

ESA Newsletter

Electrostatics Society of America - The Friendly Society

President's Message

Electrospinning and Nanofibers

Dear All:

Electrospinning is a technique producing nanofibers through an electrically-charged jet of polymer solution. High voltage is applied to a fluid droplet, either from a melt or solution, coming out from the tip of a die which acts as one of the electrodes. This leads to the droplet deformation and finally to the ejection of a charged jet from the tip of the cone accelerating towards the counter electrode, leading to the formation of continuous fibers. Thus, it is a combination of the two techniques, electrospray and spinning [1]. The principle is simple and uses electrostatic processes. The possibility of large-scale production combined with the simplicity of the process makes this technique very attractive for many different applications. It is gaining momentum as a viable technique for making nanofibers useful for various biomedical applications, including tissue engineering (making scaffold material for extra-cellular matrix and other components, via electrospun biomimetic nanofibers), drug release, wound dressing (using electrospun hemoglobin and myoglobin), enzyme immobilization, and support for bone-repair. It is also used for producing many materials for various applications such as filtration and protective material, electrical and optical applications, sensors, and nanofiber reinforced composites [1, 2]. Drug release and tissue engineering are closely related areas. A large number of biodegradable and biocompatible polymers, loaded with different drugs, have also been electrospun by conventional or modified electrospinning methods, such as co-axial electrospinning. These studies show the various advantages of electrospinning in drug delivery for in-vitro samples and need to be extended to in-vivo [1].

Yet another application of electrospinning is in the food industry. It is possible to enhance freshness, taste and flavor using bio-degradable, electrospun nanofibers for packaging. Developing smart packaging to optimize product shelf-life has been the goal of many companies, including Kraft, Heinz, and Nestle [3]. Such packaging systems would be able to repair small holes/tears, respond to environmental conditions (temperature and moisture changes), and alert the customer if the food is contaminated. The packaging market now stands at \$3.7 billion, up from \$1.1 billion in 2006. Electrospinning is used to develop novel nanofibers for highly functional ingredients and high performance packaging materials, employing both natural and synthetic polymers [4].

The Nanoforum (European nanotechnology gateway) Report on Nanotechnology in Agriculture and Food clearly enumerates the application of nanotechnology in the food industry, including smart delivery systems and packaging [3]. The use of electrospinning is envisioned for making fibers as carriers for micronutrients in food, as well as reinforcing chains in biodegradable polymers at the Univ. of Waterloo by one of our own ESA members. The focus is on developing new methodologies to control the geometry and orientation of electrospun nanofibers as carriers for micronutrients in food, and reinforcing chains in biodegradable polymers. Researchers around the world have been looking for ways to produce high aspect ratio nanofibers and continuous nanofibers in a simple and reproducible manner. The electrospinning method uses a high voltage test facility to produce nanofibers in sufficiently large quantities, enabling a variety of nanofibers from polymers.

(cont'd. on page 2)

President's Message (cont'd.)

We have 3 papers on this cost-effective, electrospinning technique from the University of Waterloo, Canada [5] in the oncoming 2010 ESA meeting in June at UNC. Overall, we have an impressive 45 abstracts accepted for this meeting, including four invited talks, two of which are from abroad (Germany and New Zealand). I look forward to hearing all these authors present their exciting research, as well as seeing other friends and family attending our ESA annual meeting. Also, please send me the nominations for the ESA awards (rsundara@purdue.edu). I am sure there are many well-qualified people in our society whom we would like to recognize.

As usual, I look forward to hearing from you.

Thank you very much and have a very productive and pleasant time.

Yours for the friendly Society,

Raji Sundararajan,
ESA President

References:

- [1] Seema Agarwal, Joachim Wendorff, and Andreas Greiner, Use of electrospinning technique for biomedical applications, *Polymer* 49:5603-5621, 2008.
- [2] G. Buschle-Diller, A. Hawkins, and J. Cooper, Electrospun nanofibers from biopolymers and their biomedical applications, in *Modified Fibers with medical and special applications*, eds. J.V. Edwards et. al., Springer, 2006.
- [3] Nanotechnology in Agriculture and Food, Nanoforum Report, <http://www.nanoforum.org>, European Nanotechnology gateway, May 2006
- [4] C. Kriegel, A. Arrechi, K. Kit, D.J. McElements, and J. Weiss, Fabrication, functionalization, and application of electrospun biopolymer nanofibers, *Critical Reviews in Food Science and Nutrition*, 48:775-797, 2008.
- [5] <http://www.power.uwaterloo.ca/HVEL/Research/Electrospinning.htm>

ESA Annual Meeting at UNC

The ESA Annual Meeting in Charlotte on June 22-24 is approaching quickly. Please remember to make your hotel reservations by May 22nd - after that date the Holiday Inn hotel, where the conference will be held, does not guarantee neither the price ((\$95/night) nor availability of the rooms. May 22 is also the deadline for early registration (\$275) - after that day the registration fee is \$300 for the ESA members. For further details please visit the conference website <http://www.electrostatics.org/conferences.html>. Good news for student authors/co-authors presenting papers: your conference fee is waived!

