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S. V. Babu, Sergiy Minko, Igor Sokolov, Cetin Cetinkaya, David Morrison, Devon Shipp, Goodarz Ahmadi, Ian Suni, John Moosbrugger, John McLaughlin, Ratneshwar Jha, Vladimir Privman, Evgeny Katz,

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Clarkson University
8 Clarkson Avenue
POTSDAM, NY 13699 -5630

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14. ABSTRACT
A team of interdisciplinary researchers from the Center for Advanced Materials Processing (CAMP) at Clarkson University summarize their research output from work on several types of efficient and robust organic, inorganic and hybrid photovoltaic (PV) devices and systems. This is a continuation of our earlier work on ARO (and other) supported projects on nanocomposite structures and self-healing materials as well as smart sensor for soldier protection.

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Report Title

Final Report

ABSTRACT

A team of interdisciplinary researchers from the Center for Advanced Materials Processing (CAMP) at Clarkson University summarize their research output from work on several types of efficient and robust organic, inorganic and hybrid photovoltaic (PV) devices and systems. This is a continuation of our earlier work on ARO (and other) supported projects on nanocomposite structures and self-healing materials as well as smart sensor for soldier protection.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
02/18/2009	36.00	S.P. Naik, S.P. Elangovan, T. Okubo, I. Sokolov, . Morphology Control of Mesoporous Silica Particles, Journal of Physical Chemistry, (2007): . doi:
02/18/2009	37.00	S.P. Naik, I. Sokolov. Room Temperature Synthesis of Nanoporous Silica Spheres and their Formation Mechnism, Solid State Communications, (2007): . doi:
02/24/2009	39.00	Sajo Naik, Igor Sokolov. Ultra-Bright Fluorescent Silica Particles: Physical Entrapment of Fluorescent Dye Rhodamine 640 in Nanochannels, , ( ): . doi:
02/24/2009	40.00	Igor Sokolov, Sajo Naik. Novel Fluorescent Silica Nanoparticles: Towards Ultrabright Silica Nanoparticles, , ( ): . doi:
02/24/2009	38.00	Y.Y. Kievsky, B. Carey, S. Naik, N. Mangan, D ben-Avraham, I. Sokolov. Dynamics of Molecular Diffusion of Rhodamine 6G in Silica Nanochannels, Journal of Chemical Physics, ( ): . doi:
03/12/2009	42.00	D. Shipp, Y. Li. Photoresponsive Lamellar Structures Utilizing Azobenzene-Modified Surfactants, Polymer Materials Science and Engineering, ( ): . doi:
03/13/2009	43.00	D. Shipp. Grafting of Polystyrene "From" and "Through" Surface Modified Titania Nanoparticles, Polymer Bulletin, (2008): . doi:
03/27/2012	46.00	Lalitha V. N. R. Ganapatibhotla, Jianping Zheng, Dipankar Roy, Sitaraman Krishnan. PEGylated Imidazolium Ionic Liquid Electrolytes: Thermophysical and Electrochemical Properties, Chemistry of Materials, (12 2010): 0. doi: 10.1021/cm102263s
03/27/2012	61.00	Evgeny Katz, Guinevere Strack, Vera Bocharova, Mary A. Arugula, Marcos Pita, Jan Hala?mek. Artificial Muscle Reversibly Controlled by Enzyme Reactions, The Journal of Physical Chemistry Letters, (03 2010): 0. doi: 10.1021/jz100070u
03/27/2012	60.00	Vera Bocharova, Tsz Kin Tam, Jan Halámek, Marcos Pita, Evgeny Katz. Reversible gating controlled by enzymes at nanostructured interface, Chemical Communications, (02 2010): 0. doi: 10.1039/b927156b
03/27/2012	58.00	Iryna Tokareva, Sergiy Minko, Ihor Tokarev. Optical Nanosensor Platform Operating in Near-Physiological pH Range via Polymer-Brush-Mediated Plasmon Coupling, ACS Applied Materials & Interfaces, (02 2011): 0. doi: 10.1021/am101250x
03/27/2012	59.00	Josiah Jebaraj J. Muthuraj, Don H. Rasmussen, Ian I. Suni. Electrodeposition of CuGaSe[sub 2] from Thiocyanate-Containing Electrolytes, Journal of the Electrochemical Society, (12 2011): 0. doi: 10.1149/1.3519997
03/27/2012	57.00	Ihor Tokarev, Sergiy Minko. Stimuli-Responsive Porous Hydrogels at Interfaces for Molecular Filtration, Separation, Controlled Release, and Gating in Capsules and Membranes, Advanced Materials, (05 2010): 0. doi: 10.1002/adma.201000165
03/27/2012	55.00	Aarti Krishnamurthy, Don H. Rasmussen, Ian I. Suni. Galvanic Deposition of Nanoporous Si onto 6061 Al Alloy from Aqueous HF, Journal of the Electrochemical Society, (12 2011): 0. doi: 10.1149/1.3521290
03/27/2012	54.00	J.P. Zheng, D.J. Crain, D. Roy. Kinetic aspects of Li intercalation in mechano-chemically processed cathode materials for lithium ion batteries: Electrochemical characterization of ball-milled LiMn2O4, Solid State Ionics, (08 2011): 0. doi: 10.1016/j.ssi.2011.06.004

