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

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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-octaocetyl-phthalocyanine (8H₂Pc, shown in Fig. 1(a)) has demonstrated ambipolar high carrier mobility with maximum hole mobility of 0.2cm²/Vs in the liquid crystalline phase measured by the time-of-flight technique[2]. In addition to its high carrier mobility, 8H₂Pc exhibits orientational anisotropy which can be utilized in vertical photodiodes to effectively increase the carrier transport in a single direction. 8H₂Pc 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) 8H₂Pc and (b) PCBM, (c) static and (d) dynamic photo response of the photodetectors at 740nm NIR irradiation with intensity of 8mW/cm²

In this work, we used a blend of 8H₂Pc 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 8H₂Pc:PCBM was 1:1 by weight and the device structure of the diode was ITO/PEIE(20nm)/8H₂Pc:PCBM(400nm)/MoO₃(3nm)/Au(70nm) with an active area of 4mm². The photodetector showed low dark current density, in the range of nA/cm², because of careful surface modification of the ITO electrode with polyethylenimine (PEIE) solution. The static and dynamic performance of the photodetector was evaluated by \( \lambda = 740\text{nm} \) NIR irradiation with light intensity, \( I_{\text{light}} = 8\text{mW/cm}² \). The detector showed good detectivity, \( D^* = (I_{\text{ph}}/I_{\text{light}})/(2qJ_{\text{d}})^{1/2} = 2.6\times10^{11}\text{cmHz}^{1/2}/\text{W} \), noise equivalent power, \( \text{NEP} = 2h\nu\times\text{BW}/\eta_{\text{ext}} = 5.1\times10^{-14}\text{W/Hz}^{1/2} \) and \( J_{\text{ph}}/J_{\text{d}} \) ratio = 1.5\times10⁴ 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 8H₂Pc, 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: