Origin of Dark Current and Detailed Description of Organic Photodiode Operation Under Different Illumination Intensities

Abstract:

Solution-processed organic-based photodetectors (OPDs) provide the opportunity to develop innovative, low cost, and large-area imaging technologies for industrial applications. However, compared to inorganic-based photodetectors, OPD devices have shown noticeably higher dark current and relatively lower sensitivity which is critical when the sensor needs to detect signals under low illumination intensities. Thus, to improve the design of OPDs, it is very important to know how opto-electrical response of the device is limited under the influences of structure, contact, and material layer properties. To analyze such limits, we employ a drift-diffusion approach to simulate a well-known and well-reproducible organic-based photodiode structure. Good agreement between current–voltage characteristics of the simulated result and experimental measurements under different illumination intensities confirms the presence of the traps is the origin of the high dark current in OPD devices. In addition, it is shown that traps have a dominant influence on the current–voltage characteristics of the device at low intensities, critical issue in several applications such as indirect X-ray detection technology. Based on this paper, to enhance OPD device performance operating in low intensities, it is recommended to put effort into processing (designing) a trap-free structure (material), rather than improving the material layer, structure, and contact properties.