UV technology

Realization of UV-emitting LEDs

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As the novel-coronavirus pandemic continues to spread globally, the effectiveness of deep-ultraviolet rays in regard to inactivating the virus is drawing attention. Mercury lamps are widely used as a deep-ultraviolet light source; however, in recent years, deep-ultraviolet LEDs, which have the advantages of low environmental load and short start-up time, have been attracting attention. The virus is inactivated and sterilization is achieved by its DNA absorbing the deep-ultraviolet light, which destroys the double-helix structure of the DNA, which thereby loses its amplification function. Accordingly, as shown in Fig. 1, the sterilization efficiency of deep-ultraviolet light is the highest in the wavelength region around 265 nm, at which deep-ultraviolet absorption rate of the DNA is high[1].

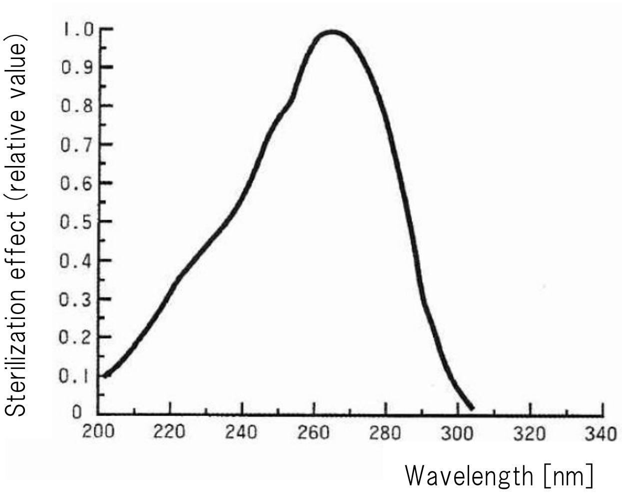

Figure 1: Dependence of sterilization effect on wavelength

Conventional deep-UV LEDs are manufactured on sapphire substrates and SiC substrates,[2-4]; however, when such substrates are used, the difference in lattice constants and the difference in coefficients of thermal expansion of the semiconductor materials are large. As a result, line defects with density of 10^8 cm^{-2} or more occur, and the resulting low luminous efficiency is a problem. Therefore, to reduce that line-defect density, methods such as epitaxial lateral overgrowth (ELO) have been innovated. The correlation between internal quantum efficiency and line-defect density has also been investigated, and it has been reported that a line defect acts as a non-emissive recombination center, so it is very important to reduce line-defect density.[5][6] To address these issues, it is very effective to use aluminum nitride (AlN) as the substrate because its physical constants (namely, lattice constant and coefficient of thermal expansion) are similar to those of the semiconductor material. As for LEDs manufactured on an AlN substrate, line-defect density can be suppressed to 105 cm^{-2} or less. What's more, taking advantage of the small difference in lattice constants makes it possible to create an LED with high output in the 265-nm wavelength band, in which sterilization efficiency is highest.

Utilizing these technologies, we launched a "sterilization LED" commercially in 2017. Moreover, we have developed a "water-sterilization module" using a 265-nm LED, and this module demonstrated sterilization performance for Escherichia (E.) coli at flow velocity of 2L/min of 99.9% or more. We commercialized a water-sterilization module based on this LED in May 2018.

In addition, with the growing interest in deep-ultraviolet LEDs against the backdrop of the novel-coronavirus pandemic, we are doubling our efforts to further improve the efficiency of LEDs. LED efficiency is expressed as the product of carrier-injection efficiency, internal quantum efficiency, and light-extraction efficiency. Given that fact, we improved (i) carrier-injection efficiency by improving the thin-film structure and (ii) light-extraction efficiency by reducing the absorption coefficient of the AlN substrate to 15-30 cm^{-1} thanks to enhanced technology for fabricating the AlN substrate.

Currently, we have begun supplying a series of LEDs (with outputs of 60 and 70 mW at drive current of 500 mA and wavelength of 265 nm) as well as high-power (80 mW or more at the same wavelength) LEDs as engineering samples (Fig. 2)[7].

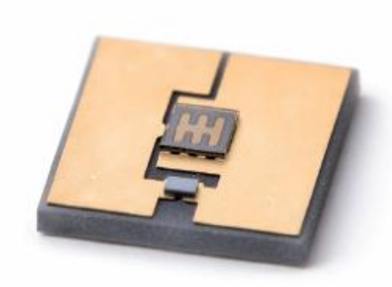

Figure 2: LED device for sterilization

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