. Maddox Foundation.