Chapter 8
Concluding Remarks & Future Scope

8.1 Concluding remark

This thesis reports synthesis and characterization of polyaniline film doped with inorganic and organic acids on PMMA substrate and the development of modified cladding (evanescent wave) fiber optic chemical sensor for the detection of ammonia gas. The sensor design is based on modified cladding approach, where a polyaniline films doped with inorganic and organic acids forms a modified cladding to an optical fiber. The sensor principle is based on intensity modulation induced in the multimode fiber due to changes in refractive index and absorption in the polyaniline modified cladding. Polyaniline film shows a change in conductivity, refractive index and absorption when exposed to ammonia. Ammonia brings about a change in the number and mobility of charge carriers in the polyaniline backbone. This thesis is organized in eight chapters which covered a literature review on fiber optic sensors which lead to the selection of modified cladding based sensors as a sensor design. The modified cladding design in optical fiber sensors provides an excellent design for this sensor development because of the high sensitivity and ease of fabrication of the sensor. Due to the sensitivity of polyaniline thin films towards ammonia gas and its ease of synthesis and stability it is selected as a best material for application as a modified cladding to the above mentioned sensor design.
During this work we have carried out the following research work

We have indigenously developed computer controlled gas sensing system and optical fiber gas sensor characterization system.

We have synthesized the polyaniline film doped with different inorganic acids such as HCl, H$_2$SO$_4$, HNO$_3$, HBr, HClO$_4$, and H$_3$PO$_4$ as a dopant and ammoniumperoxydisulfate (APS) as an oxidant, for ammonia gas sensing. The monomer: Oxidant: acid dopant ratio was varied from 1:1:1 to 1:1:4. The reaction was carried out at various temperatures for various deposition time. We have optimized the process parameters (for synthesis of polyaniline film) viz. concentration of monomer, oxidants, doping acids, deposition time and reaction temperature for better surface morphology and the sensitivity to ammonia gas. It was found that these process parameters of the chemical polymerization reaction have considerable effect on the conductivity and surface morphology of PANI film and sensitivity to ammonia gas. The following conclusions have been drawn:

(a) The polyaniline film doped with the HCl as a dopant acid provides an excellent polymer matrix for the development of ammonia sensor.

(b) The synthesized PANI-HCl film with optimized parameters viz. monomer: Oxidant: dopant ratio (1:1:4), the reaction temperature (10° C) and the deposition time (20 hour), exhibit excellent response to ammonia (20-250 ppm).

We have also synthesized the polyaniline film doped with different organic acids such as polyvinyl sulphonic acid (PVS), p-toluene sulphonylic acid (p-TSA), Acrylic acid, Malonic acid, Oxalic acid, Pthalic acid, Succinic acid, Adipic acid and Tartaric acid as a dopant and
ammoniumperoxydisulfate (APS) as an oxidant, for ammonia gas sensing. The monomer: Oxidant: acid dopant ratio was varied from 1:1:1 to 1:1:4. The reaction was carried out at various temperatures and various deposition times and the following conclusions have been drawn:

(a) The polyaniline film doped with the AA also provide an excellent to polymer matrix for the development of ammonia sensor,

(b) The synthesized PANI-AA film with optimized parameters viz. monomer: Oxidant: dopant ratio (1:1:2), the reaction temperature (10° C) and the deposition time (20 hour), exhibit excellent response to ammonia (20-250 ppm).

We have developed PANI-HCl optical fiber chemical sensor by removing the cladding of the sensing probe and depositing a layer of PANI-HCl film (with optimized process parameters). Also the parameters for the optical fiber were optimized to enhance the sensor response. The sensing element was prepared by simple technique. The modified cladding was deposited by simple chemical deposition method. The parameters for the modified cladding were optimized on PMMA substrate. And then with above optimized parameters it was deposited onto the fiber. The sensing length, source wavelength and source power have been optimized for the optical fiber sensor. The sensor was also tested for reversibility, repeatability and performance at room temperature and in ambient air. Finally, following conclusion has been drawn:

The optical fiber sensor, with the source wavelength = 650 nm, sensing length=2 cm, source power= 3.5µw and the modified cladding with
optimized parameters of PANI-HCl shows excellent response to ammonia.

Similarly PANI-AA optical fiber chemical sensor was developed by removing the cladding of the sensing probe and depositing a layer of PANI- AA film (with optimized process parameters) and the following conclusion has been drawn:

The optical fiber sensor, with the source wavelength = 650 nm, sensing length=2 cm, source power= 3.5 µw and the modified cladding with optimized parameters of PANI-AA shows excellent response to ammonia.

The PANI-AA optical fiber chemical sensor shows better response as compared to PANI-HCl optical fiber sensor.

8.2 Future Work

In spite of the excellent results achieved on the sensitivity and response of optical fiber chemical sensor, more work can be done to enhance the selectivity, environmental and thermal stability as well as sensor mechanical properties. By using the other chemo chromic materials viz. Polypyrrole, poly-N-Methylpyrrole and their composite, blends as a sensing material can be used as the modified cladding, which can be explored to sense the different hazardous gases in the atmosphere and in the industries. Various bio-enzymes can be immobilized on conducting polymer matrix, as modified cladding of the optical fiber to sense glucose, urea etc. Similarly, PCS (Plastic clad silica) optical fiber, glass optical fiber can be used for the development of optical fiber chemical sensor which has lower attenuation as compared to the plastic optical fiber. Therefore the sensitivity as well as environmental and thermal stability of the sensor can be improved.