DOCTORAL THESIS

Spectral tunable organic near-infrared photodetectors

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Abstract

Filter-free spectral tunable photodetectors (PDs) are critical for a plethora of applications in imaging, indoor light fidelity (Li-Fi), and light communications. The present band-selective light detection is realized by incorporating different optical filters with broadband inorganic semiconductor-based PDs. However, the use of the optical filters reduces the overall performance of these PDs and is not appliable in the emerging flexible and wearable applications.

The rapid advancement of the organic semiconductors offers an exciting opportunity for the development of high-performance filter-free spectral tunable organic photodetectors (OPDs). The development of OPDs has attracted tremendous interests because of the tailored optoelectronic properties of the π-conjugated organic semiconductors and the solution fabrication process of the OPDs. Apart from the rapid progresses made in improving the responsivity and detectivity of OPDs, the spectral properties of OPDs also receive intense attention.

This Ph.D. research work has been focused on developing a universal strategy to achieve high-performance filter-free band-selective and spectral tunable OPDs. The correlation between the optical profile and responsivity spectrum of the novel OPDs with a bilayer photoactive layer has been investigated. It suggests that the responsivity spectrum of the OPDs can be effectively modulated by managing the optical profile in the bilayer and multilayer photoactive layer.

A filter-free band-selective OPD model, comprising a bilayer shorter-wavelength light depletion layer/longer-wavelength light-absorbing layer architecture photoactive layer, has been developed. The depletion layer in the filter-free OPDs has a dual-function serving as a shorter-wavelength light-absorbing layer and a hole-transporting layer. The photodetection spectrum window of the filter-free band-selective OPDs, defined by the difference in wavelengths between

the transmission cutoff of the shorter-wavelength light depletion layer and the absorption edge of the longer-wavelength light-absorbing layer, can then be tuned over the different wavelength ranges by using an appropriate combination of the shorter-wavelength light depletion layer and the longer-wavelength light-absorbing layer.

A dual-mode OPD, having a trilayer visible light absorber/optical spacer/near-infrared (NIR) light absorber configuration photoactive layer, has been proposed. The dual-mode OPD exhibits electrically switchable NIR response operated under a reverse bias and visible light response operated under a forward bias. In the presence of NIR light, the trap-assisted charge-injection behavior at the organic/cathode interface in the OPDs operated under a reverse bias. The photocurrent is produced in the visible light-absorbing layer, enabled by the trap-assisted charge injection at the anode/organic interface under a forward bias.

The developed filter-free band-selective OPDs and electrically switchable dual-mode OPDs provided an attractive alternative optical detection technology to the conventional panchromatic and single-mode OPDs. The spectral tunable photodetection thus demonstrated offers a promising option for new OPD applications.

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