Chapter 5

Conclusion and Future Works

Content of this Chapter

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Conclusion and Future Scopes

5.1 Major Contributions

The main objective of this thesis is to develop some novel strategies for performance enhancement of the existing hybrid broadband photodetectors by device structural engineering and active layer material engineering. Major contributions can be summarized in the following:

Chapter 2 investigates the performance of an FTO/ZnO NRs/PCDTBT: PCBM: PbS QDs/MoOx/Ag based wideband vertical photodetector structure. The effect of the penetration of ZnO NRs into the PCDTBT: PCBM: PbS QDs on the performance improvements of the device is mainly investigated in this chapter. The ZnO NRs were allowed to enter into the active layer so that the photogenerated electrons in the active layer being very close to the NRs can be collected by the ETL very fast to reduce the dark current by reducing recombination of carriers in the active region. The combined effects of the ETL engineering, ternary nanocomposite based active material engineering and vertical structure engineering enabled to achieve high responsivities of ~ 213.77 A/W at 380 nm (UV), ~28.57 A/W at 550 nm (Visible), and ~7.22 A/W at 860 nm (NIR) as well as a high external quantum efficiency (EQE) of greater than 1000 % at a low reverse bias of -1.5V. The high EQE beyond 100% is attributed to the photomultiplication effect resulted from the induced charge tunnelling from the external circuits due to intrinsic traps at the surface of ZnO NRs near the cathode electrode.

Chapter 3 explores the merits of tetrapod shaped CdSe NCs for the first time for the performance improvement of the PCDTBT: PCBM: CdSe NCs based inorganic-organic nanocomposites based broadband UV-visible photodetectors. A vertical device structure of FTO/ZnO NRs/PCDTBT: PCBM: CdSe NCs/MoOx/Ag (similar to that considered in Chapter 2) is also used in this study. The ZnO NRs are penetrated into active layer to achieve fast collection of photogenerated electrons in the active layer as discussed in Chapter 2. Under a reverse bias voltage of -2 V, the proposed photodetector showed excellent photoresponse characteristics with a responsivity of 1.830 A/W (0.344 A/W), detectivity of $1.75\text{x}10^{12}$ ($3.3\text{x}10^{11}$) Jones, a rise time of 5.73 s (0.02 s) and fall time of 6.41s (0.14 s) at UV-375 nm (Visible-540 nm) and low light intensity of 13.1 μWcm^{-2} (41.2 μWcm^{-2}).

Chapter 4 explores the possibility of the relatively new conducting polymer PTB7 in the form of p-PTB7/n-ZnO NRs heterojunction for the UV-Visible broadband photodetector applications. The proposed vertical structure investigated in this chapter is FTO/ n-ZnO NRs/p-PTB7/MoOx/Ag where the ZnO NRs layer acts as the ETL as well as the UV absorption region while the PTB7 is used to absorb light mainly in the visible region. The main objective of this work was to replace the ternary nanocomposites of PCDTBT: PCBM: CdSe NCs (considered in Chapter 3) by a single polymer PTB7 for reducing the device cost due to the simplicity of the fabrication of the UV-Visible photodetectors. The low bandgap PTB7 polymer-based heterojunction has been used for the UV-visible photodetectors possibly for the time in this thesis. Under a relatively low reverse bias voltage of -1 V, the proposed device showed a high responsivities of ~ 307.18 A/W and ~ 33.64 A/W at 380 nm (UV) and 640 nm (Visible) wavelength respectively. The corresponding detectivities of ~ 1.56×10^{13} Jones and ~ 1.7×10^{12} Jones with the EQEs values of ~ 100.23×10^{3} %, and ~

6.51×10^3 % at 380 nm and 640 nm wavelength respectively, under a low −1 V bias. The rise time of ~ 13.8s and fall time of ~ 15s were measured from the photoresponse study of only a single cycle of the incident light wavelength 380 nm with ~ 20.07 μWcm^{-2} intensity.

5.2 Scope of Future Works

1. The degradation characteristics of the devices were not possible to study due to various difficulties during the Covid19 pandemic situation in the country. The effect of humidity on the device performance as a function of time over a period of 3-6 months may be required to investigate the performance degradation characteristics of the unpackaged device.
2. The effect of the sizes of PbS QDs and lengths of nanorods on the performance optimization may be investigated.
3. The effects of thicknesses of various layers in the proposed photodetectors on the performance optimization of all the proposed devices investigated in this thesis may be investigated.
4. The effects of various doping in the semiconducting polymers used in the active layer of various broadband photodetectors considered in the present thesis may also be taken as future research.
5. The effect of doping in the ETL and HTL layers on the broadband photodetectors may also studied in future.