Aluminum Nitride Light-emitting Diodes with the Shortest Wavelength

Blue and ultraviolet gallium nitride (GaN) light-emitting diodes (LEDs) and laser diodes are now commercially available, but the shortest wavelength λ is 365 nm, which is still in the near ultraviolet region (λ = 300–400 nm). In the deep ultraviolet (DUV) region (λ = 200–300 nm), only gas light sources, such as mercury lamps or gas lasers, are available at present. There are practical problems. The gas light sources use toxic substances, which cause serious environmental problems. Moreover, gas lasers require frequent supplies of gas and the lasers are large and inefficient. Therefore, replacing these gas light sources with semiconductor light-emitting devices would save space and greatly improve the reliability and efficiency.

Aluminum nitride (AlN) is a promising candidate as a material because it has the widest direct band gap among semiconductors, so it has been theoretically predicted that an AlN light-emitting device will emit light with the shortest wavelength among semiconductors. Moreover, the AlN light-emitting device is harmless, unlike the gas light sources. However, AlN has thus far suffered from a high density of crystalline defects and high impurity concentrations, and the p- and n-type doping technologies essential for LEDs have not been available.

By developing technologies for high-purity AlN crystal fabrication and for p- and n-type doping, NTT has overcome these problems. NTT constructed an AlN fabrication system that can endure fabrication temperatures as high as 1100°C and prevents secondary reactions of composite aluminum and nitrogen sources. Consequently, it produces high-purity AlN crystal, which is being used to create p- and n-type AlN. NTT fabricated AlN LEDs with a high-purity AlN light-emitting layer sandwiched between p- and n-type AlN layers. The LEDs emitted light with a wavelength of 210 nm, which is the shortest wavelength ever observed from any semiconductor. This demonstrates that AlN can indeed emit light in the DUV region.

Since DUV light has a very short wavelength, it can be focused to spots only a few tens of nanometers in diameter. It can therefore be applied to nanometer-scale fabrication and submicrometer-particle detection. Moreover, the energy of DUV light is high enough to decompose persistent toxic substances, such as dioxin and polychlorinated biphenyls, which cause serious environmental problems. Consequently, DUV LEDs are expected to have a wide range of applications, such as environmental protection, nanotechnology, information technology, medical treatment, sanitation, and biology. To make DUV light-emitting devices available for practical use, NTT will improve the output power of AlN LEDs by further decreasing the density of crystalline defects and impurities and by improving the doping technology.

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