Ultra-flexible Organic Imager and Sensors

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ABSTRACT

We have developed ultra-flexible and lightweight organic electronics and photonics devices with few micron substrates. Our organic imager has pixel pitches as small as 50 µm, with resolutions of up to 262 ppi. Using our ultra-flexible organic imager, we succeed to measure the spatial photoplethysmography (PPG) mapping.

1 INTRODUCTION

In order to achieve restoring functions and/or enhanced abilities, technologies to integrate electronic components with the human body have been studied intensively [1, 2]. This field is driven by welfare and biomedical applications: several products such as prosthetic limbs, cochlear implants, and pacemakers have been commercialized. Owing to the recent progresses in electronics, information, and communication technologies, devices that can be worn by people and even contacted with their skin are being functionalized electrically and promoted as wearable electronics. For example, smart glasses and contact lenses are granted electronic functions such as video recording for life-log and/or glucose monitoring, in addition to restoring vision. Furthermore, powered exoskeletons enable elderly persons to regain movement and healthy persons to enhance their ability to lift heavy objects [3]. When electronics are integrated—either worn or implanted—with the human body, it is very important to minimize invasiveness.

Given this background, technologies that introduce electronic functions to the surfaces of organs, especially skin, have attracted significant research attention. As one of the practical solutions, electronic devices are first manufactured on thin polymeric films, and then laminated on three-dimensionally curved surfaces [4–6]. Using this approach, displays and sensor arrays on foils are applied to curved surfaces such as robot bodies. Although the surfaces of biological tissues have more complicated curves than machines, the conformability of thin-film devices on foils can be improved by reducing their total thickness. The feasibility of electronic functionalization of human skins with ultrathin devices has been demonstrated by pioneering and inspiring work with Rogers and his coworkers; this is referred to as electronics tattoos or epidermal electronics [7–9]. In their work, ultrathin silicon devices and other electronics elements with a thickness of a few micrometers were directly laminated on the surface of skin. Organic thin-film devices are expected to introduce more diverse functions, which have features complementary to inorganic devices, such as large area, low cost manufacturing, and inherently mechanically softness. To make use of such functions, organic thin-film devices have been manufactured on 1-µm-thick film and exhibited mechanical flexibility with a minimum bending radius of 10 µm or less [10–12].

In this study, we have developed ultra-flexible and lightweight highly efficient, ultra-flexible, air-stable, three-color, organic light-emitting diodes (OLEDs) The total thickness of the devices, including the substrate and encapsulation layer, is only three micrometers, which is one order of magnitude thinner than the epidermal layer of the human skin. Due to the very thin substrate and neutral position, our device shows the highly flexibility and conformability. The OLEDs are directly laminated on the surface of skin and are used as indicators/displays. And also we have developed ultra-flexible organic imager which consists with a monolithically processed rectifying pixel and an organic photo diode. Our organic imager has pixel pitches as small as 50 µm, with resolutions of up to 262 ppi. Using our ultra-flexible organic imager, we succeed to measure the spatial photoplethysmography (PPG) mapping.

2 EXPERIMENT

Three-color PLEDs were manufactured on 1-µm-thick parylene films. The surface of the parylene substrate was planarized by 500-nm polyimide layer. For realizing these optical devices, indium-tin-oxide (ITO) was formed by sputter process. To reduce heat damage to the ultra-flexible substrate, the ITO was formed without substrate

