Thin-Film Device Laboratory
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 (FY2019) and plan (until Mar. 2025)

Activity 1: Dramatical Improvement of Storage Stability of Ultra-thin, highly efficient Organic Solar Cells.

Flexible organic photovoltaics (OPVs) are promising power sources for wearable electronics. However, it is challenging to develop a simple approach without complicated processes to fabricate OPVs with >12% efficiency, good environmental stability, and areal scalability.

Here we achieved ultra-thin organic solar cells having high power conversion efficiency and storage stability. We developed a new active layer film having excellent thermal stability and high efficiency. Furthermore, we developed a post-annealing process to improve the carrier injection between the active layer and the hole-transport layer. Fabricated ultra-thin organic solar cell (thickness: 3 micrometers) exhibits both high energy conversion efficiency of 13% and long-term storage stability of less than 5% deterioration after 3,000 hours of storage in the air. This corresponds that the energy conversion efficiency is improved by about 1.2 times and the long-term storage stability is improved by 15 times compared with the past maximum value.

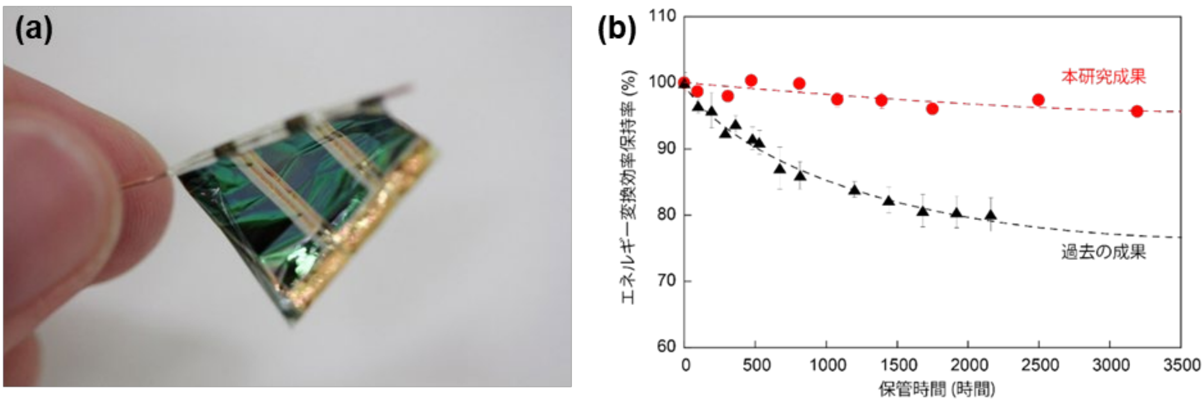

Fig. 1 (a) A photograph of ultra-thin organic solar cells having high efficiency and stability. (b) Power conversion efficiency (PCE) retention as a function of storage time.

Activity 2: Highly Stretchable Conductors with Combined Materials of Conductive Nanowires and Stretchable Polymer Nanofinbers

On-skin electronics require conductive, porous, and stretchable materials for a stable operation with minimal invasiveness to the human body. However, porous elastic conductors that simultaneously achieve high conductivity, good stretchability, and durability are rare owing to the lack of proper design for good adhesion between porous elastic polymer and conductive metallic networks.

Here we developed a manufacturing method of porous nanomesh type stretchable conductors using a combination material of highly conductive silver nanowires (Ag NW) and highly stretchable polyurethane nanofibers (PU NF). The prepared conductors have high conductivity (9190 S cm^{-1}), high stretchability (310%), and excellent cyclic durability (resistance change of less than 100% after 1000 cycles of deformation) simultaneously. Stretchability of conductive Ag NW was supported by NF with chemical bonding between these two different materials. The stretchable conductors can be directly adhered to a human skin and used as a strain sensor or conductive wiring.

