Nov/Dec 2014 • No. 228

ESA Newsletter

Electrostatics Society of America - The Friendly Society

President's Message

Dear ESA Colleagues,

I just returned from an exciting around-the-world electrostatics tour…

My first stop was Finland, where I served as the "opponent" for Maija Nyström's PhD defense at the University of Turku. Maija and her advisor, Matti Murtomaa, are both ESA members. Maija's work develops electrospraying techniques at reduced pressures to produce pharmaceutical powders with desired structure and morphology. By varying process conditions, Maija can control the particle size, porosity, extent of crystallinity and even the crystal structure. While I have served on many PhD defense committees, this defense was very different -- it was carried out in white-tie attire in front of a large audience, and I was the only person asking questions (for an hour and a half). Maija's work was very interesting and she did a great job with both the research and the defense, which made my job as the opponent easy. In the accompanying picture, Maija demonstrates her competence with the sword given to her upon her successful PhD defense (a sword is the traditional gift for PhD recipients).

I then spent a one-day layover in Vilnius, Lithuania, which had a more subtle connection to electrostatics. Most amber comes from the Baltic region of Europe, where Lithuania is located, and so many shops and outdoor stands in Vilnius sell jewelry and other products made from amber (I bought an amber keychain there). Of course, amber plays an important role in the history of electrostatics, as the ancient Greeks were familiar with electrostatic attraction involving amber, and the Greek word for amber, ἤλεκτρου (electron), gives rise to the root "electro" of electrostatics.

Next I proceeded to Ethiopia, where I visited several universities and a science and engineering center for children. I was impressed with everything I saw, but especially with the Foka Science and Engineering Center. The Foka center is located in Bishoftu, a small town about an hour's drive from Addis Ababa. The schools in Bishoftu do not have lab facilities, and Foka fills this need by providing lab and project-based activities, all at no cost to the students or schools. Several hundred children complete Foka's rigorous programs each year, where each program includes 100 hours of lab work. Of course, the electrostatics experiments at Foka were my favorites (see picture)!

After Ethiopia, I had a one-day layover in Dubai. The Dubai layover didn't have any connection to electrostatics … but I was arrested for riding on the Woman's car of the Metro (it was inadvertent!) and had to pay a fine of about $25.

My last stop was Japan. Here I attended the inaugural Static-Tribo-Electricity of Powder (STEP-1) workshop at Soka University, which was conceived of and hosted by ESA member Tatsushi Matsuyama. This was a great one-day meeting, bringing leaders in the field from all over the world. The participants included at least eight ESA members (try to find them in the picture below).

All in all it was a great trip, but I was glad to get home … in 13 days I went through 15 airports in 11 countries on 4 continents!

I'm looking forward to my next electrostatic activities, wherever they might be!

Regards,
Dan Lacks,
President, ESA
daniel.lacks@case.edu

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Shesha Jayaram, Univ. of Waterloo
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Sheryl Barringer, Ohio State Univ.
Kelly Robinson, Electrostatic Answers, LLC
Rajeswari Sundararajan, Purdue Univ.

Calendar

- Electrostatics 2015, April 12-16, 2015, Southampton Solent Univ., Southampton, UK, http://elec2015.iop-confs.org/home Contact: IoP Electrostatics Group, +44 (0)20 7470 4800, *conferences@iop.org*
- 33rd EIC (Elec Insul Conf, IEEE-DEIS), June 7-10, 2015, Seattle, WA, USA, http://sites.ieee.org/eic/ Contact: Bill McDermid, *wmmcdermid@hydro.mb.ca,*
- ESA 2015, June 16-18, 2015, California State Polytechnic University, Pomona, CA, USA, http://www.electrostatics.org/conferences.html Contact: Keith Forward, *kmforward@csupomona.edu*
- 3rd ISNPEDADM, Oct. 25-30, 2015, Le Recif Hotel, Saint Gilles les Bains, Reunion, http://isnpedadm2015.conference.univ-poitiers.fr/ Contact: Gerard Touchard, *gerard.touchard@univ-poitiers.fr, (abstracts due Feb. 16, 2015)*

Current Events (cont'd.)

