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EXPERIENCE

National Postdoctoral Fellow (Project: Synthesis of Organic-Inorganic Hybrid Perovskites for PV Applications) Centre for Energy Studies , Indian Institute of Technology- Delhi (IITD), Delhi, India from September 2019 to September 2021

Visiting Fellow (Project: Recycling of lithium-ion batteries), Smart Centre, School of Materials Science and Engineering, University of New South Wales (UNSW) Sydney, NSW 2052, Australia from July 2018 to July 2019

Project Engineer (Project: Degradation study on materials used in Si-based PV modules), National Centre for Photovoltaic Research and Education (NCPRE), Indian Institute of Technology- Bombay (IITB), Mumbai, India) from August 2016 to June 2018)

Research Associate (Project: Carbon based counter electrodes for dye sensitized solar cells), Indian Institute of Technology Bombay (IITB), Mumbai, India) from February 2016 to July 2016

Research Areas

- Ceramic Processing
- Dye Sensitized Solar Cells
- Organic Light Emitting Diodes
- Supercapacitors
- Solar PV modules
- Lithium-ion Batteries
- Recycling of E-waste
- Perovskite Solar Cells

EDUCATION

Indian Institute of Technology Bombay (IIT Bombay), Mumbai, India

- Ph.D. in Ceramics (Synthesis and characterization of ceramic carbon resistors) Supervisor- Professor Parag Bhargava (2016)
- 1 Patent (Fabrication of ceramic carbon composites with low specific resistance)
- Book Chapter in Willey publications Book on “Counter Electrodes for Dye sensitized and Perovskite Solar cells” Editors: Professor Anders Hagfeldt and Professor Sining Yun (Chapter-4: Counter electrodes for DSSCs based on carbon derived from edible sources) ISBN: 978-3-527-41367-6, January (2018)
- Book Chapter Submitted in upcoming Springer publications Book on “Springer Handbook of Inorganic Photochemistry” Editors: Professor Dr. Tsutomu Miyasaka and Dr. Ajay Kumar Jena (Chapter: Dye Sensitized Solar Cells) (2019)

Thapar University, Patiala, Punjab, India

- M.Tech in Materials Science (7.3/10) (2009)
- M.Tech- Major Project (Synthesis and Characterization of Cadmium Metal Complex Based Materials for OLEDs Applications)

Supervisors-

Professor Kulvir Singh (Thapar University, Patiala, India)

Scientist-G, Dr. M. N. Kamalasanan (National Physical Laboratory Delhi (NPL), New Delhi, India)

Principal Scientist, Dr. Ritu Srivastava (National Physical Laboratory Delhi (NPL), New Delhi, India)

- M.Tech –Minor Project (Investigate the role of additive on Cu& Co thin films in terms of properties and nucleation and growth

  Supervisor- Professor S.C. Kasyap (Indian Institute of Technology Delhi (IIT DELHI), New Delhi, India)

Choudhary Charan Singh University, Meerut, India

- M.SC. in Physics (58.89%) (2005)
- M.SC. Project- Phase shift oscillator using IC 8085 & see the phase output single

Supervisor- Dr. Keshav Kumar (M.M.H. College Ghaziabad)

Choudhary Charan Singh University, Meerut, India

- B.SC. in Physics, Chemistry, Maths (S.S.V.PG College, Hapur) (66.70%) (2003)

U.P. Board, Allahabad, India

- XIIth in Hindi, English, Maths, Physics, Chemistry (S.S.K. Inter College, Hapur) (Distinction in Physics, Chemistry and Maths 69.80%) (2000)
- Xth in Hindi, English, Maths, Science, Biology, Social Science (S.S.K. Inter College, Hapur) (61.16%) (1998)

PUBLICATIONS

1. **Rahul Kumar,** Ankur Soam, Veena Sahajwalla, Carbon coated cobalt oxide (CC-CO3O4) as electrode material for supercapacitor applications, Materials Advances, 2 (2021) 2918-2923
2. R Lakra, **R Kumar**, D Thatoi, A Soam, A mini-review: Graphene based composites for supercapacitor application, Inorganic Chemistry Communications, 133 (2021) 108929
3. DS Pattanayak, J Mishra, J Nanda, PK Sahoo, **R Kumar,** NK Sahoo, Photocatalytic degradation of cyanide using polyurethane foam immobilized Fe-TCPP-S-TiO2-rGO nano-composite, Journal of Environmental Management 297 (2021) 113312
4. **Rahul Kumar,** Ankur Soam, Synthesis and characterization of sucrose derived carbon/MnO2 nanocomposite, Materials Today: Proceedings 35 (2021) 76-78
5. R Lakra, **R Kumar**, DN Thatoi, PK Sahoo, A Soam, Synthesis and characterization of cobalt oxide (Co3O4) nanoparticles, Materials Today: Proceedings 41, 2021, 269-271
6. **Rahul Kumar**, Ankur Soam, Rumana Hossain, Irshad Mansori, Veena Sahajwalla, "Carbon coated iron oxide (CC-IO) as high performance electrode material for supercapacitor applications" Journal of Energy Storage, 32 (2020) 101737
7. **Rahul Kumar**, Ankur Soam, Veena Sahajwalla, Sucrose-derived carbon-coated nickel oxide (SDCC-NiO) as an electrode material for supercapacitor applications, Materials Advances, 1 (2020) 609-616

8. **Rahul Kumar**, Rasoul Khayyam Nekouei, Veena Sahajwalla, “In-situ carbon coated tin oxide (ISCC-SnO_2) for micro-supercapacitor application**s** accepted in Carbon Letters, 2020, https://doi.org/10.1007/s42823-020-00142-0
9. **Rahul Kumar**, Balwant K singh, Ankur Soam, Smirtiranjan Parida, Parag Bhargava, Veena Sahajwalla “In-situ carbon supported titanium dioxide (ISC-TiO_2) as high-performance electrode material for supercapacitors” Journal of Nanoscale Advances, 2020, 2, 2376-2386.
10. **Rahul Kumar**, Mamraj Singh, Ankur Soam, “Study on electrochemical properties of Silicon micro particles as electrode for supercapacitor application” accepted in Surfaces and Interfaces,2020, 19, 100524.
11. **Rahul Kumar**, Ankur Soam “Synthesis and characterization of sucrose derived carbon/MnO_2 nanocomposite Materials Today: Proceeding,2020 https://doi.org/10.1016/j.matpr.2020.02.957
12. Ankur Soam, **Rahul Kumar**, Dhirendranath Thatoi, Mamraj Singh, Influence of the Voltage Window on Nickel ferrite/Graphene Composite based Supercapacitor accepted in Journal of Inorganic and Organometallic Polymers and Materials, 2020, https://doi.org/10.1007/s10904-020-01540-7
13. **Rahul Kumar**, Veena Sahajwalla, Parag Bhargava, “Counter electrode for dye sensitized solar cell made by carbon derived from organic precursor 2-Methyl-8-hydroxyquinolinol (Mq)**”** Journal of Nanoscale Advances, 2019, 1, 3192-3199.
14. **Rahul Kumar,** Anish Raj, Sagar Mitra, Parag Bhargava, **“**Carbon derived from sucrose as anode material for lithium ion batteries” Journal of Electronic Materials 2019, 48, 7389-7395.
15. **Rahul Kumar**, Balwant K singh, Ankur Soam, Smirtiranjan Parida,Parag Bhargava, “In-situ carbon coated manganese oxide nanorods (ISCC-MnO_2NRs) as an electrode material for flexible supercapacitors” Journal of Diamond and Related Materials 94 (2019) 110-117.
16. Ankur Soam, **Rahul Kumar**, C.Mahender, Mamraj Singh, Rajiv Dusane, Dhirendranath Thatoi “Development of Paper-Based Flexible Supercapacitor: Bismuth errite/Graphene Nanocompositeas an Active Electrode Material” Journal of Alloys and Compounds 2019,813, 152145.
17. Ankur Soam, Mamraj Singh**, Rahul Kumar** “Electrophoretically Deposited BFO Nanopartcles Film for Supercapacitor Application” accepted in Russian Journal of

Electrochemistry.

