The future of ultraviolet LEDs

Nichia of Japan pioneered the development of gallium nitride blue LEDs and lasers and is now turning its attention to UV devices. **Adarsh Sandhu** reports from Tokushima, where he interviewed senior executives from the firm.

Why are ultraviolet LEDs needed and what are their major applications?
Shigeki Okauchi, General Manager of the Business Planning Department for Optoelectronic Products:
Nichia's roadmap for the development and applications of UV LEDs is based on low-power devices emitting between 3 mW and 10 mW at a central wavelength of 365 nm or 375 nm. Such low-power devices will be used for photo-catalytic deodorizing in air conditioners and refrigerators as well as identifying counterfeit banknotes.

The other area of interest is high-power output devices, typically in the range of 100 mW to over 5 W, at a wavelength of 365 nm. Applications include hardening or curing resins as part of the assembly process of plastic lenses in digital cameras and optical pickups in DVDs and CDs. During fabrication of DVDs, the UV LEDs will be used for 'gluing' or fixing plastic components to metal bases. We want to replace traditional mercury lamps with solid-state UV LEDs.

Further, by integrating UV LEDs with water cooling, we can produce UV-LED modules with an output power of over 5 W at 365 nm. Applications include replacing mercury lamps in processes such as inkjet printing and photolithography. We are aiming to have a full line-up of products by 2008.

In the future, applications of our UV LEDs will expand into biotechnology. For example, 365-nm light is thought to be particularly useful for DNA sequencing.

How large is the market?
Shigeki Okauchi:
The market for industrial applications, where UV LEDs will replace market lamps for applications such as curing resins and other high-power uses, is several hundred million US dollars. The market for low-power UV LEDs is centred on household products such as refrigerators for example. In terms of global demand for UV LEDs we estimate a demand of several million to a hundred million LEDs per year.

Nichia's 5 W 365 nm LED array module, which is now under development for applications such as inkjet printing and photolithography.

What is the main issue in the development of UV LEDs?
Takashi Mukai, Director of the Nitride Semiconductor Research Laboratory:
In a word — lifetime. We want to replace mercury lamps so our UV LEDs must have a longer lifetime than these lamps. Typical mercury lamps have a lifetime of about 1,000 hours and they are inexpensive. To compete, we must produce UV LEDs with lifetimes of, say, 10,000 hours so that although the initial cost of UV LEDs may be more than mercury lamps, the user will find it more economical in the long term. That's the business model.

What limits the lifetime of UV LEDs?
Takashi Mukai:
The simplest means of increasing the lifetime is to reduce the junction temperature. This can be done by either minimizing the heat generated at the junction or by efficiently removing this heat. Or both.

Crystalline dislocation density of UV LEDs is typically about 2×10^8 cm^{-2}. Even if it was possible to reduce the dislocation density to zero, the junction temperature would still only be reduced by about 10%. As a result, crystalline defects do not govern the junction temperature and hence the lifetime of LEDs.

We have already produced watt-class UV LEDs in the laboratory. The next step is improving the yield. It will probably take about five years before we can put them on the market.

Many research laboratories around the world are now investigating extremely short-wavelength (<300 nm) UV LEDs. Are you developing such devices?
Takashi Mukai:
We are concentrating on producing high-power devices emitting at 365 nm as opposed to trying to produce devices with much shorter wavelengths. At present, it is possible to produce high-efficiency short-wavelength devices emitting at about 350 nm but the efficiency of devices emitting at shorter wavelengths is very low.

Although research on deep-UV LEDs dominates the headlines, I think it will be a long time before they will be readily available. The major hurdle is the inefficient p-type doping using magnesium, which forms deep acceptors, and hence the poor activating efficiency. We need an alternative to magnesium for creating shallow acceptors.

The recent report by NTT published by *Nature*[1], on deep-UV structures emitting at 210 nm, fabricated using silicon-doped aluminium nitride is a good approach, but as the results show, the power output is extremely low.

Of course we are interested in wavelengths less than 365 nm, but only as a means of using such know-how to support our efforts on 365 nm wavelength devices. We think that deep-UV LEDs are not commercially viable.

Adarsh Sandhu is a professor at Tokyo Institute of Technology.

Reference

1. Taniyasu, Y., Kasu, M. & Makimoto, T. *Nature* **441,** 325–328 (2006).

Acknowledgements

This article is published in association with OplusE, a monthly Japanese magazine for professionals working in optics and photonics. www.ss-com.co.jp