03/27/2012 52.00 Elisa Martinelli, Giancarlo Galli, Sitaraman Krishnan, Marvin Y. Paik, Christopher K. Ober, Daniel A. Fischer. New poly(dimethylsiloxane)/poly(perfluorooctylethyl acrylate) block copolymers: structure and order across multiple length scales in thin films,
Journal of Materials Chemistry, (08 2011): 0. doi: 10.1039/c1jm12044a

03/27/2012 51.00 J. E. Garland, D. J. Crain, J. P. Zheng, C. M. Sulyma, D. Roy. Electro-analytical characterization of photovoltaic cells by combining voltammetry and impedance spectroscopy: voltage dependent parameters of a silicon solar cell under controlled illumination and temperature,
Energy & Environmental Science, (10 2011): 0. doi: 10.1039/c0ee00307g

03/27/2012 50.00 J.E. Garland, D.J. Crain, D. Roy. Impedance spectroscopy coupled with voltammetry for quantitative evaluation of temperature and voltage dependent parameters of a silicon solar cell,
Solar Energy, (11 2011): 0. doi: 10.1016/j.solener.2011.08.029

03/27/2012 49.00 C. M. Sulyma, C. M. Pettit, J. E. Garland, D. Roy. Surface plasmon resonance as a probe of interactions between a thin-film gold electrode and an aqueous supporting electrolyte containing 1-ethyl-3-methyl-imidazolium ethyl sulfate ionic liquid,
Surface and Interface Analysis, (12 2011): 0. doi: 10.1002/sia.4808

03/27/2012 48.00 Daniel Crain, Jianping Zheng, Christopher Sulyma, Corina Goia, Dan Goia, Dipankar Roy. Electrochemical features of ball-milled lithium manganate spinel for rapid-charge cathodes of lithium ion batteries,
Journal of Solid State Electrochemistry, (02 2012): 0. doi: 10.1007/s10008-012-1677-8

03/27/2012 47.00 D. J. Crain, J. E. Garland, S. E. Rock, D. Roy. Quantitative characterization of silicon solar cells in the electro-analytical approach: Combined measurements of temperature and voltage dependent electrical parameters,
Analytical Methods, (09 2012): 0. doi: 10.1039/c1ay05455d

03/29/2012 62.00 Pavan S. Chinthamanipeta, Qin Lou, Devon A. Shipp. Periodic Titania Nanostructures Using Block Copolymer Templates,
ACS Nano, (01 2011): 0. doi: 10.1021/nn102207y

04/02/2012 65.00 Rajdeep Singh, Ian Ivar Suni. Minimizing Nonspecific Adsorption in Protein Biosensors that Utilize Electrochemical Impedance Spectroscopy,
Journal of the Electrochemical Society, (08 2010): 0. doi: 10.1149/1.3478635

