

Performance Study of Near-Infrared Organic Photodetectors based on a Phthalocyanine Derivative and a Fullerene Derivative with Different Blend Ratios

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Phthalocyanine derivatives have been historically used as dyes and pigments for their high stability which originates from the extensive structural resonance stabilization. These materials also show semiconducting properties and good absorption in the near-infrared (NIR) spectral region and so they are potential candidates for the active material of NIR medical imaging sensors. Currently a wide variety of phthalocyanine derivatives are being investigated for their suitability as the active material of NIR organic photodetectors (OPDs) and organic solar cells[1,2]. Among these derivatives, 1,4,8,11,15,18,22,25-octaocetyl-phthalocyanine (8H₂Pc, shown in Figure 1(a)) has several advantageous properties such as high ambipolar carrier mobility with maximum hole mobility of 0.2cm²/Vs in the liquid crystalline phase, high solubility in common organic solvents and two discotic liquid crystalline phases[3]. All of these suitable physical and electrical properties make 8H₂Pc a very promising organic semiconductor material for fabricating high performance OPDs.

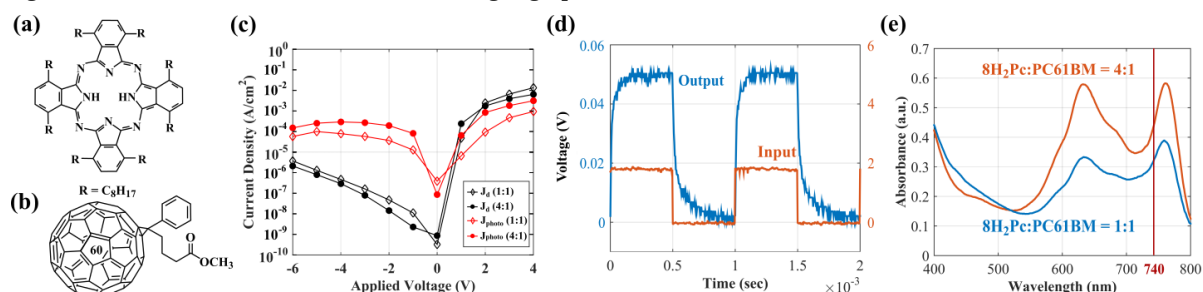


Figure 1: Molecular structures of (a) 8H₂Pc and (b) PC61BM, (c) static and (d) dynamic photoresponse of the best performing photodetector at 740nm NIR irradiation and (e) absorption spectra of the blend materials

In this work, we studied the static and dynamic performance of NIR organic photodetectors prepared with a binary blend of 8H₂Pc and a fullerene derivative, Phenyl-C₆₁-butyric acid methyl ester (PC61BM, shown in Figure 1(b)). The materials were blended in weight ratios of 4:1 and 1:1 (8H₂Pc:PC61BM) and used as the active layer to prepare vertical OPDs with inverted architecture. The device structure of the OPDs was ITO/PEIE(15nm)/[8H₂Pc:PC61BM](400nm)/MoO₃(4nm)/Au(50nm) with an active area of 4mm². The static performance of the OPDs was evaluated by $\lambda = 740$ nm NIR irradiation with light intensity, $I_{\text{light}} = 0.1\text{mW/cm}^2$. We observed that OPDs prepared with the 4:1 blend ratio showed higher specific detectivity and responsivity (shown in Figure 1(c)). The best performing device showed very good maximum specific detectivity, $D_{\text{max}}^* = (J_{\text{ph}}/I_{\text{light}})/(2qJ_{\text{d}})^{1/2} = 2.87 \times 10^{13}\text{cmHz}^{1/2}/\text{W}$, maximum responsivity, $R_{\text{max}} = 1.94\text{A/W}$ and maximum $J_{\text{ph}}/J_{\text{d}}$ ratio = 1.35×10^4 at -2V bias. The dynamic performance of the OPDs was evaluated by a 1kHz square wave of $\lambda = 740$ nm NIR irradiation with light intensity, $I_{\text{light}} = 26.5\text{mW/cm}^2$. Figure 1(d) shows the dynamic photoresponse of the prepared NIR OPDs with rise time of 84 μsec and fall time of 128 μsec at -2V bias. We think that the OPDs prepared with 4:1 blend ratio perform better because of higher absorption in the NIR region by the blend material (shown in Figure 1(e)). Therefore, in this 8H₂Pc:PC61BM blend system, PC61BM is not necessarily acting as an acceptor but it is improving the thin film morphology of the active layer. We believe that these NIR OPDs have significant prospect as practical sensors for future NIR imaging devices.

References:

- [1] Min-Soo Choi *et al.*, **Organic Electronics** 61, 164-169 (2018)
- [2] Tetsuro Hori *et al.*, **Appl. Phys. Express** 3, 101602 (2010)
- [3] Hiroaki Iino *et al.*, **Appl. Phys. Lett.** 87, 132102 (2005)