Jan/Feb 2018 • No. 244

ESA Newsletter

Electrostatics Society of America - The Friendly Society

President's Message

With the winter coming close to its end, everyone is looking forward to the start of spring soon. Which means it is time to think about spring and summer activities. As we all remember, the year 2017 was another eventful year for the ESA with the well-attended annual meeting in Ottawa. I am eagerly waiting to meet you and many more new attendees in June this year. Preparations for the 2018 Joint Electrostatics Conference are progressing well under the leadership of the conference chair, Prof. Mark Horenstein, the technical program chair Prof. Shubho Banerjee, and the key person in coordinating the electrostatic demonstrations, Dr. Kelly Robinson. The highlights of the upcoming meeting are the venue, keynote talks, electrostatics demonstrations, and presentations/participations from around the world. Peeping into the list of abstracts that are in submission, I can assure you that there is something new for each of us; to listen and to learn from others. Participants from more than a dozen countries are expected to attend the meeting this year. A preliminary list of keynote speakers may be found in this newsletter (see p. 3). Topics for discussion from the experts include electrostatic technologies used in environmental pollution control and indoor air cleaning, charge transport mechanisms and self-charging of radioactive dust and its bearing for nuclear safety. Moreover, the student presentations, invited lectures, and of course, other regular papers, will all add to the multidisciplinary forum that is expected at the Joint meeting.

It is time to visit the ESA web site for the details of our 2018 Electrostatics Joint Conference, in Boston, and to plan your trip (*http://electrostatics.org/annualmeeting.html*). Abstract submission date has been extended to March 22nd 2018; meaning you still have plenty of time. Likewise, we have extended the nominations for ESA Awards until 30th April 2018. Please take a moment to think and consider nominating those who deserve recognition. Your input in this endeavour is highly appreciated.

As always, please lend your continued support to ESA by your participation as a presenter, exhibitor, or simply as an observer, maybe even as a mentor. If you have not paid ESA dues, not to worry; along with your registration, you can pay your ESA membership fees! Thanks to Prof. Keith Forward for his contributions to a well-maintained ESA website. Looking forward to creating great memories this summer with you and everyone who loves ESA activities.

For the Friendly Society
Shesha Jayaram, *shesha.jayaram@uwaterloo.ca*
President, Electrostatics Society of America

Calendar

- 36th Electrical Insulation Conference, June 17-20, 2018, Hyatt Regency, San Antonio, TX, *http://electricalinsulationconference.com.,* Contacts: Diego Robalino, *diego_robalino@ieee.org* and David McKinnon, *davmckin@gmail.com, (Abstract deadline: Oct. 15)*
- 2018 Electrostatics Joint Conference, June 18-20, 2018, Boston University, Boston, MA, *http://www.electrostatics.org/annualmeeting.html* Contact: Mark Horenstein *mnh@bu.edu*
- 211th Conference of the Societe Francaise D'Electrostatique (SFE), August 29-31, 2018, Grenoble, France, *https://sfe2018.sciencesconf.org/?forward-action=index&forward-controller=index&lang=en* Contact: Nelly Bonifaci & Olivier LeSaint *sfe2018@sciencesconf.org*

ESA Officers

President:
Shesha Jayaram, Univ. of Waterloo
Vice President and Awards Chair:
Maciej Noras, Univ. of North Carolina
Executive Council:
David Go, Univ. of Notre Dame
Poupak Mehrani, Univ. of Ottawa
Rajeswari Sundararajan, Purdue Univ.

Electrostatic Demo Session

At the upcoming ESA Meeting scheduled for June 2018 in Boston, MA, we are planning to hold a special session devoted to electrostatics demonstrations. The goal is to provide demonstrations on a variety of topics including electrostatic fundamentals, educational experiments, safety topics, and research projects. Our session will build upon the demonstration sessions held during our 2012, 2014 and 2016 ESA Annual Meetings.

We are pleased that we have 5 confirmed participants, and we are seeking a couple of volunteers for a sixth.

1. Bob Morse (Teacher, retired, Washington DC) returns with some of his clever, inexpensive demos. Though they were originally conceived to demonstrate electrostatic principles to his high school students, they enlighten us all!

