

From: "mk" <mk@iitk.ac.in>
Subject: [Scdt] Correction: PhD Open Seminar: Ms. Sangh Mitra (17106273) MSE Dept. on 21th June @ 3:30 PM in FB421
Date: Mon, June 13, 2022 9:26 am
To: "Acadstaff" <acadstaff@lists.iitk.ac.in>,"Dpgc_mse" <dpgc_mse@iitk.ac.in>,"Msepg" <msepg@lists.iitk.ac.in>,"Scdt" <scdt@lists.iitk.ac.in>

On 2022-06-13 09:24, mk wrote:

> Department of Materials Science and Engineering
>
> PhD Open Seminar Announcement
>
> Ms. Sangh Mitra (17106273) will present her PhD Open Seminar on
>
> Title: Printed Graphene Electrodes and Polymer Hydrogel Electrolyte for
> Flexible Solid-State Supercapacitors
>
> Date: 21th June 2022 (Tuesday)
>
> Time: 3:30 pm
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> Venue: FB 421
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> All interested are welcome to attend.
>
> Monica Katiyar
>
> (Thesis Supervisor)

> Abstract:

>
> The shift of energy resources from conventional to renewable has
> created demand for all kinds of energy storage devices. Concomitantly,
> there is extensive research being done to make electrodes with higher
> energy densities at lower cost and electrolytes in solid-state with
> high conductivity and flexibility/portability. In this thesis, graphene
> film on copper and polyvinyl alcohol/phosphoric acid (PVA/H3PO4) are
> investigated as potential candidates for electrode and electrolyte,
> respectively, for flexible solid-state supercapacitors (SSCs). Graphene
> was chosen as an active material owing to its high surface area and
> excellent electrical conductivity to improve charge storage. PVA
> polymer electrolyte was used as it is semicrystalline in nature and
> shows higher ionic conductivity than poly(acrylonitrile) (PAN),
> poly(vinylidene fluoride) (PVDF), poly(methyl methacrylate) (PMMA), and
> polyethylene oxide (PEO). Moreover, it is biodegradable, nontoxic, and
> inexpensive. Furthermore, adding H3PO4 to the polymer network provides
> free charge carriers to improve the order of ionic conductivity from
> 10^{-14} to 10^{-3} S cm⁻¹ as it is a good proton (H⁺) conductor [1] due to
> its ability to self-ionize (low acid dissociation constant [2] $7.5 \times$
> 10^{-3} at 25 °C).

>
> The advantages of graphene electrodes are its high surface area, ease
> of fabrication for large-scale production, and long-life cycle.
> Problems in making graphene electrodes with chemical vapor deposition
> (CVD) involves no scalability, complex instrumentation, high-cost, and
> difficulty to achieve desired thickness. Likewise, formation of
> graphene electrodes using slurry coating involves mixing active
> material with binder and other additives which obstructs its active
> sites and creates poorly connected volume (dead volume) in the
> electrode. Moreover, the films formed are non-uniform and prone to
> detach from the substrate. Thus, to promote large-scale production,
> printed graphene electrodes are attractive and easy to fabricate due to
> simplicity of wet chemical processing. To achieve this goal, the first
> challenge is to form a stable dispersion (ink) of graphene which is not
> possible, due to absence of oxygen functional groups. The problem is

> handled by forming stable dispersion of graphene oxide (GO) for forming
> GO film on copper, which can be later reduced to graphene/reduced
> graphene oxide (rGO). The developed procedure allows direct growth of
> rGO film on desired substrate and a facile integration in device.
>
> A process for fabrication of binder-free multilayer GO films on copper
> using electrophoretic deposition (EPD) is developed. Briefly, GrO
> flakes were synthesized by oxidation of graphite flakes using Tours'
> method. Next, powdered GrO flakes were dispersed in deionized water to
> form a stable dispersion (zeta potential: -43.1 mV) of exfoliated and
> suspended GO flakes. EPD was done to form GO films on copper in a
> symmetrical two-electrode system. To achieve substrate-intact, thick,
> and dense GO film, electric field of 5 V cm⁻¹ was kept constant while
> deposition time was varied as 60 s, 120 s, 180 s, 240 s and 300 s,
> respectively. To understand the kinetics of film formation at different
> time durations, structural, morphological, and topological studies were
> done. The structural studies indicated decrease in interlayer spacing
> and an increase in density due to close-packing of GO flakes with time.
> The improvement in crystallinity of the films was evident by the
> decrease in intensity ratio of the D and G bands (ID/IG) ratio. The
> morphological analyses indicated random stacking and overlapping of GO
> flakes parallel to the substrate. The topography of the films indicated
> decrease in roughness of GO films with deposition time.
>
> To fabricate rGO electrodes, GO film on copper was reduced using flash
> sintering. The reduction of GO is necessary because attachment of
> oxygen groups after oxidation of graphite is responsible for structural
> defects and destruction of π - π conjugation which hampers the ballistic
> movement of electrons, making GO films insulator. Reducing GO recovers
> the conductivity in rGO film. Flash sintering was used as it allows
> rapid, clean, and eco-friendly formation of substrate-intact rGO films
> on large scale. To accomplish complete conversion of GO to rGO, the
> effect of pulse energy at constant pulse duration and number of pulses
> was studied. The structural studies indicated decrease in interlayer
> spacing, restored crystallinity and removal of oxygen groups as found
> by the decrease in ID/IG ratio and an increase in C/O ratio. The
> morphology of multilayer rGO film showed fluffy structure with voids
> while topography showed increased roughness due to rearrangement of rGO
> flakes upon removal of gaseous by-products up on sintering. The
> adsorption isotherm of rGO film showed specific surface area (SSA) of
> 373 m² g⁻¹, and mesoporous structure with average pore size of 10.8 nm,
> which is highly beneficial for supercapacitors. The cyclic voltammetry
> (CV) analysis of rGO film showed substantial improvement in electrical
> conductivity for specific capacitance (C_{sp}) of 475.8 F g⁻¹ at scan rate
> of 2 mV s⁻¹. The reduction was further evident by an enhancement in
> contact angle from ~ 66° to ~ 81°.
>
> Finally, the rGO electrodes were used to make symmetric supercapacitor
> by sandwiching PVA/H₃PO₄ electrolyte between them. The structural
> studies revealed decrease in crystallinity, improvement in flexibility
> and mechanical strength on addition of acid to PVA. A PVA/H₃PO₄
> hydrogel electrolyte was developed using freeze-drying and electrolyte
> soaking which showed ionic conductivity of 0.03 S cm⁻¹. The comparative
> study of PVA/H₃PO₄ gel electrolyte, freeze-dried PVA and hydrogel
> electrolyte was also carried out. In the first case, a PVA/H₃PO₄ gel
> electrolyte was sandwiched between rGO electrodes. The device showed
> stable potential window of 0.6V and C_{sp} of 42 mF cm⁻², at 2 mA cm⁻². In
> the second case, a hydrogel electrolyte was sandwiched between rGO
> electrodes. For this, the charge-discharge test revealed higher stable
> potential window of 0.7 V and C_{sp} of 187.4 mF cm⁻², at 2 mA cm⁻², which
> is substantially higher than rGO based supercapacitors reported in the
> literature so far. Thus, this work demonstrates the successful
> fabrication of graphene electrodes, hydrogel electrolyte and an
> all-solid-state graphene supercapacitor.

Links:

[1] <https://www.sciencedirect.com/topics/chemistry/proton-conductor>

[2]

<https://www.sciencedirect.com/topics/chemistry/acid-dissociation-constant>

Attachments:

untitled-[2].html	
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