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Calendar

- ✦ ESA-2010, June 22-24, 2010, Univ. of North Carolina, Charlotte, NC Contact: Maciej Noras, Tel: 704-687-3735, mnoras@uncc.edu, website: <http://www.electrostatics.org>
- ✦ SFE 2010, Aug 30 - Sept 1, 2010, Montpellier, France, Contact: SFE2010 Organizing Committee, Tel: +33 4 67 14 34 85, sfe2010@univ-montp2.fr, website: <http://www.electrostatics.org>
- ✦ IEEE-IAS 2010 Annual Meeting, Electrostatic Processes Committee, Oct. 3-7, 2010, Houston, Texas, website: <http://www.ewh.ieee.org/soc/ias/2010/home.htm>
- ✦ IEEE-DEIS CEIDP 2010, Oct. 17-20, 2010, Purdue University, West Lafayette, Indiana, Contact: Rajeswari Sundararajan, Tel: +1 765 494 6912, rsundara@purdue.edu, website: <http://ewh.ieee.org/soc/dei/ceidp/ceidp2010.htm>
- ✦ Electrostatics 2011, 13th Int'l. Conf. on Electrostatics, April 10-14, 2011, Bangor University, Wales, UK, Contact: Dawn Stewart, Tel: +44 (0)20 7470 4800, dawn.stewart@iop.org, website: <http://www.electrostatics2011.org>

Current Events

Helicopters, Dust, Sparkling Display

(Thanks to Bob Benedetti for this topic)



The pictures shown here, and many more, were taken by Michael Yon in Afghanistan. The visual display appears to be electrostatically created by the combination of high speed rotors and a dry, dusty environment. Unfortunately, there is a very serious side to this story as well, involving military action and the loss of lives. For a moving account, along with more background and pictures, visit Michael Yon's website:

<http://www.michaelyon-online.com/the-kopp-etchells-effect.htm>



Penn team uses self-assembly to make molecule-sized particles with patches of charge

Physicists, chemists and engineers at the University of Pennsylvania have demonstrated a novel method for the controlled formation of patchy particles, using charged, self-assembling molecules that may one day serve as drug-delivery vehicles to combat disease and perhaps be used in small batteries that store and release charge.

Researchers demonstrated that the positive electrical charges of calcium ions — just like the calcium in teeth and bone — can form bridges between negatively charged polymers that would normally repel each other. The polymers, similar to the lipids that make the membranes surrounding living cells, have both a water-loving part linked to a water-repelling part. On the surfaces of these cell-sized polymer sacks, the calcium ions create calcium-rich islands or patches on top of negatively-charged polymer. Copper ions also work, and the patches can be made to coalesce and cover half of the particle. This polarized structure is the basic arrangement needed to set up, for example, the two electrodes of a microscopic battery. They could also one day be functionalized into docking sites to enhance targeted delivery of drug-laden particles to cells.

While the concept seems simple, that opposite charges attract, the creation and control of patches on one small particle has been a challenge. Scientists like Dennis E. Discher, principal investigator of the study and a professor of chemical and biomolecular engineering at Penn, are designing materials at the nanoscale because future technologies will increasingly rely on structures with distinct and controlled surfaces. Physicians, for example, will improve medical therapies by wrapping drugs within the bioengineered polymer sacks, or by creating tiny biomedical sensors. Green energy production and storage will also require structures with scales no longer measured by inches, but by micrometers and nanometers.

The collaboration involved faculty from Penn's School of Engineering and Applied Science, the School of Medicine and the School of Arts and Sciences, and demonstrated, more specifically, the selective binding of multivalent cationic ligands within a mixture of both polyanionic and non-ionic amphiphiles that all co-assemble into either patchy sacks called vesicles or molecular cylinders called worm-like micelles. Similar principles have been explored with lipids in the field of membrane biophysics because calcium is key to many cellular signaling processes. The trick is that the energy of attraction of opposite charges must be adjusted to find a balance with the large entropic price for localization into spots. If the attractions are too

Current Events (cont'd.)

large, the ions precipitate, just like adding too much sugar to tea or coffee.

Using a little bit of acid or a little of base, the patchy polymer vesicles and cylinders can be made with tunable sizes, shapes and spacings. Assemblies with single large patches are called Janus assemblies, named after the double-faced Roman god, and the assemblies generally last for years because these are polymer-based structures. "The key advance we present in this study is the restricted range of conditions that are required for self assembly in these solutions," Discher said. "We show that, in addition to polymers, negatively-charged cell lipids which are involved in all sorts of cell-signaling processes like cell motion and cancer mechanics, can also make domains or islands with calcium."

