Thin-Film Device Laboratory (2023)
Chief Scientist: Takao Someya (Ph.D.)

(0) Research field

CPR Subcommittee**:** Engineering

Keywords: Organic Electronics, Organic solar cells, Flexible electronics, Printing technology, stretchable conductors

(1) Long-term goal of laboratory and research background

Our laboratory is aiming to develop novel applications of thin-film devices such as organic electronics as well as to explore their fundamental study. More specifically, electronic and/or photonic devices are integrated on the ultra-thin films or rubber sheets to produce next-generation information devices having excellent mechanical flexibility. These flexible devices are cooperatively linked with state-of-the-art silicon technologies such as ultralow power wireless chips and applied to flexible systems. Moreover, by utilizing the biocompatible electronics such as flexible devices, emerging region that fuses the machine and the biological will be investigated to advance unique bio-medical and robotics applications. Furthermore, the rapid prototyping with the technique of digital fabrication will be utilized to establish various kinds of new systems and services that support humans and consequently the new manufacturing parading that can respond to rapid changes of society and meet their needs will be realized.

(2) Current research activities (FY2023) and plan

(A-1) Ultra-Thin Organic Solar Cells for Long-Term Operation Underwater

Organic solar cells, known for their exceptional flexibility, have gained attention as a promising power source for wearable sensors. In such applications, waterproof properties are essential since it is inevitable for moisture to come into contact with clothing and skin in daily life. However, there has been no encapsulation technology that can completely waterproof these ultra-thin organic solar cells while maintaining their flexibility. This necessitated a fundamental improvement in the structure of organic solar cells.

Our team has successfully developed an organic solar cell that combines waterproof and ultra-flexible properties. By oxidizing silver at the anode/power generation layer interface and incorporating silver oxide at the interface between the anode and the power generation layer, we succeeded in creating an organic solar cell with a "hole transport layer-free" structure, which lacks the conventional hole transport layer that is weak to water. After depositing silver directly onto the power generation layer, a 24-hour heating process in the atmosphere formed silver oxide at the interface, dramatically improving the energy conversion efficiency from 0.2% to 14.3%. This ultra-thin solar cell maintained an energy conversion efficiency retention rate of 89% even after being submerged in water for 4 hours. It also demonstrated high stability, with an energy conversion efficiency retention rate of 96% after undergoing mechanical deformation through 300 cycles of 30% compression strain and recovery underwater. Furthermore, in a test where light was introduced to generate power while submerged, continuous operation for over 60 minutes was achieved. This development is expected to significantly contribute to the future of long-term stable power applications for wearable devices, serving as an environmental energy source that can be attached to clothing.

Future plan, By applying the waterproof organic solar cell structure to other devices such as photodetectors, we aim to develop wearable sensors that can operate underwater. Additionally, we plan to expand this technology to organic solar cells where the electrode components are fabricated using a coating process.

Figure 1. Ultra-Thin Organic Solar Cell Capable of Long-Term Operation Underwater

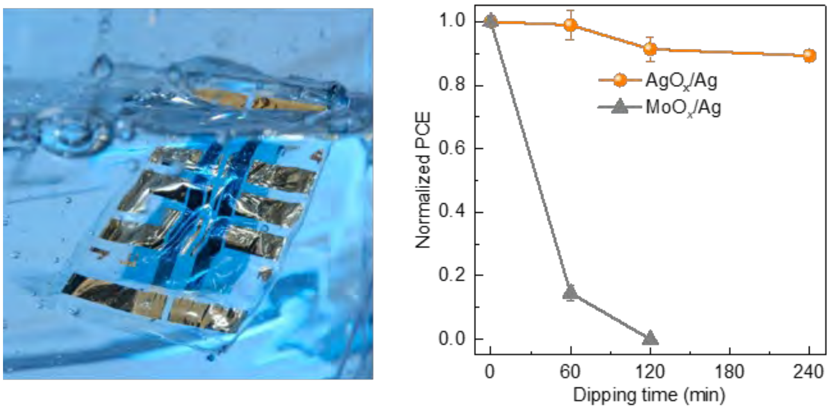

Figure 2. Changes in Characteristics of Ultra-Thin Organic Solar Cells After Water Immersion

(Left) The ultra-thin organic solar cell immersed in water. (Right) The relationship between immersion time and energy conversion efficiency retention rate. In conventional devices using MoOx/Ag, the energy conversion efficiency retention rate drops significantly to below 20% after 60 minutes. In contrast, devices using AgOx/Ag maintain a high energy conversion efficiency retention rate of 89% even after 240 minutes.

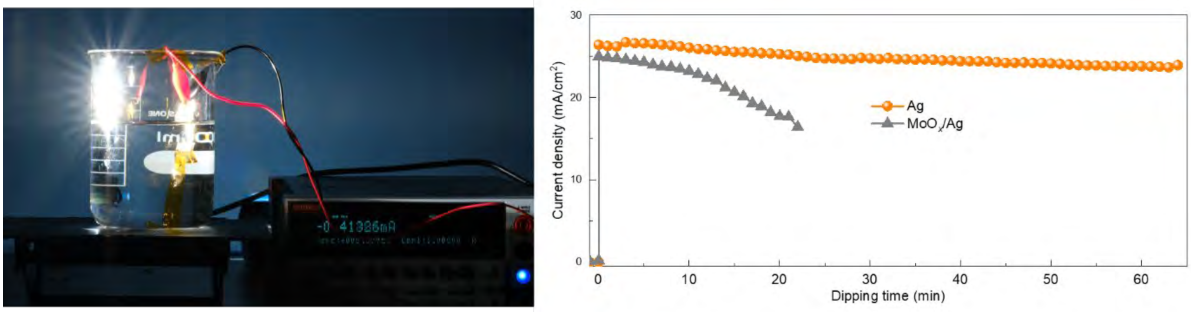

Figure 3. Operation Test of Ultra-Thin Organic Solar Cell Underwater

(Left) Actual underwater operation test. The ultra-thin organic solar cell is immersed in water, and simulated sunlight is applied from the side while measuring the short-circuit current value. (Right) Changes in short-circuit current density (JSC) over time during underwater operation. In conventional devices using MoOx/Ag, the current density rapidly decreases from 25 mA/cm^2 to 15 mA/cm^2 within 20 minutes. In contrast, devices using AgOx/Ag maintain a high current density, only decreasing slightly from 27 mA/cm^2 to 25 mA/cm^2 even after 60 minutes.

(3) Members

(Chief Scientist)
Takao Someya
(Senior Research Scientist)
Kenjiro Fukuda
(Research Scientist)
Sunghoon Lee
(Postdoctoral Researcher)
Lulu Sun
Joo Sung Kim

(4) Representative research achievements

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2. R. Guo, W. Wang, M. Takakuwa, K. Fukuda, T. Someya, "In Silico Design of Freeform Solar Cell Structures from High-Throughput Artificial Intelligence-Generated Configurations", **Solar RRL**, 7, 2300594 (2023).
3. S. Park, M. Takakuwa, K. Fukuda, S. Lee, T. Yokota, T. Someya, "Toward ultraflexible organic electronic devices", **MRS Bulletin**, 48, 999-1012 (2023).
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Laboratory Homepage
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