Sep/Oct 2012 • No. 215

ESA Newsletter

Electrostatics Society of America - The Friendly Society

President's Message

Dear Colleagues,

The beginning of our field is often attributed to the Greek philosopher Thales of Miletus. Thales lived from ~ 624 BC to ~ 545 BC, in the Greek colony Miletus which is on the Aegean coast of present-day Turkey. If you look up 'Electrostatics' on Wikipedia, you'll find it says "Amber, for example, can acquire an electric charge by friction with a material like wool. This property, first recorded by Thales of Miletus, was the first electrical phenomenon investigated by man." While we know not to blindly trust Wikipedia, the Encyclopedia Britannica has been saying something similar for many years; for example, the 1798 edition of Encyclopedia Britannica said "… Thales, who first observed the attractive power of amber". And the introductions of many scientific papers and textbooks mention that Thales either discovered electrostatics, or was the first to carry out experiments of electrostatic charging.

Earlier this year I was curious to learn more about Thales' experiments. So I contacted my colleague Paul Iversen, a professor in the Department of Classics here at Case Western Reserve University. Paul specializes in Hellenistic civilization, and his research involves finding and deciphering transcriptions in Greek ruins in present day Turkey.

I asked Paul whether he could help me research Thales' experiments. When Paul got back to me about an hour later, he had already completed the research.

I learned that there are only a few contemporary sources from the classical period (and they are all online and searchable). There are no extant writings from Thales, and it is not clear whether he had ever written anything. All that is known about Thales comes from the later writings of five others over a period of 800 years: Herodotus (~484 –425 B.C.), Plato (424 – 348 B.C.), Aristotle (384 – 322 B.C.), Pliny the Elder (23– 79 A.D.) and Diogenes Laërtius (~200 – 250 A.D.).

Herodotus mentions amber, but not in connection to Thales or electrostatics. Plato mentions electrostatics, but not in connection to Thales. Aristotle mentions Thales in connection to magnetism but not electrostatics. Pliny mentions magnetism, but not in connection to Thales. It is only Diogenes who mentions Thales in connection to electrostatics (and this was 800 years after Thales lived!).

The only connection of Thales to electrostatics in any ancient source is one sentence from Diogenes: "Aristotle and Hippias say that he [Thales] attributed a share of soul to inanimate things, taking his proof from the magnet and from amber" (electrostatics was associated with amber at the time, in fact, the Greek word for amber is ἠλέκτρου, giving us the root "electro").

So there is no accuracy to statements that Thales discovered or first-noticed electrostatic charging, or that he carried out any electrostatics experiments – this is an embellishment of later writers, which has been perpetuated by authors quoting secondary sources.

Paul and I wrote a paper on this topic in the Journal of Electrostatics, if you're interested in reading more [Iversen and Lacks, J. Electrostat. 70, 309 (2012)].

Regards,

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

Current Events

Electric Fish Charges up Research on Animal Behavior

Miles O'Brien and Ann Kellan

An electric eel can generate enough current to stun its prey, just like a Taser. Weakly electric fish can also generate electricity, but not enough to do any harm. "Weakly electric fish are unique in that they produce and detect electric fields. They use these electric fields in social communication and to detect objects," explains Johns Hopkins University neuroethologist Eric Fortune.

Fortune has traveled to Ecuador to study weakly electric knifefish in their native habitat, even placing acoustical instruments underwater so he could listen to and record their electrical hums.

Back at Johns Hopkins University, research collaborator and mechanical engineer Noah Cowan and the rest of the team use Fortune's field data to help with their observations and experiments in the lab. With support from the National Science Foundation (NSF), they are studying the knifefish to learn more about how the brains of animals work to control their behavior.

"We see how they interact in the wild and then we create very controlled experiments in the lab that allow us to probe specific scientific questions. Researchers want to better understand how these fish use their electric field as a sixth sense, not only to communicate with each other, but to navigate their surroundings and find their next meal," explains Cowan. "There's a small organ in the tail of the weakly electric fish that generates an electric field that envelops the entire animal," continues Cowan. When an object passes through the field, the fish has receptors on its skin to detect the object. "There are little voltage sensors all over the surface of the skin and as an object comes by, the voltage changes and it says, 'Ah-ha, lunch,' or it says, 'I'm going to be lunch,' and it swims away."

