List of figures

| Figure No. | Figure Caption | Page No. |
|-------------|---|----------|
| Figure 1.1 | Large area based application of CPs and its composites [2]. | 2 |
| Figure 1.2 | (i) Chemical structure of CPs, (ii) conductivity comparison of | 4 |
| | undoped (pristine) and doped polymers [7]. | |
| Figure 1.3 | (a) Generation of polaron, bipolaron and bipolaron bands as a | 4 |
| | result of doping level in various CPs (b) Formation of neutral, | |
| | positive and negatively charged soliton, (c) formation of two | |
| | charged solitons on a chain of trans-PA [6]. | |
| Figure 1.4 | (a) Schematic representation of the semi-crystalline structure | 13 |
| | of P3HT (b) High resolution-TEM micrograph showing the | |
| | packing of P3HT chains, (inset: SAED pattern) [35]. | |
| Figure 1.5 | Arrangement of polymer backbone from solution (bulk) to | 15 |
| | ordered array. | |
| Figure 1.6 | (a) TEM image of AgNP superlattice, histogram (PSD= | 15 |
| | 4.1±0.23 nm) (b) HR-TEM (interparticle distance=1.51 nm) | |
| | (c) 2-D Fourier transform spectrum of (b) [52]. | |
| Figure 1.7 | Deposition type on hydrophilic and hydrophobic substrates | 19 |
| | for transfer of Langmuir monolayers: (a) Z-type, (e) Y-type, | |
| | (f) X-type. | |
| Figure 1.8 | Various steps involved in Langmuir technique. Step 1: A-C) | 21 |
| | solvent spreading, Step 2: Barrier compression, Step 3: | |
| | Substrate stamping (Schaefer style), Step 4: Substrate lifting. | |
| Figure 1.9 | SP vs. area $(\pi$ -A) isotherm depicting various monolayer phase | 22 |
| | transitions. | |
| Figure 1.10 | Energy level diagram of metal-semiconductor (n-type) | 26 |
| | interface (a) before and (b) after the contact. | |
| Figure 1.11 | Energy level diagram of metal-semiconductor (p-type) | 27 |
| | interface (a) before and (b) after the contact. | |
| Figure 1.12 | Energy level diagram of metal-semiconductor interface for | 28 |
| | ohmic behaviour (a) before and (b) after the contact. | |

| Figure 2.1 | Reaction scheme for the synthesis of PIn. | 37 |
|-------------|--|----|
| Figure 2.2 | Experimental setup for electrochemical synthesis of PIn. | 38 |
| Figure 2.3 | Schematic representation of interfacial polymerization of 5- | 39 |
| | AIn at aqueous/organic solvent system. The top phase is an | |
| | aqueous solution of APS and bottom phase is | |
| | monomer/Chloroform solution. | |
| Figure 2.4 | Schematic representation of hydrothermal synthesis of MoS ₂ | 40 |
| | nanosheets, their exfoliation, and MoS2-PIn nanocomposite | |
| | formation. | |
| Figure 2.5 | Biphasic system with chloroform at bottom containing | 43 |
| | various DDAB concentration labelled as (1) 5, (2) 10, (3) 25, | |
| | (4) 50 and (5) 75 mM and upper layer containing hydrosol (a) | |
| | Before phase transfer (b) After phase transfer. | |
| Figure 2.6 | Photograph of LB film deposition system. | 44 |
| Figure 2.7 | Photograph of Nuclear Magnetic Resonance (NMR) | 45 |
| | spectrometer and its basic working principle. | |
| Figure 2.8 | Electronic transitions in a molecule. | 46 |
| Figure 2.9 | Basic instrumentation of UV-Vis spectrometer. | 47 |
| Figure 2.10 | (a) A simple schematic diagram of the FT-IR spectrometer (b) | 47 |
| | Photograph of FT-IR spectrometer. | |
| Figure 2.11 | Physical process involved in XPS. | 49 |
| Figure 2.12 | Schematic representation of the experimental setup of CV. | 50 |
| Figure 2.13 | Photograph of our SEM and HR-SEM. | 52 |
| Figure 2.14 | (a) Photograph of TEM (b) Layout of optical component of | 52 |
| | TEM instrument. | |
| Figure 2.15 | A simple schematic diagram of the AFM. | 53 |
| Figure 2.16 | Schematic diagram of Thermal Evaporating vacuum system. | 55 |
| Figure 2.17 | (a) Schematic diagram of ITO/Semiconductor LB (or LS) | 56 |
| | film/Al sandwiched structure, and (b) Photograph of | |
| | sourcemeter. | |
| Figure 3.1 | (a) ¹ H-NMR spectrum and (b) FT-IR spectrum of | 61 |
| | electrochemically synthesized PIn. | |
| | | |

Figure 1.13 Oxidative polymerization mechanism of indole.