2. Ken MacKillop (Static Clean, North Billerica MA) is pondering demonstrating methods of measuring partial discharge for various high-voltage products such as cable and HV transformers and other encapsulated HV electronics.

3. Steve Cooper (Athens, GA), an expert and inventor of an electrostatic liquid spray nozzle, will demonstrate electrostatic spraying.

4. Kevin Coldren (Simco-Ion, Hatfield, PA) will demonstrate the latest static dissipation technologies from Simco-Ion, an industry leader in static control.

5. Kelly Robinson (Electrostatic Answers, Rochester NY) will demonstrate how to measure charge densities using an electrostatic fieldmeter. And he will bring his Van de Graaff generator, Mr. Electro (thanks to Humphrey Wong for this).

6. Duke Davis (Wabash Instruments, Wabash IN) has volunteered to participate as a coach / mentor. We are seeking volunteers to work with Duke to demonstrate some of the excellent educational equipment from Wabash Instruments.

We have plenty of room for additional participants. Of course, more is better! If you have a favorite demonstration to share or have an idea for a new one, this event is for you. Please let me know if you need to borrow equipment for your demonstration (fieldmeter, electrostatic voltmeter, Van de Graaff generator, electrophorus, power supply, ... whatever you need) and I will do my best to support your demo. If you have any questions about our session, please contact Kelly Robinson, who is coordinating the demonstration session.

Kelly Robinson, PE, PhD
Owner, Electrostatic Answers
kelly.robinson@electrostaticanswers.com

2018 Electrostatics Joint Conference

Boston University
Boston, Massachusetts, USA
June 18 - 20, 2018

The Electrostatic Society of America (ESA), Institute of Electrostatic Japan (IEJ), International Electrostatic Assembly (IEA), Industry Applications Society (IEEE-IAS) Electrostatic Processes Committee, and La Societé Francaise d'Electrostatique (SFE) invite papers in all scientific and technical areas involving electrostatics. The scope of the conference ranges from the fundamental physics underlying electrostatics to applications in industry, atmospheric and space sciences, medicine, energy, and other fields. The meeting will bring together experts across the diverse field to present the latest developments in electrostatics.

Anticipated Technical Session Topics

- Atmospheric and space applications
- Biological and medical applications
- Breakdown phenomena
- Contact charging and triboelectric effects
- Electrically-induced flows and electrokinetics
- Flows, forces and fields
- Gas discharges and microplasmas
- Electrospinning
- Material processing
- Measurements and instrumentation
- Particle control and charging
- Safety and hazards

Photonics Center Boston University

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

Student paper competition: Presentations by students (undergraduate and graduate) are eligible; please indicate participation when submitting abstract.

Important dates:

March 22, 2018 Abstract submission deadline extended (submit on-line at http://www.electrostatics.org)
April 1, 2018 Notification of paper acceptance
May 16, 2018 Final manuscripts due
June 17, 2018 Reception (6-9PM)
June 18, 2018 Conference begins (8AM)
June 20, 2018 Conference ends after evening banquet (7 PM – 10 PM)

Keynote speakers:

Dr. Wamadeva Balachandran (Brunel University) – Potential of Electrostatic Technologies for Environmental Pollution Control
Dr. Atsushi Ohsawa (National Institute of Occupational Safety and Health, Japan)- A unified expression of the charges transferred by brush discharges and the onset criterion of propagating brush discharges on charged insulating coats or liners
Dr. Hak-Joon Kim (Korea Institute of Machinery and Materials) - Novel air cleaning technologies for indoor air quality using electrostatic precipitation with near-zero ozone generation
Dr. Mamadou Sow (Institut de Radioprotection et de Sûreté Nucléaire , France) - Self -charging of radioactive dust and its bearing for nuclear safety

Contact information:

For questions regarding the technical program and abstract submission, contact
Technical Chair: Dr. Shubho Banerjee, Rhodes College, Memphis, banerjees@rhodes.edu , (901) 843-3585

For questions about local arrangements and conference hosting, contact
General Chair: Dr. Mark Horenstein, Boston University, mnh@bu.edu, (617) 353-9052

About Boston University: Boston University is a private research university located in Boston, Massachusetts. The university has over 33,000 undergraduate and graduate students from more than 130 countries, nearly 10,000 faculty and staff, 17 schools and colleges, and 250 fields of study. The conference venue is the Photonics Center which houses the Dept. of Electrical and Computer Engineering.

ESA Award Nominations

Dear Friends,

The ESA is accepting nominations for the following awards:

The **ESA Distinguished Service Award** recognizes outstanding service to the ESA over an extended period of time, with a demonstrated long-term commitment to the growth and continued well-being of the Society (requirement: 10 years as ESA member).

The **ESA Lifetime Achievement Award** recognizes outstanding contributions to the field of Electrostatics, as shown by the pervasiveness of the contributions in understanding certain problems or important practical benefits resulting from the work (requirement: 10 years working in field of Electrostatics).

The **ESA Honorary Life Member Award** recognizes exceptional contributions to both the ESA and to the field of Electrostatics, sustained over much of a career (requirements: 10 years as ESA member, 20 years working in field of Electrostatics).

The **ESA Rising Star Award** recognizes significant contributions at an early stage of a career to the field of Electrostatics, Requirements: age of 40 or younger, but cannot be a student).

The **ESA Entrepreneur Award** recognizes companies and/or individuals that implement electrostatics-related technologies and are recognized as having a meaningful impact in the industry and/or academia.

The **Teacher of the Year Award** recognizes outstanding teachers who use Electrostatics to stimulate learning, inspire students, or otherwise encourage and energize the learning process in a formal educational setting in grades K-12 (requirement: 3 years teaching Electrostatics).

The **Student of the Year Award** recognizes middle or high school students who demonstrate outstanding achievement in Electrostatics, as showcased in laboratory projects, papers or presentations.

The ESA is also accepting nominations for induction to the Electrostatic Hall of Fame. This honor recognizes and records for posterity those individuals who have made extraordinary contributions to the field of Electrostatics. Nominees do not need to be still living. The Hall of Fame has three categories: (1) advancement of the fundamental knowledge of Electrostatics; (2) promotion of interest in the field of Electrostatics; (3) innovations using Electrostatics technology in industry.

The list of the award recipients is available at *http://electrostatics.org/esaawardwinners.html*

Nominations should be submitted electronically to the ESA Award Chair, Prof. Maciej Noras at *mnoras@uncc.edu*, by **April 30, 2018**. The nomination should be in the form of a letter from an ESA member that includes a description of how the accomplishments of the nominee satisfy the award requirements (including citations of publications or patents when relevant), the contact information of the nominator and nominee, and the names and contact information of 3 other ESA members who endorse the nomination. For the Teacher and Student awards, endorsements from two faculty members of the nominee's institution should substitute for the ESA member endorsements.

Thank you in advance for all the submissions,

Sincerely,
Maciej Noras

Current Events

Paper-Based Supercapacitor Uses Metal Nanoparticles to Boost Energy Density

John Toon

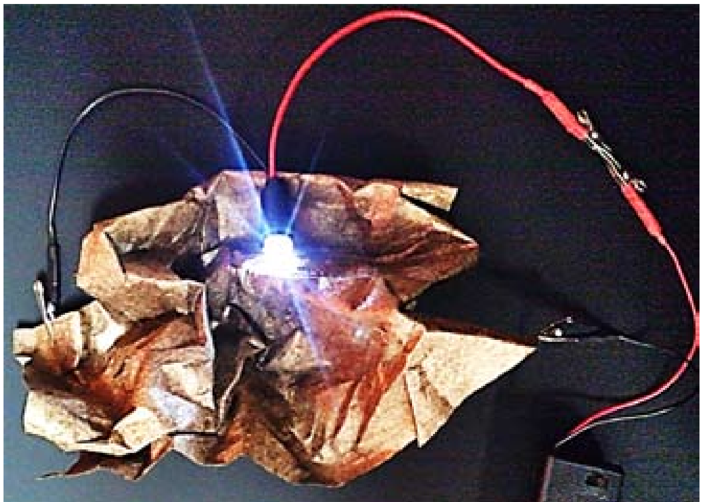
Using a simple layer-by-layer coating technique, researchers from the U.S. and Korea have developed a paper-based flexible supercapacitor that could be used to help power wearable devices. The device uses metallic nanoparticles to coat cellulose fibers in the paper, creating supercapacitor electrodes with high energy and power densities – and the best performance so far in a textile-based supercapacitor.

By implanting conductive and charge storage materials in the paper, the technique creates large surface areas that function as current collectors and nanoparticle reservoirs for the electrodes. Testing shows that devices fabricated with the technique can be folded thousands of times without affecting conductivity.

"This type of flexible energy storage device could provide unique opportunities for connectivity among wearable and internet of things devices," said Seung Woo Lee, an assistant professor in the Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. "We could support an evolution of the most advanced portable electronics. We also have an opportunity to combine this supercapacitor with

(cont'd. p. 5)

Image shows that the flexible metallized paper developed in this research retains its conducting properties even when crumpled and folded. (Credit: Ko et al., published in Nature Communications)



energy-harvesting devices that could power biomedical sensors, consumer and military electronics, and similar applications."

The research, done with collaborators at Korea University, was supported by the National Research Foundation of Korea and reported September 14 in the journal Nature Communications.

Energy storage devices are generally judged on three properties: their energy density, power density and cycling stability. Supercapacitors often have high power density, but low energy density – the amount of energy that can be stored – compared to batteries, which often have the opposite attributes. In developing their new technique, Lee and collaborator Jinhan Cho from the Department of Chemical and Biological Engineering at Korea University set out to boost energy density of the supercapacitors while maintaining their high power output.

They began by dipping paper samples into a beaker of solution containing an amine surfactant material designed to bind the gold nanoparticles to the paper. Next they dipped the paper into a solution containing gold nanoparticles. Because the fibers are porous, the surfactants and nanoparticles enter the fibers and become strongly attached, creating a conformal coating on each fiber.

By repeating the dipping steps, the researchers created a conductive paper on which they added alternating layers of metal oxide energy storage materials such as manganese oxide. The ligand-mediated layer-by-layer approach helped minimize the contact resistance between neighboring metal and/or metal oxide nanoparticles. Using the simple process done at room temperatures, the layers can be built up to provide the desired electrical properties.

"It's basically a very simple process," Lee said. "The layer-by-layer process, which we did in alternating beakers, provides a good conformal coating on the cellulose fibers. We can fold the resulting metallized paper and otherwise flex it without damage to the conductivity."

Though the research involved small samples of paper, the solution-based technique could likely be scaled up using larger tanks or even a spray-on technique. "There should be no limitation on the size of the samples that we could produce," Lee said. "We just need to establish the optimal layer thickness that provides good conductivity while minimizing the use of the nanoparticles to optimize the tradeoff between cost and performance."

The researchers demonstrated that their self-assembly technique improves several aspects of the paper supercapacitor, including its areal performance, an important factor for measuring flexible energy-storage electrodes. The maximum power and energy density of the metallic paper-based supercapacitors are estimated to be 15.1 mW/cm2 and 267.3 uW/cm2, respectively, substantially outperforming conventional paper or textile supercapacitors.

The next steps will include testing the technique on flexible fabrics, and developing flexible batteries that could work with the supercapacitors. The researchers used gold nanoparticles because they are easy to work with, but plan to test less expensive metals such as silver and copper to reduce the cost.

(excerpted from *http://www.news.gatech.edu/2017/10/06/paper-based-supercapacitor-uses-metal-nanoparticles-boost-energy-density*)

Spinning a lighter, safer electrode

A group of Drexel University researchers have created a fabric-like material electrode that could help make energy storage devices -- batteries and supercapacitors -- faster and less susceptible to leaks or disastrous meltdowns. Their design for a new supercapacitor, which looks something like a furry sponge infused with gelatin, offers a unique alternative to the flammable electrolyte solution that is a common component in these devices.

The electrolyte fluid inside both batteries and supercapacitors can be corrosive or toxic and is almost always flammable. To keep up with our advancing mobile technology, energy storage devices have been subject to material shrinking in the design process, which has left them vulnerable to short circuiting -- as in recent cases with Samsung's Galaxy Note devices -- which, when compounded with the presence of a flammable electrolyte liquid, can create an explosive situation.

So instead of a flammable electrolyte solution, the device designed by Vibha Kalra, PhD, a professor in Drexel's College of Engineering, and her team, used a thick ion-rich gel electrolyte absorbed in a freestanding mat of porous carbon nanofibers to produce a liquid-free device. The group, which included Kalra's doctoral assistant Sila Simotwo and Temple researchers Stephanie L. Wunder, PhD, and Parameswara Chinnam, PhD, recently published its new design for a "solvent-free solid-state supercapacitor" in the American Chemical Society journal Applied Materials and Interfaces. "We have completely eliminated the component that can catch fire in these devices," Kalra said. "And, in doing so, we have also created an electrode that could enable energy storage devices to become lighter and better."

Supercapacitors are another type of energy storage device. They're similar to batteries, in that they electrostatically hold and release energy, but in our technology -- mobile devices, laptops, electric cars -- they tend to serve as a power backup because they can disburse their stored energy in a quick spurt, unlike batteries that do so over long period of use. But, like batteries, supercapacitors use a flammable electrolyte solution, as a result they're vulnerable to leakage and fires.

Not only is the group's supercapacitor solvent-free -- which means it does not contain flammable liquid -- but the compact design is also more durable and its energy

Drexel researchers have developed a solid-state, free-standing electrode that can make energy storage devices safer by eliminating their flammable electrolyte solution. The electrode uses a carbon fiber mat, made by the process of electrospinning shown here. Credit: Drexel University

storage capacity and charge-discharge lifespan are better than comparable devices currently being used. It is also able to operate at temperatures as high as 300 degrees Celsius, which means it would make mobile devices much more durable and less likely to become a fire hazard due to abuse.

"To allow industrially relevant electrode thickness and loading, we have developed a cloth-like electrode composed of nanofibers that provides a well-defined three-dimensional open pore structure for easy infusion of the solid electrolyte precursor," Kalra said. "The open-pore electrode is also free of binding agents that act as insulators and diminish performance."

The key to producing this durable device is a fiber-like electrode framework that the team created using a process called electrospinning. The process deposits a carbon precursor polymer solution in the form of a fibrous mat by extruding it through a rotating electric field -- a process that, at the microscopic level, looks something like making cotton candy. The ionogel is then absorbed in the carbon fiber mat to create a complete electrode-electrolyte network. Its excellent performance characteristics are also tied to this unique way of combining electrode and electrolyte solutions. This is because they are making contact over a larger surface area.

If you think of an energy storage device as a bowl of corn flakes, then the place where energy storage happens is roughly where the flakes meet the milk -- scientists call this the "electrical double layer." It's where the conductive electrode that stores electricity meets the electrolyte solution that is carrying the electric charge. Ideally, in your cereal bowl, the milk would make its way through all the flakes to get just the right coating on each -- not too crunchy and not too soggy. But sometimes the cereal gets piled up and the milk -- or the electrolyte solution, in the case of our comparison -- doesn't make it all the way through, so the flakes on top are dry, while the flakes on the bottom are saturated. This isn't a good bowl of cereal, and its electrochemical equivalent -- an electron traffic jam en route to activation sites in the electrode -- is not ideal for energy storage.

Kalra's solid-state supercapacitor is like putting shredded wheat in the bowl, instead of cornflakes. The open architecture lets the milk permeate and coat the cereal, much like the ionogel permeates the carbon fiber mat in Kalra's solid-state supercapacitor. The mat provides a greater surface area for ions from the ionogel to access the electrode, which increases the capacity and improves the performance of the energy storage device. It also eliminates the need for many of the scaffolding materials that are essential parts of forming the physical electrode, but don't play a role in the energy storage process and contribute a good bit to the device's overall weight.

"State of the art electrodes are composed of fine powders that need to be blended with binding agents and made into a slurry, which is then applied into the device. These binders add dead weight to the device, as they are not conductive materials, and they actually hinder its performance," Kalra said. "Our electrodes are freestanding, thus eliminating the need for binders, whose processing can account for as much as 20 percent of the cost of manufacturing an electrode." The next step for Kalra's group will be applying this technique to the production of solid-state batteries as well as exploring its application for smart fabrics.

(from *https://www.sciencedaily.com/releases/2017/09/170920113559.htm*)

Electricity, eel-style: Soft power cells could run tomorrow's implantables

Inspired by the electric eel, a flexible, transparent electrical device could lead to body-friendly power sources for implanted health monitors and medication dispensers, augmented-reality contact lenses and countless other applications.