Each knifefish can generate its own frequency that, in some cases, can change when another knifefish comes near. One reason may be to avoid jamming each others' signals, and another may be to communicate. "When two fish come near each other, their two pitches begin to interact much like two singers' pitches would interact," says Cowan.

The researchers also want to study what happens when more than two interact. When their electric fields overlap, does it heighten or reduce their ability to detect predators and prey? If grouping together is a benefit, a chorus of hums might prove more beneficial for these fish than going solo. "The fact that there are multiple frequencies present at the same time and they're moving around

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Calendar

- 12th Int'l. Conf. of Electrostatics, Electrostatics - 2013, April 2013, Budapest, Hungary, Contact: *info@electrostatics2013.org* website: http://www.electrostatics2013.org/
- ESA 2013, June 11-13, 2013, Cocoa Beach, Florida, USA, Contact: Charlie Buehler
- ESA 2014, June 17-19, 2014, Univ. of Notre Dame, South Bend, Indiana, USA, Contact: David Go

Current Events (cont'd.)

together is a complicated puzzle that we haven't yet figured out," says Cowan.

Another piece of the research puzzle is learning when the fish relies on its electro-sense over its other five senses. When the lights go out and it's hard for the fish to see, they seem to rely on it more for navigation. Their electro-sense is a lot better than vision in places where the water gets turbid. The electric field goes right through it. Knifefish are also agile swimmers propelled by long ribbon fins. "They can swim forward, backward, and rotate rapidly," notes Cowan. Their sixth sense and enhanced agility are making them good role models in the development of small submersible robots. Malcolm MacIver, a mechanical and biomedical engineer at Northwestern University, and his team are developing a nimble robot that can swim backwards and forwards. It may one day be able to use a similar "sixth sense" to monitor the health of coral reefs, or to navigate the dark, murky waters of an oil spill.

(excerpted from *http://phys.org/news/2012-04-electric-fish-animal-behavior.html*)

Revolutionary Technology Enables Objects To Know How They Are Being Touched

A doorknob that knows whether to lock or unlock based on how it is grasped, a smartphone that silences itself if the user holds a finger to her lips and a chair that adjusts room lighting based on recognizing if a user is reclining or leaning forward are among the many possible applications of Touché, a new sensing technique developed by a team at Disney Research, Pittsburgh, and Carnegie Mellon University.

Touché is a form of capacitive touch sensing, the same principle underlying the types of touchscreens used in most smartphones. But instead of sensing electrical signals at a single frequency, like the typical touchscreen, Touché monitors capacitive signals across a broad range of frequencies. This Swept Frequency Capacitive Sensing (SFCS) makes it possible to not only detect a "touch event," but to recognize complex configurations of the hand or body that is doing the touching. An object thus could sense how it is being touched, or might sense the body configuration of the person doing the touching. SFCS is robust and can enhance everyday objects by using just a single sensing electrode. Sometimes, as in the case of a doorknob or other conductive objects, the object itself can serve as a sensor and no modifications are required. Even the human body or a body of water can be a sensor.

"Signal frequency sweeps have been used for decades in wireless communication, but as far as we know, nobody previously has attempted to apply this technique to touch interaction," said Ivan Poupyrev, senior research scientist at Disney Research, Pittsburgh. "Yet, in our laboratory experiments, we were able to enhance a broad variety of objects with high-fidelity touch sensitivity. When combined with gesture recognition techniques, Touché demonstrated recognition rates approaching 100 percent. That suggests it could immediately be used to create new and exciting ways for people to interact with objects and the world at large."

In addition to Poupyrev, the research team included Chris Harrison, a Ph.D. student in Carnegie Mellon's Human-Computer Interaction Institute, and Munehiko Sato, a Disney intern and a Ph.D. student in engineering at the University of Tokyo. The researchers will present their findings May 7 at CHI 2012, the Conference on Human Factors in Computing Systems, in Austin, Texas, where it has been recognized with a prestigious Best Paper Award.