18. Ankur Soam, Kaushik Parida, **Rahul Kumar**, Pravin Kavle and Rajiv Dusane, “Silicon-MnO2 Core-Shell Nanowires as Electrodes for Micro-Supercapacitor Application” Journal of Ceramics International, 2019, 45, 18914-18923.
19. Ankur Soam, **Rahul Kumar,** Mahender C, Balwant Kumar, Mamraj Singh Smrutiranjan Parida, Rajiv O Dusane, “Synthesis of Nickel Ferrite Nanoparticles Supported on Graphene Nanosheets as Composite Electrodes for High Performance Supercapacitor” Journal of Chemistry Select, 2019,4,9952-9958.
20. **Rahul Kumar,** Parag Bhargava, “Synthesis and characterization of carbon based counter electrode for dye sensitized solar cells (DSSCs) using organic precursor 2-2’Bipyridine (Bpy) as a carbon material” Journal of Alloys and Compounds 748 (2018) 905-910.
21. Ankur Soam, C. Mahender, **Rahul Kumar**, Mamraj Singh, “Power performance of BFO-graphene composite electrodes based Supercapacitor” Mater. Res. Express 6 (2019) 025054
22. Santoshini Nayak, Ankur Soam, Jyotirmayee Nanda, Mahender Chegonda, Mamraj Singh; Debananda Mohapatra, **Rahul Kumar** "Sol-gel synthesized BiFeO3-Graphene nanocomposite as efficient electrode for supercapacitor application" Journal of Materials Science: Materials in Electronics 29 (2018) 9361-9368.
23. **Rahul kumar,** Siva Sankar Nemala, Sudhanshu Mallick and Parag Bhargava, “High efficiency dye sensitized solar cell made by carbon derived from sucrose” Optical Materials 64 (2017) 401-405.
24. **Rahul kumar,** Venu Madhav, More,Shyama Prasad Mohnty, Siva Sankar Nemala, Sudhanshu Mallick and Parag Bhargava “A simple route to making counter electrode for dye sensitized solar cells (DSSCs) using sucrose as carbon precursor”Collodial and Interface Science 4 (2015) 146-150.
25. **Rahul Kumar**, Parag Bhargava, Fabrication of a counter electrode using glucose as carbon material for dye sensitized solar cells, Materials Science in Semiconductor Processing 40 (2015) 331-336.
26. **Rahul kumar,** Siva Sankar Nemala, Sudhanshu Mallick and Parag Bhargava, “Fabrication of carbon based counter electrode for dye sensitized solar cells (DSSCs) using sugar free as a carbon material” Journal of Solar Energy 144 (2017) 215–220.
27. **Rahul Kumar,** Ankur Soam, Rajiv O Dusane and Parag Bhargava “Silicon

nanowires-sucrose derived carbon composite for supercapacitors” Journal of Materials Science: Materials in Electronics accepted (2017) (DOI: 10.1007/s10854-017-8105-x).

28. **Rahul Kumar,** Parag Bhargava “Synthesis and characterization of low specific resistance alumina-clay–carbon composites by colloidal processing using sucrose as a soluble carbon source for electrical applications” RSC Advances 6 (2016) 8705-8713.
29. **Rahul Kumar** and Parag Bhargava “Fabrication of low specific resistance ceramic carbon composites by slip casting” Asian Ceramic Societies 3 (2015) 262-265.
30. **Rahul Kumar** and Parag Bhargava “Fabrication of low specific resistance alumina-clay-carbon composite by using glucose as soluble carbon source” Bulletin of Materials Science (2017) DOI: 10.1007/s12034-017-1463-4.
31. **Rahul Kumar** and Parag Bhargava “In-situ growth of silica nanowires in ceramic carbon composites” Journal of Asian Ceramics Societies 5 (2017) 304-312.
32. **Rahul Kumar**, Parag Bhargava, Ritu Srivastava, Priyanka Tyagi “Synthesis and Electroluminescence properties of Tris [5-choloro- 8- hydroxyquinoline] Aluminium Al(5-Clq)3 ” Journal of Semiconductors 36 (2015) 064001-5.
33. **Rahul Kumar,** Ritu Srivastava, Punita Singh “Synthesis and electroluminescence characterization of a new aluminum complex, [8-hydroxyquinoline] bis [2, 2’bipyridine] aluminum Al(Bpy)2q” Journal of Semiconductors 37 (2015) 13001-5.
34. **Rahul Kumar,** Parag Bhargava, Ritu Srivastava, Punita Singh “Synthesis and electroluminescence properties of a new aluminium complex [5-choloro- 8-hydroxyquinoline] bis [2,2’bipyridine] Aluminium Al(Bpy)2(5-Clq)” Journal of Molecular Structure” 1100 (2015) 592-596.
35. **Rahul Kumar,** Ritu Srivastava, Akshaykumar, M.N. Kamalasanan and K.singh “Green-light–emitting electroluminescent device based on a new cadmium complex.” Euro Physics Letters 90 (2010) 57004
36. **Rahul Kumar,** Parag Bhargava, Gayatri Chauhan, and Ritu Srivastava “Synthesis and Characterization of Cadmium Complex and Its Application in Organic Light Emitting Diodes (OLEDs)” Advance Science Letters 20 (2014)

1001-1004.