The soft cells are made of hydrogel and salt, and they form the first potentially biocompatible artificial electric organ that generates more than 100 volts. It produces a steady buzz of electricity at high voltage but low current, a bit like an extremely low-volume but high-pressure jet of water. It's perhaps enough to power a small medical device like a pacemaker.

While the technology is preliminary, Michael Mayer, a professor of biophysics at the Adolphe Merkle Institute of the University of Fribourg in Switzerland and the corresponding author on a paper about the device, believes it may one day be useful for powering implantable or wearable devices without the toxicity, bulk or frequent recharging that come with batteries. Further down the road, it could even lead to bioelectric systems that could generate electricity from naturally occurring processes inside the body.

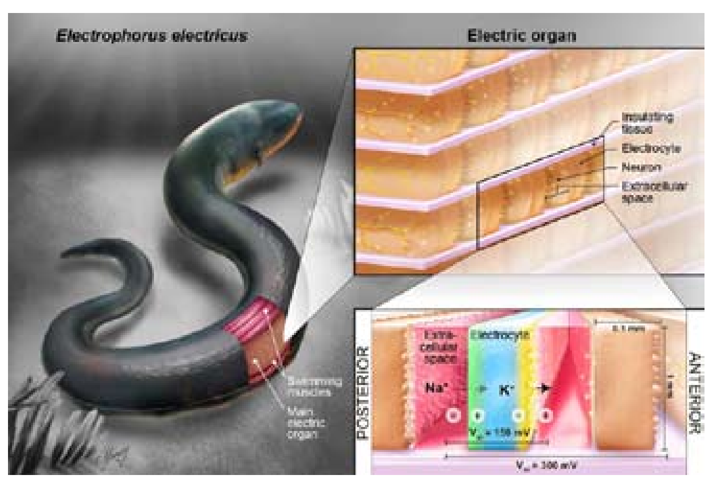
The device can't hold a candle to the electric eel, which can pump out far more power in short bursts to zap prey or defend itself. But the researchers say they've taken an important first step that advances fundamental understanding of soft power sources. The team includes researchers from the University of Michigan, the Adolphe Merkle Institute at the University of Fribourg and the University of California-San Diego. The work is detailed in a study published in the December 14 issue of Nature.

"The eel polarizes and depolarizes thousands of cells instantaneously to put out these high voltages," said study co-author Max Shtein, U-M associate professor of materials science and engineering. "It's a fascinating system to look at from an engineering perspective—its performance metrics, its fundamental building blocks and how to use them."

One secret to the eel's success is a phenomenon called transmembrane transport. Specialized electrical organs contain thousands of alternating compartments, each with an excess of either potassium or sodium ions. The compartments are separated by selective membranes that, in the eel's resting state, keep the two ions separate. When the eel needs to create a jolt of electricity, the membranes allow the ions to flow together. This creates a burst of power.

The researchers built a similar system, though instead of sodium and potassium, they used the sodium and chloride that are naturally combined in common table salt, dissolved in water-based hydrogel. Using a specialized printer at the Adolphe Merkle Institute, they printed thousands of tiny droplets of the salty gel on a plastic sheet, alternating them with hydrogel droplets of pure water. The alternating droplets are similar to the eel's compartments.

Next, the team needed to mimic the eel's selective membrane that keeps the compartments separate. They used a second sheet of alternating droplets, this one made of charge-selective hydrogel. Each droplet allows either positively charged sodium or negatively



This artist's rendering shows how the eel's electrical organs generate electricity by moving sodium (Na) and potassium (K) ions across a selective membrane. Image Credit: Caitlin Monney charged chloride to pass, excluding the other.

