CHAPTER 5

Conclusion and Future Scope

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5.1 Introduction

The basic objective of the present thesis is to investigate the spectrum selectivity and responsivity analysis of some ZnO colloidal quantum dots (CQDs) UV photodetectors. We have investigated mainly three device structures: Au/ZnO CQDs based UV Schottky photodiodes grown on Si substrates, Ag/ZnO QD/Ag MSM UV photodetector on glass substrates and ZnO NPs coated Ag/ZnO QD/Ag MSM UV photodetectors fabricated on glass substrates. The ZnO QDs layer has been used as the active layer in all the UV detectors under study. In this chapter, we will summarize the major observations presented in the various chapters of the thesis. We have also tried to outline some scopes for future works related to the areas considered in the present thesis. The thesis are summarized chapter-wise as following.

5.2 Summary and Conclusion

Chapter 1 presents a brief introduction to photodetectors, popular device structures and required semiconductor materials for the UV detection applications. The various performance parameters to characterize the overall performance of the photodetector techniques as well as size-dependent physical, electronic and optoelectronic properties of the photodetector are also briefly discussed in this chapter. A detailed literature survey on the ZnO based UV photodetectors in general and spectrum selective UV photodetectors, in particular, have been carried discussed. The literature survey shows that there is ample opportunities for research in the area of fabrication and

characterization of colloidal ZnO QDs based spectrum selective photodetectors using low-cost large-area solution processed techniques. Based on the observations of the literature survey, the future scopes of the present thesis have been outlined at the end of this chapter.

In **chapter 2** we have prepared low cost solution processed ZnO QDs and the fabrication of highly sensitive and spectrum selective Au/ZnO QDs Schottky photodiodes. The obtained results in this chapter can be summarized as follows:

- ZnO CQDs with particle size of 2.87 nm which is equivalent to the Bohr's radius have been successfully synthesized by the hot-injection method.

- The analysis of the transmittance of Au thin film and absorbance of the ZnO QDs shows a narrow window for the spectrum selective response in the UV region with FWHM of ~90 nm with respect to ~345 nm center wavelength which gives the total visible-blind UV characteristics of the photodetector.

- The photodiode has the highest responsivity and contrast ratio of 41.17 A/W and 2.289 x 10^4 respectively under the UV illumination (λ=365 nm) of 800 $\mu W/cm^2$ optical power density.

- The photodiode exhibits a fast response (73.1 ms) and quick full recovery (17.85 ms) at an applied bias of -5 V. This shows that the ZnO QDs based Schottky photodiodes under study have fast reliable detection properties under repeated illumination of UV light pulses.

Chapter 3 investigates the fabrication and characterization of a low-cost solution processed ZnO QDs based MSM spectrum selective photodetector on glass substrates.

The device uses an Ag interdigitated electrode structure on the ZnO CQDs layer but with no additional layer for optical filtering. The measured results in this chapter can be summarized as following:

- The ZnO CQDs annealed in the ambient environment at 450 ºC has been used as the active layer in the detector. The UV MSM photodiode shows a FWHM of ~49 nm with peak responsivity and detectivity of ~15.04 A/W and ~1.97×10^{14} $cmHz^{1/2}W^{-1}$ at 2 V for ~360 nm respectively.

- The analysis of the time response characteristics of spectrum selective ZnO QDs based UV MSM detectors give the rise time and recovery time of 7.2 sec and 18.5 sec respectively.

- The bandgap of the ZnO QDs is observed to be decreased from 3.23 eV to 3.13 eV with the change in the annealing temperature from 450 ºC to 600 ºC due to the increase in particle size. This shows the spectrum selectivity of the ZnO QDs can easily be tuned in the UV region by changing annealing temperature of the ZnO QDs active layer.

Chapter 4 demonstrates the filtering and scattering effects on the spectrum selectivity and responsivity of the ZnO nanoparticles (NPs) coated Ag/ZnO QD/Ag photodetector under front and back illuminations respectively. The measured results can be summarized as following,

- The ZnO NPs layer acts as a filter layer under front illumination to provide a spectrum selectivity with FWHM of ~25 nm and responsivity of ~6 A/W at an applied bias of 2 V. This shows that the ZnO NPs layer acts as the filtering layer under front illumination which improves the selectivity (i.e. reduces the FWHM)

at the cost of reduced responsivity as compared to the results discussed in Chapter-3

- Under back illumination, the ZnO NPs coated ZnO CQDs based MSM UV detector gives the responsivity ~20 A/W with the FWHM of ~49 nm at an applied bias of 2 V. The responsivity is enhanced under back illumination by more than three times with respect to the device without a ZnO NPs layer considered in Chapter-3 while maintaining the same FWHM of 49 nm. The enhancement in the responsivity under back illumination is attributed to the scattering effects of ZnO NPs layer. A part of UV light passing through the ZnO QDs layer after absorption is scattered and entered into the active layer for secondary absorption to enhance the photocurrent and responsivity of the device.

- The use of the ZnO NPs layer in the photodetectors can provide an additional flexibility for improving either the spectrum selectivity at the cost of reduced responsivity under front illumination or the responsivity of the detector with fixed selectivity under back illumination.

  The proposed photodetector exhibits moderate rise time of 3.5 sec and decay time of 6.3 sec at an applied bias of 2 V. The detection properties of the photodetector are found to be stable and reproducible under both the front and back UV illuminations.

5.3 Future Scope of the Thesis

This thesis presents some investigations on the electro-optical characteristics of ZnO QDs based spectrum selective photodetectors. Based on the constraints and

limitations of the works carried out in this thesis, we will discuss some future scopes of works as given below:

- Doped colloidal ZnO QDs of multiple materials can be explored for band tunable spectrum selectivity from deep UV to blue visible region.
- The ZnO QDs as an n type semiconductor can be explored as an electron transport layer in the field of solar cell applications.
- Attempts can be made to achieve p-type doped ZnO QDs by solution process. The UV detection of ZnO QDs based p-n junction photodetector can be studied.
- The band gap tuning property of QDs by varying the size of the QDs can be used to achieve spectrum selective tunable photodetectors.