Both Touché and smartphone touchscreens are based on the phenomenon known as capacitive coupling. In a capacitive touchscreen, the surface is coated with a transparent conductor that carries an electrical signal. That signal is altered when a person's finger touches it, providing an alternative path for the electrical charge. By monitoring the change in the signal, the device can determine if a touch occurs. By monitoring a range of signal frequencies, however, Touché can derive much more information. Different body tissues have different capacitive properties, so monitoring a range of frequencies can detect a number of different paths that the electrical charge takes through the body. Making sense of all of that SFCS information, however, requires analyzing hundreds of data points. As microprocessors have become steadily faster and less expensive, it now is feasible to use SFCS in touch interfaces, the researchers said.

"Devices keep getting smaller and increasingly are embedded throughout the environment, which has made it necessary for us to find ways to control or interact with them, and that is where Touché could really shine," Harrison said. Sato said Touché could make computer interfaces as invisible to users as the embedded computers themselves. "This might enable us to one day do away with keyboards, mice and perhaps even conventional touchscreens for many applications," he said.

Among the proof-of-concept applications the researchers have investigated is a smart doorknob. Depending on whether the knob was grasped, touched with one finger or two, or pinched, a door could be programmed to lock or unlock itself, admit a guest, or even leave a reply message, such as "I'll be back in five minutes."

In another proof-of-concept experiment, they showed that SFCS could enhance a traditional touchscreen by sensing not just the fingertip, but the configuration of the rest of the hand. They created the equivalent of a mouse "right click," zoom in/out and copy/paste functions depending on whether the user pinched the phone's screen and back with one finger or two, or used a thumb.

The researchers also were able to monitor body gestures, such as touching fingers, grasping hands and covering ears by having subjects wear electrodes similar to wristwatches on both arms. Such gestures could be used to control a smartphone or other device.

They also showed that a single electrode attached to any water vessel could detect a number of gestures, such as fingertip submerged, hand submerged and hand on bottom. Sensing touch in liquids might be particularly suited to toys, games and food appliances.

(excerpted from *http://www.cmu.edu/news/stories/archives/2012/may/may3_disneyresearch.html*)

Berkeley Lab Scientists Generate Electricity From Viruses

Dan Krotz

Imagine charging your phone as you walk, thanks to a paper-thin generator embedded in the sole of your shoe. This futuristic scenario is now a little closer to reality. Scientists from the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) have developed a way to generate power using harmless viruses that convert mechanical energy into electricity.

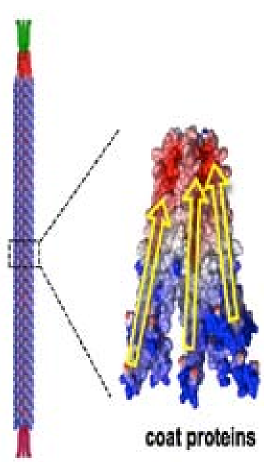
Current Events (cont'd.)

The scientists tested their approach by creating a generator that produces enough current to operate a small liquid-crystal display. It works by tapping a finger on a postage stamp-sized electrode coated with specially engineered viruses. The viruses convert the force of the tap into an electric charge. Their generator is the first to produce electricity by harnessing the piezoelectric properties of a biological material. Piezoelectricity is the accumulation of a charge in a solid in response to mechanical stress.

The milestone could lead to tiny devices that harvest electrical energy from the vibrations of everyday tasks such as shutting a door or climbing stairs. It also points to a simpler way to make microelectronic devices. That's because the viruses arrange themselves into an orderly film that enables the generator to work. Self-assembly is a much sought after goal in the finicky world of nanotechnology.

The scientists describe their work in a May 13 advance online publication of the journal Nature Nanotechnology. "More research is needed, but our work is a promising first step toward the development of personal power generators, actuators for use in nano-devices, and other devices based on viral electronics," says Seung-Wuk Lee, a faculty scientist in Berkeley Lab's Physical Biosciences Division and a UC Berkeley associate professor of bioengineering. He conducted the research with a team that includes Ramamoorthy Ramesh, a scientist in Berkeley Lab's Materials Sciences Division and a professor of materials sciences, engineering, and physics at UC Berkeley; and Byung Yang Lee of Berkeley Lab's Physical Biosciences Division.