Co-flowing liquids can stabilize chaotic "whipping" in microfluidic jets

John Toon

Industrial wet spinning processes produce fibers from polymers and other materials by using tiny needles to eject continuous jets of liquid precursors. The electrically charged liquids ejected from the needles normally exhibit a chaotic "whipping" structure as they enter a secondary liquid that surrounds the microscopic jets. But the liquid jets sometimes form a helical wave. And that was intriguing to Alberto Fernandez-Nieves, an associate professor in the School of Physics at the Georgia Institute of Technology.

By controlling the viscosity and speed of the secondary liquid surrounding the jets, a research team led by Fernandez-Nieves has now figured out how to convert the standard chaotic waveform to the stable helical form. Based on theoretical modeling and experiments using a microfluidic device, the findings could help improve industrial processes that are used for fiber formation and electrospray. The research, conducted in collaboration with the University of Seville in Spain, was supported by the National Science Foundation (NSF). It was reported Sept. 8, 2014, in the early online edition of the journal Proceedings of the National Academy of Sciences (PNAS).

2015 Annual Meeting of the Electrostatic Society of America

California State Polytechnic University, Pomona
Pomona, CA
June 16 - 18, 2015

Call for Papers

Abstract Submission
Opens: January 1, 2015
Closes: March 1, 2015

Important Dates

March 15	Notification of abstract acceptance
May 10	Early registration deadline
May 17	Final manuscript deadline
June 16	Conference begins (9 AM)
June 17	Conference banquet (evening)
June 18	Conference ends (noon)

Keynote Speakers
- Dr. Matti Murtomaa, University of Turku
- Dr. Zhong Lin Wang, Georgia Tech
- Dr. Kim Woodrow, University of Washington
- Dr. Leslie Yeo, RMIT Melbourne

California State Polytechnic University, Pomona (Cal Poly Pomona) is proud to be hosting the 2015 Annual Meeting of the Electrostatic Society of America (ESA). The meeting will bring together experts across the diverse field to present the latest developments in electrostatics.

Anticipated Technical Session Topics
- Contact charging and triboelectric effects
- Gas discharges and microplasmas
- Breakdown phenomena, safety and hazards
- Electrically-induced flows and electrokinetics
- Atmospheric and space applications
- Biological and medical applications
- Electrospinning and material processing
- Measurements and instrumentation

Conference information, including abstract submission, registration, student travel grants and lodging, will be updated and available at http://www.electrostatics.org

Conference Chair
Prof. Keith M. Forward
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Cal Poly Pomona

Technical Chair
Prof. Peter Ireland
peter.ireland@newcastle.edu.au
University of Newcastle

"We are developing an understanding of the basic coupling between hydrodynamic and electric fields in these systems," said Fernandez-Nieves. "The issue we examined is fundamental physics, but it could potentially lead to something more interesting in fiber generation through electro-spinning."

In conventional industrial processes, tiny metal needles apply an electric field as they eject the polymer-containing solution. In the laboratory, the researchers used a glass-based microfluidic device to create the jets so they could more closely examine what was happening. Using a conductive liquid, ethylene glycol, allowed them to apply an electrical field to produce electrified jets. "When you charge these polymer solutions, the jets themselves move out of axis, which creates a chaotic phenomenon known as whipping," Fernandez-Nieves explained. "This off-axis movement causes the jet to abruptly move in all directions, and in the industrial world, all that motion seems to be beneficial from the standpoint of making thinner fibers."

The researchers experimented with many variables as their liquid jets emerged into a co-flowing secondary liquid inside the microfluidic device. Those variables included the applied electrical field, the flow rate of the ejected liquid and the secondary liquid, the viscosities of the liquids, the needle diameters and the physical geometry of microfluidic device.