37. **Rahul kumar,** Ankur Soam, Parag Bhargava, "Synthesis and Characterization of Lanthanum Complex Bis (5-Choloro-8hydroxy quinoline)(2-2'bipyridine) Lanthanum $La(Bpy)(5\text{-}Clq)_2$" accepted in International Journal of Nano and Bio Materials.
38. **Rahul Kumar** and Parag Bhargava "Synthesis and Characterization of A New Cadmium Complex, Cadmium [(1,10-phenanthroline)(8-hydroxyquinoline)]" Procedia Materials Science 10 (2015) 37-43.
39. **Rahulkumar,** K.Singh, R.Srivastava, M.N. Kamlasanan "Synthesis and Electroluminescence Characterization of Cadmium Complex." Journal of Nano and Electronic Physics 3 (2011) 514-520.
40. **Rahul Kumar "**Synthesis and characterization of a new photoluminescent material bis (8-hydroxy quinoline) (1-10 phenanthroline) aluminum Al $(Phen)q_2$" Journal of Nano and Electronic Physics 4 (2017) 04030-3.
41. **Rahul Kumar,** K. Singh, R. Srivastava and M.N.Kamalasanan "A New Cadmium Complex Material for Yellowish-Green Light Electroluminescent Devices."IEEE proceeding ISBN:978-1-4799-1377-0 page 585-588.
42. **Rahul Kumar,** Veerta Singh, Javid Ali "Synthesis and Characterization of a New Photoluminescent Material Tris (2-methyl-8-hydroxy quinoline) Europium Eu(mq)3 Invertis Journal of Renewable Energy, Vol. 6, No. 1, 2016 ; pp. 1-5.
43. **Rahul Kumar** "Synthesis and Characterization of a new aluminium complex Bis [5-choloro- 8-hydroxyquinoline][2,2'bipyridine] Aluminium $Al(Bpy)(5\text{-}Clq)_2$" Journal of Nano and Electronic Physics 4 (2017) 04003-4.
44. **Rahul Kumar** and Parag Bhargava "Synthesis and characterization of a new aluminium complex Tris-[1-10 Phenanthroline] Aluminium" AIP Proceedings, 1728, 020025 (2016); DOI: 10.1063/1.4946075
45. **Rahul Kumar** and Parag Bhargava "Synthesis and Characterization of a New Photoluminescent Material (8-hydroxy quinoline) bis (2-2'bipyridine) Lanthanum La(Bpy)2q" AIP Proceedings 1728, 020629 (2016); DOI: 10.1063/1.4946680
46. **Rahul Kumar** and Parag Bhargava "Synthesis and Characterization of a New Photoluminescent Material Tris (2-methyl-8-hydroxy quinoline) Lanthanum $La(mq)_3$" AIP Proceedings 1731, 140006 (2016); DOI: 10.1063/1.4948172

47. **Rahul Kumar** and Parag Bhargava "Synthesis and Characterization of a New Photoluminescent Material Tris (5-Choloro 8-hydroxy quinoline) Lanthanum La(5-Clq)$_3$" Materials Today Proceeding, Materials Today: Proceedings 3 (2016) 1737–1741.
48. **Rahul Kumar** and Parag Bhargava, "Synthesis and Characterization of a new aluminium complex Bis [8-hydroxyquinoline][2,2'bipyridine] Aluminium Al(Bpy)q$_2$" accepted in DAE Solid State Physics Symposium 2017.
49. **Rahul kumar,** Ankur Soam, Parag Bhargava, "Synthesis and Characterization of a New Photoluminescent Material (5-Choloro-8-hydroxy quinoline) bis (2-2'bipyridine) Lanthanum La(Bpy)$_2$(5-Clq)" AIP Proceedings 1832,140014 (2017) DOI: 10.1063/1.4980796.
50. **Rahul Kumar,** Shashwata Chattopadhyay, Chetan Singh Solanki, Sarita Zele, Parag Bhargava, "Study of Ethylene Vinyl Acetate (EVA) Films used in Photovoltaic Modules" Journal of Nano and Electronic Physics, 10(5), 05043-1-05043-3, 2018
51. **Rahul Kumar,** Parag Bhargava, "Characterization of Different type of Backsheet films used in PV modules' Journal of Nano and Electronic Physics. Vol. 10 No 6, 06029(4pp) (2018).

52. **Rahul Kumar**, Rumana Hossain, Veena Sahajwalla, Recycling of lithium-ion batteries using soluble carbon sources under preparation.

BOOK CHAPTERS

1. **Rahul Kumar**, Parag Bhargava "Counter Electrodes for Dye sensitized and Perovskite Solar cells" Editors: Professor Anders Hagfeldt and Professor Sining Yun (Chapter-4: Counter electrodes for DSSCs based on carbon derived from edible sources) (Wiley Publications) ISBN: 978-3-527-41367-6, January 2019

2. Amrut Agasti, Lekha Peddikakkandy, **Rahul Kumar**, Shyama Prasad Mohanty, Vivekanand Gondane, Sudhanshu Mallick, Parag Bhargava, Book Chapter Submitted in upcoming Springer publications Book on "Springer Handbook of Inorganic Photochemistry" Editors: Professor Dr. Tsutomu Miyasaka and Dr. Ajay Kumar Jena (Dye Sensitized Solar Cells)

PATENT

Rahul Kumar and Parag Bhargava, “Fabrication of ceramic carbon composites with low specific resistance”, India patent no-317,522

ABSTRACT of Ph.D. THESIS

Ceramic carbon resistors (CCRs) are used in high voltage circuit breakers as switching resistors, which damp out the high frequency transient overvoltages of magnitude more than the rated voltage, generated during switching operation of a circuit breaker. During such applications in electrical power applications the materials have to sustain high currents of the order of 420 Ampere in a short time duration around 20 seconds. Switching resistors in high voltage circuit breakers require use of materials with low specific resistance which can sustain high temperatures for short durations, have high thermal conductivity and thermal shock resistance. Materials that satisfy these requirements can be produced by dispersing a conducting phase such as carbon black, graphite, CNT, graphene in ceramic matrix thus forming ceramic carbon composites (CCCs). Dispersion of these ultrafine forms of carbon to obtain contiguity at lower volume fractions is a challenge.

In the doctoral work, CCCs were prepared using alumina-clay as the matrix and two type of carbon sources, insoluble carbon source (carbon black and graphite) and soluble carbon source (sucrose). Initially, CCCs were fabricated both through slip casting and powder compaction route. It was observed that all alumina-clay carbon composite sintered (1400^{o}C) samples, prepared using carbon black or graphite and produced by slip casting or powder compaction, showed in-situ formation of silica nanowires.

CCC samples prepared with silica bearing glass when sintered in presence of carbon black or graphite did not show silica nanowire formation.

It is known from prior reports in the literature that carbon when added to ceramic matrices inhibited densification resulting in poor mechanical properties. Thus, to obtain enhanced mechanical properties it is desired to minimize the amount of carbon yet achieve desired electrical conductivity. Studies have shown

that electrical percolation with use of conducting carbon forms can be achieved at lower amounts with finer particle size. Thus, electrically conducting nanosized carbon like carbon black (CB) was preferred over coarser graphite particles for preparation of CCCs with the alumina-clay matrix materials. Also, it was evident from early work that the strength of CCCs produced via powder compaction was lower than of those produced by slipcasting. Thus, in the remaining part of the work slip casting (colloidal processing approach) was used as an alternative to powder compaction and also to achieve enhanced dispersion of nanosized carbon such as carbon black.

Two types of slurries, CB slurry and alumina-clay slurry were made independently and mixed together at a later stage to make CCCs. Electrical, thermal and mechanical properties of the CCCs have been studied. Electrical percolation could be achieved only at and above 4wt % carbon black as indicated by the resistor behaviour at that content in CCCs. Specific resistance of CCCs varied between 200 ohm-cm to 32ohm-cm for samples having 4- 8wt% carbon black content. Thermal conductivity of the CCCs increased with increase in sintered density as was the case for samples with decreasing carbon black content. Mechanical strength of CCCs decreased with increase in carbon carbon black content owing to inhibited densification.