The piezoelectric effect was discovered in 1880 and has since been found in crystals, ceramics, bone, proteins, and DNA. It's also been put to use. Electric cigarette lighters and scanning probe microscopes couldn't work without it, to name a few applications.



The M13 bacteriophage has a length of 880 nanometers and a diameter of 6.6 nanometers. It's coated with approximately 2700 charged proteins that enable scientists to use the virus as a piezoelectric nanofiber.

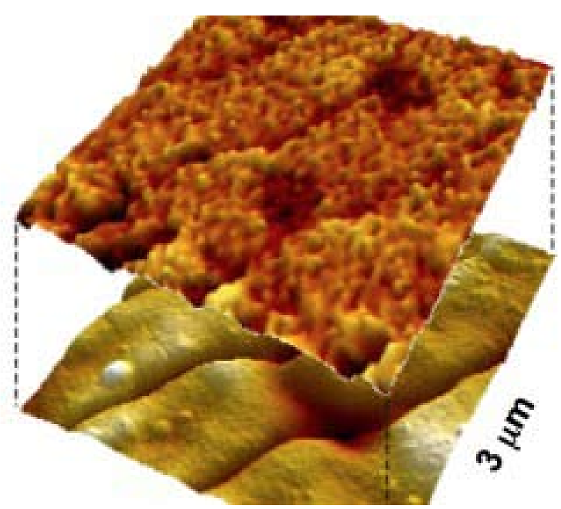
But the materials used to make piezoelectric devices are toxic and very difficult to work with, which limits the widespread use of the technology.

Lee and colleagues wondered if a virus studied in labs worldwide offered a better way. The M13 bacteriophage only attacks bacteria and is benign to people. Being a virus, it replicates itself by the millions within hours, so there's always a steady supply. It's easy to genetically engineer. And large numbers of the rod-shaped viruses naturally orient themselves into well-ordered films, much the way that chopsticks align themselves in a box.

These are the traits that scientists look for in a nanobuilding block. But the Berkeley Lab researchers first had to determine if the M13 virus is piezoelectric. Lee turned to Ramesh, an expert in studying the electrical properties of thin films at the nanoscale. They applied an electrical field to a film of M13 viruses and watched what happened using a special microscope. Helical proteins that coat the viruses twisted and turned in response—a sure sign of the piezoelectric effect at work.

Next, the scientists increased the virus's piezoelectric strength. They used genetic engineering to add four negatively charged amino acid residues to one end of the helical proteins that coat the virus. These residues increase the charge difference between the proteins' positive and negative ends, which boosts the voltage of the virus.

The scientists further enhanced the system by stacking films composed of single layers of the virus on top of each other. They found that a stack about 20 layers thick exhibited the strongest piezoelectric effect.



The bottom 3-D atomic force microscopy image shows how the viruses align themselves side-by-side in a film. The top image maps the film's structure-dependent piezoelectric properties, with higher voltages a lighter color.

The only thing remaining to do was a demonstration test, so the scientists fabricated a virus-based piezoelectric energy generator. They created the conditions for genetically engineered viruses to spontaneously organize into a multilayered film that measures about one square centimeter. This film was then sandwiched between two gold-plated electrodes, which were connected by wires to a liquid-crystal display.

When pressure is applied to the generator, it produces up to six nanoamperes of current and 400 millivolts of potential. That's enough current to flash the number "1" on the display, and about a quarter the voltage of a triple A battery.

"We're now working on ways to improve on this proof-of-principle demonstration," says Lee. "Because the tools of biotechnology enable large-scale production of genetically modified viruses, piezoelectric materials based on viruses could offer a simple route to novel microelectronics in the future."

(excerpted from *http://newscenter.lbl.gov/news-releases/2012/05/13/electricity-from-viruses/*)

Plastic Power: Triboelectric Generator Produces Electricity by Harnessing Frictional Forces Between Transparent Polymer Surfaces

Researchers have discovered yet another way to harvest small amounts of electricity from motion in the world around us – this time by capturing the electrical charge produced when two different kinds of plastic materials rub against one another. Based on flexible polymer materials, this "triboelectric" generator could provide alternating current (AC) from activities such as walking.