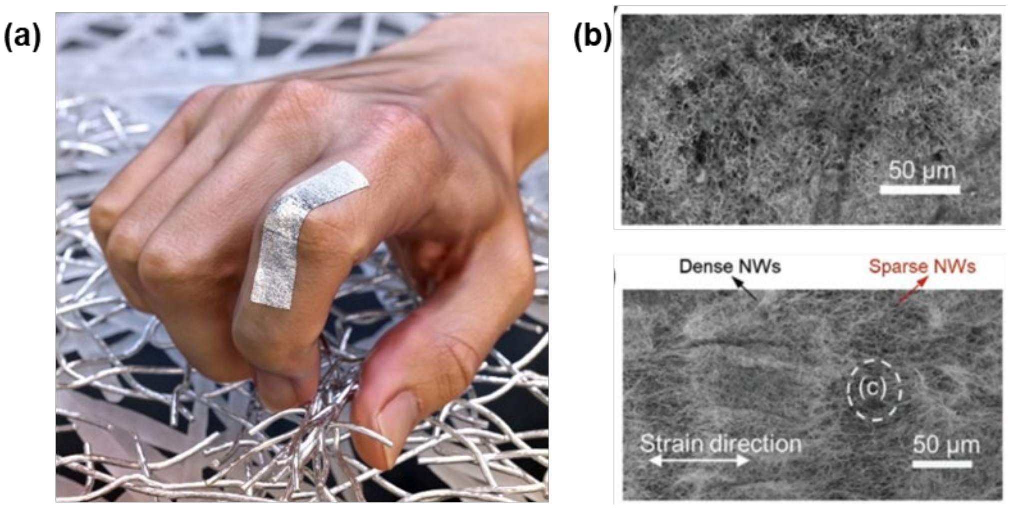

Fig. 2 (a) A schematic illustration of a stretchable conductor adhered to human skin. (b) SEM images of stretchable conductor with no strain (top) and 100% tensile strain (bottom).

Plan

Since the basic research results on ultra-thin organic solar cells and stretchable conductors were obtained, we will expand to research on the integration of energy storage devices and solar cells. After building a flexible and lightweight energy harvesting/storage system, we will begin to establish high-throughput manufacturing technology for electronic devices using printing technologies. After that, we will pursue system-level integration research including sensors, etc., and aim to contribute to the fields such as soft robots and biometric sensors.

(3) Members as of March, 2020

(Chief Scientist)
Takao Someya

(Senior Research Scientist)
Kenjiro Fukuda

(Postdoctral Researcher)
Steven Rich

(Junior Research Associate)
Zhi Jiang

(Student Trainee)
Jiabin Wang

(4) Representative research achievements

1. Highly Stretchable Metallic Nanowire Networks Reinforced by the Underlying Randomly Distributed Elastic Polymer Nanofibers via Interfacial Adhesion Improvement", Zhi Jiang, Md Osman Goni Nayeem, Kenjiro Fukuda, Su Ding, Hanbit Jin, Tomoyuki Yokota, Daishi Inoue, Daisuke Hashizume, Takao Someya, , Advanced Materials, 31, 1903446 (2019).
2. "Organic Photovoltaics: Toward Self-Powered Wearable Electronics", Kilho Yu, Steven Rich, Sunghoon Lee, Kenjiro Fukuda, Tomoyuki Yokota, and Takao Someya, Proceedings of the IEEE, 107, 2137-2154 (2019).
3. "Ultrathin Organic Electrochemical Transistor with Nonvolatile and Thin Gel Electrolyte for Long - Term Electrophysiological Monitoring", Hyunjae Lee, Sunghoon Lee, Wonryung Lee, Tomoyuki Yokota, Kenjiro Fukuda, Takao Someya, *Advanced Functional Materials*, 29, 1906982 (2019).
4. "Efficient and Mechanically Robust Ultraflexible Organic Solar Cells Based on Mixed Acceptors", Wenchao Huang, Zhi Jiang, Kenjiro Fukuda, Xuechen Jiao, Christopher R. McNeill, Tomoyuki Yokota, Takao Someya, *Joule*, 4, 128-141 (2020).
5. "Highly efficient organic photovoltaics with enhanced stability through the formation of doping-induced stable interfaces", Zhi Jiang, Fanji Wang, Kenjiro Fukuda, Akchheta Karki, Wenchao Huang, Kilho Yu, Tomoyuki Yokota, Keisuke Tajima, Thuc-Quyen Nguyen, and Takao Someya, , Proceedings of the National Academy of Sciences of the United States of America, 117, 6391-6397 (2020).

Laboratory Homepage
https://www.riken.jp/en/research/labs/chief/thin_film_device/index.html
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