# Wide-Bandgap III-N Ultraviolet Light Emitters and Power Electronic Devices


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The wide-bandgap semiconductors in the AlInGaN alloy system have been developed to provide materials for many advanced electronic and optoelectronic devices. This has been especially important for ultraviolet (UV) emitters and high-voltage and high-power electronic devices. In this talk, I will discuss the State-of-the-Art for III-N UV-C lasers operating at wavelengths <250nm and III-N bipolar transistors.

UV lasers are of interest for a number of applications including water purification, food sanitation, bio-agent detection, optical memory storage, and medical sterilization. Mature UV light sources such as dye lasers, quadrupled Nd:YAG, and excimer lasers suffer from several disadvantages including, containing toxic materials, a large footprint, high power consumption, and extreme fragility. Thus a compact and efficient semiconductor-based alternative is desirable. This work describes AlGaN/AlN multiple-quantum-well structures specifically optimized for optical pumping studies operating at room temperature. A native c-plane (0001) AlN substrate is employed for the metalorganic-chemical-vapor deposition growth of AlGaN/AlN heterostructures at ~ 1130 °C. The layer structure consists of eight 3 nm $Al_{0.6}Ga_{0.4}N$ quantum wells with 6 nm $Al_{0.75}Ga_{0.25}N$ quantum barriers between a 200 nm AlN buffer layer and 8 nm AlN cap layer. The wafer is then cleaved along m-plane to form laser bars with a cavity length of ~1.4 mm. One of the facets is then coated with 6 pairs of $SiO_2$/$HfO_2$ forming high reflection coating which has reflectivity of ~ 99.8% at 245 nm. The AlGaN MQWs are photopumped with a 193 nm ArF excimer laser, which operates with a pulse width of 20 ns at a repetition rate of 10 Hz. A 35% reduction in threshold power density is observed when the HR coating is coated on one of the facets. The peak wavelength of the laser emission spectrum was measured as 245.3 nm. The material growth technology and the optical properties of these deep-UV lasers will be further discussed.

The III-N materials system offers a greatly increased power-switching performance and a dramatic theoretical advantage in the standard Figures of Merit for power electronic devices compared to Si- and other III-V- based power devices. III-N devices are also more suitable for operation in harsh environments because of their wider bandgap properties. These attractive properties of III-N materials have led to increased interest in their commercial application for “low-frequency” power switching applications. In addition, the III-Ns potentially offer a heterojunction bipolar transistor (HBT) technology with excellent high-power and high-speed performance for highly linear power amplifiers. We report continued improvement of GaN-based *npn* double-heterojunction bipolar transistors (DHBTs) grown by metalorganic chemical vapor deposition (MOCVD) with state-of-the-art high collector current density ($J_C$) and low knee voltage ($V_{knee}$). For HBTs grown on sapphire, the common-emitter *I-V* characteristics show a high $J_C$ ~19.8 kA/cm$^2$ and $J_C$ = 28.6 kA/cm$^2$ from the Gummel plot with a offset voltage ($V_{offset}$) of < 0.22V and a $V_{knee}$ < 2.1 V. The measured $BV_{CEO}$ is 110 V. These values are among the best values reported to date for III-nitride (III-N) HBTs, suggesting that these DHBTs would be viable for high-power radio-frequency (RF) applications.