CHAPTER 7

SUMMARY AND OUTLOOK

In this thesis work we have developed a chemical process where metal nano-particles can be incorporated well inside the wall of the polymer nanotubes using salts in which metal is in the anionic part and the salt should be oxidizing in nature e.g. Chloroauric acid (\(H\text{AuCl}_4\)), Sodium tetrachloropalladiate (\(Na\text{PdCl}_4\)) etc. Here we have only focused on the gold nanoparticles. Chemically synthesized nanotubes are found to have very low doping concentration hence very low carrier density. These nanotubes have enabled us to study quasi-one dimensional electronic transport properties. A laboratory was also setup during this thesis work to perform required low temperature measurements. The following results are obtained during this thesis work:

• Polypyrrole nanotubes show the behavior of the pinned CDW state. We have incorporated gold nanoparticles successfully inside the wall of the polypyrrole nanotubes. Due to the gold incorporation the localization length increases in the system. As a result the electron-electron interac-
tion increases in the system which results in the stabilization of electronic correlation up to higher temperature. The doping is also reduced in the gold-incorporated system compared to pure polypyrrole nanotubes as a result the screening of coulomb pinning centers is less. For this reason we need the higher threshold voltage during the onset of the sliding motion. We have also studied the dependence of doping and disorder by changing the diameter of the nanotube, combining HAXPES and magneto-transport measurements. We have also studied in details the effect of gold incorporation on the few basic properties of the pinned CDW state e.g. gap voltage, power-law, switching, hysteresis, capacitance etc.

- From the in-situ x-ray diffraction study we have found that the size of the incorporated nanoparticles does not change with time, only number of nanoparticles increases. The size of the incorporated nanoparticles controls by chloroauric acid concentration for nanotubes whose diameter is greater than 100 nm whereas for lesser diameter nanotubes the incorporated particles size is independent of chloroauric acid concentration. Existence of any significance micro-strain has been clearly ruled out from the W-H analysis of the gold x-ray diffraction data.

Even though gold-incorporated nanotube is a composite system still, it does not behave as a percolating network at low temperature. We have observed that with the increase of the volume fraction of gold in the system the conductivity in the system decreases up to a certain limit and above some critical volume fraction the conductivity in the system certainly increases and then the system acts as normal percolating network. Below the critical concentration the system used to show all properties of the pinned CDW state at low temperature. The huge value of dielectric
constant is one of the interesting properties of a CDW system. By tuning the diameter and gold concentration in nanotubes we have succeeded to reach the colossal value of dielectric constant $10^7$ which is more or less flat over the frequency and temperature zone from $1Hz - 10^6Hz$ and 4K-90K.

• We have studied the dynamics CDW state in polypyrrole nanotubes using Fukuyama, Lee, and Rice model. The classic point which comes out from the above mentioned model is that the relaxation time of CDW and the dc conductivity used to follow an activated behavior with same activation energy. This property is clearly followed by the CDW state in polypyrrole nanotubes.

• We have shown true metallic behavior of a conducting polymer nanowires in the switched state and the observed insulator to metal transition is consistent with the model where metallic ground state is reached as the range of electron-electron interaction increases.
List of Acronyms used more than once

**PPY** Polypyrrole

**AuPPy** gold-incorporated polypyrrole nanotube

**CDW** Charge Density Wave

**WC** Wigner Crystal

**EEI** electron-electron interaction

**SEM** Scanning Electron Microscope

**EBL** Electron Beam Lithography

**TEM** Transmission Electron Microscope

**XRD** X-ray Diffraction

**mM** millimolar

**W-H** Williamson - Hall

**MIT** Metal Insulator Transition