CCCs were also fabricated by using alumina-clay slurries with addition of sucrose as a soluble carbon source. Sucrose is converted into conducting carbon with heat treatment at high temperature. CCCs made by soluble source (sucrose) sintered at 1400oC showed resistor behaviour even at carbon content less than 1wt % produced by graphitization of sucrose at high temperature. Raman spectroscopic scans over a wide area of the samples confirmed uniform distribution of carbon within the ceramic matrix. Resistivity of the alumina-clay-carbon composites varied between 30 ohm-cm to 2 ohm-cm for sucrose addition (equivalent carbon content) of 2 – 9wt %. The resistivity of the composite samples produced with use of 2wt % (carbon equivalent) sucrose was lower by several orders of magnitude than that of samples produced by dispersing 2wt % carbon black as the conducting phase. Mechanical and thermal conductivity of the

CCCs decreased with higher sucrose content additions. This is due to the increase in porosity with increasing sucrose additions in CCCs. Since sucrose is soluble and coverts into conducting carbon by pyrolysis at relatively low temperatures its use makes the entire processing to achieve carbon ceramic resistors with desired characteristics relatively easy. The same recipe can also be used to make spray dried granules and the CCRs may be prepared through powder compaction with obvious benefits in terms of faster rate of production as is the case with dry powder compaction.

ACHIEVEMENTS

- Assistant Editor- General Chemistry (ISSN: 2414-3421)
- Editorial member- International Journal of Materials Science and Applications (IJMSA) (ISSN: 2327-2643)
- Editorial member -Current Electronics and Telecommunications
- Editorial member-Semiconductor Science and Information Devices (SSID)
- Editorial member- SCIREA Journal of Energy
- Editorial member -SCIREA Journal of Physics
- Editorial member- SCIREA Journal of Chemistry
- Editorial member-SCIREA Journal of Materials
- Editorial member-SCIREA Journal of Metallurgical Engineering
- Editorial member- Applied Engineering (Science Publishing Group)
- Science and Engineering Research Board: National Post-doctoral fellowship (SERB-NPDF 2019)
- Crompton Greaves Research Fellowship (During time period of Ph.D.)
- Reviewer of a grant proposal on functional graded materials (FGMs) worth 70 lakhs.
- DST and CSIR travel grant 2013.
- Visiting fellow at UNSW Sydney (July 2018-July 2019)
- Reviewer of several journals like, Journal of Applied Materials and Interfaces (ACS), Journal of Organic Chemistry (ACS), Journal of

Colloid and Interface Science, Journal of Alloys and Compounds, Journal of Asian Ceramic Societies, Journal of Molecular Structure, Journal of King Saud University-Science, Journal of Physics and Chemistry of Solids, Molecular Simulation/Journal of Experimental Nanoscience, Indian Journal of Engineering and Materials Sciences and Journal of Energy,Ecology and Environment, Applied Energy Materials (ACS), Resources, Conservation & Recycling, Polymer Bulletin

- Reviewer of DAE Solid State Physics Symposium (One of the prestigious symposium on Solid State Physics in India).

CERTIFICATES

1-N.S.S. certificate in Thapar University

2- National conference on Ferroelectrics & Dielectric Materials in Thapar participation. Member in SPMS society (Thapar university,India)

3- National Conference MR-10 in IIT Bombay (India)

4- International Symposium on Semiconductor Materials and Devices (ISSMD-2011)- Poster presentation held on Baroda(India)

5- International Conference on Advanced Nano materials and Emerging Engineering Technologies (ICANMEET-2013)-Oral Presentation held on Chennai (India)

6- Materials Science and Technology (MS&T 2013) –Oral Presentation held on Montreal (Canada)

7- International Conference on Nano science & Nanotechnology (ICNN-2013) held on Lucknow, U.P (India)

8- International Conference on Nanotechnology (NANOCON-2014) – Oral Presentation held on Pune (India)

9- International Conference on Condensed Matters & Applied Physics (ICC-2015) held on Bikaner, Rajasthan (India)

10- DAE Solid State Physics Symposium (DAE-SSPS-2015) Oral Presentation held on Nodia, U.P (India)

11- International Conference on Materials Science and Technology

(ICMTech-2016) poster presentation held on New-Delhi (India)

12- Conference on Emerging Materials (CEMAT-2016) poster presentation held on Bangalore (India)

13- DAE Solid State Physics Symposium (DAE-SSPS-2016) poster presentation held on Odisha (India)

14- DAE Solid State Physics Symposium (DAE-SSPS-2017) poster presentation held on Mumbai (India)

DETAILS OF REFEREES

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PERSONAL DETAILS

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DECLARATION

I hereby declare that all the above information is true to the best of my knowledge.

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A simple route to making counter electrode for dye sensitized solar cells (DSSCs) using sucrose as carbon precursor

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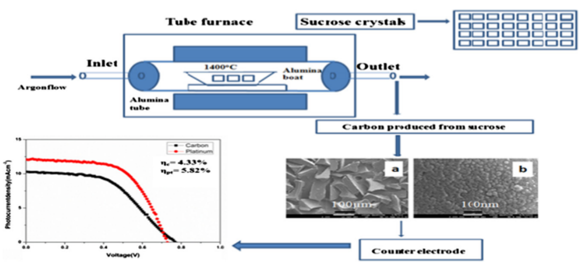
G R A P H I C A L   A B S T R A C T



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A B S T R A C T

Dye sensitized solar cells (DSSCs) have attracted much attention in recent years due to low cost fabrication as compared to silicon-based and thin film solar cells. Though, platinum is an excellent catalytic material for use in preparation of counter electrodes (CEs) for DSSCs it is expensive. Alternatives to replacement of platinum (Pt) that have been examined are carbon materials, conductive polymers and hybrids. In this work, counter electrode for DSSCs was fabricated using carbon material obtained from graphitization of sucrose at high temperature. A slurry of the carbon produced from sucrose graphitization was made with polyvinylpyrrolidone (PVP) as a surfactant and a coating was obtained by doctor blading the slurry over the FTO glass substrate. The current density (Jsc) and open circuit voltage (V_{OC}) of fabricated cell (area 0.25 cm^2) was 10.28 mA cm^{-2} and 0.76 V respectively. The efficiency of the cell was 4.33% which was just slightly lower than that obtained for similar cells using platinum based counter electrode.

1. Introduction

In recent years, dye sensitized solar cells (DSSCs) have attracted a great deal of attention due to their simple fabrication and low production cost. DSSCs are typically composed of porous nanostructured oxide film on a TCO glass with adsorbed dye molecules as a anode, an electrolyte containing iodide/triiodide redox couple or a suitable hole conductor, and a platinized fluorine-doped tin oxide (FTO) glass as the counter electrode [1–5]. Transition metal compounds (TMCs), carbon materials, conductive polymers and hybrids have been used as alternatives to the Pt counter electrode

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Synthesis and characterization of carbon based counter electrode for dye sensitized solar cells (DSSCs) using sugar free as a carbon material

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Dye-sensitized solar cells

ABSTRACT

Dye sensitized solar cells (DSSCs) are a low cost alternative to silicon-based and thin film solar cells. Usually DSSCs utilize platinum to catalyze the iodine redox couple and complete the electric circuit. Though, platinum is an excellent catalytic material for use in preparation of counter electrodes (CEs) for DSSCs but it is expensive. Alternatives to replacement of platinum (Pt) that have been examined are carbon materials, conductive polymers. In this work, counter electrode for DSSCs was fabricated using carbon material obtained from carbonization of sugar free at high temperature. Slurry of the carbon produced by carbonization was made with polyvinylpyrrolidone (PVP) as a surfactant and a coating was obtained by doctor blading the slurry over the FTO glass substrate. The DSSCs based on produced carbon CE show a maximum power conversion efficiency of 6.72% (area 0.25 cm^2), which is comparable to 8.19% of the cell with the conventional Pt CE at the same experimental conditions. The current density (Jsc) and open circuit voltage (V_{OC}) of the DSSCs was 17.10 mA cm^{-2} and 0.66 V respectively.