04/02/2012 63.00 Qin Lou, Pavan S. Chinthamanipeta, Devon A. Shipp. Mechanism of Titania Deposition into Cylindrical Poly(styrene-,
Langmuir, (12 2011): 0. doi: 10.1021/la2031686

04/02/2012 64.00 Rajdeep Singh, Pranav P. Sharma, Ruth E. Baltus, Ian I. Suni. Nanopore immunosensor for peanut protein Ara h1,
Sensors and Actuators B: Chemical, (03 2010): 0. doi: 10.1016/j.snb.2009.11.039

07/19/2007 14.00 Igor Sokolov, Yaroslav Y. Kievsky, Jason M. Kaszpurenko. Self-Assembly of Ultrabright Fluorescent Silica Particles,
, ( ): . doi:

08/09/2008 35.00 D. Abdallah, M.J. Cully, Y. Li, D. A. Shipp. Stoichiometric Complexes of Polyelectrolyte and AZO-Functionalized Surfactant,
, ( ): . doi:

11/06/2012 66.00 Lin Wu, Jacek Jasinski, Sitaraman Krishnan. Carboxybetaine, sulfobetaine, and cationic block copolymer coatings: A comparison of the surface properties and antibiofouling behavior,
Journal of Applied Polymer Science, (05 2012): 0. doi: 10.1002/app.35233

11/06/2012 68.00 Sitaraman Krishnan, Marvin Y. Paik, Christopher K. Ober, Elisa Martinelli, Giancarlo Galli, Karen E. Sohn, Edward J. Kramer, Daniel A. Fischer. NEXAFS Depth Profiling of Surface Segregation in Block Copolymer Thin Films,
Macromolecules, (05 2010): 0. doi: 10.1021/ma902866x

11/27/2012 69.00 Tsz Kin Tam, Marcos Pita, Oleksandr Trotsenko, Mikhail Motornov, Ihor Tokarev, Jan Hala?mek, Sergiy Minko, Evgeny Katz. Reversible “Closing” of an Electrode Interface Functionalized with a Polymer Brush by an Electrochemical Signal,
Langmuir, (03 2010): 4506. doi: 10.1021/la903527p

11/27/2012 70.00 Ihor Tokarev, Iryna Tokareva, Venkateshwarlu Gopishetty, Evgeny Katz, Sergiy Minko. Specific Biochemical-to-Optical Signal Transduction by Responsive Thin Hydrogel Films Loaded with Noble Metal Nanoparticles,
Advanced Materials, (03 2010): 1412. doi: 10.1002/adma.200903456

11/27/2012 71.00 Tsz Kin Tam, Marcos Pita, Mikhail Motornov, Ihor Tokarev, Sergiy Minko, Evgeny Katz. Electrochemical Nanotransistor from Mixed-Polymer Brushes,
Advanced Materials, (04 2010): 1863. doi: 10.1002/adma.200903610

11/27/2012 72.00 Tsz Kin Tam, Marcos Pita, Mikhail Motornov, Ihor Tokarev, Sergiy Minko, Evgeny Katz. Modified Electrodes with Switchable Selectivity for Cationic and Anionic Redox Species,
Electroanalysis, (01 2010): 35. doi: 10.1002/elan.200900442

11/27/2012 73.00 Sergiy Minko, Evgeny Katz, Mikhail Motornov, Ihor Tokarev, Marcos Pita. Materials with Built-in Logic,
Journal of Computational and Theoretical Nanoscience, (03 2011): 356. doi: 10.1166/jctn.2011.1699

11/27/2012 75.00 Qin Lou, Devon A. Shipp. Recent Developments in Atom Transfer Radical Polymerization (ATRP): Methods to Reduce Metal Catalyst Concentrations,
ChemPhysChem, (10 2012): 3251. doi: 10.1002/cphc.201200166

11/30/2012 80.00 S. V. S. B. Janjam, B. C. Peethala, D. Roy, S. V. Babu. Chemical Mechanical Planarization of TaN Wafers Using Oxalic and Tartaric Acid Based Slurries,
Electrochemical and Solid-State Letters, (10 2010): 1. doi: 10.1149/1.3247070