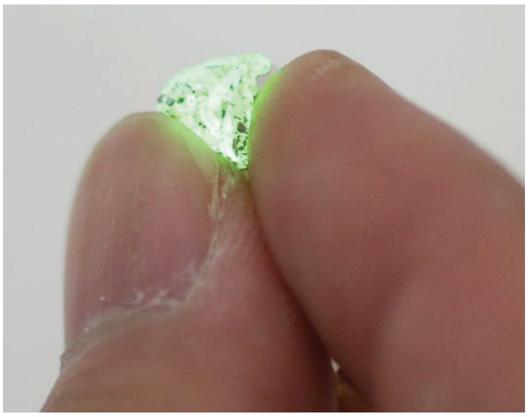

Figure 1. Ultra-flexible organic light emitting diode

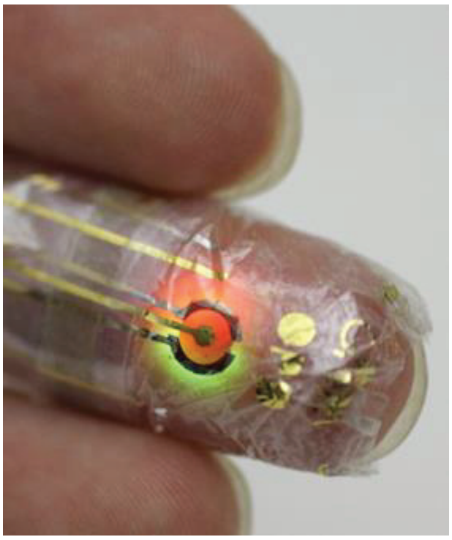

Figure 2. Ultra-flexible organic pulse oximetry

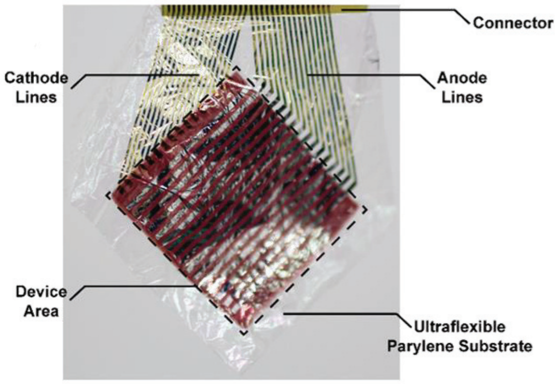

Figure 3. Ultra-flexible organic imager

heating. Thanks to a reduction of the device thickness (3 μm) and placement of the active layer in the neutral strain position, our ultrathin PLESs and OPDs show the good mechanically flexibility. Our OLEDs wasn't broken even when bent with a bending radius of 100 μm on the tip of a razor and crumpled (Fig. 1) [13].

By integrating ultra-flexible green and red OLEDs with an OPD, a flexible and conformable reflective pulse oximetry has been demonstrated. The pulse oximetry was laminated to skin using adhesive tape with a thickness of 6 μm. The total thickness was approximately 30 μm. In order to detect pulse waves and blood oxygen levels, the device was turned over and wrapped around a finger. While the driving voltage of the OLEDs was set at 5 V, the open-circuit voltage (Voc) of the OPD was monitored to measure the absorption of green and red light in the blood to the pulse (Fig. 2).

And also we have developed ultra-flexible organic imager which consists with a monolithically processed rectifying pixel and an organic photo diode. Our organic imager has pixel pitches as small as 50 μm, with resolutions of up to 262 ppi (Fig. 3) [14].

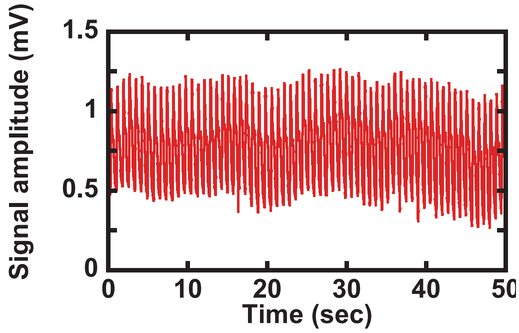

Figure 4. Output signal of organic photodetector. We succeed to detect the pulse wave.

3 RESULTS

Figure 4 shows the output signal of our ultra-flexible organic photodetector. We wrapped the device around the finger and measure the output voltage of the organic photodetector. The signal shows the high S/N ratio. And also using 2 colors OLED, we succeed to detect the difference of blood oxygen ratio. In the case of 99% of oxygen ratio, the output signal of the organic photodetector was almost same when the red or green OLED was emitted. On the other hand, in the case of 90% of oxygen ratio, the output signal was dramatically decreased when the green OLED was emitted. This is because the absorption coefficient of hemoglobin and oxyhemoglobin is not same between green light and red light.

4 CONCLUSIONS

We succeed to measure the blood oxygen ratio by using our ultra-flexible organic photonic system. And also, we measured the spatial photo plethysmography (PPG) distribution by applying our high sensitive all organic ultra-flexible imager.

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