31

| Figure 3.2 | FAB Mass spectrum of electrochemically synthesized PIn. | 61 |
|------------|--|----|
| Figure 3.3 | Pressure vs. area $(\pi$ -A) isotherm of PIn at room temperature | 62 |
| | (marked points display different pressures 20, 30 and 40 | |
| | mN/m under study). Inset shows photograph of PIn solution | |
| | prepared for LB study. | |
| Figure 3.4 | Tapping mode AFM and SEM images of monolayer LB film | 64 |
| | of PIn at different deposition pressures (as marked in | |
| | isotherm) (a & b) @ 20 mN/m, (c & d) @ 30 mN/m, (e & f) | |
| | @ 40 mN/m respectively. Each inset shows the magnified | |
| | image encircled region | |
| Figure 3.5 | (a) SEM image of single layer LB film of PIn. Inset shows the | 65 |
| | magnified image encircled region (b) AFM image of single layer | |
| | LB film of PIn. | |
| Figure 3.6 | Topographic AFM 3D images of monolayer PIn LB film | 65 |
| | deposited at different SP (a) 20 mN/m, (b) 30 mN/m, (c) 40 | |
| | mN/m respectively. | |
| Figure 3.7 | Schematic representation of plausible arrangement of PIn | 67 |
| | molecules onto water subphase at different SP (20, 30 and 40 | |
| | mN/m). | |
| Figure 3.8 | (a) UV-Vis absorption spectra of PIn (solution) and LB film of | 67 |
| | PIn with inset depicting its band gap.(b) Raman spectra of PIn | |
| | (Powder) synthesized electrochemically and PIn LB film | |
| | (monolayer and 5 layers), respectively. | |
| Figure 3.9 | (a) J-V characteristics of LB film of PIn single layer (1 L), 3 | 73 |
| | layers (3 L), and 5 layers (5 L) respectively (b) semilog plot | |
| | of single layer, 3 layers and 5 layers. | |
| Figure 4.1 | ¹ H-NMR spectra of (a) 5-AIn (b) 5-APIn. | 79 |
| Figure 4.2 | FT-IR spectra of (a) 5-AIn (b) 5-APIn. | 81 |
| Figure 4.3 | Plausible mechanism of polymerization of 5-AIn. | 83 |
| Figure 4.4 | UV-visible spectrum of (a) 5-AIn (b) 5-APIn (Inset shows | 84 |
| | optical band gap of 5-APIn) | |
| Figure 4.5 | Gel permeation chromatogram of 5-APIn. | 85 |
| Figure 4.6 | XRD pattern of 5-APIn. | 85 |

| Figure 4.7 | SEM images of 5-APIn formed at the interface after (a) 3 | 86 |
|-------------|---|----|
| | min, (b) 5 min, (c) 15 min, (d) magnified form of image (c), | |
| | (e) 60 min and (f) after 24h. | |
| Figure 4.8 | TGA and DTA curves of 5-AIn (a & a') and 5-APIn (b & b') | 88 |
| | respectively. | |
| Figure 4.9 | CV of (a) bare Au electrode (b) 5-APIn/Au. The inset shows | 89 |
| | an enlarged view of similar CV plot. | |
| Figure 4.10 | CV of (a) bare Au electrode and 5-APIn/Au in presence of | 90 |
| | $0.5~M~H2SO4$ at scan rate (b) $20~mVs^{\text{-}1},$ (c) $50~mVs^{\text{-}1}$ and (d) | |
| | 100 mV s^{-1} . | |
| Figure 4.11 | Schematic representation of redox recyclability behavior of 5- | 91 |
| | APIn in 0.5M H2SO4. | |
| Figure 4.12 | EIS of (a) bare Au electrode, (b) 5-APIn/Au. (inset: EIS data | 92 |
| | fitted by ZSimp software for bare Au electrode and 5- | |
| | APIn/Au with their electrical equivalent circuit.) | |
| Figure 4.13 | Electron distribution for the 5-APIn (a) HOMO and (b) | 92 |
| | LUMO energy levels obtained at the wB97XD/6-31G* level | |
| | of theory in gas phase. Here blue, gray and white balls | |
| | represent N, C and H-atoms respectively. | |
| Figure 4.14 | Pressure-area (π-A) isotherm of 5-APIn depicting various | 94 |
| | regions I, II, III, IV (inset shows 5-APIn dispersion) | |
| Figure 4.15 | SEM images 5-APIn LS film deposited at different pressures | 97 |
| | (a) 35, (b) 45, (c) magnified image of b, (d) 55 mN/m, and (e) | |
| | multilayer (5L) LS film lifted at 45 mN/m. | |
| Figure 4.16 | Tapping-mode AFM image of 5-APIn fabricated at optimum | 97 |
| | pressure (45 mN/m) via LS method (a) 2D (b) 3D (c) and (d) | |
| | horizontal and vertical surface profile. | |
| Figure 4.17 | Raman spectra of (a) 5-APIn LS film and (b) 5-APIn powder | 98 |
| | (bulk). | |
| Figure 4.18 | Pictorial representation depicting the 5-APIn dispersion | 99 |
| | spread over water subphase (a) before and (b) after | |
| | compression upto 45 mN/m and its LS film fabrication. | |
| Figure 4.19 | (a) log J vs. V plot and (b) log J vs. log V plot of sandwiched | 99 |

