Surface Engineering of CVD Grown Carbon Nanostructures for Supercapacitor Electrode Applications

A THESIS

submitted by

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Declaration by the Research Scholar

I hereby declare that the entire work embodied in this Thesis entitled "**Surface Engineering of CVD Grown Carbon Nanostructures for Supercapacitor Electrode Applications**" is the result of investigations carried out by me in the ***School of Engineering***, Indian Institute of Technology Mandi, under the supervision of ***Dr. Viswanath Balakrishnan***, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgments have been made wherever the work described is based on finding of other investigators.

IIT Mandi (H.P.) Signature:

Date: **Piyush Kumar Avasthi**

Declaration by the Research Advisor

I hereby certify that the entire work in this Thesis has been carried out by ***Piyush Kumar Avasthi,*** under my supervision in the ***School of Engineering,*** Indian Institute of Technology Mandi, and that no part of it has been submitted elsewhere for any Degree or Diploma. In keeping with the general practice, due acknowledgements have been made wherever the work described is based on finding of other investigators.

IIT Mandi (H.P.)

Signature:

Date:

Dr. Viswanath Balakrishnan

PREAMBLE

Engineering the materials for storing energy is well explored in last decade which led the energy storage market at new heights and continued to play important role towards meeting future energy demands. However, certain aspects such as interfacial interaction between supercapacitor electrodes and electrolytes are not well explored for high surface area materials. Recently surface engineering of electrode gained considerable influence on energy storage performance. It is well known that surface and interfacial chemistry of electrode-electrolyte plays a pivotal role in energy storage and hence, understanding that aspect becomes quite important. Various approaches have been adopted to engineer the electrode surface, for example nanoparticles decoration, chemical functionalization, annealing, electro deposition, sputtering, and conformal coating using ALD etc. Nevertheless, how this surface engineering affects the wettability and their correlation with energy storage performance is not much explored and warrants detailed investigation.

The current doctoral thesis is mainly focused on surface engineering in the light of wettability aspect for supercapacitor performance. Different CVD grown/thermal oxidation based materials developed and their contact angle aspects have been explored using multiple approaches. In order to tune the wettability, electrolyte engineering, conformal coating of metal oxides, plasma treatment and hybrid approaches have been employed. In terms of device fabrication, symmetric and asymmetric configurations have been adopted. Detailed electrochemical measurements and analysis have been carried out and results are discussed in the light of above mentioned aspects. By adding small amount of organic solvent in aqueous electrolyte followed by few nm metal oxide coating on carbon nanotubes based electrode, 102 fold increase in energy density is achieved due to change in wettability. Similarly around 10 fold increase in specific capacitance is observed for plasma treated carbon nano fibers (CNF) with tuned wettability as compared to untreated CNF. Efforts are also made to develop large scale flexible electrodes with superior supercapacitor performances. Solid state devices have been fabricated which showed excellent cyclic stability with 87% capacitance retention after 25000 charge discharge cycles in case of iron oxide//CNT asymmetric supercapacitor device and 28% increase in capacitance after 10000 charge discharge cycles for CNF based symmetric supercapacitor device. The prototype demonstration in serially connected device geometry has been presented for practical applications such as glowing of different LEDs and rotation of miniature fans.

DEDICATION

Dedicated to lord "Radhe-Krishna", my father Shri Ashok Avasthi, my mother Smt. Santosh Devi, my brother Punit, my sister Seema, my nephews Shanu, Hanu, Nonu and my grandparents.

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