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Write-up

Project Title: Development of Electrochemical Hybrid Supercapacitors based on Conducting Polymer Electrodes and Polymer Electrolytes for Energy Storage

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Under the above project, we have developed the following configurations of the electrical double layer supercapacitors and hybrid supercapacitors, and thoroughly characterized:

(1) EDLCs based on gelled MWCNT-electrodes and gel polymer electrolyte (PVdF- HFP/ionicliquid blend film)

The EDLCs with modified MWCNTs as binderless electrodes in the form of 'bucky gel' with pyrrolidinium-based IL and ionic liquid (BMPTFSI) and PVdF-HFP based polymeric gel electrolytes have been constructed and characterized.

(2) EDLCs with coconut shell derived micro-/mesoporous activated carbon and plastic crystalline gel polymer electrolytes

Novel configurations of solid state EDLCs have been reported with plastic crystalline succinonitrile based gel polymer electrolytes and the coconut-shell derived activated carbon electrodes. The typical cell with ionic liquid-based gel electrolyte offers the higher values of specific capacitance of 254 F g^{-1}, energy density of 33-35 Wh kg^{-1}, pulse power density of 10.3 kW kg^{-1} and continuous power density of 12 kW kg^{-1}.

(3) Pseudo-capacitors fabricated with (PEDOT-PSS)-$RuO_2.xH_2O$ composite electrodes and a proton conducting gel polymer electrolyte (PVP-PVA/$EMIHSO_4$ blend films)

Recently, a novel configuration of quasi-solid-state, flexible, redox supercapacitors (pseudocapacitors) based on poly (3.4-ethylenedioxythiophene): poly(styrene sulfonate) PEDOT:PSS and PEDOT:PSS/ruthenium oxide composite electrodes using a proton conducting polymer electrolyte. The proton conducting polymer electrolyte comprises of a protic ionic liquid 1-ethyl 3-methyl imidazolium hydrogen sulphate ($EMIHSO_4$) immobilized in a blend of polymers PVA and PVP. The symmetrical PEDOT:PSS based pseudocapacitor shows high rate capability as observed by impedance analysis and cyclic voltammetry. The high values of knee frequency (966 Hz), time constant (70 ms) and quasi-rectangular CV profile at high scan rate up to 15 V s^{-1} show excellent rate capability of PEDOT-PSS based redox supercapacitor. A specific capacitance of ~ 33 F

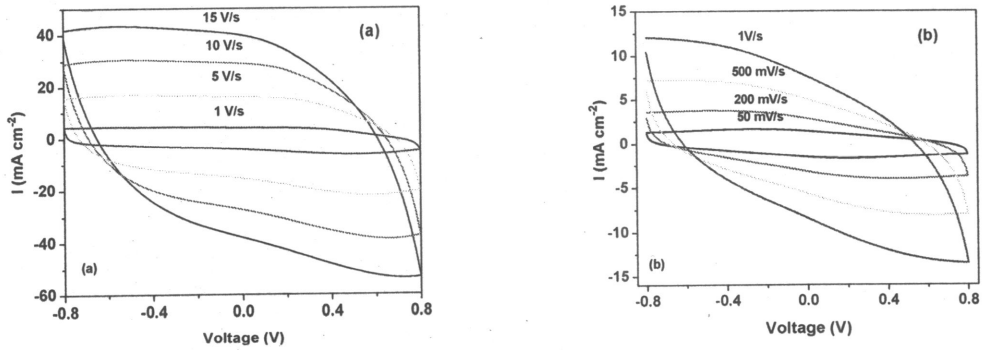

Figure: Cyclic voltammograms of the pseudocapacitor cells with the (a) PEDOT-PSS, and (b) PEDOT-PSS/RuO_2 electrodes at different scan rates.

g^{-1} along with a pulse power ~ 24 kW kg^{-1} in PEDOT-PSS based supercapacitor is reported. Improvement in energy density (in terms of specific capacitance ~ 57 F g^{-1}) has been obtained with the incorporation of $RuO_2.xH_2O$ in the electrode material. The rate performance of the capacitor with PEDOT-PSS/RuO_2 composite electrodes is reduced to a pulse power of 4.3 kW kg^{-1}. Cyclic voltammograms of the pseudocapacitor cells with the PEDOT-PSS and PEDOT-PSS/RuO_2 electrodes, as shown in the above figure, confirm the high rate performance of the cells.

