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# ESA Newsletter

Electrostatics Society of America - The Friendly Society

## *President's Message*

### Electrostatic Drug Delivery

Dear ESA Members:

Every 1.5 minutes, there is a cancer death in the US. A mother, wife, sister, friend – a woman, dies every 13 minutes of breast cancer, again in the US. It is estimated that 12.7 million cancer cases and 7.6 million deaths have occurred in 2008 and it is only increasing. You will also be shocked to know, as I am, that only 2% of the drug goes into the body during the treatment. The response rate of FDA approved most commonly used breast cancer drugs shows how pitifully low they are (10-25 % on the low end, 20-68 % on the high end) [1]. In addition, taking the drugs orally has its own disadvantages, such as having to go through the digestive tract and possibly being metabolized. Hence it has to be formulated differently, at the end all these efforts leading to the drug delivery difficulties. It is indicated that only 10% of drugs work for 90% of people or 90% of drugs work for only 10% of the population. Cancer is advancing from being number two in causing deaths to number one, thanks to the improvements in cardiac disease treatments and increase in the cancer incidence. Once a disease of affluent, industrialized nations, now cancer is everywhere, from Kenya to Korea to China to India [2]. Many potential drugs that were devised for treating cancer and other diseases could not be successful, due to the inherent difficulties encountered in its delivery to cells. Drug delivery paths and mechanisms are always a challenge due to the hydrophilic and hydrophobic bilayer lipid membranes which are by nature designed to screen out exogenous molecules to protect us. Hence it is not easy to upload molecules as the plasma membranes of our body cells are non- or less permeable to most molecules needing to be delivered. To enhance quality of care and life, we need alternate, physical treatments which are complementary/supplementary to the current treatment modalities, as not everyone responds well to the existing treatment modalities. There are inoperable, chemo-resistant, and/or radio-resistant tumors that desperately call for other techniques and electrostatics to come to our rescue, as often happens in many other fields of application.

Electrical pulses of high intensity (1.2-1.3 kV/cm) and short duration (100μs) could transiently open up pores (hence the name, "Electroporation") in the cell plasma membrane due to enhanced electric field ($E \sim 1V/10nm = 10^8 V/m$ across the membrane). This results in the temporary dielectric breakdown of the cell membrane, which act like highly leaky capacitors, and enable the molecules enter the cell. As the application of pulses is for a very short duration, they eventually reseal and make the drug molecules act at the targeted tumor. The drug could be injected intratumorally or intravenously, a few minutes before the application of the pulses. When used to deliver chemo drugs, this technique is called Electro-Chemo-Therapy (ECT). Its success has been attested by the various clinical trails and ongoing treatments for extreme cases of melanomas, sarcomas, and other skin cancers, including head and neck cancers [3-6]. When surgery, radio and chemotherapies didn't work, patients suffering from chest wall breast carcinoma benefited from ECT [5, 6]. An extension of the electroporation is the drug-free or drugless irreversible electroporation wherein no drug is used, only more number of higher intensity and longer duration pulses (compared to ECT) are used to control the proliferation of the tumor cells, including a successful clinical trial for prostate cancer [7]. In addition, nanomedicine is another emerging technique to treat cancers and it is exciting to know that electrostatics plays a major role in the fabrication of nanoparticles of various types.

In the upcoming 2011ESA Annual Meeting at Case Western Reserve University, we have papers on irreversible electroporation and electric field distribution due to electric pulses used for electroporation of tumors. This group's research is unique in the use of lower intensity and longer duration pulses.

Dr. Jim Leary, one of our distinguished speakers and a world class researcher from Purdue University, will deliver his exciting keynote talk on electrostatic interactions of nanoparticles with cells for drug/gene delivery. We have other stimulating topics and papers in various fields to make our ESA 2011 Annual Meeting another successful event. Prof.

(cont'd. p.2)

# President's Message (cont'd.)

Daniel Lacks of Case Western Reserve University, is contributing a lot of his time and efforts, both as the Technical Chair, and as the general conference chair, taking care of both the sessions and the local arrangements so we all can have a great conference. He is assisted by his colleague Prof. Mohan Sankaran and Dr. Keith Forward of MIT in his endeavors. Many thanks to him and others who are contributing to the Annual Meeting.

I also look forward to seeing many of you next week at the meeting. This will be my last message as there will be a leadership transition, as you know from the slate of officers listed in our previous newsletter. I have immensely enjoyed my service as the ESA President and will continue to serve in various positions in the future. I can't thank you enough for all the support, encouragement and inspiration received from many of you and I am grateful for this wonderful opportunity.

Thank you so very much. Have a very productive and pleasant time.

Yours for the friendly Society,
*Raji Sundararajan,*
*ESA President*

References:


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[4] Gehl, J. and Geertsen P. F. Efficient palliation of haemorrhaging malignant melanoma skin metastases by electrochemotherapy. Melanoma Research 10, 1-5 (2000).

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[6] Luca Campana, et al., "Bleomycin-based electrochemotherapy: clinical outcome from a single Institution's experience with 52 patients", Annals of Surgical Oncology, 16:191-99, 2009

[7] Boris Rubisnky (Ed.), Irreversible Electroporation, Springer, 2010


# Calendar

- ESA-2011, June 14-16, 2011, Case Western Univ., Cleveland, OH Contact: Dan Lacks, *daniel.lacks@case.edu,* website: http://www.electrostatics.org
- IEEE-IAS Annual Meeting, Electrostatic Processes Committee, Oct. 9-13, 2011, Orlando, FL, Contact: Lucien Dascalescu, *lucian.dascalescu@univ-poitiers.fr.* , website: *http://ewh.ieee.org/soc/ias/2011/home.htm*
- 2nd ISNPEDADMSA (New electrical tech. for environment), Nov. 14-19, 2011, Noumea, New Caledonia, Contact: Gerard Touchard, *gerard.touchard@univ-poitiers.fr,* website: http://lea.sp2mi.univ-poitiers.fr/noumeameeting/
- ESA-2012, Joint ESA/IEJ/IAS/SFE Meeting, June 12-14, 2012, Univ. of Waterloo, Waterloo, Ontario, Canada, Contact: Shesha Jayaram, *jayaram@uwaterloo.ca,* website: http://www.electrostatics.org

# Current Events

### Microbial Hair: It's Electric

*Carl Marziali*

Some bacteria grow electrical hair that lets them link up in big biological circuits, according to a USC biophysicist and his collaborators. The finding suggests that microbial colonies may survive, communicate and share energy in part through electrically conducting hairs known as bacterial nanowires. "This is the first measurement of electron transport along biological nanowires produced by bacteria," said Mohamed El-Naggar, assistant professor of physics and astronomy at USC College. El-Naggar was the lead author of a study appearing online in Proceedings of the National Academy of Sciences.

Knowing how microbial communities thrive is the first step in finding ways to destroy harmful colonies, such as biofilms on teeth. Biofilms have proven highly resistant to antibiotics. The same knowledge could help to promote useful colonies, such as those in bacterial fuel cells under development at USC and other institutions. "The flow of electrons in various directions is intimately tied to the metabolic status of different parts of the biofilm," El-Naggar said. "Bacterial nanowires can provide the necessary links … for the survival of a microbial circuit."

A bacterial nanowire looks like a long hair sticking out of a microbe's body. Like human hair, it consists mostly of protein. To test the conductivity of nanowires, the researchers grew cultures of Shewanella oneidensis MR-1, a microbe previously discovered by coauthor Kenneth Nealson, the Wrigley Professor of Geobiology at USC College. Shewanella tend to make nanowires in times of scarcity. By manipulating growing conditions, the researchers produced bacteria with plentiful nanowires.

(cont'd. p.5)

Electrostatics
Society of America

# 2011 Annual Meeting of the Electrostatics Society of America

June 14-16, 2011
Case Western Reserve University, Cleveland, OH, USA

The 2011 Annual Meeting will be held on the campus of Case Western Reserve University.

The meeting features 58 talks, and begins with lunch on Tuesday June 14 at noon, and ends Thursday June 16 at 4 PM.

The banquet will be held Wednesday night, June 15. The venue is the Crawford Auto Aviation Museum, which showcases antique, vintage, and classic automobiles, motorcycles, bicycles and aircraft.

Registration and housing information available at the conference website:

*http://www.electrostatics.org/conferences.html*

Conference Chairs
Daniel J. Lacks, Case Western Reserve University, daniel.lacks@case.edu
R. Mohan Sankaran, Case Western Reserve University, mohan@case.edu

Technical Program Chair
Keith Forward, MIT, kforward@mit.edu

# Electrostatic Demonstrations Workshop

At the upcoming joint ESA/IEJ/IAS/SFE Meeting set for June 14-16, 2012, in Waterloo, Ontario, Canada, plans are afoot for a special half-day workshop devoted to electrostatics demonstrations. Though the format is yet to be decided upon, the goal will be to assemble electrostatics experts from around the world and representing the diverse field of safety training, consulting, and education to present their favorite demonstrations. After each short presentation, there will be time scheduled to discuss the demonstration, focusing on the principles and practical lessons it conveys. The last part of the session will be an open discussion intended to engage all attendees in development of some strategies for promoting electrostatics demonstrations as a way to re-instill fun and enthusiasm in science learning at all levels. An effort will be made to schedule a special evening presentation for area high school science teachers looking for ways to excite their students with new enthusiasm for electrostatics.

If you have a favorite demonstration to share or have an idea for a new one, this is the event for you. Please direct questions and suggestions for this session to me. I am open to your ideas.

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# ESA OFFICERS

**President**:
Rajeswari Sundararajan, Purdue Univ.
**Vice President:**
Dan Lacks, Case Western Reserve Univ.
**Executive Council**
Sheryl Barringer, Ohio State Univ.
Steve Cooper, Mystic Tan, Inc.
Kelly Robinson, Electrostatic Answers, LLC

# Election of ESA Council Members

The ESA Bylaws provide for the election of officers every two years. Members vote for a complete slate of candidates at the annual meeting, and anyone is eligible to nominate or be part of a slate.

At this time, we have one nominated slate of candidates for this years election:

**Corrected Slate of ESA Officers for 2011-2013**
**President**
Dan Lacks, Case Western Reserve Univ.
**Vice President**
Shesha Jayaram, Univ. of Waterloo
**Executive Council**
Sheryl Barringer, Ohio State Univ.
Kelly Robinson, Electrostatic Answers, LLC
Rajeswari Sundararajan, Purdue Univ.

If anyone would like to nominate an alternate slate, please inform me well before the June conference so that we can prepare election materials for the business meeting. Absent an alternate slate, we will likely approve the current nominated slate by acclamation.

Rajeswari Sundararajan, ESA President
*rsundara@purdue.edu*

### ESA Elections By-Laws - New Council Slates Are Sought

Based on Article 4 of the ESA Constitution, the term of the present ESA Council ends on June 30, 2008 and the new Council term of office begins on July 1, 2008. It is now time for the Secretary (address found on back page of this ESA Newsletter) to receive slates of nominees for the upcoming (7/1/1 - 6/30/13) term.

Since the Council shall be nominated as a full slate, the presenter of that slate is responsible for checking with all the members of that slate to insure each nominee is willing to serve. A slate consists of five members: the President, the Vice-President and three Council Members.

If more than one slate is presented to the Secretary, a ballot will be mailed out about April 30 (or as soon as reasonably possible) with the deadline for receipt of the ballots by the Secretary being May 31, 2011. If only one slate is presented (then as tradition has held) no ballots will be mailed, and the Membership present at the ESA Annual Meeting will be asked to vote on the slate. If no slates are presented, then, as Article 4b states, "If extraordinary circumstances prevent the election of a new Council, the existing Council shall continue in office, year by year, until an election can be held."

The bacteria then were deposited on a surface dotted with microscopic electrodes. When a nanowire fell across two electrodes, it closed the circuit, enabling a flow of measurable current. The conductivity was similar to that of a semiconductor—modest but significant. When the researchers cut the nanowire, the flow of current stopped. Previous studies showed that electrons could move across a nanowire, which did not prove that nanowires conducted electrons along their length. El-Naggar's group is the first to carry out this technically difficult but more telling experiment.

Electricity carried on nanowires may be a lifeline. Bacteria respire by losing electrons to an acceptor—for Shewanella, a metal such as iron. (Breathing is a special case: Humans respire by giving up electrons to oxygen, one of the most powerful electron acceptors.) Nealson said of Shewanella: "If you don't give it an electron acceptor, it dies. It dies pretty rapidly."

In some cases, a nanowire may be a microbe's only means of dumping electrons. When an electron acceptor is scarce nearby, nanowires may help bacteria to support each other and extend their collective reach to distant sources. The researchers noted that Shewanella attach to electron acceptors as well as to each other, forming a colony in which every member should be able to respire through a chain of nanowires. "This would be basically a community response to transfer electrons," El-Naggar explained. "It would be a form of cooperative breathing."

*(excerpted from http://uscnews.usc.edu/science_technology/microbial_hair_its_electric.html)*

### UC Breakthrough May Lead to Disposable e-Reader

*John Bach*

Electrical Engineering Professor Andrew Steckl's research into an affordable, yet high-performance, paper-based display technology is being featured this week as the November cover story of ACS Applied Materials and Interfaces, one of the scientific journals for the American Chemical Society, the world's largest scientific society.

In the research, Steckl and UC doctoral student Duk Young Kim demonstrated that paper could be used as a flexible host material for an electrowetting device. Electrowetting (EW) involves applying an electric field to colored droplets within a display in order to reveal content such as type, photographs and video. Steckl's discovery that paper could be used as the host material has far-reaching implications considering other popular e-readers on the market such as the Kindle and iPad rely on complex circuitry printed over a rigid glass substrate.

Andrew Steckl's research is featured on the cover of the November issue of ACS Applied Materials & Interfaces. The American Chemical Society (ACS) is the world's largest scientific society.

"One of the main goals of e-paper is to replicate the look and feel of actual ink on paper," the researchers stated in the ACS article. "We have, therefore, investigated the use of paper as the perfect substrate for EW devices to accomplish e-paper on paper." Importantly, they found that the performance of the electrowetting device on paper is equivalent to that of glass, which is the gold standard in the field. "It is pretty exciting," said Steckl. "With the right paper, the right process and the right device fabrication technique, you can get results that are as good as you would get on glass, and our results are good enough for a video-style e-reader."

Steckl imagines a future device that is rollable, feels like paper yet delivers books, news and even high-resolution color video in bright-light conditions. "Nothing looks better than paper for reading," said Steckl, an Ohio Eminent Scholar. "We hope to have something that would actually look like paper but behave like a computer monitor in terms of its ability to store information. We would have something that is very cheap, very fast, full-color and at the end of the day or the end of the week, you could pitch it into the trash."

Disposing of a paper-based e-reader, Steckl points out, is also far simpler in terms of the environmental impact. "In general, this is an elegant method for reducing device complexity and cost, resulting in one-time-use devices that can be totally disposed after use," the researchers pointed out. Steckl's goal is to attract commercial interest in the technology for next-stage development, which he expects will take three to five years to get to market.

*(http://www.uc.edu/news/NR.aspx?id=12779)*

### Graphene Ultracapacitor Could Shrink Systems

*Joseph Calamia*

The ultracapacitor—the battery's quicker cousin—just got faster and may one day help make portable electronics a lot smaller and lighter, according to a group of researchers. John Miller, president of the electrochemical capacitor company JME, in Shaker Heights, Ohio, and his team reported the new ultracapacitor design this week in Science.

Ultracapacitors don't store quite as much charge as batteries but can charge and discharge in seconds rather than the minutes batteries take. This combination of speed and energy supply makes them attractive for things like regenerative braking, where the ultracapacitors would have only seconds to recharge as a car comes to a stop. But sometimes a second is still too long: Using nanometer-scale fins of graphene, the researchers built an ultracapacitor that can charge in less than a millisecond. This agility, its designers say, means that the devices could replace the ubiquitous bulky capacitors that smooth out the ripples in power supplies to free up precious space in gadgets and computers.

The ultracapacitor's secret weapon is its surface area: While batteries store charge chemically, capacitors store it electrostatically—in electric fields formed between conducting surfaces. The larger the surface area on these conducting surfaces, the more room there is for charge. Ultracapacitors achieve this by using tiny nanometer-scale pores, such as those found in activated carbon, and boost how much charge each pore can hold by filling them with an ionic solution.

For decades, the goal has been to increase the total amount of charge an ultracapacitor can store while retaining its small size. More energy storage means that the capacitors can work quickly in applications that demand more energy than traditional capacitors, and deliver that energy faster than batteries can.

The price of hoarding charge—cramming it into hard-to-access nanotube tangles and activated carbon pores—is that some of the nimbleness needed to do the things ordinary capacitors can do has been sacrificed, says Miller. "Many people are trying to make these more battery-like," he says. "What we've done is make them more capacitor-like." Miller and his team got some of that nimbleness back by redesigning the ultracapacitor's electrodes.

One team member, Ron Outlaw, a material scientist at the College of William and Mary, in Williamsburg, Va., came up with an electrode consisting of up to 4 sheets of graphene—a one-atom-thick form of carbon with unusual electronic properties. The graphene was formed so that it stuck out vertically from a 10-nanometer-thick graphite base layer—what Miller describes as rows of 600-nm-tall "potato chips" standing on edge. It is much easier to get charge on and off chip surfaces, he says, than it is to get it off what he calls the "stacked potato chips" of earlier graphene ultracapacitors or off the "Swiss cheese–like" surface of activated carbon ultracapacitors. The earlier designs led to discharge "traffic jams."

Miller's team, which also included Brian Holloway, a program manager at the Defense Advanced Research Projects Agency (DARPA), tested its graphene ultracapacitor in a filtering circuit, part of an AC rectifier. Many rectifiers leave a slight AC echo behind, called a "voltage ripple," and it's the capacitor's job to smooth it out. In order to do that, the capacitor needs to respond well at double the AC frequency—120 hertz in the United States.

Most commercial ultracapacitors fail at this filtering role at around 0.01 Hz, but when Miller's team tested its ultracapacitor in such a 120-Hz filtering circuit, it did the job. That means the smaller ultracapacitors could replace the big electrolytic capacitors that do the filtering now. Miller estimates that a commercial version, operating at 2.5 volts, could be less that one-sixth the size of any other 120-Hz filtering technology.

"I think the work is exciting and marks an important advance that also looks reasonably likely to lead to improved methods for electrical energy storage while preserving good AC filtering performance," says Rod Ruoff, a professor of mechanical engineering at the University of Texas at Austin and cofounder of Graphene Energy, which is also developing graphene ultracapacitors.

Outlaw says this is only a first effort. He is already increasing the capacitance of the device by making the nanosheets more parallel and taller—attempting to find the ideal balance between creating more charge storage space and restricting the flow of ions in the electrolyte. Still, he says this original work is already a major advance. "We are approaching an order of magnitude reduction in size and weight, which means great benefits to the electronics in many industries such as NASA, airlines, and the military," he says.

*(http://spectrum.ieee.org/semiconductors/nanotechnology/graphene-ultracapacitor-could-shrink-systems)*

### Charging makes nano-sized electrodes swell, elongate and spiral

*Mary Beckman*

New high resolution images of electrode wires made from materials used in rechargeable lithium ion batteries shows them contorting as they become charged with electricity. The thin, nano-sized wires writhe and fatten as lithium ions flow in during charging, according to a paper in this week's issue of the journal Science. The work suggests how rechargeable batteries eventually give out and might offer insights for building better batteries.

Battery developers know that recharging and using lithium batteries over and over damages the electrode materials, but these images at nanometer scale offer a real-life glimpse into how. Thin wires of tin oxide, which serve as the negative electrode, fatten by a third and stretch twice as long due to lithium ions coursing in. In addition, the lithium ions change the tin oxide from a neatly arranged crystal to an amorphous glassy material.

"Nanowires of tin oxide were able to withstand the deformations associated with electrical flow better than bulk tin oxide, which is a brittle ceramic," said Chongmin Wang, a materials scientist at the Department of Energy's Pacific Northwest National Laboratory. "It reminds me of making a rope from steel — you wind together thinner wires rather than making one thick rope."

In one of the videos, shown here, the nanowire appears like a straw, while the lithium ions seem like a beverage being sucked up through it. Repeated shape changes could damage the electrode materials by introducing tiny defects that accumulate over time.

In previous work at DOE's Environmental Molecular Sciences Laboratory on the PNNL campus, Wang, PNNL chemist Wu Xu and other colleagues succeeded in taking a snapshot of a larger nanowire of about one micrometer — or one-hundredth the width of a human hair — that had been partially charged. But the experimental set-up didn't show charging in action.

To view the dynamics of an electrode being charged, Wang and Xu teamed up with Jianyu Huang at DOE's Center for Integrated Nanotechnologies at Sandia National Laboratories in New Mexico and others. The team used a specially outfitted transmission electron microscope to set up a miniature battery. This instrument allowed them to image smaller wires of about 200 nanometers in diameter (about a fifth the width of the previous nanowires) while charging it.

Rechargeable lithium ion batteries work because lithium ions love electrons. Positively charged lithium ions normally hang out in the positive electrode, where a metal oxide shares its electrons with lithium. But charging a battery pumps free electrons into the negative electrode, which sits across a lake of electrolytes through which lithium ions can swim but electrons can't. The lithium desires the electrons on the negative side of the lake more than the electrons it shares with the metal oxide on the positive side. So lithium ions flow from the positive to the negative electrode, pairing up with free electrons there.

But electrons are fickle. Using a battery in a device allows the electrons to slip out of the negative electrode, leaving the lithium ions behind. So without free electron companions, the lithium ions return to the positive electrode and the metal oxide's embrace.

Wang's miniature battery included a positive electrode of lithium cobalt oxide and a negative electrode made from thin nanowires of tin oxide. Between the two electrodes, an electrolyte provided a conduit for lithium ions and a barrier for electrons. The electrolyte was specially designed to withstand the conditions in the microscope.

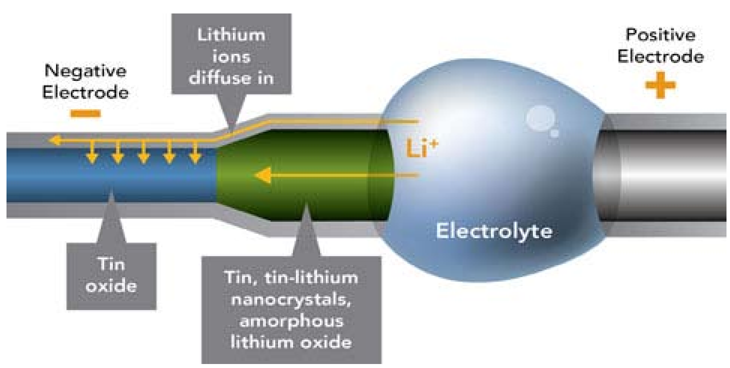
When the team charged the miniature battery at a constant voltage, lithium ions wicked up through the tin oxide wire, drawn by the electrons at the negative electrode. The wire fattened and lengthened by about 250 percent in total volume, and twisted like a snake.

In addition, the microscopy showed that the wire started out in a crystalline form. But the lithium ions changed the tin oxide to a glassy material, in which atoms are arranged more randomly than in a crystal. The researchers concluded the amount of deformation occurring during charging and use might wear down battery materials after a while. Even so, the tin oxide appeared to fare better as a nanowire than in its larger, bulk form.

"We think this work will stimulate new thinking for energy storage in general," said Wang. "This is just the beginning, and we hope with continued work it will show us how to design a better battery."

Future work will include imaging what happens when such a miniature battery is repeatedly charged and discharged. When a battery gets used, the lithium ions must run back through the tin oxide wire and across the electrolyte to the positive electrode. How much structural damage the receding lithium leaves in its wake will help researchers understand why rechargeable batteries stop working after being recharged so many times.

(*excerpted from [http://www.pnl.gov/news/release.aspx?id=832](http://www.pnl.gov/news/release.aspx?id=832)*)




This nano-sized battery reveals how positive lithium ions flood the negative electrode (blue), changing the size, shape and nature of the material (the green part of the electrode). Some rechargeable materials might be more resilient than others to the repeated shape-changing.

**Electrostatics**
**Society of America**

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