The triboelectric generator could supplement power produced by nanogenerators that use the piezoelectric effect to create current from the flexing of zinc oxide nanowires. And because these triboelectric generators can be made nearly transparent, they could offer a new way to produce active sensors that might replace technology now used for touch-sensitive device displays.

"The fact that an electric charge can be produced through this principle is well known," said Zhong Lin Wang, a Regents professor in the School of Materials Science & Engineering at the Georgia Institute of Technology. "What we have introduced is a gap separation technique that produces a voltage drop, which leads to a current flow, allowing the charge to be used. This generator can convert random mechanical energy from our environment into electric energy."

The triboelectric generator operates when a sheet of polyester rubs against a sheet made of polydimethysiloxane (PDMS). The polyester tends to donate electrons, while the PDMS accepts electrons. Immediately after the polymer surfaces rub together, they are mechanically separated, creating an air gap that isolates the charge on the PDMS surface and forms a dipole moment.

If an electrical load is then connected between the two surfaces, a small current will flow to equalize the charge potential. By continuously rubbing the surfaces together and then quickly separating them, the generator can provide a small alternating current. An external deformation is used to press the surfaces together and slide them to create the rubbing motion.

"For this to work, you have to use to two different kinds of materials to create the different electrodes," Wang explained. "If you rub together surfaces made from the same material, you don't get the charge differential."

The technique could also be used to create a very sensitive self-powered active pressure sensor for potential use with organic electronic or opto-electronic systems. The force from a feather or water droplet touching the sur-

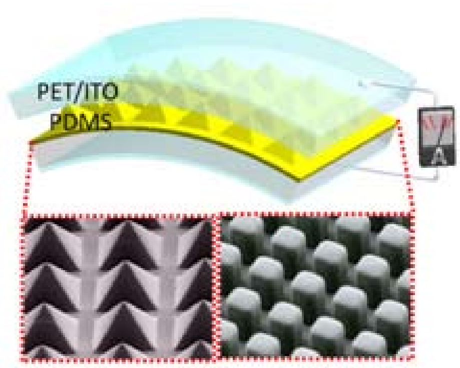


Diagram shows a new high-output, flexible and transparent trioboelectric nanogenerator produced from transparent polymer materials. (Image courtesy of Zhong Lin Wang)

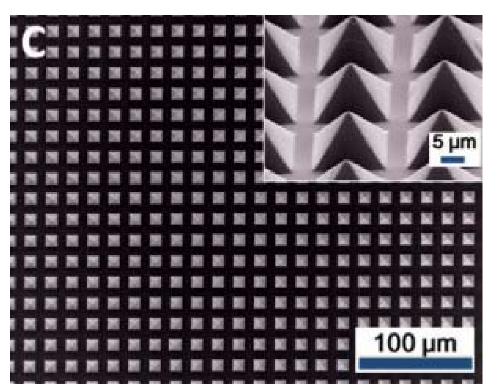
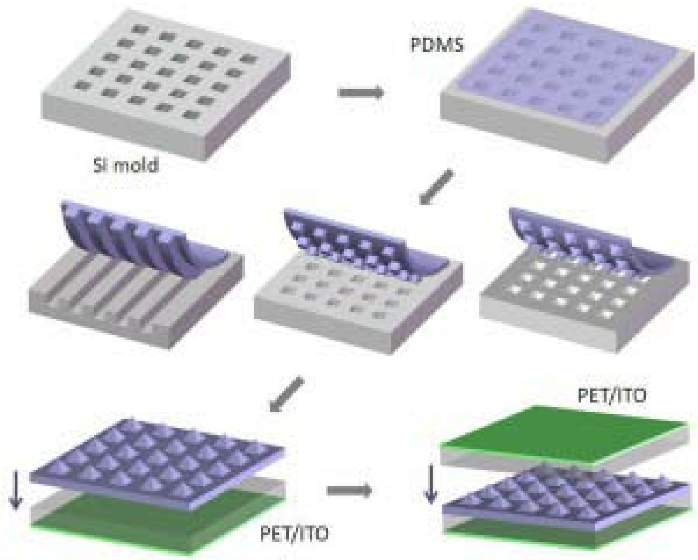


Image shows pyramid patterns created in a polymer sheet to increase current production in the triboelectric generator. (Image courtesy of Zhong Lin Wang)



Schematic shows the fabrication process for the triboelectric nanogenerators and pressure sensors. A patterned silicon wafer serves as the mold for fabrication of PDMS thin films with micro-patterned features. (Image courtesy of Zhong Lin Wang)

face of the triboelectric generator produces a small current that can be detected to indicate the contact. The sensors can detect pressure as low as about 13 millipascals.

