Fast and Sensitive Near Infra-Red Photodetector Based on a Liquid Crystalline Phthalocyanine Derivative

Tokyo Tech[1], °(M1) Shahriar Kabir[1], Yukiko Takayashiki[1], Jun-ichi Hanna[1], Hiroaki Iino[1]
E-mail: kabir.s.aa@m.titech.ac.jp

Organic semiconductor devices have several advantages over inorganic semiconductor devices such as lightweight, flexibility, uniform large area film formation and low-cost fabrication. In the field of medical imaging, organic semiconductor devices can be highly effective for these distinct properties. Generally, the phthalocyanine derivatives show good absorption in the near infra-red (NIR) spectral region, making them potential candidates for the active material of NIR medical imaging sensors[1]. Among the phthalocyanine derivatives, 1,4,8,11,15,18,22,25-octaocltyl-phthalocyanine ($8H_2Pc$, shown in Fig. 1(a)) has demonstrated ambipolar high carrier mobility with maximum hole mobility of $0.2cm^2/Vs$ in the liquid crystalline phase measured by the time-of-flight technique[2]. In addition to its high carrier mobility, $8H_2Pc$ exhibits orientational anisotropy which can be utilized in vertical photodiodes to effectively increase the carrier transport in a single direction. $8H_2Pc$ is also highly soluble in common organic solvents and so it is a perfect candidate for preparing thin film devices by spin-coating method.

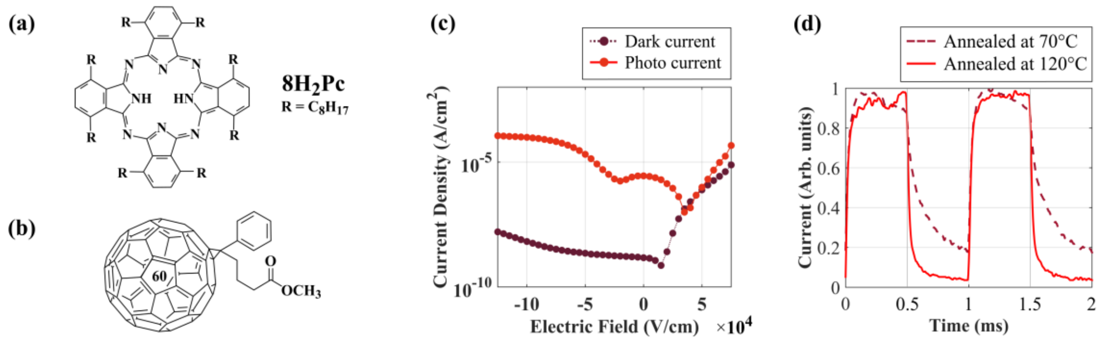

Figure 1: Chemical structures of (a) $8H_2Pc$ and (b) PCBM, (c) static and (d) dynamic photo response of the photodetectors at 740nm NIR irradiation with intensity of $8mW/cm^2$

In this work, we used a blend of $8H_2Pc$ and a fullerene derivative, 1-(3-methoxy-carbonyl)-propyl-1-1-phenyl-(6,6)C61 (PCBM, shown in Fig. 1(b)), as the active layer to prepare vertical photodiode with inverted architecture. The blend ratio of $8H_2Pc$:PCBM was 1:1 by weight and the device structure of the diode was ITO/PEIE(20nm)/$8H_2Pc$:PCBM(400nm)/MoO_3 (3nm)/Au(70nm) with an active area of $4mm^2$. The photodetector showed low dark current density, in the range of nA/cm^2, because of careful surface modification of the ITO electrode with polyethylenimine (PEIE) solution. The static and dynamic performance of the photodetector was evaluated by λ = 740nm NIR irradiation with light intensity, I_{light} = $8mW/cm^2$. The detector showed good detectivity, $D^* = (J_{ph}/I_{light})/(2qJ_d)^{1/2} = 2.6\times10^{11}cmHz^{1/2}/W$, noise equivalent power, $NEP = 2h\nu\times BW/\eta_{ext} = 5.1\times10^{-14}W/Hz^{1/2}$ and J_{ph}/J_d ratio = 1.5×10^4 at -4V bias. The rise and fall time between 10% and 90% of the steady state values of dark current and photo current was 58μsec at -6V bias. This fast response time was possible after annealing the device at 120°C, the liquid crystal phase temperature of $8H_2Pc$, as shown in Fig. 1(d). This improvement of dynamic performance after annealing indicates that liquid crystallinity of the active material is a significant factor for the good performance of this organic NIR photodetector.

References:

[1] Schechtman, B. H. and Spicer, W. E. **J. Mol. Spectrosc.** 33, 28 (1970).
[2] Iino, H. *et al.* **Appl. Phys. Lett.** 87, 132102 (2005).

© 2019年 応用物理学会