| | structure Al/APIn LS film/ITO. | |
|-------------|--|-----|
| Figure 5.1 | Characterizations of MoS ₂ nanosheets synthesized via hydrothermal process (a) TEM (inset showing SAED pattern) (b) HRTEM image, (c) intensity profile graph depicting interlayer distance, (d) EDS elemental analysis, (e) XRD pattern. | 109 |
| Figure 5.2 | (a) HAADF-STEM, (b) TEM image and element mapping images of MoS ₂ (c) S, (d) Mo. | 109 |
| Figure 5.3 | (a) UV-vis and (b) vibrational spectroscopy of (i) MoS ₂ nanosheets, (ii) PIn and (iii) MoS ₂ -PIn composite. | 110 |
| Figure 5.4 | (a) XRD pattern and (b) TGA of (i) PIn and (ii) MoS ₂ -PIn nanocomposite (bulk). | 112 |
| Figure 5.5 | TEM micrographs of drop casted MoS ₂ -PIn nanocomposite at different scale bars (a) 200 nm (b) 50 nm. | 113 |
| Figure 5.6 | (a) HAADF-STEM and (b) element mapping images of MoS ₂ -PIn nanocomposite (bulk drop casted): (c) C, (d) N, (e) S, (f) Mo. | 113 |
| Figure 5.7 | CV curves of (a) GCE, (b) MoS ₂ /GCE, (c) PIn/GCE, (d) MoS ₂ -PIn-1/GCE, and (e) MoS ₂ -PIn-2/GCE (f) MoS ₂ -PIn-3/GCE in a 5 mM [Fe(CN) ₆] ^{3-/4-} mixture (1:1); 0.1 M KCl (Scan rate 20 mVs ⁻¹). | 114 |
| Figure 5.8 | TEM micrographs of LS films of (a) MoS ₂ -PIn-1 and (b) MoS ₂ -PIn-3 (dark patches pointed with arrows represent MoS ₂). | 114 |
| Figure 5.9 | Pressure vs. Area $(\pi$ -A) isotherm of (a) PIn and (b) MoS ₂ -PIn nanocomposite. | 117 |
| Figure 5.10 | Schematic representation of assembly of MoS ₂ -PIn on water subphase initially, after barrier compression and LS film fabrication. | 117 |
| Figure 5.11 | TEM micrographs of LS films of (a,b) PIn and (c,d) MoS ₂ - | 120 |

PIn.