11/30/2012 81.00 Naresh K. Penta, P. R. Dandu Veera, S. V. Babu. Role of Poly(diallyldimethylammonium chloride) in Selective Polishing of Polysilicon over Silicon Dioxide and Silicon Nitride Films,
Langmuir, (04 2011): 0. doi: 10.1021/la104257k

11/30/2012 82.00 Naresh K. Penta, John B. Matovu, P.R. Dandu Veera, Sitaraman Krishnan, S.V. Babu. Role of polycation adsorption in poly-Si, SiO2 and Si3N4 removal during chemical mechanical polishing: Effect of polishing pad surface chemistry,
, (09 2011): 21. doi: 10.1016/j.colsurfa.2011.07.039

11/30/2012 83.00 Naresh K. Penta, P. R. Dandu Veera, S. V. Babu. Charge Density and pH Effects on Polycation Adsorption on Poly-Si, SiO,
ACS Applied Materials & Interfaces, (10 2011): 4126. doi: 10.1021/am2010114

11/30/2012 84.00 B. C. Peethala, H. P. Amanapu, U. R. K. Lagudu, S. V. Babu. Cobalt Polishing with Reduced Galvanic Corrosion at Copper/Cobalt Interface Using Hydrogen Peroxide as an Oxidizer in Colloidal Silica-Based Slurries,
Journal of the Electrochemical Society, (04 2012): 582. doi: 10.1149/2.073206jes

TOTAL: **40**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received		Paper
05/13/2009	29.00	Yin Huang, Melissa C. Bell, Ian I. Suni. Impedance Biosensor for Peanut Protein Ara h1, , ( ): . doi:
07/18/2007	3.00	Igor Sokolov, Alexander Dementsov, Vladimir Privman. Modeling of Self-Healing Polymer Composites Reinforced with Nanoporous Glass Fibers, Journal of Computational and Theoretical Nanoscience, ( ): . doi:
07/18/2007	6.00	Igor Sokolov, Yaroslav Kievsky, Swaminathan. Fluorescent Silica Colloids for Study and Visualization of Skin Care Products, , ( ): . doi:
11/27/2012	76.00	Q. Lou, D. A. Shipp. Poly(glycidyl methacrylate-block-styrene) for Photolithographically Patternable Resist Material, ACS Symposium Series, (03 2012): 115. doi:
TOTAL:		**4**

Number of Papers published in non peer-reviewed journals:

(c) Presentations

1. S. Krishnan, J. L. Lebga, L. Wu, J. B. McLaughlin, S. Rock, D. Roy, “Thermophysical and Electrochemical Properties of Self-Assembling Amphiphilic Ionic Liquids,” Talk presented at the 2012 AIChE Annual Meeting, October 28-November 2, 2012, Pittsburgh, PA.
2. J. B. McLaughlin, S. Krishnan, L. Wu, L. V. N. R. Ganapatibhotla, X. Jia, D. Roy and J.P. Zheng, “Self-Consistent Field Modeling of Microstructure Formation in Fluorinated "Block" Ionic Liquids for Photovoltaic Cells”, Talk presented at the 2011 AIChE Annual Meeting, October 16-21, 2011, Minneapolis, MN.
3. L. Ganapatibhotla, J. P. Zheng, D. Roy and S. Krishnan, "Solid Organic Electrolytes and Ionic Liquids, with Poly(ethylene glycol) and Semifluorinated Alkyl Side Chains, for Photovoltaic and Energy Storage Applications", Presented at the 2010 AIChE Annual Meeting, Salt Lake City, Utah, November 7-12, 2010.
4. D. Roy, “Electro-Analytical Characterization of Solar Cells”, Talk presented at the Center for Advanced Materials Processing Fall 2010 Symposium, Potsdam, NY; October 14, 2010.

