Flexible Near-infrared Organic Photodetector with a Liquid Crystalline Phthalocyanine Derivative for Photoplethysmography

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Organic semiconductors are suitable for the fabrication of flexible, wearable, and skin-conformal devices due to their characteristic soft nature and easy, large-area processability. In this study, flexible near-infrared (NIR) organic photodetectors (OPDs) (device structure: Fig. 1 (a)) were prepared on 25 μm flexible polyethylene terephthalate (PET) substrates (Fig. 1 (b)) with active layer of a liquid crystalline organic semiconductor 1,4,8,11,15,18,22,25-octaoctyl- phthalocyanine ($8H_2Pc$) and phenyl-C61-butyric acid methyl ester ($PC_{61}BM$). To compare the performance of the flexible devices with rigid devices, OPDs on top of glass substrates were also prepared and characterized.

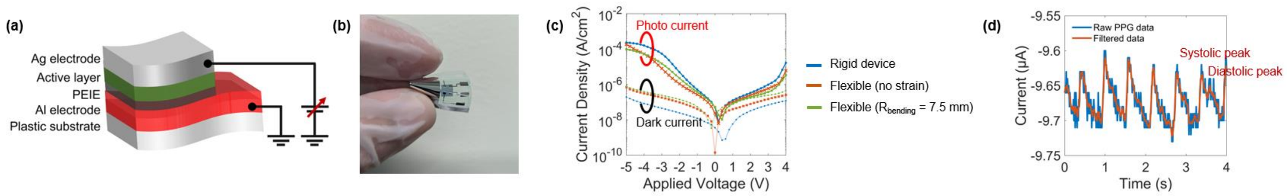

Fig. 1 (a) Schematic illustration and (b) photograph of the flexible OPD and (c) current-voltage characteristics of rigid and flexible devices with and without bending strain, and (d) photoplethysmogram observed with a rigid OPD.

As shown in Fig. 1 (c), at -5 V reverse bias, the dark current density (J_{dark}) of the flexible device was approximately 1 order higher and photo current density (J_{photo}) was slightly lower compared to that of the rigid device. This may have originated because of the relatively rougher surface of the plastic substrate resulting in defects and pinholes in the solution processed active layer. Due to these change in J_{dark} and J_{photo}, the external quantum efficiency (EQE) and shot-noise-limited detectivity (D^*_{sh}) at NIR wavelength of 740 nm of the rigid device were 12% and 2.8×10^{11} Jones, respectively, while they were 9% and 1.1×10^{11} Jones, respectively, of the flexible device. These measurements were carried out when the flexible OPD was placed flat on a glass substrate without any strain. Measurements were also taken when it was bent with a radius of 7.5 mm (thickness of the index finger of an average human subject). Even under this strain, the device performed ideally with EQE of 5% and D^*_{sh} of 5.7×10^{10} Jones indicating very good mechanical flexibility and durability of the OPD. The overall comparison of all the devices is given in Table I. This flexible OPD has the potential to be used in vital signal monitoring as demonstrated in Fig. 1 (d) where a rigid device was used to observe the photoplethysmogram signal of a human subject with NIR light of 740 nm in ambient conditions.[1]

Table I. Summary of figures of merit of NIR OPDs prepared on glass and plastic substrates. All the measurements are at 740 nm, 3.4 mW/cm² with -5 V reverse bias.

Sample name	J_{photo}/J_{dark}	R (mA/W)	EQE (%)	D^*_{sh} (Jones)
Rigid device	1.2×10^3	68.6	12%	2.8×10^{11}
Flexible device (No strain)	2.6×10^2	53.1	9%	1.1×10^{11}
Flexible device ($R_{bending}$ = 7.5 mm)	1.3×10^2	28.5	5%	5.7×10^{10}

Reference: [1] S. Kabir, Y. Takayashiki, J. Hanna, H. Iino, *Jpn. J. Appl. Phys.* 2023, **62**, SC1013.