While producing a whipped jet in a viscous dielectric material – polydimethylsiloxane oil – the researchers were surprised to see the chaotic motion switch over to a steady-state helical structure. "We were able to stabilize the structure associated with the whipping behavior and found that the stable structure is a helix with a conical shape," said Fernandez-Nieves. "You can picture it as a conical envelope, and inside the envelope you have a helix. Once the viscosity of the outer liquid is sufficient, you stabilize the structure and get this beautiful helix."

Georgia Tech postdoctoral fellow Josefa Guerrero used a high-speed, microscope-based video camera operating at 50,000 frames per second to study the waveforms emerging from the experimental jets, which were less than five microns in diameter. The video allowed precise examination of the waveforms produced when the liquid flowed out of the glass needle and into the second liquid flowing around it.

"By developing the model, we were able to balance the importance of the different forces in the experiment," explained Fernandez-Nieves. "The helix was part of the solutions in the model and it reproduced some aspects of the experimentally observed helices."

Once the jets were stabilized by the viscous secondary liquid, the properties of the helix were controlled by the electrical charge. In the experiment, the researchers applied approximately 1,000 volts to generate the jets.

"We learned that the outer fluid plays a major role in stabilizing the structure of the jets," Fernandez-Nieves added. "Once the structure is stable, the details of the properties of the helical structure depend on the charge."

Ultimately, the stable jets break up into spherical droplets. The researchers have not yet formed fibers with their experimental setup.

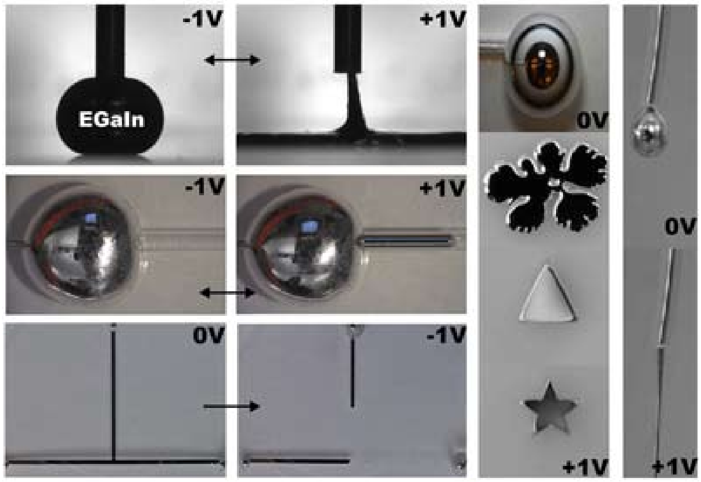
(excerpted from *http://www.news.gatech.edu/2014/09/08/co-flowing-liquids-can-stabilize-chaotic-"whipping"-microfluidic-jets*)

Researchers Control Surface Tension to Manipulate Liquid Metals

Dr. Michael Dickey & Matt Shipman

Researchers from North Carolina State University have developed a technique for controlling the surface tension of liquid metals by applying very low voltages, opening the door to a new generation of reconfigurable electronic circuits, antennas and other technologies. The technique hinges on the fact that the oxide "skin" of the metal – which can be deposited or removed – acts as a surfactant, lowering the surface tension between the metal and the surrounding fluid.

The researchers used a liquid metal alloy of gallium and indium. In base, the bare alloy has a remarkably high surface tension of about 500 milli-newtons (mN)/meter, which causes the metal to bead up into a spherical blob. "But we discovered that applying a small, positive charge – less than 1 volt – causes an electrochemical reaction that creates an oxide layer on the surface of the metal, dramatically lowering the surface tension from 500 mN/meter to around 2 mN/meter," says Dr. Michael Dickey, an associate professor of chemical and biomolecular engineering at NC State and senior author of a paper describing the work. "This change allows the liquid metal to spread out like a pancake, due to gravity."



Liquid metals normally form a spherical shape due to their large surface tension. By applying a small voltage to the metal in water, a surface oxide forms on the surface of the metal and lowers the surface tension. Reversing the bias can remove the oxide and return the metal to a large surface tension. These phenomena can be utilized to control the shape of the metal and get it to flow in and out of capillaries. Image credit: Mohammad Khan.

The researchers also showed that the change in surface tension is reversible. If researchers flip the polarity of the charge from positive to negative, the oxide is eliminated and high surface tension is restored. The surface tension can be tuned between these two extremes by varying the voltage in small steps.

"The resulting changes in surface tension are among the largest ever reported, which is remarkable considering it can be manipulated by less than one volt," Dickey says. "We can use this technique to control the movement of liquid metals, allowing us to change the shape of antennas and complete or break circuits. It could also be used in microfluidic channels, MEMS, or photonic and optical devices. Many materials form surface oxides, so the work could extend beyond the liquid metals studied here."

Dickey's lab had previously demonstrated a technique for "3-D printing" liquid metals, which used the oxide layer formed in air to help the liquid metal retain its shape – the exact opposite of what the oxide layer does to the alloy in a basic solution. "We think the oxide's mechanical properties are different in a basic environment than they are in ambient air," Dickey says.

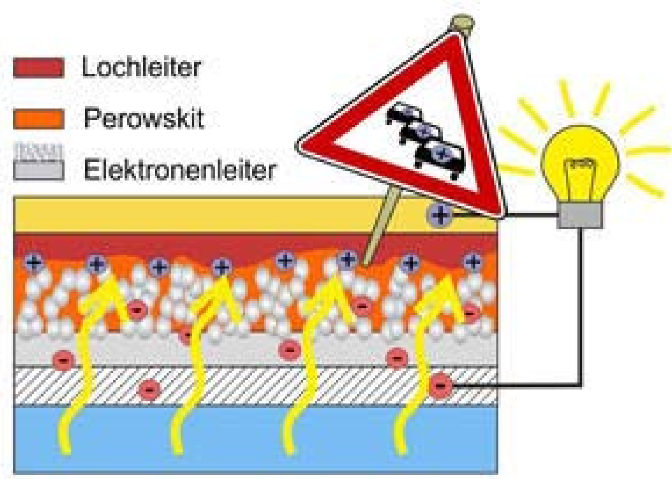
(excerpted from https://news.ncsu.edu/2014/09/dickey-surface-tension-2014/)

Charge transport jamming in solar cells

Conventional silicon solar cells could have an inexpensive competitor in the near future. Researchers from the Max Planck Institute for Polymer Research in Mainz, together with scientists from Switzerland and Spain, have examined the working principle of an innovative type of solar cell, where an organic-inorganic perovskite compound acts as the light absorber. The scientists observed that charge carriers accumulate in a certain layer in these photovoltaic elements. If this jam can be dissolved, the already considerable efficiency of these solar cells could be further improved. Perovskite-based solar cells could play a prominent role among the renewable energy carriers in future. Unlike the established silicon solar cells, which are costly and energy-intensive to manufacture, these cells are made cheap materials and are simple to produce.

Perovskite solar cells generate electricity with the help of a layer consisting of an organic-inorganic compound which crystallises in a perovskite structure. The ions in this structure form a cubic arrangement, i.e. a rectangular lattice. "Perovskite materials absorb light extremely well," says Rüdiger Berger, explaining how the solar cell works. "The light absorbed by the perovskite layer snatches an electron from an atom, creating a positively-charged electron vacancy, which we also refer to as a 'hole'. Then all we have to do is channel the electrons to one electrode and the holes to another one – and electricity is produced."

In the solar cell, the perovskite structure rests on a porous layer of titanium oxide which collects the electrons generated under illumination and transports them to the lower electrode. Above the perovskite there is a layer consisting of the organic hole conductor Spiro-OMeTAD, which transports the holes to the upper elec-



Traffic jam in the solar cell: In a perovskite solar cell, the perovskite layer itself (orange) is located between a porous layer of titanium oxide (grey) which channels the electrons to the upper electrode (yellow). The Mainz-based Max Planck researchers established that the positively charged holes accumulate in the perovskite layer.

trode. "The many different layers in the solar cell are extremely important. They ensure the effective separation of the two charge carriers," says Rüdiger Berger's colleague Stefan Weber. "However, the charge carriers have to overcome a small barrier every time they jump from one material to the other. These barriers act like a construction site on a busy freeway where the vehicles clog. This charge transport jamming in the solar cell leads to losses and thus to a lower efficiency."

In several test series, the researchers found that a strong accumulation of positive charges takes place in the perovskite layer upon exposure to light. They suppose that the reason for this positive charging is that the titanium dioxide electron conductor works much more effectively than the hole conductor. The holes do not reach their electrode as fast as the electrons and accumulate on the way. The excess of positive charges in the perovskite layer then generates an opposing electric field which slows down the charge transport even further.

To observe the charge transport within the solar cell, the Mainz-based researchers cleaved the cell in the middle and polished the broken surface until it was smooth using a finely focussed ion beam. With the help of Kelvin probe force microscopy, they mapped the electrical potential in each layer of the solar cell. From this potential map, the researchers could derive the field distribution and thus the charge transport through the different layers of the cell.

"We could for the first time correlate the charge distribution with the individual material layers in the cell", says Rüdiger Berger. "The charge transport jamming of positive charges in the illuminated perovskite layer tells us that the transport through the hole conductor currently constitutes the bottleneck for the efficiency of the solar cell" If a more effective hole conductor could be used, the efficiency of the perovskite solar cells could be increased well above the 20% mark and thus offer a genuine alternative to the conventional silicon solar cells.

(excerpted from *http://www.mpg.de/8431287/efficiency_perovskite-solar-cell*)

This Method of Robotic Pickup Could Stick

Kevin Bullis

The sticky effect seen when you rub a balloon on your hair could be used to help robots pick things up, greatly expanding what machines can do in factories. Grabit, a spinoff of SRI International, has developed a simple and cheap robotic hand that makes use of electrostatic attraction. Grabit's robot hand, which was demonstrated at the RoboBusiness conference in Boston last week, is a little more complex than the balloon trick: for example, it uses

Grabit's gripper has flexible electrostatic appendages.

powered electrodes to sustain the electrostatic attraction, and alternating polarities to avoid charge buildup and keep the device from collecting dust.

The new hand is part of a broader trend toward cheap, versatile robotic grippers. This new generation of graspers could expand the use of robots and let them collaborate more closely with humans.

Electrostatic attraction is already used in some areas of manufacturing—for example, to hold microchip wafers in place. But the trick works best with clean, flat, smooth surfaces because the strength of the static cling depends on the size of the contact area. Electrostatic attraction is not suited to manipulating ultra-thin sheets of semiconductor material, for example, because these sheets are often curved. And it's not ideal for picking up irregularly shaped items.

Grabit's gripper, however, uses flexible materials that have the same electrostatic properties. Part of the company's innovation was developing materials that can conform to an object but still stand up to the wear and tear of factory use, says company CTO Harsha Prahlad.

The flexible surface of the grabber lets it support more weight and distribute the gripping force more evenly than conventional robots that use suction to pick things up. This improvement could allow robots to take on new manufacturing tasks, including jobs that involve handling delicate materials such as thin semiconductors for new, advanced solar cells. But the technology also offers a cheap way to pick up just about anything—fabric, bags of chips, 50-pound boxes of paper, single pieces of paper, mobile phones.

(excerpted from *http://www.technologyreview.com/news/531946/this-method-of-robotic-pickup-could-stick/?utm_campaign=newsletters&utm_source=newsletter-daily-all&utm_medium=email&utm_content=20141024*)

Imaging Electric Charge Propagating Along Microbial Nanowires

The claim by microbiologist Derek Lovley and colleagues at the University of Massachusetts Amherst that the microbe Geobacter produces tiny electrical wires, called microbial nanowires, has been mired in controversy for a decade, but the researchers say a new collaborative study provides stronger evidence than ever to support their claims. UMass Amherst physicists working with Lovley and colleagues report in the current issue of Nature Nanotechnology that they've used a new imaging technique, electrostatic force microscopy (EFM), to resolve the biological debate with evidence from physics, showing that electric charges do indeed propagate along microbial nanowires just as they do in carbon nanotubes, a highly conductive man-made material.

Physicists Nikhil Malvankar and Sibel Ebru Yalcin, with physics professor Mark Tuominen, confirmed the discovery using EFM, a technique that can show how electrons move through materials. "When we injected electrons at one spot in the microbial nanowires, the whole filament lit up as the electrons propagated through the nanowire," says Malvankar. Yalcin, now at Pacific Northwest National Lab, adds, "This is the same response that you would see in a carbon nanotube or other highly conductive synthetic nano-filaments. Even the charge densities are comparable. This is the first time that EFM has been applied to biological proteins. It offers many new opportunities in biology."

Lovley says the ability of electric current to flow through microbial nanowires has important environmental and practical implications. "Microbial species electrically communicate through these wires, sharing energy in important processes such as the conversion of wastes to methane gas. The nanowires permit Geobacter to live on iron and other metals in the soil, significantly changing soil chemistry and playing an important role in environmental cleanup. Microbial nanowires are also key components in the ability of Geobacter to produce electricity, a novel capability that is being adapted to engineer microbial sensors and biological computing devices."

He acknowledges that there has been substantial skepticism that Geobacter's nanowires, which are protein filaments, could conduct electrons like a wire, a phenomenon known as metallic-like conductivity. "Skepticism is good in science, it makes you work harder to evaluate whether what you are proposing is correct," Lovley points out. "It's always easier to understand something if you can see it. Drs. Malvankar and Yalcin came up with a way to visualize charge propagation along the nanowires that is so elegant even a biologist like me can easily grasp the mechanism."

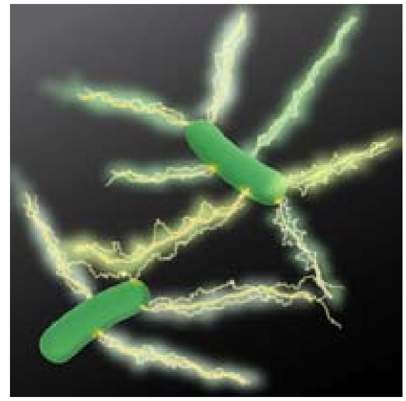


Image credit: Sibel Ebru Yalcin, Ernie Carbone and Gokhan Gungor

Biologists have known for years that in biological materials, electrons typically move by hopping along discrete biochemical stepping-stones that can hold the individual electrons. By contrast, electrons in microbial nanowires are delocalized, not associated with just one molecule. This is known as metallic-like conductivity because the electrons are conducted in a manner similar to a copper wire.

Malvankar, who provided the first evidence for the metallic-like conductivity of the microbial nanowires in Lovley and Tuominen's labs in 2011, says, "Metallic-like conductivity of the microbial nanowires seemed clear from how it changed with different temperature or pH, but there were still many doubters, especially among biologists." To add more support to their hypothesis, Lovley's lab genetically altered the structure of the nanowires, removing the aromatic amino acids that provide the delocalized electrons necessary for metallic-like conductivity, winning over more skeptics. But EFM provides the final, key evidence, Malvankar says. "Our imaging shows that charges flow along the microbial nanowires even though they are proteins, still in their native state attached to the cells. Seeing is believing. To be able to visualize the charge propagation in the nanowires at a molecular level is very satisfying.I expect this technique to have an especially important future impact on the many areas where physics and biology intersect." he adds.

Tuominen says, "This discovery not only puts forward an important new principle in biology but also in materials science. Natural amino acids, when arranged correctly, can propagate charges similar to molecular conductors such as carbon nanotubes. It opens exciting opportunities for protein-based nanoelectronics that was not possible before." Lovley and colleagues' microbial nanowires are a potential "green" electronics component, made from renewable, non-toxic materials. They also represent a new part in the growing field of synthetic biology, he says. "Now that we understand better how the nanowires work, and have demonstrated that they can be genetically manipulated, engineering 'electric microbes' for a diversity of applications seems possible."

(excerpted from *http://www.umass.edu/newsoffice/article/imaging-electric-charge-propagating-along*)

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