Towards Highly Efficient Wavelength-Stable Red Light-Emitting Diodes Using Eu-Doped GaN

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After the groundbreaking invention of blue and green light-emitting diodes (LEDs) employing nitride semiconductors ($In_xGa_{1-x}N$/GaN), full-color large-screen LED displays could be developed by combining these blue and green LEDs with conventional red LEDs ($In_xGa_yAl_{1-x-y}P$/GaAs). Blue LEDs can also be combined with yellow phosphor to produce ultra-small, ultra-light white LEDs that have long lives and are easily driven. Against this backdrop, there has been a strong demand to develop red LEDs using nitride semiconductors. Researchers are aggressively pursing a quantum well structure with higher indium content aimed at producing even longer wavelengths. However, lattice mismatch with $In_xGa_{1-x}N$/GaN leads to crystal degradation and the efficiency of light emission is greatly limited by piezoelectric fields.

We have developed new properties and functions with rare-earth (RE)-doped III-V semiconductors grown by atomically-controlled organometallic vapor phase epitaxy (OMVPE) to create new devices that make effective use of these properties and functions. Throughout the course of our research, we have focused on europium (Eu) ions that have been widely used as an activator for red phosphor, and have succeeded in growing Eu-doped GaN layers with high crystalline quality by OMVPE, as well as developing the world's first red LED that operates at room temperature using Eu-doped GaN as the active layer [1]. Since then, we have steadily increased the light output from our red LEDs and at present have achieved a sub-mW output level at an injected current of 20 mA [2]. The corresponding external quantum efficiency (EQE) is 0.23%, which is comparable to that of commercially available N-doped GaP green LEDs. Even higher EQE values are observed for smaller injection currents, suggesting that the number of optically active Eu ions may be a bottleneck. While still greater brightness is required for the red LEDs to become practical, this invention will enable LEDs of the three primary colors to be integrated on the same substrate, which could lead to the development of ultra-small, high-resolution LED displays and next-generation LED lighting. In the presentation, current understanding of Eu luminescent sites formed in GaN and future strategies for the improved light output of the LEDs will be demonstrated.

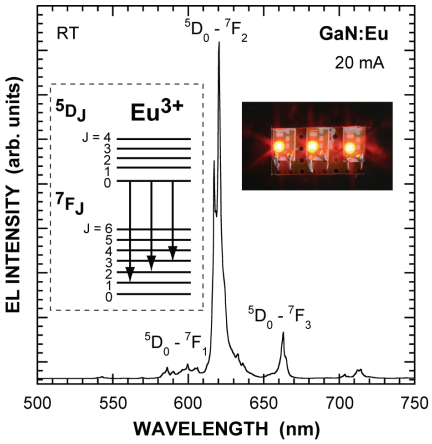

Fig. 1. EL spectrum from a red LED using Eu-doped GaN

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References

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