Challenges and Breakthroughs in the Development of AlGaN-based UVC Lasers

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Despite the rapid progress in III-nitride-based laser diodes, sub-300 nm UV semiconductors lasers have not been realized yet, mainly due to technical and scientific barriers arising from the lack of proper crystalline substrates and poor understanding of defect control in the wide bandgap semiconductors. In addition to low dislocation density, reduction in non-radiative centers and compensating point defect are required to achieve high internal quantum efficiency (IQE). AlGaN-based technology developed on single crystalline AlN substrates offers a pathway to address these challenges. We achieved lasing at room temperature in AlGaN-based MQW structures with a threshold below 50 kW/cm^2 and lasing wavelength from 237 to 280 nm (Fig. 1). All structures were grown on 500 nm of pseudomorphic undoped $Al_{0.7}Ga_{0.3}N$ on AlN substrates using low-pressure metal-organic chemical vapor deposition. Above threshold, the laser output was 100% TM polarized for wavelengths <240 nm and 100% TE polarized for wavelengths >240 nm. An elliptically shaped far-field pattern, as expected for a laser, was also recorded. Cavity modes were observed for 1.5 mm long cavities. However, the spectral resolution limited the direct observation of individual longitudinal modes. With a cavity length <500 μm, well-defined longitudinal cavity modes were recorded for the first time in photo-pumped deep UV lasers for undoped and doped laser structures. The line width of each longitudinal mode was as narrow as 0.01 nm. Up to this point, much effort has been focused on reducing the optical lasing threshold and improving the quality of the active region. Now, attention is being spent on waveguide design and current injection. It is encouraging that doping did not affect the lasing characteristics or the index of refraction, verifying previous ellipsometry studies on Si and Mg doped AlGaN. Finally, a symmetric waveguide structure with 60 nm thick top and bottom Si and Mg doped AlGaN both with doping concentrations of ~10^{19} cm^{-3} was investigated. Determining the lasing threshold is highly dependent on the assumed absorption coefficient of the top waveguide layer, but the conservative estimate is a threshold below 50 kW/cm^2. Our results demonstrate that AlGaN based sub-300 nm UV lasers with low threshold can be achieved on AlN substrates. We anticipate this achievement to serve as a starting point towards realizing electrically pumped sub-300 nm UV lasers on AlN.

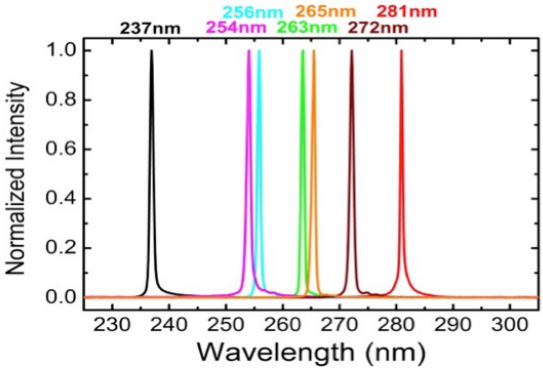

Fig.1. Light emission of various optically pumped lasers with emissions in the mid-UV range