Non Peer-Reviewed Conference Proceeding publications: Number 7

1. L. Wu, S. Rock, D. Roy, J. B. McLaughlin, and S. Krishnan, “Structure–Property Correlations in Block-Oligomer Ionic Liquid Electrolytes,” The 2012 Annual Meeting of the Center for Advanced Materials Processing, Albany, New York (May 2012).
2. D. J. Crain, J. P. Zheng and D. Roy, "Characterization of Rapid-Recharge Li ion Batteries", Poster presented at the CAMP Fall Meeting, October 10-11, 2011.
3. D. J. Crain, J.P. Zheng D. Roy, "Characterization of Electrode Materials for Li ion Batteries with Improved Cyclability", Poster presented at the Annual Technical Meeting of CAMP; May 19, 2011.
4. L. Wu, S. Krishnan, X. Shi, D. Roy, "Electrochemical Properties of Novel PEGylated Electrolyte Blend for Dye Sensitized Solar Cells and Lithium Ion Batteries", Poster presented at the Annual Technical Meeting of CAMP; May 19, 2011.
5. J. E. Garland, D. J. Crain, S. E. Rock, D. Roy, “Electroanalytical Characterization of Resistive Power Losses in a Single Crystal Silicon Solar Cell”, Poster presented at the Annual Technical Meeting of CAMP; May 19, 2011.
6. D.J. Crain, J. P. Zheng and D. Roy, "Characterization of Electrode Materials for Rapid-Recharge Li ion Batteries", Poster presented at the Center for Advanced Materials Processing Fall 2010 Symposium, Potsdam, NY; October 14, 2010.
7. S. Krishnan, "Nanostructured Electrolytes with Low Fluidity and High Conductivity for Solar Cells and Fuel Cell Membranes", Clarkson University Center for Advanced Materials Processing, 2011 Annual Technical Meeting (May 20, 2011).
8. Poly(Glycidyl Methacrylate-block-styrene): Merging “Top-Down” and “Bottom-Up” Approaches for Hierarchical Photoresist Patterning, Q. Lou, D. A. Shipp, Am. Chem. Soc., Polym. Prepr. 2011, 52(2), 493-494.
9. Preparation of Nanostructured Titanium Dioxide Using Block Copolymer Templates, P. S. Chinthamanipeta, Q. Lou, D. A. Shipp Am. Chem. Soc., PMSE Prepr. 2010, PMSE-297.
10. Optimization of Depositions Conditions of Titanium Dioxide in Block Copolymer Templates, Q. Lou, P. S. Chinthamanipeta, D. A. Shipp, Am. Chem. Soc., Polym. Prepr. 2010, 51(2), 345-346.
11. Photoresponsive Lamellar Structures Utilizing Azobenzene-Modified Surfactants, D. Abdallah, Y. Li, D. A. Shipp Am. Chem. Soc., PMSE. Prepr. 2007, 96, 146-147.

Manuscripts: Number of Manuscripts: 1

1. S. E. Rock, L. Wu, D. J. Crain, S. Krishnan, and D. Roy “Interfacial Electrochemistry of a Solvent Free PEGylated Imidazolium Bistriflamide Ionic Liquid Electrolyte at a LiMn2O4 Cathode for Lithium Ion Batteries,” manuscript for ACS Appl. Mater. Interfaces.

Number of Presentations: 4.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received		Paper
11/30/2012	77.00	S V. Babu, Deepankar Roy, Sathish Babu Janjam. Single Dispersion to Polish both Bulk Cu and Residual Cu along with Barrier Layers, ISTC/CSTIC 2009 (CISTC). 2009/05/24 00:00:00, Shanghai, China. : ,
TOTAL:	**1**	

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received		Paper
02/24/2009	41.00	Sajo P. Naik, Igor Sokolov. Microporous and Mesoporous Materials, ( )
03/18/2009	44.00	C. Ispas, I. Sokolov, S. Andreescu. Mesoporous Silica for Enzyme Immobilization: Fabrication, Characterization and Biosensing Applications, ( )
03/18/2009	45.00	S.P. Naik, I. Sokolov. Synthesis of Mesoporous Silica Fibers and Discoids Endowed with Circular Pore Architecture using Disodium Trioxosilicate as Silica Source, ( )
05/13/2009	30.00	Yin Huang, Ian Ivar Suni. Degenerate Si as an Electrode Material for Electrochemical Biosensors, ( )
07/19/2007	13.00	Sajo Naik, Igor Sokolov. Ultra-Bright Fluorescent Silica Particles: Physical Entrapment of Fluorescent Dye Rhodamine 640 in Nanochannels, ( )
07/19/2007	12.00	Sajo P. Naik, S.P. elangovan, Tatsuya Okubo, Igor Sokolov. Morphology Control of Mesoporous Silica Particles, ( )
07/19/2007	15.00	Igor Sokolov. Assembly of Super-Bright Fluorescent Silica Particles, ( )
07/19/2007	16.00	Igor Sokolov, Sajo Naik. Synthesis of Ultra-Bright Luminescent Silica Nanoparticles, ( )
TOTAL:	**8**	