| Figure 5.12 | (a) HAADF-STEM and (b) element mapping images of | 120 |
|-------------|--|-----|
| | MoS ₂ -PIn LS film: (c) C, (d) N, (e) S, (f) Mo. | |
| Figure 5.13 | Tapping mode AFM and phase contrast images of LS films of | 121 |
| | (a,b) PIn and (c,d) MoS ₂ -PIn. | |
| Figure 5.14 | (a) Current density-voltage (J-V) measurement (b) Semi-log | 121 |
| | plot for 5 layered LS film fabricated Al/PIn/ITO (black curve) | |
| | and Al/ MoS ₂ -PIn/ITO (red curve) device structure. | |
| Figure 6.1 | UV-vis spectra of (a) deionised water, (b) chloroform, (c) | 130 |
| | pure silver hydrosol, (d) supernatant aqueous phase (after | |
| | phase transfer; shown in inset) and (e) chloroform subphase | |
| | (after phase transfer; shown in inset). | |
| Figure 6.2 | FT-IR spectra of (a) pure DDAB (b) silver organosol. | 131 |
| Figure 6.3 | XPS spectra of silver organosol. | 131 |
| Figure 6.4 | XRD pattern of silver NPs in organic phase. Inset shows | 132 |
| | amplified diffraction pattern corresponding to (111), (200), | |
| | (220) and (311) planes of fcc silver. | |
| Figure 6.5 | TEM image of (a) silver hydrosol (inset: SAED pattern) (b) | 134 |
| | silver organosol (inset: SAED pattern) | |
| Figure 6.6 | TEM images of silver colloid in organic phase (inset: | 134 |
| | histogram depicting PSD) with varying DDAB concentration | |
| | namely (a) 5 mM (b) 10 mM (c) 25 mM (d) 50 mM (e) 75 | |
| | mM and (f) plausible structure for DDAB acting as AgNP | |
| | stabilizer. | |
| Figure 6.7 | Trend of increasing median particle dimension (diameter) and | 137 |
| | the corresponding width of distribution represented as error | |
| | bars. | |
| Figure 6.8 | (a) UV-Vis spectra of (i) organosol (ii) PIn, (iii) Ag-PIn, and | 138 |
| | (b) FT-IR spectra of (i) PIn and (ii) Ag-PIn. | |
| Figure 6.9 | Pressure vs area $(\pi$ -A) isotherm for (a) PIn, and Ag-PIn along | 140 |
| | with schematic depicting the phenomena at various regions, | |
| | (b) compression-expansion curve for PIn and Ag-PIn | |
| | nanohybrid at SP=30 mN/m, (c) compression-relaxation | |
| | phenomena at three different SPs (30, 40, and 50 mN/m) from | |

| | different regions (II, III and IV) of the isotherm, (d) | |
|-------------|---|-----|
| | compression-relaxation cycle of Ag-PIn film. | |
| Figure 6.10 | TEM micrograph of a single time lifted layer PIn LS film at | 143 |
| | 30 mN/m SP at (a) low magnification (inset: SAED) and (b) | |
| | high magnification (inset: d-spacing). | |
| Figure 6.11 | (a) TEM image (inset: SAED pattern), (b) HAADF image and | 143 |
| | (c) elemental mapping of drop cast Ag-PIn nanohybrid film. | |
| Figure 6.12 | TEM micrograph of AgNP-PIn Langmuir film deposited at | 144 |
| | 40 mN/m at different magnification scale (a) 50 nm and (c) | |
| | 20 nm; FT of Region 1 and 2. | |
| Figure 6.13 | GIWAXS 2D q plot of (a) PIn and (b) Ag-PIn LS film | 145 |
| Figure 6.14 | Tapping mode atomic force micrographs of (a) PIn and (c) | 146 |
| | Ag-PIn Langmuir film deposited at 30 and 40 mN/m | |
| | respectively with their corresponding (b) and (d) roughness | |
| | distribution. | |
| Figure 6.15 | Phase contrast micrographs of (a) PIn and (c) Ag-PIn | 147 |
| | Langmuir film deposited at 30 and 40 mN/m respectively | |
| | with their corresponding (b) and (d) grain segment. | |
| Figure 6.16 | (a) Film lifting method of type 1 and 2 for contact angle | 148 |
| | measurements of LS film of (b) 1-PIn, (c) 2-PIn and (d) Ag- | |
| | PIn LS films, (e) and (f) Kelvin probe force micrographs of | |
| | (b) and (d) LS films respectively. | |
| Figure 6.17 | UV-vis spectra of LS films (a) PIn and (b) Ag-PIn. | 149 |
| Figure 6.18 | Raman spectra of (a) PIn and (b) Ag-PIn LS films (inset: | 150 |
| | SERs effect) | |
| Figure 6.19 | Current density-voltage (J-V and J-V ²) characteristics of 5L | 151 |
| | LS film of pristine PIn and Ag-PIn nanohybrid. | |
| Figure 6.20 | XPS spectra of C 1s and N 1s for (a & b) PIn LS film, (c & d) | 155 |
| | Ag-PIn LS film. | |
| Figure 6.21 | XPS spectra for the silver present in organosol and Ag-PIn | 155 |
| | LS film. | |
| Figure 6.22 | XPS spectra of Ag-PIn LS film: (a) N1s and (b) C1s | 156 |
| | spectrum. Peak positions are mentioned for the fitted | |

components.

Figure 6.23 Schematic representing the partial charge transfer from PIn to

AgNPs resulting in lowering of BE, SERS phenomena and
enhancement in charge transport property of Ag-PIn
nanohybrid.