Because the devices can be made approximately 75 percent transparent, they could potentially be used in touch screens to replace existing sensors. "Transparent generators can be fabricated on virtually any surface," said Wang. "This technique could be used to create very sensitive transparent sensors that would not require power from a device's battery."

While smooth surfaces rubbing together do generate charge, Wang and his research team have increased the current production by using micro-patterned surfaces. They studied three different types of surface patterning – lines, cubes and pyramids – and found that placing pyramid shapes on one of the rubbing surfaces generated the most electrical current: as much as 18 volts at about 0.13 microamps per square centimeter.

Wang said the patterning enhanced the generating capacity by boosting the amount of charge formed, improving capacitance change due to the air voids created between the patterns, and by facilitating charge separation.

To fabricate the triboelectric generators, the researchers began by creating a mold from a silicon wafer on which the friction-enhancing patterns are formed using traditional photolithography and either a dry or wet etching process. The molds, in which the features of the patterns are formed in recess, were then treated with a chemical to prevent the PDMS from sticking. The liquid PDMS elastomer and cross-linker were then mixed and spin-coated onto the mold, and after thermal curing, peeled off as a thin film. The PDMS film with patterning was then fixed onto an electrode surface made of indium tin oxide (ITO) coated with polyethylene terephthalate (PET) by a thin PDMS bonding layer. The entire structure was then covered with another ITO-coated PET film to form a sandwich structure.

"The entire preparation process is simple and low cost, making it possible to be scaled up for large scale production and practical applications," Wang said.

The generators are robust, continuing to produce current even after days of use – and more than 100,000 cycles of operation, Wang said. The next step in the research will be to create systems that include storage mechanisms for the current generated.

"Friction is everywhere, so this principle could be used in a lot of applications," Wang added. "We are combining our earlier nanogenerator and this new triboelectric generator for complementary purposes. The triboelectric generator won't replace the zinc oxide nanogenerator, but it has its own unique advantages that will allow us to use them in parallel."

(excerpted from http://gtresearchnews.gatech.edu/triboelectric-generator-produces-electricity-from-friction/)

New Ultracapacitor Delivers a Jolt of Energy at a Constant Voltage

Chemical batteries power many different mobile electronic devices, but repeated charging and discharging cycles can wear them out. An alternative energy storage device called an ultracapacitor can be recharged hundreds of thousands of times without degrading, but ultracapacitors have their own disadvantages, including a voltage output that drops precipitously as the device is discharged. Now a researcher from the University of West Florida has designed an ultracapacitor that maintains a near steady voltage.

Standard capacitors store energy in an electric field created when opposite electrical charges collect on two plates separated by a thin insulating material. In ultracapacitors the surface area of the plates is increased with a coating of porous activated carbon, which is packed with tiny holes and cracks that can capture charged particles. The space between the plates is filled with an electrolyte solution containing positive and negative ions. As charge accumulates on the plates, they attract ions, creating a double-layer of stored energy.

Current Events (cont'd.)

In both standard capacitors and ultracapacitors, the voltage drops as the stored charge is released. Most electronic devices, however, require constant voltage to operate. An electronic circuit called a DC-DC converter can change the dropping voltage of the capacitor into a constant voltage output, but the converters experience problems below one volt. "A significant portion of the energy of the ultracapacitor is held below one volt," notes Ezzat Bakhoum, a professor of electrical engineering at the University of West Florida. "Operation in that region is very difficult because the DC-DC converter cannot function at such low voltage. Applications where the use of an ultracapacitor is precluded because of this problem include low-voltage systems in electric vehicles, hand-held power tools, toys, and cameras, just to name a few."

