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Flexible UV sensors could be used in wearables

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To enable the development of wearable devices that possess advanced ultraviolet (UV) detection functions, scientists from Nanyang Technological University, Singapore (NTU Singapore) have created a new type of light sensor that is both flexible and highly sensitive. Their work has been published in the journal *ACS Nano*.

While invisible to the human eye, UV rays surround us in our environment, and excessive exposure can cause health issues including skin cancer and premature skin ageing. The intensity of UV rays is typically reported through an index during weather reports, but a wearable device — such as a T-shirt or watch that monitors the actual personal UV exposure throughout the day — would be a more useful and accurate guide for people seeking to avoid sun damage.

UV light sensors, also known as photodetectors, are used in a wide range of systems, from smartphones to biomedical imaging. Over the past decades, gallium nitride (GaN) has gained prominence as the ideal material to fabricate UV light sensors, largely due to its superior properties in emitting, regulating, transmitting and sensing light. However, most GaN-based UV sensors today are built on rigid layers, limiting their use in flexible and wearable products.

While researchers elsewhere have developed flexible GaN-based UV sensors, they have not attained the level of performance required for state-of-the-art use. Two of their biggest challenges are low responsivity and low sensitivity.

Overcoming limitations

The NTU team overcame these constraints by creating their flexible UV light sensors on a semiconductor wafer measuring 20 cm in diameter, using free-standing single-crystalline layers of GaN and aluminium gallium nitride (AlGaN), arranged using membranes that consist of two different thin semiconductor layers (heterostructure membranes).

This type of semiconductor structure, which can be fabricated using existing industrial compatible methods, allows the material to be easily bent, making it suitable for use in flexible sensors. At the same time, the chemical composition of the material changes with depth, meaning that high performance is maintained even when it comes under strain.

In lab tests, the NTU flexible UV light sensors created using the novel combined AlGaN and GaN operated at exceedingly high levels of responsivity and sensitivity. Subjected to multiple bending and high temperature tests, they also maintained good performance.

Under a range of external strains (compressive, flat, and tensile), the sensors recorded a responsivity level of 529–1340 ampere/watt (unit used to measure the ability of a device to transfer an optical signal to an electrical signal), which is about 100 times higher than existing UV sensors. This responsivity remained stable after 100 cycles of repetitive bending, demonstrating the sensors' potential to be integrated into wearables.

UV-enabled wearable tech

Assistant Professor Kim Munho, the lead researcher on the study, said the high performance of the flexible UV light sensors proves that it would be feasible to manufacture large-scale lightweight and flexible electronics for use in future relevant light-based applications. The team's achievement could also lead to significant advances in UV optoelectronic devices and circuits, he said, as product engineers could now look forward to developing UV-enabled wearable systems.

"While the performance of the rigid form of GaN-based UV light sensors has been greatly improved with various structural innovations over the past years, a flexible version remains in its infancy and their performance is far behind that of the rigid counterparts," Asst Prof Kim said.

"Our high-performance flexible UV light sensors that we have created pave the way forward for a wide range of future wearable applications, such as in personal smart health monitoring, where people can accurately measure their UV exposure levels throughout the day to reduce their risk of skin cancer."

The project to develop the flexible UV light sensors took the NTU team two years of design, fabrication and testing. Moving forward, the researchers are looking to devise eye-type UV imagers and other applications using their innovation.

Image credit: NTU Singapore