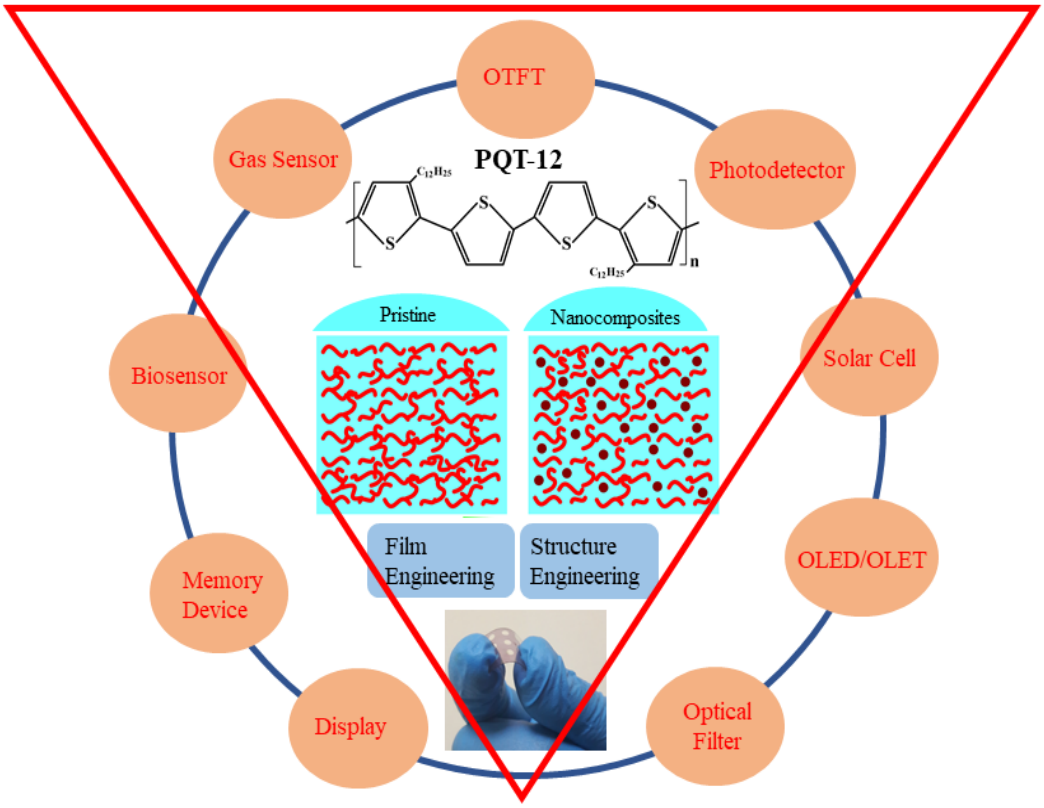
CHAPTER 6

Conclusion and Future Scope

Contents



CHAPTER 6

Conclusion and Future Scope

7.1 Introduction

The primary objective of this thesis is to provide some insights into the fabrication and characterization of PQT-12 polymer-based organic thin film devices for gas sensing and photodetection applications. This chapter presents the chapter-wise objectives and major findings of the thesis as described in the following section.

7.2 Chapter-Wise Major Observations

Chapter-1 introduces the conducting polymers and their importance in organic electronic devices for sensing applications. Various organic thin film characterization techniques such as AFM, SEM, TEM, XRD, CV, FTIR, spectrophotometry, UV-Vis spectroscopy, and photoluminance spectroscopy have been briefly introduced. A detailed literature survey on PQT-12 and other related conducting polymer based gas and optical sensors have been discussed. Based on the research gaps observed from the literature survey, the scope of the thesis is outlined at the end of this chapter.

Chapter-2 reports the fabrication and characterization of PQT-12 based thin film MSM structure for ammonia and nitrogen dioxide gas sensing applications. The sensor is fabricated on a flexible polyamide substrate with an Au based interdigitated electrode structure. The major observations and finding from the chapter are summarized below:

- The surface and structural morphologies analysed by XRD, AFM, SEM, FTIR and CV measurements confirm the suitability of PQT-12 film for the electrical and gas sensing applications.
- The resistivity of the PQT-12 film is increased under the exposure of ammonia gas due to increase in the trap charges in the PQT-12 molecules.
- An ammonia gas response of as high as 8.6% for 100 ppm ammonia with a detection limit of 300 ppb, response time of 8 s and recovery time of 103 s is obtained at room temperature and low bias voltage of 5 V.
- Contrary to the ammonia gas, the conductivity of the PQT-12 film is increased under NO_2 gas exposure due to the modulation of redox levels and partial positive charge transfer to the film by the electronegativity of the NO_2 gas. This results in the decreased resistance of the PQT-12 film and hence the increased sensor current with increased NO_2 gas concentration.
- A NO_2 gas response of ~24% with a response time of ~41 s is measured for 100 ppb of NO_2 gas. The gas response is increased with the NO_2 gas concentration upto the maximum gas response of ~48% at 500 ppb NO_2 gas. The sensor has a detection limit of 32 ppb for NO_2 gas. However, recovery time for NO_2 is extremely high which prevent from the reusability of the proposed sensor.
- Although the gas response of the MSM sensor is good enough for the detection of low concentration of nitrogen dioxide at low bias operation, but the ammonia gas response of only 8.6% at 100 ppm appears to be poor and hence needs further improvement by film/device structure engineering.