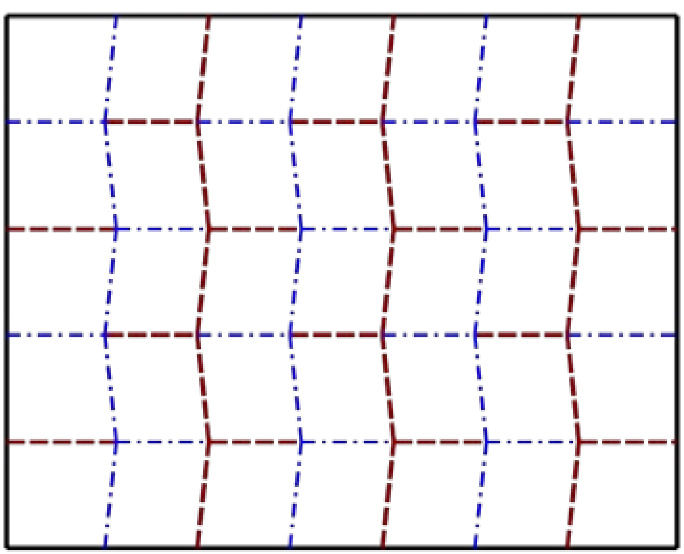
To generate power, the two sheets are pressed together, connecting saline and freshwater droplets across the charge-selective droplets in series. As the salty and fresh solutions mix, the charge-selective droplets move the sodium and chloride ions in opposing directions, producing an electric current.

The researchers took one final trick from the eel: its thousands of compartments can shuffle ions instantaneously, producing a coordinated jolt just when it's needed. The researchers needed to do something similar with their thousands of alternating cells, combining them all in exactly the right order, simultaneously.

Shtein, along with graduate students Anirvan Guha of the Adolphe Merkle Institute and Thomas Schroeder and Aaron Lamoureux of U-M, solved the problem with an origami technique called a Miura fold. Invented by a Japanese astrophysicist, the Miura fold is often used to fold solar panels into satellites at launch, then unpack them into large sheets once they're in space.

The used the idea in reverse, alternating all four droplet types in a precise pattern on a flat sheet that had been laser-scored in a Miura pattern. When pressure was applied, the sheet quickly folded together, stacking the cells in exactly the right positions.

"The electric organs in eels are incredibly sophisticated; they're far better at generating power than we are," Mayer said. "But the important thing for us was to replicate the basics of what's happening."



Crease pattern for a Miura fold. The parallelograms of this example have 84° and 96° angles. By Dmcq - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=17473684

(from *http://ns.umich.edu/new/multimedia/videos/25325-electricity-eel-style-soft-power-cells-could-run-tomorrow-s-implantables*)

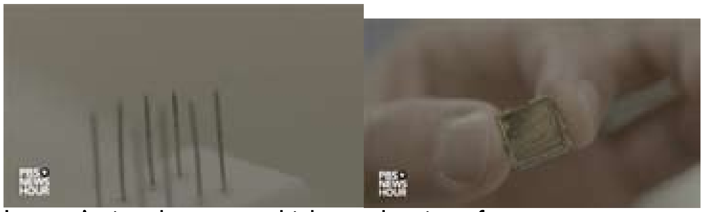
These tiny satellites, equipped with ion thrusters, could change how we explore space

Nsikan Akpan

TCubeSats, low-cost, bite-sized satellites inspired by the tubes used to hold Beanie Babies, were invented in 1999 as educational tools. Their creators — engineering professors Bob Twiggs and Jordi Puig-Suari — hoped building satellites the size and shape of Rubik's Cubes would help students of all ages how to design and engineer efficiently. Now, aerospace suppliers and governments across the globe see the tools as the future of space commercialization and deep space exploration. They want to turn CubeSats into tools for low Earth orbit activities like telecommunications and reconnaissance. Companies like SpaceX, Virgin Galactic, Boeing and Airbus, for instance, want to create a space internet — a network of thousands of CubeSats that provide high speed broadband to remote parts of the world. And people like Paulo Lozano, director of the Space Propulsion Lab at the Massachusetts Institute of Technology, say sending the tiny satellites to asteroids could help improve space research (or even save the planet from an asteroid attack, he said). "Instead of going to an asteroid every five, 10 years the traditional way, release a fleet of these tiny little CubeSats and visit 100 asteroids because it's so cheap," he said. "Because some of these asteroids, especially the very small ones, have the potential to collide with the Earth. Detecting them in time is important [for stopping them], but also knowing their composition."

Over the first decade of the CubeSat era, universities dominated the landscape, sending two of every three devices into space. Today, commercial companies and militaries have taken over, launching 70 percent of CubeSats in the last five years. But there's still one big problem: CubeSats can't move once they're in space — which limits their survival to months or years and makes them dangerous.