1. Introduction

Dye sensitized solar cells (DSSCs) are photochemical cells that convert photons into electrical energy (Sharifi et al., 2014). The current studies on DSSCs are mainly focus on dye synthesis, photo anode solid (or quasi liquid) electrolyte and counter electrodes (CEs). As an important part of DSSCs, counter electrode usually consists of conductive glass loaded with platinum or carbon as catalysts, which can enhance the charge transfer between CE and electrolyte interface, decrease the recombination possibility of I_3 and the electrons in the conduction band in TiO_2. Platinum CEs have superior performance due to high catalytic activity and high conductivity (Calogero and Marco, 2008; Tennakone et al., 2002; Gratzel, 2001). However, platinum is a noble metal and both of the fabrication methods, electrochemical deposition and sputtering used to prepare counter electrodes are high energy consuming and high cost of the platinum, which would limit the industrial applications (Nogueira and De Paoli, 2000; Lee et al., 2008). Therefore a lot of research is being done to find a new alternative material with low cost, good electrical conductivity, good chemical stability and good catalytic activity to replace the platinum (Rani et al., 2008; Geens et al., 2000; Ganesan et al., 2008; Shi et al., 2008). Recently carbonaceous materials including carbon black, graphite, hard carbon spheres, carbon nanotubes, graphene and carbon material produced from sucrose and glucose have been used in DSSCs to fabricate CEs due to their good conductivity and extremely low cost (Cha et al., 2009; Kay and Grätzel, 1996; Murakami et al., 2006; Ramasamy et al., 2008; Suzuki et al., 2003; Nam et al., 2010; Roy-Mayhew et al., 2010; Kumar et al., 2015; Kumar and Bhargava, 2015; Ma et al., 2015). One of the known limitations with use of these materials has been the poor adhesion of carbon based materials to the substrate. In this work, we report the fabrication of counter electrode using carbon material produced from the carbonization of sugar free at 1400 °C in flowing argon.

2. Experimental details

2.1. Materials

Sugar free (Zydus Wellness, India, chemical name of this material is Aspartame (N-(L-α-Aspartyl)-L-phenylalanine,1-methyl ester) and chemical formula is $C_{14}H_{18}N_2O_5$) Polyvinylpyrrolidone PVP (Sigma Aldrich, K-32) and ethanol (Changshu Yangyuan Chemical, China AR Grade) were used for preparation of carbon based counter electrode. Fluorine doped tin oxide (FTO) glass substrates (TEC8, sheet resistance 8–9 Ω □$^{-1}$, Pilkington), TiO_2 nanopowder (P25, Degussa), Polyethylene glycol (M_w = 600) PEG-600 (Thomas Baker) $RuL_2(NCS)_2$ (L = 2,2 -bipyridyl-4,4-dicarboxylic acid)

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Fabrication of a counter electrode using glucose as carbon material for dye sensitized solar cells

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ABSTRACT

Carbon material was produced from the graphitization of glucose at high temperature in flowing argon. The produced carbon material was characterized using Scanning electron microscopy, Transmission electron microscopy, Raman spectroscopy and XRD. Carbon slurry of the produced carbon was made in ethanol by using polyvinylpyrrolidone (PVP) as surfactant. Carbon slurry was coated homogeneously on fluorine doped tin oxide (FTO) glass by a doctor blade technique and applied as counter electrode for dye synthesized solar cell. The current density (J) and open circuit voltage (V_{OC}) of fabricated cell was 8.30 mA cm^{-2} and 0.77 V respectively. The efficiency of the cell was 3.63%, which is comparable to 5.82% of cell with platinum counter electrode under the same experimental conditions.

1. Introduction

Dye sensitized solar cells (DSSCs) have attracted much attention due to ease of fabrication, low cost and high conversion efficiency [1–2]. The DSSCs consists of a dye sensitized TiO_2 nanocrystalline electrode, liquid electrolyte acts as a redox couple, counter electrode which collects the electrons arriving from the external circuit and catalyze the I_3^-/I^- redox-coupled regeneration reaction in electrolyte [3]. Platinum is the commonly used material to fabricate the counter electrode for DSSCs due to its high catalytic activity [4] but high cost of this material is the major issue. A lot of research is going on to replace the platinum by other alternatives like carbon materials, conducting polymers, inorganic materials, multiple compounds and composites to fabricate the counter electrodes for DSSCs [5–7]. These materials also have good performances in DSSCs.

Among all the materials carbon materials (carbon black, graphite, carbon nanotubes, graphene etc.) have been studied by many researchers [8–14] as a promising alternatives to substitute the Pt for DSSCs due to their high conductivity, easy fabrication and good catalytic activity. In this work, we report the fabrication of carbon material produced from the graphitization of glucose at high temperature in flowing argon. Carbon slurry was made by using produced carbon material with PVP and carbon film was coated on FTO glass substrate by the doctor blade technique for the fabrication of counter electrode used in DSSCs.

2. Experimental details

2.1. Materials and methods

Carbon material was produced from the graphitization of glucose (Glucon-D, Heinz) (5 g) at high temperature (1400° C) in flowing argon. Carbon slurry from produced carbon was prepared as follows, PVP (K-32, Sigma-Aldrich) (0.12 gm) solution was prepared in ethanol (10 ml), carbon

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Synthesis and characterization of carbon based counter electrode for dye sensitized solar cells (DSSCs) using organic precursor 2-2′Bipyridine (Bpy) as a carbon material

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ABSTRACT

Dye sensitized solar cells (DSSCs) have attracted much attention in recent years due to low cost fabrication as compared to silicon-based and thin film solar cells. Carbon materials are alternatives to Pt as a counter electrode in dye sensitized solar cells due to their low cost and good catalytic properties. Carbon was derived from carbonization of 2-2′Bipyridine (Bpy) at high temperature. Carbon slurry was prepared using polyvinylpyrrolidone (PVP) as a surfactant and carbon coating was obtained by doctor blading the slurry over the FTO glass substrate. DSSCs based on carbon showed short circuit current density J_{SC} of 13.10 mAcm^{-2} which is higher than Pt (11.80 mAcm^{-2}) while power conversion efficiency (PCE) of 5.24% and fill factor (FF) of 0.61 which is lower than PCE of 5.51% and FF of 0.70 of the cells with platinum (Pt) based counter electrode.