Number of Manuscripts:

Books

Received Paper

TOTAL:

Patents Submitted

Solid Organic Electrolytes, U. S. Patent Application no. 12/778,410 (2010).

Patents Awarded

Awards

From Professor Krishnan: A report of our project has been featured in the special themed issue on "Future Electroanalytical Developments" of the journal [Crain et al., Anal. Methods 4 (2012) 106 – 117, published by RSC]"

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
John Garland	0.17	
Daniel Crain	0.00	
Jianping Zheng	0.00	
Lalitha Ganapatibhotla	0.00	
Lin Wu	1.00	
Pavan Chinthamanipeta	0.50	
Qin Lou	0.50	
FTE Equivalent:	**2.17**	
Total Number:	**7**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Xinli Jia	0.40
Dalia Abdallah	1.00
FTE Equivalent:	**1.40**
Total Number:	**2**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Sitaraman Krishnan	0.04	No
Dipankar Roy	0.00	
John McLaughlin	0.00	
FTE Equivalent:	**0.04**	
Total Number:	**3**	

Names of Under Graduate students supported

NAME	PERCENT SUPPORTED	Discipline
Tyler Mosher	0.00	Physics B.S.
Theodore Glave	0.00	Chemical & Biomolecular Engineering B.S.
Sydney Laramie	0.00	Chemical & Biomolecular Engineering B.S.
Joshua Franclemont	0.00	Chemical & Biomolecular Engineering B.S.
FTE Equivalent:	**0.00**	
Total Number:	**4**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	7.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:	7.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:	6.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	5.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	3.00

Names of Personnel receiving masters degrees

NAME	
Lalitha Ganapatibhotia	
Total Number:	**1**

Names of personnel receiving PHDs

NAME	
John Garland	
Daniel Crain	
Jianping Zheng	
Pavan S. Chinthamanipeta	
Qin Lou	
Total Number:	**5**

Names of other research staff

NAME	PERCENT SUPPORTED
Xinli Jia	0.40
FTE Equivalent:	**0.40**
Total Number:	**1**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Project 2:

Problems studied

Since most commonly used organic liquid electrolytes of dye sensitized solar cells (DSSCs) are volatile and flammable, they limit the long-term stability and high temperature operations of these cells. We have addressed these issues through the development and characterization of non-volatile, non-flammable and polymerizable IL electrolytes. In a parallel effort, we have developed an electro-analytical approach to quantitative testing of laboratory scale photovoltaic cells. Since the IL electrolytes should also be usable for certain energy-storage as well as sensor devices, we have investigated supporting active materials for energy storage, focusing specifically on LiMn2O4 cathodes for Li ion (solar) batteries. Furthermore, we have explored the adsorption characteristics of ILs on Au thin films for sensor-type applications.

Summary of the most important results

We have synthesized and characterized an imidazolium iodide ionic liquid containing an ¿-perfluoroalkyl poly(ethylene glycol) (PEG) tail [1]. The solid phase of this material was accomplished through the generation of ionic clusters by electrostatic interactions, as well as through microphase separation of the immiscible perfluoroalkyl and PEG segments of the cation used. We have performed self-consistent mean field calculations to probe the formation of nanostructures in the ionogel. The high conductivity, and the non-volatile, gel-like properties of this electrolyte will be useful to support the function of high-performance, leakage-proof DSSCs. We have also synthesized and characterized certain PEGylated ILs [2]. These latter ILs exhibit satisfactory conductivities (~0.13 mS cm¿1at room temperature) despite their relatively high viscosities, and support a temperature-independent electrochemical window of ~2 V.

