PhD Thesis Abstract- Muhammad Yasin (2011-NUST-DirPhD-EE-42)

In recent years, solution processed semiconducting layers based devices, such as Solar Cells (SCs), Field Effect Transistors (FETs) and Light Emitting Diodes (LEDs) have attracted much interest as potential, inexpensive and flexible alternatives to inorganic devices. Despite considerable understanding of device physics, investigation of well-known solution processed semiconductors based devices having simpler configurations and optimal performance is crucial to further developments in this area. This research work mainly focuses on the fabrication and characterization of solution processed semiconducting films based electronic devices having simpler architectures.

Firstly, Organic Solar Cells (OSCs) were developed to investigate the effect of polymer intrinsic properties on the performance of the devices. Secondly, Organic Field Effect Transistors (OFETs) were investigated with a motivation to develop low cost sensors for photo, strain, bend and displacement sensing applications. Lastly, parallel plate capacitor type structures were developed to study the electrical properties of Graphene Oxide (GO), Cobalt & Magnesium doped Lead Zirconate Titanate ($PbTi_{0.5}Zr_{0.3}(Co_{1-x}Mg_x)_{0.2}O_3$) Ceramics and Methacrylate-based Side Chain Liquid Crystalline Polymers (SCLCP) with an aim to explore their potential for electronic device applications.

Polymer-Fullerene BHJ based Solar Cells (OSCs) were fabricated using different batches of poly[2-methoxy,5-(30,70-dimethyl-octyloxy)]-p-phenylene vinylene (MDMO-PPV) in order to investigate the effect of polymer intrinsic properties i.e. molecular weights, polydispersity (PDI) values, charge carrier densities (N_A) and band gap energies (E_g) on the performance of the devices. Devices were under dark as well as UV-Vis illuminations. Results showed that polymer intrinsic properties significantly influenced on the structural properties of active layers. Efficiency of the devices was found highest for polymer having higher PDI and N_A. It was attributed to the increased photon absorption capability and favorable nano morphology of active layer for MDMO-PPV batch with higher PDI and N_A values.

Organic Bulk Hetero-Junction (BHJ) based transistors were fabricated in MESFET configuration with top gate and bottom drain source contacts on glass and flexible PET substrates for sensing applications. Semiconducting layers of the devices were based on P3HT:PCBM blends which were processed using spin coating technique. Gate and drain/source electrodes of the transistors were made using Aluminum and Silver, respectively, using physical vapor deposition technique. Electrical performance of the devices was explained with the help of energy band diagrams. Organic Transistors developed on glass substrates using P3HT:PCBM (1:1 & 1:0.8 wt/wt ratios) and P3HT:MR:PCBM blends (1:0.2:1 wt/wt ratio) were investigated as photo sensors. Results showed that MESFET based photo sensitive devices followed the behavior of typical low voltage phototransistors with weak saturation trend, in particular under illumination. Photo responsivity of the devices was found to increase with illumination intensity and to decrease with negative

gate voltage. Further, phototransistors developed using the blend of P3HT:MR:PCBM were found to have higher photo sensitivity values than P3HT:PCBM blends based photo detectors. Organic MESFET based devices developed on glass and flexible substrates with 1:1 wt/wt ratio of P3HT and PCBM blends were also investigated for strain and displacement sensing applications. Increase in displacement and compressive bending results in increase of drain to source current. Further, drain to source resistance was reduced from 15.40 MΩ to 13.15 MΩ when displacement was varied from 0 to 250μm.

Electrical and dielectric properties of Graphene Oxide (GO), $PbTi_{0.5}Zr_{0.3}(Co_{1-x}Mg_x)_{0.2}O_3$ Ceramics and SCLCPs with varying lengths of aliphatic spacer were studied as Metal-Insulator-Metal (MIM) capacitors using temperature dependent parallel plate impedance spectroscopic technique. Analyses showed that GO film possses Direct Current (DC) and Correlated Barrier Hopping (CBH) mechanisms of conductivity at low and high frequency ranges, respectively. Analysis of $PbTi_{0.5}Zr_{0.3}(Co_{1-x}Mg_x)_{0.2}O_3$ Ceramics with varying values of composition exhibited high magnitude of dielectric ($\varepsilon_r = 4261$) over a wide range of temperature at 100 kHz. Dielectric constants of the SCLCP films were found to increase with the decrease of flexible spacer length. Detailed analysis revealed that the conductivity of SCLCP films followed Quantum Mechanical Tunneling (QMT) and CBH conductivity mechanisms at low frequency regime and, Super Linear Power Law (SLPL) and DC conductivity mechanisms at high frequency region. Impedance spectroscopic results suggest that, solution processed films being investigated using impedance spectroscopy can be proposed as model systems for applications in large area flexible arrays and other advanced microelectronic devices.