1. Introduction

Dye sensitized solar cells (DSSCs) are known as low-cost photovoltaics devices and have attracted much attention in the last years for their capability to provide low cost power. Dye-sensitized solar cells (DSSCs) have attracted much attention due to their moderate energy conversion efficiency, low cost, environment-friendliness, simple fabrication procedure [1–3]. A typical DSSC constitutes a photoanode and counter electrode (CE) with a liquid electrolyte formed of a redox couple (triiodide/iodide) filled in between [4–6]. The photoanode in DSSCs is usually a porous film of sintered TiO_2 nanoparticles deposited on fluorine-doped tin dioxide (FTO) sensitized by dye molecules, the CE is generally a platinum coated FTO glass substrate. When dye molecules are illuminated with sunlight, electrons are promoted into the LUMO of the dye and these electrons are injected into TiO_2, followed by their diffusion to the electrode and going across the external load the electrons are transferred through the redox couple at the counter electrode back to reduce the dye molecules. The counter electrode plays an important part in catalyzing the transfer of electrons from the electrode to the I_3^- which is a part of the redox couple. The I^-/I_3^- redox couple is essential for regenerating the sensitizer (dye) after the electron injection.

The mass production of DSSCs has been restricted due to higher cost and poor stability of platinum. For a counter electrode in DSSCs, it must possess high conductivity and good catalytic activity for electrolyte regeneration, as well as good stability. A large number of studies have reported various alternatives to platinum including carbon, conductive organic polymers, and inorganic materials such as various sulphides. Currently, the important issues are seek for the economical and highly catalytic materials to replace Pt for sustainable development [7–11]. There are many low cost materials, such as carbon materials [12–20], conductive polymers [21–24], alloys [25], metal oxide [26,27], metal carbides [28] transition metal based materials including metal nitrides [29–32] and metal sulphides [33–35] have been used as novel counter electrodes and demonstrated outstanding catalytic performance for the triiodide reduction. Carbon materials have attracted much attention compared to the other counter electrode materials due to their relatively low cost, high catalytic activity and good stability. Amongst the Pt-free CEs, carbon materials are the widest researched CE materials. The highest PCE (14.3%) of DSSCs is based on the FTO/Au/GNP (graphene nanoplatelet). The low cost, simple preparation and good stability render carbon materials stronger

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Synthesis and characterization of low specific resistance alumina-clay–carbon composites by colloidal processing using sucrose as a soluble carbon source for electrical applications

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Switching resistors in high voltage circuit breakers require the use of materials with low specific resistance which can sustain high temperatures for short durations, have high thermal conductivity and thermal shock resistance. Materials that satisfy these requirements can be produced by dispersing a conducting phase such as carbon black, graphite, CNT, graphene in ceramic matrix. Dispersion of these ultrafine forms of carbon to obtain contiguity at lower volume fractions is a challenge. In this work, alumina-clay–carbon composites were fabricated by using alumina-clay slurries with addition of sucrose as a soluble carbon source. Sucrose is converted into conducting carbon with heat treatment at high temperatures. Alumina-clay–carbon composites made using a soluble source (sucrose) sintered at 1400 °C showed resistor behaviour even at carbon contents less than 1 wt% produced by graphitization of sucrose at high temperature. Raman spectroscopic scans over a wide area of the samples confirmed uniform distribution of carbon within the ceramic matrix. Resistivity of the alumina-clay–carbon composites varied between 30 ohm cm to 2 ohm cm for sucrose additions (equivalent to carbon content) of 2–9 wt%. The resistivity of the composite samples produced with the use of sucrose was significantly lower than that of samples produced by dispersing carbon black as the conducting phase.

1. Introduction

From the perspective of electrical insulation, ceramic materials are among the best insulators with resistivity at room temperature exceeding 10^{14} ohm cm. There are applications that require the use of ceramic materials that have low resistivity such that these materials can allow passage of large electrical currents and yet sustain high temperatures. Also, these materials must have high thermal conductivity in order to sustain thermal shock. High voltage linear resistors are one such application which requires these materials to have the capability of handling energies ranging from joules to mega joules, at frequencies up to mega Hz. These high voltage resistors can be used in applications such as electrical transmission, traction, AC/DC drives, pulse power, dummy loads, induction heating and pulse forming networks.[1] Besides appropriately doping ceramic materials, resistivity of ceramic materials can be lowered by dispersing a conducting phase in amounts that results in contiguity of the conducting phase in three dimensions or formation of a percolating network.[2–6] Processing of ceramics with electrically conducting phase dispersed into the matrix has been undertaken through both dry and wet powder processing.[7–12] While it can be a challenge to disperse ultrafine particles in dry powder processing, it is relatively easier to achieve dispersion of ultrafine particles in the wet state, by breaking down agglomerates and promoting adsorption of dispersant molecules from solution which ensures that the particles remain deagglomerated.

Ceramic composites with dispersed conductive particles can be prepared from slurries either by compaction of spray dried granules produced from the slurries or by slipcasting or gelcasting of the slurries.[13–18] The percolation threshold of the fillers depends upon their physical characteristics such as particle size and aspect ratio. For low aspect ratio fillers such as carbon black and graphite, assuming a particle size of 2–5 µm, the amount to be added was found to be at least 20 vol%, whereas the amount of additive required to achieve percolation with high-aspect-ratio carbon nanotubes (CNTs) was reduced to less than 12 vol%.[19–23] Indeed, it is not optimal for the conductive filler such as carbon to occupy a large volume of the ceramic matrix since it inevitably leads to degradation of the intrinsic structural properties of the host ceramics either due to non-homogeneous dispersion of the conductive filler or due to inhibited densification.[24]

In one of the studies, the electrical resistivity of pure alumina sintered in an oxygen atmosphere at 1500 °C was found to be around 10^{12} ohm cm.[25] The bulk resistivity of a sample sintered

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Fabrication of low specific resistance ceramic carbon composites by slip casting

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ABSTRACT

Ceramic carbon composites (CCCs) utilize carbon as the conducting phase and can be used as resistors for high voltage electrical applications. To obtain superior mechanical properties it is desired to minimize the amount of carbon yet achieve desired electrical conductivity. Thus, electrically conducting nanosized carbon like carbon black (CB) was used with the matrix materials. Uniform dispersion of CB in ceramic matrix leading to a percolating network at lowest possible volume fraction is a challenge. The present work reports colloidal processing approach to overcome these challenges. Fabrication of CCCs was done by slip casting. Two types of slurries, CB slurry and alumina–clay slurry, were made independently and mixed together at a later stage to make CCCs. Electrical, thermal and mechanical properties of the CCCs have been studied.

1. Introduction

Switching resistors serve the purpose of reducing current chopping and reduce the high magnitude in rush currents when power apparatus like capacitor banks, shunt reactors and no-load transformers are switched on. With the capability of sustaining a vast range of energies ceramic carbon resistors (CCRs) are being used in this application from the inception of high voltage circuit breakers. With regard to handling high energy per unit volume, CCRs are superior to any other materials. Ceramic carbon resistors are used in 420 kV SF_6 gas circuit breakers as switching resistors. Ceramic carbon composites (CCCs) used as CCRs are typically composed of an insulating matrix (ceramic) and electrically conducting carbon. The conductivity of the composite depends upon the amount of each phase present in the composite. As the amount of conducting carbon is increased particles begin to contact each other and a continuous conducting network is formed throughout the volume of the composite and resistivity of the composite decreases [1–5]. The amount of filler needed, to reach the percolation threshold, depends upon its physical characteristics such as particle size and aspect ratio. Typically, around 20 vol% of low-aspect-ratio fillers such as carbon black (CB) and graphite need to be added [6,7] whereas for high-aspect-ratio fillers such as carbon nano tubes (CNTs) the amount of additive required is reduced to less than 12 vol% [8–10]. The addition of conductive filler such as carbon black particles which do not sinter to each other can lead to degradation in mechanical properties and thus it is desired that its addition is kept to a minimum which still yields the desired electrical properties. Dry powder mixing often does not result in a homogeneous dispersed conducting phase leading to low electrical conductivity, low strength of sintered compacts, and poor reproducibility of fabrication. To overcome these problems, powder composites have been processed and consolidated using colloidal techniques. In this work, we report the fabrication of CCCs by slip casting and characterization of their electrical, thermal and mechanical properties. The sample microstructure and their physical properties have been analyzed in terms of the dispersion of carbon black.