Chapter-3 reports a comparative investigation of the electrical and ammonia sensing characteristics of pristine PQT-12 film and PQT-12/CdSe QDs composite film based OTFTs fabricated by conventional spin coating method. The major finding of this chapter can be summarized as follows:

- ❖ The OTFT based device provides better ammonia gas response over MSM sensor discussed in Chapter-2. Ammonia gas response of ~41% (which is much larger than 8.6% response of the MSM sensor) for 100 ppm is obtained in pristine PQT-12 based OTFT sensor. Further, the composite PQT-12/CdSe QDs based OTFT sensor has the maximum gas response of ~51% at 100 ppm of ammonia gas.
- ❖ The composite PQT-12 film based OTFT provides better characteristics over the pristine PQT-12 based device. The field effect mobility, threshold voltage, on/off current ratio, and subthreshold swing for the pristine PQT-12 film based OTFT are 1.4×10^{-3} cm^2/Vs, -22.1 V, 3.6×10^2, and 7.9 V/dec, respectively while the respective parameter values for the PQT-12/CdSe QDs composite film based OTFT are 4.2×10^{-3} cm^2/Vs, -14.4 V, 1.9×10^3, and 5.2 V/dec.
- ❖ The ammonia gas response in PQT-12/CdSe QDs composite based OTFT sensor is ~43% while it is ~34% in the pristine PQT-12 based OTFT for 80 ppm of ammonia gas.
- ❖ The PQT-12/CdSe QDs composite film based OTFT sensor has better linearity in the gas response over the pristine PQT-12 film based device.

Chapter-4 investigates the electrical and ammonia gas sensing characteristics of PQT-12 based OTFT sensors fabricated by using a relatively new method namely the floating-film transfer method (FTM). The performance of FTM-based OTFT sensor has been compared with that of the conventional spin-coated OTFT sensor. The major observations are summarized below:

- In ambient condition, the values of the field effect mobility, threshold voltage, on/off current ratio and subthreshold swing for the FTM-based OTFT are 8.77×10^{-3} cm^2/V-s, -13.9 V, 843 and 8.5 V/dec, respectively. The values are significantly changed when the device is exposed to the ammonia gas.
- A gas response of 56.4%, response time of ~45 s, recovery time of ~85 s, and a detection limit of 404 ppb at 80 ppm of ammonia gas has been achieved for FTM coated devices. The device shows the best response among all the ammonia sensors considered in the previous chapters.
- All the performance parameters of the FTM-coated PQT-12 film based OTFT ammonia sensor are observed to be superior to the spin-coated OTFT and are in good agreement with the other ammonia gas sensors.

Chapter-5 investigates the electrical and optical properties of PQT-12 based OTFT (phototransistor) fabricated by the FTM technique considered in Chapter-4. The major observations of this chapter are listed below:

- The maximum absorbance of the FTM-based PQT-12 film is observed at ~540 nm with significant side peaks at 505 nm and 583 nm due to the better-oriented film than conventional spin-coated PQT-12 film. The intensity and sharpness of the side luminescence peaks of the PQT-12 film under study are larger than those of the spin-coated PQT-12 film at 612 nm and 661 nm due to lower charge trapping sites in the FTM-based PQT-12 film.
- The drain current of the transistor increases with the incident light intensity. The field effect mobility is increased from 7.8×10^{-2} cm^2/Vs to 8.9×10^{-2}

cm^2/Vs and the threshold voltage (magnitude) is decreased from -8.1 V to -5.3 V when the illumination intensity is changed from zero (i.e. dark condition) to 200 $\mu W/cm^2$ at ~540 nm wavelength.

- The maximum responsivity of ~11.3 A/W has been obtained for 5 $\mu W/cm^2$ incident light intensity at ~540 nm wavelength.

7.3 Future Scope of Work

- Flexible OTFT sensors based on the PQT-12 polymer can be fabricated on polyamide, PET, PEN, clothes etc. for wearable and smart sensor technology applications.
- Composites of PQT-12 polymer with nanoparticles/quantum dots of other materials such as ZnO, TiO_2, SnO_2 etc. can be investigated for gas sensing and optoelectronics applications.
- Metal nanostructures upon/under the PQT-12 film may be used for producing a plasmonic effect to enhance the optical properties of the film.
- FTM-coated PQT-12 film can be used as a hole transport layer (HTL) for photodetectors, solar cells, light emitting diodes etc.