So Bakhoum has designed an ultracapacitor that maintains a near-constant voltage without a DC-DC converter. The ultracapacitor is fitted with an electromechanical system that can slowly lift the core of the device out of the electrolyte solution as the stored charged is released. As the electrolyte drains away, the device can hold less charge, thus lowering, its capacitance. Since the voltage of the capacitor is related to the ratio of the stored charge to the capacitance, the system maintains a steady voltage as charge is siphoned off. Bakhoum built and tested a prototype of the new ultracapacitor. After attaching a 35-watt load to the device, he found he could successfully program the voltage to stay within a 4.9 to 4.6 volt range. Testing also showed that the constant-voltage mechanism operates with a 99 percent efficiency or higher. The lifetime of the electromechanical motor is expected to be about the same as the lifetime of the ultracapacitor's core, Bakhoum writes.

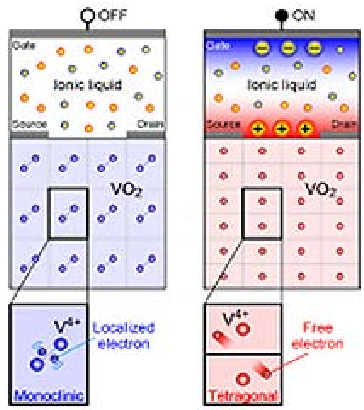
For Bakhoum, future research steps include modifying the design of the constant-voltage ultracapacitor system so that it can be installed at any angle. He may also explore whether the same type of constant-voltage approach is suitable for new, high-energy-density ultracapacitors.

(excerpted from http://www.sciencedaily.com/releases/2012/07/120719103225.htm)

New transistor can switch the state of matter

Sixty years after the transistor began a technological revolution that transformed nearly every aspect of our daily lives, a new transistor brings innovations that may help to do so again. Developed at RIKEN, the device uses the electrostatic accumulation of electrical charge on the surface of a strongly-correlated material to trigger bulk switching of electronic state. Functional at room temperature and triggered by a potential of only 1V, the switching mechanism provides a novel building block for ultra low power devices, non-volatile memory and optical switches based on a new device concept.

After shrinking for many decades, conventional electronics is approaching quantum scaling limits, motivating the search for alternative technologies to take its place.



Among these, strongly-correlated materials, whose electrons interact with each other to produce unusual and often useful properties, have attracted growing attention. One of these properties is triggered in phase transitions: applying a small external voltage can induce a very large change in electric resistance, a mechanism akin to a switch that has many potential applications.

Now, researchers at the RIKEN Advanced Science Institute have created the world's first transistor that harnesses this unique property. Described in a paper in Nature, the device uses an electric-double layer to tune the charge density on the surface of vanadium dioxide (VO2), a well-known classical strongly-correlated material. Thanks to the strong correlation of electrons and electron-lattice coupling in VO2, this surface charge in turn drives localized electrons within the bulk to delocalize, greatly magnifying the change of electronic phase. A potential of only 1V, they show, is enough to switch the material from an insulator to a metal and trigger an astounding thousand-fold drop in resistance.

The electronic phase, however, is not the only thing that changes in this insulator-to-metal transition: using synchrotron radiation from RIKEN's SPring-8 facility in Harima, the research group analyzed the crystal structure of the VO2, showing that it, too, undergoes a transformation, from monoclinic to tetragonal structure. Electric-field induced bulk transformation of this kind is impossible using conventional semiconductor-based electronics and suggests a wide range of potential applications.

(excerpted from http://www.rdmag.com/news/2012/07/new-transistor-can-switch-state-matter)

Electrostatics
Society of America

30 Shalimar Drive
Rochester, NY 14618

ESA Information

ESA Home Page: http://www.electrostatics.org

Dan Lacks
ESA President
Department of Chem. Eng.
Case Western Reserve Univ.
Cleveland, OH 44106
(216)368-4238
daniel.lacks@case.edu

Steve Cooper
Secretary/Treasurer
540 Morton Rd.
Athens, GA 30605
706-255-5518
steve@mt-ind.com

Mark Zaretsky
Newsletter Editor
30 Shalimar Drive
Rochester, NY 14618
585-588-6351
mark.zaretsky@kodak.com

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