2. Experimental

2.1. Fabrication of ceramic carbon composite

CCCs were made by slip casting a blend of two types of slurries – CB and alumina–clay slurries. CB (Vulcan X-72, Cabot, Nitrogen adsorption method, specific surface area 270 m^2/g) slurry was prepared using pre-optimized amount (21 wt%) of polyvinyl pyrrolidone (PVP) (K-30 Spectrochem, molecular weight 60,000) with respect to CB, added to 30 ml water and stirred on a magnetic

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In-situ carbon coated manganese oxide nanorods (ISCC-MnO_2NRs) as an electrode material for supercapacitors

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ABSTRACT

The fabrication of energy storage devices with lowering the cost and improving the performance has always been the need for society. Therefore, supercapacitors with special features such as light-weight, easy portability and remarkable charging/discharging rate capability have widely been studied in the literature. In the present work, In-situ carbon coated manganese oxide nanorods (ISCC-MnO_2NRs) have been studied for the supercapacitor application. ISCC-MnO_2NRs were prepared by slip casting method followed by annealing at 1200 °C. During heat treatment, sucrose has transformed into conducting carbon and coated on the surface of MnO_2. ISCC-MnO_2NRs were examined by FEG-SEM, FEG-TEM, XRD, FT-IR, BET and Raman spectroscopy. The measurement of the electrochemical properties of the material was carried out in the two-electrode configuration using 1 M Na_2SO_4 aqueous solution as an electrolyte. The specific capacitance of ISCC-MnO_2NRs was found to be 28.24 F/g at the current density of 1 A g^{-1} with energy density of 0.98 Wh/kg. This work suggests ISCC-MnO_2NRs may be a promising electrode material for the supercapacitor.

1. Introduction

Supercapacitors (SCs) are efficient energy storage devices which are in research focus in recent years because of their high power density [1–4]. The values of energy density, power density, charging/discharging rate and cyclic stability may be increased by combining two or three different materials into a single electrode. Presently, to combine electrical double-layer capacitors (EDLCs) with faradaic pseudocapacitors capacitor has been gaining much interest due to the increased in power density, cycle life, and relatively high energy density. However, the growing demand for efficient energy storage presently has not been fulfilled by SCs. SCs have the combined properties of lithium-ion batteries and traditional capacitors. SCs exhibit relatively high energy densities and they are lighter in weight and smaller in size compared with traditional capacitors [5]. SCs are charged and discharged quickly in seconds, while lithium-ion batteries require minutes to hours, and they are environmental friendly. SCs are commonly used in aerospace, defense science, new energy vehicles, information technology, electronics industry, and many other areas [6]. Flexible energy storage devices have also attracted much attention from last few years because of their potential applications in various electronic systems [7–13].

Transition metal oxides (TMOs, where M represents Fe, Co, Ni, or Mn etc.) are potential candidates to replace the traditional carbonaceous materials because of higher theoretical specific capacities [14–17]. Manganese oxide (MnO_2) has been generally used in Duracell (alkaline) based batteries, electrolysis, photocatalytic activities, and water purification. MnO_2 has also been used in water-cleaning due to its ability to absorb toxic ions [18]. The modification of chemical structure and morphology of manganese oxides has become more important due to its use in energy storage and conversion. MnO_2 has attracted a lot of attention because of its low cost, relatively high theoretical capacity (756 mAh g^{-1}), low conversion potential, wide potential window, an abundant resource of Mn, and environmental friendliness [19–21]. However, MnO_2 has main issues such as significant volume expansion (> 170%) and intrinsically poor electronic conductivity during the charge/discharge process. It typically results in low rate capability and poor cycle life [20]. These days, the hybridization of MnO_2 with highly conductive and electrochemically stable materials is considered as a promising and efficacious strategy to enhance the electronic conductivity of MnO_2 [21,22]. However, the enhancements in rate capability and cycling performance are still required for practical applications [23,24]. To solve these problems, a lot of efforts have been made in the past few years. Fabricating the multifarious crystal structure, improving the morphology, and fabricating the composites are the

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Sucrose-derived carbon-coated nickel oxide (SDCC-NiO) as an electrode material for supercapacitor applications

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Sucrose-derived carbon-coated nickel oxide (SDCC-NiO) was successfully synthesized *via* a colloidal method. Nickel oxide and sucrose were used to synthesize SDCC-NiO, where sucrose worked as a soluble source of carbon in the process. Sucrose was converted into carbon during annealing in an inert atmosphere and coated on the surface of nickel particles. SDCC-NiO was characterized *via* Brunauer–Emmett–Teller (BET) method, X-ray diffraction (XRD), Raman spectroscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS). The as-prepared SDCC-NiO was used as an electrode material. SDCC-NiO exhibited the maximum specific capacitance of 473 F g^{-1} at a scan rate of 5 mV s^{-1} in a 1 M KOH electrolyte with an energy density of 4.5 kW kg^{-1} at a current density of 15 A g^{-1}.

1. Introduction

The industry of hybrid electric vehicles and portable electronic devices is growing rapidly and there is a need for high-power energy storage devices to fulfill the urgent demand for a sustainable energy system.[1] Supercapacitors have excited a great scientific interest due to their applications in energy storage. The merits of supercapacitors comprise high power density and a long lifespan. Moreover, supercapacitors are safe, cheap, and maintenance-free.[2] Electrode materials play an important role in the performance of supercapacitors. Carbon-based materials such as activated carbon, carbon fibers, carbon nanotubes, and graphene have been used as electrode materials for electric double-layer capacitors (EDLCs) due to high surface area and long cycling life stability.[3–5] However, transition-metal oxides such as RuO_2, MnO_2, NiO, Co_3O_4, ZnO, SnO_2, and TiO_2 and conducting polymeric materials such as (polyaniline (PANI), polythiophene, and polypyrrole (PPy)) have been used as electrode materials for pseudocapacitors due to their much higher energy storage capacity than carbon-based materials.[6–23] Among transition-metal oxides, nickel oxide/hydroxide with its high theoretical capacitance, environment-friendly nature, high thermal stability, and abundance has been considered as one of the most promising candidates. However, the high resistivity of pure nickel oxide leads to poor rate capability and cycle stability, which has extremely limited its practical applications.[24–27] The capacitance of carbon-based supercapacitors can be improved by metal oxides, which can also contribute pseudo-capacitance apart from the double-layer capacitance of carbon materials.[28] Therefore, it is beneficial to combine metal oxides with carbon materials to develop hybrid materials that could incorporate the merits of both components and reduce the shortcomings of each component. This combination could improve the performance of SCs to meet energy storage demands in a sustainable way.[28–30]