(4) Studies on Gel Polymer Electrolytes based Hybrid Supercapacitors

Olivine lithium iron phosphate-carbon ($LiFePO_4$/multiwalled carbon nanotubes, MWCNTs) nanocomposite cathode material, prepared by in-situ sol gel precursor method, has been used to fabricate the hybrid supercapacitors, Two configurations of the hybrid cells with pure LiFePO4 and its composite with MWCNTs have been fabricated for comparison:

Cell-1: MWCNTs | Gel Polymer Electrolyte | $LiFePO_4$

Cell-2: MWCNTs | Gel Polymer Electrolyte | $LiFePO_4$@MWCNTs

The results have been compared with the structural and morphological performances of $LiFePO_4$@MWCNT are compared with pristine $LiFePO_4$ and MWCNTs using SEM, XRD, Raman studies. Ionic liquid/LiTFSI incorporarted poly(vinylidene fluorideco-hexafluoropropylene)-based gel polymer electrolyte (GPE) was applied as separator-cum- electrolyte. The electrochemical performances of MWCNTs//$LiFePO_4$, and MWCNTs//$LiFePO_4$@MWCNTs coin-type polymer hybrid supercapacitor were analyzed by cyclic voltammetry, ac impedance and galvanostatic charge/discharge tests. It is indicated that $LiFePO_4$@MWCNTs nanocomposite can be used as the cathode materials in hybrid supercapacitors and gives the better performance in terms of energy density (19.8 Wh kg^{-1}), power density (0.52 kW kg^{-1}) as compared to symmetric EDLC (using MWCNTs electrodes). The typical charge-discharge characteristics are shon in the following figure:

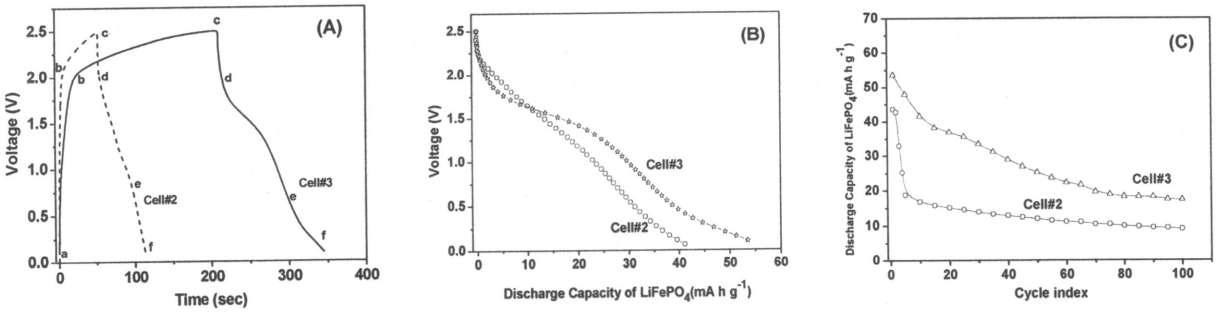

Figure: (A) hybrid supercapacitor Cell#2 and Cell#3, **(B)** Specific capacity vs. voltage profile of the Cell#2 and Cell#3, and **(C)** Cycle stability of the hybrid supercapacitor for 100 cycles.

Future Scope

There is a vast scope for future work in this field.Some hybrid supercapacitors would be looked into in order to enhance their several electrical and electrochemical performances, such as capacity, energy density, power density, working potential of the device and to reduce the internal resistance of the devices. After proper optimization and lamination, the commercialization of these supercapacitors is practically possible for their low and high energy density applications.