Research team develops a washable, transparent, and flexible OLED with MXene nanotechnology

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Transparent and flexible displays, which have received a lot of attention in various fields including automobile displays, bio–health care, military, and fashion, are in fact known to break easily when experiencing small deformations. To solve this problem, active research is being conducted on many transparent and flexible conductive materials such as carbon nanotubes, graphene, silver nanowires, and conductive polymers.

A joint research team led by Professor Kyung Cheol Choi from the KAIST School of Electrical Engineering and Dr. Yonghee Lee from the National Nano Fab Center (NNFC) announced the successful development of a water-resistant, transparent, and flexible OLED using MXene nanotechnology. The material can emit and transmit light even when exposed to water.

This research was published as a front cover story of *ACS Nano* under the title "Highly Air-Stable, Flexible, and Water-Resistive 2D Titanium Carbide MXene-Based RGB Organic Light-Emitting Diode Displays for Transparent Free-Form Electronics."

MXene is a 2D material with high electrical conductivity and optical transmittance, and it can be produced on a large scale through solution processes. However, despite these attractive properties, MXene's applications were limited as a long-term electrical device due to its electrical properties being degraded easily by atmospheric moisture and water. The material was therefore unable to be systemized into the form of a matrix that can display information.

Professor Choi's research team used an encapsulation tactic that can protect materials from oxidation caused by moisture and oxygen to develop a MXene-based OLED with a long lifespan and high stability against external environmental factors. The research team first focused

on analyzing the degradation mechanism of MXene's electrical conductivity, and then concentrated on designing an encapsulation membrane.

The team blocked moisture and provided flexibility through residual stress offset, ultimately producing a double-layered encapsulation membrane. In addition, a thin plastic film with a thickness of a few micrometers was attached to the top layer to allow washing in water without degradation.

Through this study, the research team developed a MXene-based red(R)/green(G)/blue(B) OLED that emits a brightness of more than 1,000 cd/m^2 that is detectable by the naked eye even under sunlight, thereby meeting the conditions for outdoor displays. As for the red MXene-based OLED, the researchers confirmed a standby storage life of 2,000 hours (under 70% luminescence), a standby operation life of 1,500 hours (under 60% luminescence), and a flexibility withstanding 1,000 cycles under a low curvature of under 1.5mm.

In addition, they showed that its performance was maintained even after six hours of immersion under water (under 80% luminescence). Furthermore, a patterning technique was used to produce the MXene-based OLED in the form of a passive matrix, and the team demonstrated its use as a transparent display by displaying letters and shapes.

Ph.D. candidate So Yeong Jeong, who led this study, said, "To improve the reliability of MXene OLED, we focused on producing an adequate encapsulation structure and a suitable process design." She added, "By producing a matrix-type MXene OLED and displaying simple letters and shapes, we have laid the foundations for MXene's application in the field of transparent displays."

Professor Choi said, "This research will become the guideline for

applying MXene in electrical devices, but we expect for it to also be applied in other fields that require flexible and transparent displays like automobiles, fashion, and functional clothing. And to widen the gap with China's OLED technology, these new OLED convergence technologies must continue to be developed."

More information: So Yeong Jeong et al, Highly Air-Stable, Flexible, and Water-Resistive 2D Titanium Carbide MXene-Based RGB Organic Light-Emitting Diode Displays for Transparent Free-Form Electronics, *ACS Nano* (2023). DOI: 10.1021/acsnano.3c00781

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