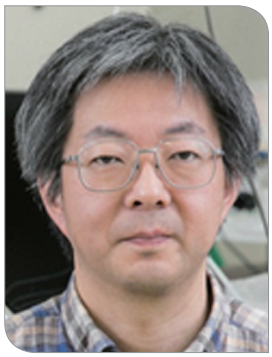
Plenary 1

- Date / Time: May 24 (Tue.), 2022 / 13:15–14:00
- Place: Convention Hall A
- Session Chair: Jong Kyu Kim (POSTECH, Korea)
- Title: Progress of Deep-UV LEDs by Increasing Light-Extraction Efficiency



Prof. Hideki Hirayama
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• Biography

Hideki Hirayama received his PhD of Eng. from Tokyo Institute of Technology in 1994. In the same year, he became a research scientist at RIKEN. He became a Team Leader to manage the Terahertz Quantum Device Team in 2005. In 2012, he was appointed as a Chief Scientist of Quantum Optodevice Laboratory. He has also concurrent positions as visiting professor of Saitama University, Tokyo University of Science and Tokushima University. He won a Japan IBM Science Prize in Electronics in 2010, an Ichimura Science Prize in 2011, a Science and Technology Award from the Minister of Education, Culture, Science and Technology in 2014, a Compound Semiconductor Electronics Achievement Award (Prof. Isamu Akasaki Award) of The Japan Society of Applied Physics in 2019, etc. His research focuses on crystal growth of AlGaN/AlN nitride-semiconductors and development of deep-UV LEDs. He is also developing terahertz quantum cascade lasers (THz-QCLs).

Abstract

Progress of deep-UV LEDs by increasing light-extraction efficiency

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AlGaN UVC light-emitting diodes (LEDs) are attracting a great deal of attentions for applications of sterilization, water purification, in the medical fields, and so on. However, the wall-plug efficiency (WPE) of the UVC LED is still much smaller than that of blue LEDs, and the increase of WPE is a recent main subject for an AlGaN UVC LED. The main cause for reducing WPE is a significant reduction in light-extraction efficiency (LEE) owing to a heavy light absorption by p-GaN contact layer.

In the previous approach, we achieved dramatic increase of the external quantum efficiency (EQE) of 275 nm UVC LED by introduced a transparent p-AlGaN contact layer, a highly-reflective (HR) p-type electrode, an AlN template grown on patterned sapphire substrate (PSS) and a lens like mold, and obtained the EQE of 20.3 % due to increase in LEE. We also obtained the maximum WPE of 10.8 % for a 280 nm UVC LED under the injection current below 30mA for the LED with transparent p-AlGaN contact layer.

Far-UV light with a wavelength shorter than 230 nm are harmless to human body and have a strong effect for virus inactivation, and are attracting much attention as a light source for anti-virus measures "in manned spaces". We developed 230 nm LED panel for conducting the inactivation of the SARS-COV-2 virus. The EQE drops rapidly in the wavelength shorter than 250 nm, so, we tried to increase the efficiency and output power of the 230 nm LEDs. AlGaN-based 230 nm LEDs were grown on a sapphire/AlN templates by a low pressure MOCVD. We have fabricated 1.1 x 1.2 mm flip-chip LEDs mounted on a ceramic square sub-mount after the process of the n-electrode of V/Al/Ni/Au and the p-electrode of Ni/Au. Quartz lenses (NGK Insulators Ltd.) were also attached to the ceramic sub-mount. The EQE and output power of the 232 nm LED were significantly increased by introducing "polarization doped transparent p-type contact layer" and demonstrated to be 0.53% and 3.2 mW in the maximum values, respectively. We mounted 42 pieces of 230 nm LEDs in parallel to produce a panel with an equivalent output power to 14.7 mW. The radiation pattern of the LED panel was improved drastically by attaching the lenses. We also conducted the SARS-COV-2 virus inactivation demonstration using the 230 nm LEDs at the same time.

We also demonstrated the LEE increase of the 230 nm and 280 nm LEDs by introducing the reflective photonic crystals (R-PhCs) fabricated on the p-contact layers.

References:

[1] H. Hirayama, N. Maeda, S. Fujikawa, S. Toyota and N. Kamata, "Recent progress and future prospects of AlGaN-based high-efficiency deep-ultraviolet light-emitting diodes", Jap. J. Appl. Phys. (Selected Topic), vol. 53, pp. 100209 1-10 (2014).

[2] T. Takano, T. Mino, J. Sakai, N. Noguchi, K. Tsubaki and H. Hirayama, "Deep-ultraviolet light-emitting diodes with external quantum efficiency higher than 20% at 275 nm achieved by improving light-extraction efficiency, Applied Physics Express, Vol. 10, No. 3, pp.031002-1-4, (2017).

[3] Y. Kashima, N. Maeda, E. Matsuura, M. Jo, T. Iwai, T. Morita, M. Kokubo, T. Tashiro, R. Kamimura, Y. Osada, H. Takagi and H. Hirayama, "High-external quantum efficiency (10%) AlGaN deep-ultraviolet light emitting diodes achieved by using highly reflective photonic crystal on p-AlGaN contact layer", Applied Physics Express, vol. 11, pp. 012101 1-4, (2018).