Zhang *et al.* prepared monolithic NiO aerogels *via* a facile citric acid-assisted sol–gel method and this material exhibited the maximum specific capacitance of 797 F g^{-1} at a scan rate of 10 mV s^{-1}.[31] Yuan *et al.* fabricated the graphene oxide/nickel oxide glassy electrode *via* electrodeposition, and this material showed the maximum specific capacitance of 890 F g^{-1} at a scan rate of 5 mV s^{-1}.[32] Liu *et al.* prepared a nanocomposite based on NiO nanosheets with controllable size and thickness on carbon cloth *via* a cost-effective and scalable chemical precipitation method. This material exhibited the maximum specific capacitance of 600.3 F g^{-1} at a scan rate of 1 A g^{-1}.[33]

Zhu *et al.* synthesized a reduced graphene oxide/Ni oxide composite *via* homogeneous co-precipitation and this composite exhibited the maximum specific capacitance of 770 F g^{-1} at a scan rate of 2 mV s^{-1}.[34] Dar *et al.* studied the morphology and property control of NiO nanostructures prepared *via* electrodeposition (nanorods, nanotubes, and nanoporous films). These nanostructures exhibited the maximum specific capacitance

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Green-light–emitting electroluminescent device based on a new cadmium complex

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Abstract – A new cadmium complex is synthesized to investigate its stability and applicability for a luminescent device. The as-prepared Cd(Bpy)q sample is characterized by Fourier-transformed infra-red spectroscopy (FTIR), thermal gravimetric analyzer (TGA) and photoluminescence (PL). The prepared sample shows excellent thermal stability up to 380 °C. A maximum is observed at 240 nm in absorption spectra which is attributed to the π-π^* transition. An organic-light–emitting diode (OLED) has been fabricated using this material. The fundamental structures of the device exhibit ITO/α-NPD/Cd(Bpy)q/BCP/Alq_3/LiF/Al. The electroluminescence (EL) device emits bright green light with maximum luminescence 1683 cd/m^2 at 20 V.

Introduction. – Luminescent organometallic compounds have been attracting much attention in recent years because of their potential application as organic-light–emitting diodes (OLEDs) [1,2]. The OLEDs exhibit higher sensitivity and efficiency than inorganic-light–emitting diodes due to the requirement of low drive voltage with variable color emission. Therefore, a lot of efforts has been focused to synthesize new coordination compounds to improve the efficiency and thermal stability of OLEDs. The properties can further be enhanced by development of better material or more efficient device structures. Ma *et al.* [3] have reported a highly efficient device based on osmium complexes. However, the performance of the device is less than 2 cd/A. On the other hand, Li *et al.* [4] have reported a highly efficient device based on rhenium complexes. They have reported that the maximum brightness and efficiency are 7.15 cd/A and 3686 cd/m^2, respectively. Among all these materials, cadmium complexes could play an important role to fabricate variable OLED due to their wide spectral response. So, extensive research work is going on to synthesize new cadmium complexes containing new ligands to produce a number of novel luminescent cadmium complexes [5–7]. These new complexes can be used as emitters and electron transporters in OLEDs [8–13]. Basically, the coordination numbers of cadmium complexes are variable, which can be exploited to synthesize new emitter materials with varying optoelectronic properties. Additionally, Cd complexes exhibit good thermal, chemical and photochemical stability. In the present study, a new cadmium complex $(2,2'$ bipyridine) 8-hydroxyquinoline (Cd(Bpy)q) is synthesized using a chemical processing route. As-prepared materials are characterized for their structural, optical and photoluminescence (PL) properties. The new Cd complexes are used as an emitter layer to fabricate a device which emits green light with good efficiency and higher brightness than osmium-containing device.

Experimental details. – The synthesis process of the Cd(Bpy)q complex is shown in fig. 1(a). Bipyridine (Bpy), 8-hydroxyquinoline (q) and cadmium acetate (metal ligand) was taken in 1 : 1 : 1 molar ratio in ethyl alcohol to synthesize the Cd(Bpy)q complex. The solution of bipyridine and 8-hydroxy quinoline were mixed and kept at 90 °C for 2 h. After that, mixture was allowed to cool up to 70 °C. At this stage, a solution of cadmium acetate (0.267 g in 3 ml of deionized water), was also added dropwise in the reaction mixture. After 2 h of stirring a yellowish precipitate was observed. The yellow precipitate was separated, filtered and dried at 90 °C in a vacuum oven.

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Carbon Derived from Sucrose as Anode Material for Lithium-Ion Batteries

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Carbon materials are used as anode material in lithium-ion batteries (LiBs) due to their promising cyclic performance and high protection. Carbon material was produced by sucrose at high temperature in flowing argon. Carbon material was used as anode material in LiBs and exhibited the reversible capacity of 180 mA h/g at a specific current of 135 mA/g even at 100 charge–discharge cycles. Carbon material also exhibited the discharge capacity of 118 mA h/g after the 50th cycle and indicates the ~ 93% capacity retention of the cell after the 50th cycle.

Key words: Carbon material, carbonization, lithium-ion batteries, cycle stability

INTRODUCTION

Recharge batteries and electrical double layer capacitors are energy-storage devices, which have drawn much attention in the last few years due to their applications in bulk electricity storage at power stations renewable sources such as solar energy, electric vehicles, wind power, and portable electronic devices.[1] LiBs are used in portable electronics over the last two decades because of their excellent energy density. Mizushima et al.[2] developed the lithium-ion battery in 1981 and it made its first acquaintance in the market in 1991 by Sony Corporation. LiBs are presently one of the best battery technologies in the world because of their high energy densities, moderate power densities, high voltage, long cycling life, low toxicity, low self-discharge, and high reliability. LiBs are highly desired for advanced portable devices.[3,4] Nevertheless, LiBs are expected with enhanced power and energy density, lower cost and enhanced safety to fulfil the requirements of new markets. Electric double-layer capacitors (EDLCs) are utilized in many applications and have more power capability than lithium batteries, however, their energy density is low. New markets are requiring LiBs with higher power density, energy density and lower cost.[5–9] The most important components of LiBs are electrode materials (cathode and anode materials) which largely determines their performance. There are many cathode materials such as $LiCOO_2$, $LiMnO_2$, $LiFePO_4$, $Li_4Ti_5O_{12}$, $LiNiMnCoO_2$, $LiNiCoAlO_2$, etc. which are used in lithium-ion batteries.[10] But it is worth to notice that Eglitis and Borstel et al.[11,12] theoretically, by means of ab initio calculations, predicted a high voltage 5 Volt LiB using $Li_2CoMn_3O_8$ as a battery cathode material.

Graphite is utilized widely as an anode material in the commercial LiBs, but there are some issues with graphite such as low safety and poor stability so graphite may not fulfil the growing requirement for the next generation. The main issue is the potential safety problem for dendritic lithium which prohibits the wide applications of graphite in electric vehicles.[13–15]

Carbon materials are used as anode material in LiBs due of their superior cyclic performance and better safety. Fullerene, carbon nanotubes (CNT),

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