MASTER'S THESIS

Spectral-Selective Organic/Perovskite Hybrid Photodetectors

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Abstract

Spectral-selective photodetectors have attracted enormous research efforts as they can sense more than one wavelength band in a single device without integrating external colour filters, allowing them for a plethora of applications in imaging, optical communications, and biomedical imaging. Solution-processable materials, such as organic and perovskite semiconductors, are particularly suitable for fabricating spectral-selective photodetectors due to their tunable photophysical and optoelectronic properties. The solution-processed dual-band photodetectors, in previous studies, usually incorporate charge blocking layers interposed between the two active layers to realize dual-band photodetection through bias modulation. However, those interlayers commonly have negligible light absorption, causing evident spectral crosstalk due to the possibility of light penetration.

This thesis discusses the use of the light-absorbing pristine organic donor material-based interlayers, the related operational mechanisms, and the performance of the spectral-selective photodetectors. In terms of photophysical property, the interlayer minimizes the possible light penetration and thereby mitigates the spectral crosstalk by absorbing the light in the preferred wavelength range. The interlayer also realizes the dual-band photodetection in two distinct bands when the interlayer absorbs additional light beyond the absorption range of the front active layer. The pristine donor-based interlayer acts as an electron depletion layer with severely imbalanced carrier mobilities for electrons and holes, providing an energy barrier for electrons. The use of a pristine donor-based interlayer also has a unique feature to achieve dual-band photodetection, at the same time, reduces the noises in the photodetectors operated under different biases.

The performance and the operating mechanism of the proposed spectral-selective photodetectors have been analysed and supported by the first example in the thesis. The photodetectors, comprising a layer configuration of ITO/SnO_2/$FA_{0.85}Cs_{0.1}K_{0.05}PbI_3$/PTB7-

Th/PTB7-Th:COTIC-4F/ZnO/Ag, operated under a forward bias of 3.6 V, have a high responsibility of 355 mA/W over the short-wavelength range from UV to 800 nm, and that of 400 mA/W over the long-wavelength range from 800 to 1150 nm when the photodetectors are operated under a reverse bias of -3.6 V. The spectral crosstalk over the short-wavelength detection band is lowered by one order of magnitude as compared to that measured for a control device with an 80 nm thick transparent CuSCN interlayer. One order of magnitude reduction in the shot noise is observed in the photodetectors with a 700 nm thick PTB7-Th interlayer, operated under a forward bias, tripling the detectivity over the short-wavelength range.

The next part of the thesis presents the further mitigation of the crosstalk in the spectral-selective hybrid photodetectors. This is realized by using an interlayer with an absorption cut-off between the perovskite film and the organic photoactive layer. One example, comprising a layer structure of ITO/SnO_2/$FAPbBr_{1.5}Cl_{1.5}$/PBDB-T/PTB7-Th:$PC_{71}BM$/ZnO/Al, demonstrates a photo-insensitive feature over the wavelength range from 480 to 680 nm.

Taking the advantage of the unique spectral-selective feature of the hybrid photodetectors, bifacial transparent photodetectors with three detection bands are further demonstrated. Compared to the structure of the aforementioned photodetectors, the multispectral photodetectors have an upper transparent ITO contact. It has a spectrally-overlap-free dual-band photodetection function when light is incident from the glass substrate side. When the upper ITO electrode faces the incoming light, the photodetector has a broadband response behaviour. The accomplishments of the spectral-selective perovskite/organic hybrid photodetectors in this project help advance the multispectral detection photodetector technology, offering an exciting opportunity for various applications in imaging, wellness monitoring and artificial intelligence.