NAIST® Research Highlights

Nara Institute of Science and Technology | **Surface and Materials Science Laboratory** www.naist.jp/en

Semiconductors

120-fold boost in photoluminescence

Analysing and refining semiconductor surfaces dramatically increases the efficiency of luminescent devices

Careful preparation of semiconductor surfaces can greatly enhance the efficiency of semiconductor materials widely used in light-emitting diode (LED) displays and many other applications, according to research conducted at NAIST in Japan. "Luminescence efficiencies can be increased by more than 100 times," says Ken Hattori, one of the researchers in the study.

Hattori and colleagues at NAIST, working with collaborators at Osaka University, investigated the semiconductor gallium nitride. "Blue light from gallium nitride is now used everywhere in displays and other applications," says Hattori. However, typically only a very thin surface region — no deeper than a few hundred nanometres — emits light. This is because material near the surface reabsorbs light created deeper in the semiconductor.

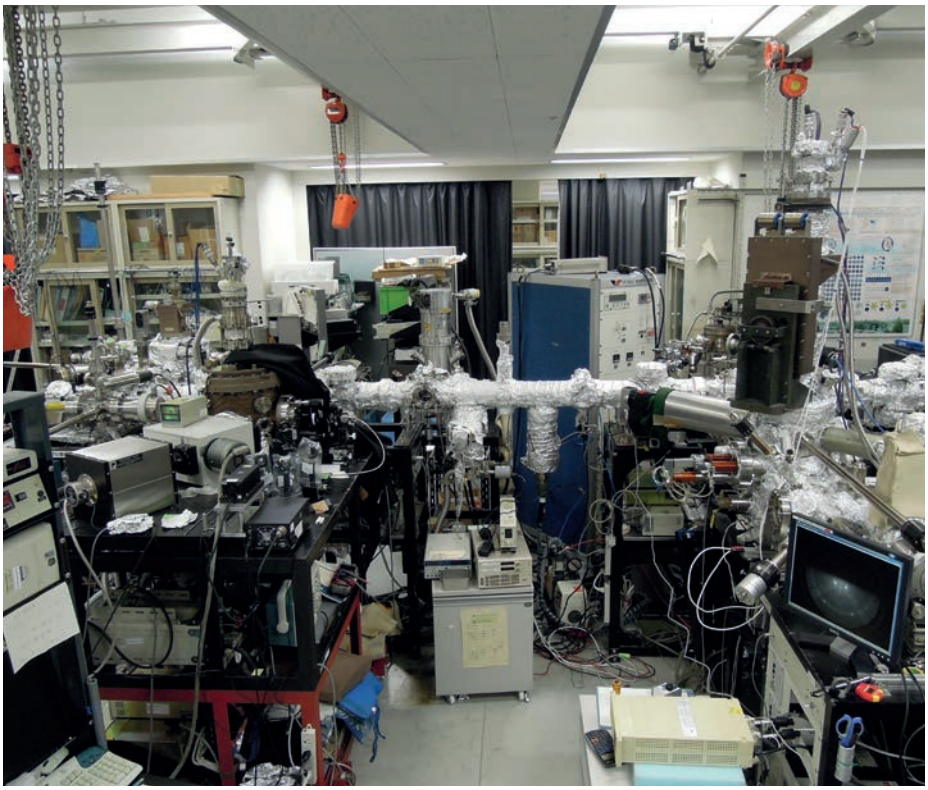
> **"Improving the quality of the layers near the gallium nitride surface will be key to making much higher performance luminescence devices."**

Mechanical polishing is currently the final stage in the commercial production of gallium nitride crystals, but this process can damage layers in the crucial region near the surface. The relationship between the quality and chemistry of the surface layers, and the material's luminescence efficiency, had not been well studied, a deficiency this research addressed.

The team used sophisticated surface-science techniques to examine the effects of removing physically damaged layers and oxide-containing layers under ultrahigh vacuum conditions. These techniques included specialized chemical etching and physical treatments with ultrapure water and gas. The researchers also investigated the role of hydrogen contamination, since hydrogen can penetrate crystals from solutions used in their production.

The team found that removing physically damaged layers and oxides near the surface and reducing the concentration of hydrogen in the crystals resulted in an approximately 120-fold improvement in photoluminescent efficiency[1]. While semiconductor manufacturers have already attempted to remove damaged and oxide-containing layers, they used a less sophisticated process that is clearly much less efficient than that developed by the NAIST team and their colleagues.

"Improving the quality of the layers near the gallium nitride surface will be key to making much higher performance luminescence devices," explains Hattori. Given the plethora of LEDs and similar systems in all areas of modern technology, this research could lead to considerable industrial and economic benefits. The researchers believe that the findings could be applied to other semiconductor materials. Their next step is to conduct similar studies on other semiconductors to see if the striking enhancements achieved with gallium nitride can be replicated more generally. NAIST has one of the biggest complex surface-analysis systems in the world (see figure). "This gives us significant advantages," says Hattori.



The NAIST complex surface-analysis system is one of the biggest and most sophisticated in the world.

Reference

1. Hattori, A. N., Hattori, K., Moriwaki, Y., Yamamoto, A., Sadakuni, S. *et al.* Enhancement of photoluminescence efficiency from GaN(0001) by surface treatments. *Japanese Journal of Applied Physics* **53,** 021001 (2014).

More information about the group's research can be found at the Surface and Materials Sciences Laboratory webpage:
http://mswebs.naist.jp/LABs/daimon/index-e.html