Development of Sustainable Smart Society via Transformative Electronics

[*]H. Amano, Y. Robin, S. Y. Bae, K. Nagamatsu, M. Kushimoto, M. Deki, T. Nishitani, D. Sato, A. Tanaka, S. Nitta, Y. Honda, and M. Pristovsek
Nagoya University, Nagoya, Japan
[*]*amano@nuee.nagoya-u.ac.jp*
Keywords GaN, blue LEDs, DUV LEDs, power devices, transformative electronics

Nowadays, electronics is everywhere and especially in advanced system designed to transform various kind of energy into another form and vise versa, operating under different mode such as DC/AC, AC/AC, and DC/DC. Whatever the primary and secondary form of the energy – chemical, biologic, mechanic or electromagnetic – an efficient energy transformation is one of the highest-priority issues for electronics.

I believe that group III nitride semiconductors are the most promising materials for this purpose. So far, GaN and related nitride materials have had a major impact on human lives. Their most important applications are based on the blue LEDs. Portable games machines and cellular or smart phones are very familiar items. Until the end of the 1990's, all these devices had monochrome displays. Nowadays people can enjoy full-color portable games thanks to blue LEDs. All LCD displays including televisions and PCs are illuminated by nitride based back light LEDs. However, the applications of blue LEDs are not only limited to displays. In combination with phosphors, they can act as a white light source and be used in more efficient general lighting. For instance, in Japan, about three-quarters of general lighting systems composed of incandescent and fluorescent lamps will be replaced with LED lamp systems by 2020. This will reduce the total electricity consumption by 7%, corresponding to a saving of 1 trillion yen per year.

AlGaN-based deep-UV LEDs are effective for the sterilization and purification of water. In 2015, UNICEF reported that 663 million people still lack access to safe drinking water and 2.4 billion people do not use safe sanitation facilities. New water sterilization and purification systems have been commercialized, in which high-power DUV LEDs are installed. Other applications of DUV LEDs include chemical and biological agent detection, space communication, high capacity data storage, curing of resins and inks, detecting counterfeit money, photolithography, and dermatology.

This material system is also promising for electron devices. In mobile or smart phone base stations, microwave and millimeter-wave amplifiers employing GaAs-based heterojunction field-effect transistors (HFETs) are being replaced with those employing GaN-based HFETs because of their capability of higher-power operation. GaN and related materials are thought to have potential use for high-frequency transistors that can be operated with a frequency over 100 GHz. By replacing Si-based power devices such as insulated gate bipolar transistors or super-junction MOSFETs with GaN-based power devices, the average efficiency of inverters or converters can be improved from 95% to more than 99% in principle. As a result, we can expect an additional 9.8% reduction of electricity consumption in Japan.

In addition, a new application of this material system has recently been proposed: as a photocathode or electron emitter. Compared with conventional GaAs photocathodes, GaN and InGaN photocathodes have much longer lifetimes and higher quantum yields. Short (micro- to nanosecond-level) high-power pulsed operation is possible, which is very promising for observing the blurring of moving objects.

To realize a sustainable smart society based on nitride semiconductor devices and systems, several problems must be solved. In this presentation, I would like to discuss the current status of our understanding of nitride semiconductors, especially the problems that have to be solved, and the future prospects of these material systems.