Of the 750 or so CubeSats sent into space so far, almost all have lacked their own propulsion systems. The tiny satellites are transported alongside regular cargo, and then flung into space. But without their



Lozano's tiny thrusters, which are the size of quarters, generate these ion sprays. Engineered like microchips, a single thruster contains a grid of 500 needles — each a solar powered, custom-built nozzle for spewing ions. Multiple thrusters can be packed onto a single CubeSat to allow for a variety of motions or extra propulsion. Photo by Matthew Ehrichs

own rockets, the CubeSats cannot maneuver on their own. Most fall slowly back to Earth, but some remain in orbit for years, where they join the other 100 million pieces of space debris that are at risk of colliding with other satellites and space stations. The U.S. Air Force, whose Joint Space Operation Center monitors more than 23,000 orbiting objects larger than four inches in diameter, issues about 700,000 of these collision warnings to satellite owners per year. Imagine what would happen if thousands of CubeSats were added to the fray. What CubeSats need to stay in space are mini boosters, and scientists like Lozano are racing to build them.

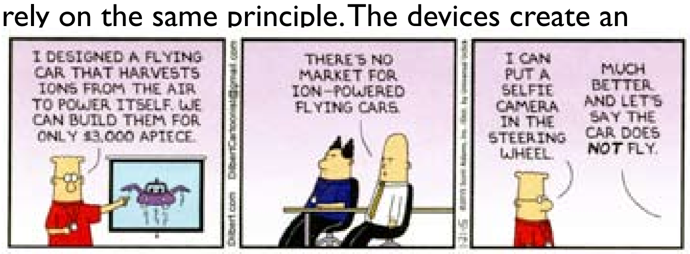
Lozano's early work focused on big chemical rockets — the kind that you see strapped to space shuttles or on SpaceX missions. He knew these conventional rockets require huge fuel tanks — too big to be carried by CubeSats. Meanwhile, government standards limit how much chemical propellant can be carried by secondary cargo like CubeSats in order to prevent accidental explosions. So, Lozano needed an alternative. His inspiration: static electricity and tiny drops of salt water. Static electricity is caused by an imbalance between positive and negative charges in an object. Rub a balloon on your sweater, and its rubber surface becomes covered in negative charge (electrons). Place the balloon near your positively charged hair, and it tugs on the strands until you have a misshapen mohawk.

Lozano's team designed a set of mini thrusters that rely on the same principle. The devices create an electric field that tugs on the charged particles in salt water until they peel off. The result is a spray made of charged molecules called ions. This ion spray doesn't create a lot of force. It's always less than a millinewton, which is akin to the force produced when a mosquito lands on your arm. But the spray moves very fast, and even a small action creates a reaction in the frictionless vacuum of outer space. Use this to move ions in one direction, and a CubeSat will move uber fast in the other. Lozano said the best chemical rockets produce a fiery exhaust that moves at about 9,000 miles per hour. His electrospray thrusters can go more than 111,000 miles per hour, he said.

The thrusters, which look like computer microchips, are the size of quarters. The chips contain a grid of 500 needles — each a custom-built nozzle for spewing ions. His team tests them inside a large vacuum chamber at their lab in Boston. "In an ideal situation, all of the ions would have the same energy, but the physics of these ion beams makes it so that some ions have less energy than others," said Catherine Miller, an MIT doctoral and NASA Space Technology Research Fellow. By studying how energy is distributed among the ion beams, she can calculate and standardize how each thruster will perform.

Only three propulsion boosters for CubeSats have had successfully demoed in space, Lemmer said. Lozano's system was one of them, through a partnership with the Aerospace Corporation in 2015. But Lemmer, who published a comprehensive review of CubeSat propulsion systems last year, said Lozano's ion engines stand out because each one can produce so much thrust.

"Dr. Lozano's system is probably the frontrunner for the possibility for deep space missions," Lemmer said. "In order to go interplanetary, you're going to have to have an electric propulsion system because they are so much more efficient." (excerpted from *https://www.pbs.org/newshour/science/these-tiny-satellites-equipped-with-ion-thrusters-could-change-how-we-explore-space*)



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