Department of Chemical Engineering
Indian Institute of Technology Delhi

May 25, 2020

Sub: Ph.D. Viva Voce Examination of Mr. Rupesh M. Tamgadge

Mr. Rupesh M. Tamgadge (Entry No.: 2014CHZ8174) will defend his Ph.D. thesis entitled "Improving Energy Density and Response Time of Supercapacitors Through Electrochemical Treatment and Defect Engineering" on **Wednesday, June 03, 2020 at 4:00 PM** through video conferencing**.** The link to join the online viva voce examination will be communicated in due course.

All are cordially invited.

(Anupam Shukla)
Supervisor

CC.
External Examiner: Prof. Somenath Ganguly (IIT Kharagpur)
SRC members
Prof. A. Verma
Prof. Ali Haider
Prof. P. P. Ingole (Chemistry Deptt.)
HOD, Chem. Engg. Deptt.
Ph.D. Coordinator, Chem. Engg. Deptt.
Faculty members, Chem. Engg. Deptt.

Abstract

Electrochemical capacitors, also known as supercapacitors, have high power density, rapid charge-discharge rate, long cycle life (>100000 cycles) and low maintenance cost. A supercapacitor is ideally suited for applications requiring frequent and pulse power inputs. However, a supercapacitor has low specific energy (~1-10 kWh/kg compared ~250 kWh/kg for Li-ion battery), and the capacitive behavior is shown for signals with frequency up to 5 Hz. Increase in attractiveness and applications of supercapacitor requires (i) increase in specific energy, and (ii) improvement in the frequency response to kHz levels. In this work, our focus was to use cheap, widely available material and simple electrode synthesis route to improve specific energy or frequency response.

We used synthetic and commercially available forms of highly oriented pyrolytic graphite (HOPG), and carbon fiber paper (CFP) for the synthesis of self-standing, binder-free supercapacitor electrodes. Partial electrochemical exfoliation of HOPG was performed to grow vertically oriented graphene (VOG) on the top surface. It led to an increase in the functional surface area of electrodes while keeping the electrolyte resistance low. Exfoliation was carried out in different sulfate-based salt solutions and aqueous H_2SO_4 acid. Parameters like intercalation before exfoliation, current density of exfoliation, time of exfoliation, etc. were optimized to get electrode with maximum aerial capacitance. Electrochemical treatment (anodization) of CFP in sulfuric acid solution of different concentration was used to improve the areal capacitance of the CFP electrode. The areal capacitance obtained at optimized current density and electrolyte concentration (2.4 F/cm^2 at discharge current density 2 mA/cm^2) is more than twice the best-reported literature value for carbon-based electrodes.

In addition to carbon-based material, anatase (TiO_2), was for pseudocapacitive electrode was also studied. Anatase is an attractive l because of its low cost, wide availability, excellent stability, and it is amenable to easy synthesis in different morphologies. Realized specific capacitance of anatase is low due poor electronic conductivity. Anatase powder was nanostructured and fluorine-doped using hydrothermal treatment with HF, and the doped material showed oxygen vacancies and easily ionizable donor levels in the bandgap. The specific capacitance of the doped anatase was about four times the pristine anatase. Finally, a kHz frequency response anatase pseudocapacitive electrode was prepared by anodization of titanium and followed by electrochemical reduction to improve electronic conductivity. The supercapacitor made from the electrode could filter fully rectified AC signal (120 Hz). The device showed capacitive behavior up to 50 kHz frequency (SRF: self-resonance frequency, the frequency up to which the device show a predominantly capacitive behavior) and its areal capacitance at SRF was significantly better than carbon-based electric double layer capacitors (EDLC). The supercapacitor could filter rectified AC signals of 50 kHz frequency with variance much better than the carbon electrode EDLC.