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

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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 $AlN/Al_xGa_{1-x}N$ (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 $Al_xGa_{1-x}N$ thickness. The control of $Al_xGa_{1-x}N$ and AlN thickness provides "coarse" and "fine" adjustment of the effective bandgap. Keeping the AlN thickness constant and changing the $Al_xGa_{1-x}N$ thickness provides the coarse control of 400 ± 30 meV/ML. Keeping the $Al_xGa_{1-x}N$ 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 $1x10^{18}$ - $2x10^{19}$ cm^{-3} with mobility of 30 - 10 cm^2/Vs. For analogous p-type alloys hole concentration of $2x10^{17}$-$1x10^{18}$ 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 $AlN/Al_xGa_{1-x}N$ thickness ratio.
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