【Grant-in-Aid for Scientific Research (S)】

Flexible imaging systems integrated with power sources for high-precision measurement of biological signals

Principal Investigator	The University of Tokyo, Graduate School of Engineering, Professor SOMEYA Takao	Researcher Number:90292755
Project Information	Project Number: 22H04949 Keywords: Imager, Organic photodetector, Low-temperature poly-silicon, Pulse wave	Project Period (FY): 2022-2026

Purpose and Background of the Research

●Outline of the Research

As wearable devices become more advanced and multifunctional, their primary use is rapidly shifting from "seeing" information on a display to "measuring" biological information as a sensor. However, non-invasive biological signal measurement by existing wearable devices has a problem in that measurement accuracy deteriorates significantly during activity. For example, although reflection waves of pulse signals can be easily measured with a wristband device at rest, they cannot be measured during activity. The establishment of technology that can measure medical-grade biological signals with high accuracy during exercise and daily activities is awaited.

The purpose of this study is **to clarify an ultimate performance of hybrid flexible imager consisting of organic and inorganic semiconductors and to demonstrate that biological signals can be measured with high medical-grade precision during activity**. Specifically, the high-resolution and high-speed flexible imager will be fabricated by vertically integrating an active matrix of thin-film transistors made of low-temperature polysilicon (LTPS), an inorganic semiconductor, and a photodetector made of a conductive polymer, an organic semiconductor, as the photosensitive layer, on the same polymer substrate. This imager's electrical performance, mechanical durability, and environmental stability will be dramatically improved and applied to wearable sensors to measure pulse waves (photoplethysmogram) during activity to achieve medical-grade measurement accuracy that can even analyze the time variability of blood pressure

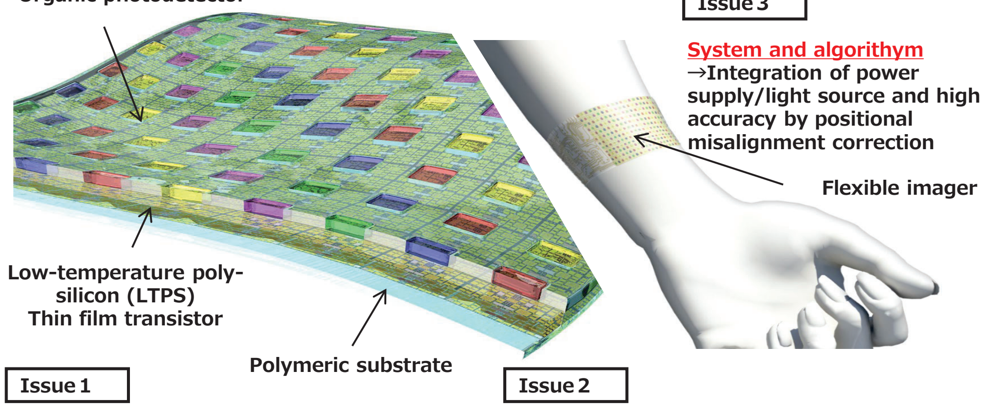

Figure1 Three main issues in this study

The first issue is to improve the sensitivity of the sensor. To measure tiny changes without being affected by noise generated during operation, the photodetector should be more sensitive to increase the signal intensity. Higher efficiency increases the photocurrent, which also speeds up the imager's operation. In addition, the spatial resolution can be increased because the photosensitive area of one cell can be reduced while maintaining the signal-to-noise ratio. Furthermore, to improve image quality, crosstalk and dark current are reduced to increase the contrast ratio.

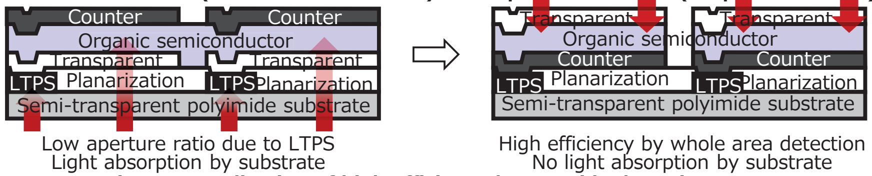

Figure 2 Realization of high efficiency by top-side detection

The second issue is to improve reproducibility by improving the mounting method. If the position of the sensor moves due to human movement, the reliability of the measurement will deteriorate. On the other hand, if the sensor is strongly fixed to the skin, pressure is applied to the inside of the body, causing pain, and inhibiting natural blood flow. To fix the sensor to the skin just right without applying external pressure, a highly durable and flexible sensor is essential. For the measurement of the signals with the area, a rigid imager cannot be fitted to curved surfaces. Therefore, the mechanical durability and environmental stability of flexible imagers should be improved.

The third issue is systemization and algorithm development. A flexible imager, a light source, and a power supply will be integrated to make a system. Even if the sensor can be worn just right without applying pressure to the skin, the positional relationship between the sensor and a soft measurement target such as a blood vessel will constantly change during activity. Therefore, motion artifacts (noise originating from human movement) remain, which cannot be removed by only improving the attachment method. This artifact will be removed by a positional misalignment correction algorithm like the anti-shake function of cameras.

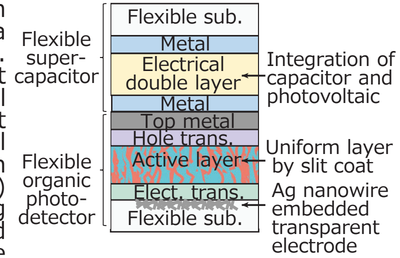

Figure 3 Power supply integration

Expected Research Achievements

The core academic questions on wearable device research are: "How can we measure biological signals during activity? And to what extent can measurement accuracy be improved?" In preparation for challenging these questions, past studies, both my own and others, have been conducted from three perspectives. The first is to improve the performance of the sensor, such as by increasing its sensitivity, so that it can detect even tiny changes; the second is to improve the reproducibility of measurement by using an attachment method that prevents misalignment, and the third is to establish a systemization and analysis method that includes a power supply. Hybrid devices that combine the advantages of mechanically flexible organic semiconductors and electrically high-performance inorganic semiconductors are extremely promising as new technology to simultaneously solve the three problems. **This study will elucidate the ultimate performance of hybrid devices with the goal of accurately measuring biological signals during activity.**

Previous studies have discriminated against whether the values of biological signals measured by wearable devices are in the normal range and have been used to guide treatment. The reason why only this discrimination method has been used is that only medical data from fixed-point observations in hospitals have been accumulated, and as a result, there are only diagnostic criteria based on such medical data. This study focuses on the continuous measurement of temporal changes in biological signals during activities of daily living and constructs the scientific theory behind the measurement technology for this purpose.

Homepage Address, etc.	http://www.ntech.t.u-tokyo.ac.jp/ someya-sec@ee.t.u-tokyo.ac.jp