We have developed an electro-analytical approach to quantitative characterization of solar cells. Crystalline Si cells have been used to establish the analytical protocols of this method [3-6]. We have demonstrated how this method can evaluate the temperature and voltage sensitive features of the minority carrier lifetimes, series and shunt resistances and back surface field parameters of a solar cell. Apart from displaying their characteristic temperature dependencies, the parameters measured in this way have responded to variations of the cell voltage, and exhibited mutually interacting features of the observed effects [3-5]. These results have shown how the characteristic features of charge recombination in the quasi-neutral and space charge regions of the solar cell could be resolved with D.C. voltage dependent A.C. impedance measurements.

The diode-like electrical behavior of a DSSC has been studied to evaluate the detailed charge recombination characteristics of the cell [6]. A forward biased dark DSSC has been used to preferentially activate the recombination reactions, and the kinetics of these reactions have been probed by using electrochemical impedance spectroscopy (EIS) and linear sweep voltammetry (LSV). The ohmic and non-ohmic series resistances of the DSSC have been separated, and their origins have been investigated. The characteristic impedance parameters of the different active interfaces of the multi-component solar cell have been obtained from complex nonlinear least square (CNLS) analysis of the EIS data. Among these parameters, the electron lifetime and the resistance of charge transfer at the TiO2-electrolyte interface have followed the same diode-like voltage dependence of the D.C. current. We have shown that, this diode feature of the DSSC played a critical role in determining the overall performance of the cell.

The electro-analytical studies of DSSCs carried out through our project show that, strategically selected experimental control variables, coupled with CNLS analysis of experimental data can enable the component-specific resolution of EIS. This in turn helps to resolve the individual impedance parameters of the FTO-TiO2 and Pt-FTO interfaces from those of the TiO2 anode film in a DSSC [6]. EIS also detects the different electrical characteristics of the morphologically different TiO2 layers included in the photo-anode of the cell. Furthermore, the power-consuming series resistance (Rs) of the DSSC is determined directly from CNLS-analyzed EIS results; the ohmic and non-ohmic components of this resistance also are resolved in this approach [6]. These Rs data facilitate an accurate evaluation of the internal voltage of the DSSC, and allow for a rigorous examination of the cell's electrical attributes.

We have tested a cathode of lithium manganese oxide using a mixture of nanometric and micrometric active particles [7,8]. The goal of this specific study was to explore selected materials for energy storage components (such as Li ion solar batteries) that could be integrated with solar powered devices. To conduct these experiments, commercially available particles were mechano-chemically modified by ball-milling. Ragone plots, recorded using galvanostatic measurements indicated enhanced power delivery characteristics of the ball-milled material compared to its unprocessed counterpart [8]. The processed material also exhibits improved resistance against electrolyte reactions and surface film formation. Due to these advantageous electrochemical attributes, the ball-milled cathode material also has served as an adequately suited system for exploring various fundamental aspects of Li intercalation [8]. Scan rate dependent slow scan cyclic voltammetry has helped to identify the kinetic and diffusion controlled features of Li transport in the processed active particles. The observations have been substantiated further by using EIS and by measuring the voltage dependent charge transfer resistance and diffusion coefficient of Li transport.

We have combined SPR and electrochemical measurements to study the interactions of a gold film electrode with concentration dependent electrolytes of an IL [9]. The purpose of this particular study was to understand the adsorption characteristics of an IL on a typical sensing electrode, and to further explore IL based device applications. Voltage- and/or

electrolyte-induced variations were detected in the critical angles and SPR angles measured in the attenuated total reflection geometry. The optical response of the bulk electrolyte strongly affected the SPR angles; the critical angle data helped to separate these effects from those arising strictly from the electrode surface. The optical parameters of the Au-electrolyte system were determined by fitting the SPR angle-spectra to calculated results of a multi-layer reflectivity model. The results demonstrated how angle resolved SPR measurements could be used to determine the surface adsorption characteristics of ILs.

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