The work is representative of national research into soft matter, materials constructed from organic molecules like lipids, peptides and nucleic acids. A properly designed molecular system can produce a wide array of nanostructures and microstructures, emulating and extending what is found in nature.

http://www.eurekalert.org/pub_releases/2009-10/uop-ptu102009.php

Battery made of paper charges up

The approach relies on the use of carbon nanotubes - tiny cylinders of carbon - to collect electric charge. While small-scale nanotube batteries have been demonstrated before, the plain paper approach lends itself to making larger devices more cheaply. The work, published in Proceedings of the National Academy of Sciences, could lead to "paintable" energy storage. Because of its structure of millions of tiny, interconnected fibres, paper is a good candidate to hold on to carbon nanotubes, providing a scaffold on which to build devices. However, paper is also mechanically tough, and can be bent, curled or folded, more than the metal or plastic surfaces that are currently used or under development.

A team of researchers at Stanford University started with off-the-shelf copier paper, painting it with an "ink" made of carbon nanotubes. The coated paper is then dipped in lithium-containing solutions and an electrolyte to provide the chemical reaction that generates a battery's electric current. The paper acts to collect the electric charge from the reaction. Using paper in this way could reduce the weight of batteries, typically made with metal current collectors, by 20%.

The team's batteries are also capable of releasing their stored energy quickly. That is a valuable characteristic for applications that need quick bursts of energy, such as

electric vehicles - although the team has no immediate plans to develop vehicle batteries.

Liangbing Hu, lead author on the research, said the most important aspect of the demonstration was that paper is an inexpensive and well-understood material - making wider usage of the technology more likely. "Standard copier paper used in our everyday life can be a solution in storing energy in a more efficient and cheap way," Dr. Hu told BBC News. "The experienced technology developed in the paper industry over a century can be transferred to improve the process and performance of these paper-based devices."

The team says that adaptations to the technique in the future could allow for simply painting the nanotube ink and active materials onto surfaces such as walls. They have even experimented with a number of textiles, paving the way for batteries made largely of cloth.

<http://news.bbc.co.uk/2/hi/technology/8401566.stm>

Electric field propels worms to test new drugs

A Nobel-winning process for testing new drugs to treat diseases such as Huntington's, Parkinson's, and muscular dystrophy is getting an electrical charge. Researchers at McMaster University have developed a way to propel and direct microscopic-sized worms (*C. elegans* nematodes) along a narrow channel using a mild electric field. The discovery opens up significant possibilities for developing high-throughput micro-screening devices for drug discovery and other applications.

"This is the first time that worms have been stimulated to move in a micro-channel device in a very precise and directed way," said Bhagwati Gupta, assistant professor of biology. "It will allow researchers to study in real time how a proposed drug affects neurons and muscles that control motion of a live specimen."

The research is described in the January 21, 2010 issue of Lab on a Chip, a leading international journal in the field of nanotechnology and bioengineering. The researchers demonstrate movement of the worms forward and in reverse inside a microchannel, guided by the direction of the electric field (electrotaxis).

"The electrotaxis of the worms has the potential to automate what is currently a slow, manual process for drug screening on worms," said Ravi Selvaganapathy, assistant professor of mechanical engineering. "The system is fairly easy and inexpensive to scale up to conduct rapid screening of tens of thousands of chemicals in worms to identify drug candidates in a cost-effective manner. Such discovery could accelerate clinical trials in people by allowing scien-

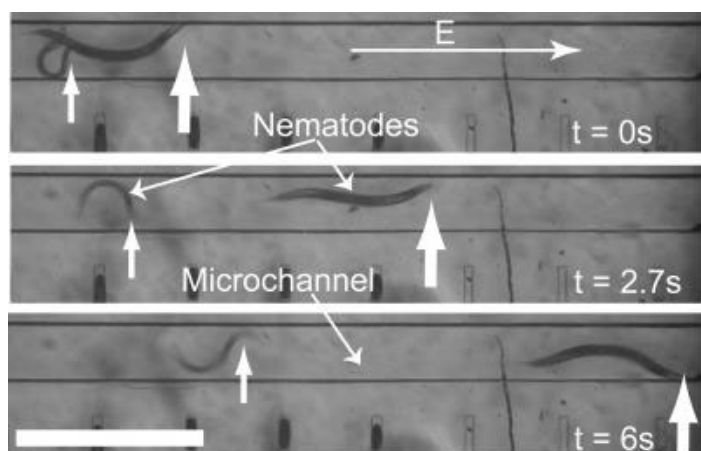
Current Events (cont'd.)

tists to focus only on relevant drugs and would use limited resources more efficiently."

Currently, researchers observe worms individually under a microscope as they move in a random manner or in a direction forced by pressure. The new development retains a worm's natural motion and causes no harm to the worm. A surprising observation was that the response of the worms was dependent on its age and neuronal development. This allows for large numbers of worms to be sorted and handled in an automated manner. The findings promise to impact other research areas as well. It will allow researchers to study how neurons respond to electricity. It can also be used to fabricate new kinds of devices to handle and manipulate large numbers of worms.

The use of *C. elegans* as a genetic model organism was first undertaken by Sydney Brenner in 1974. He was presented with the Nobel Prize in Physiology or Medicine in 2002 for his work in this area. Researchers working with *C. elegans* were also awarded Nobel prizes in 2006 and 2008. *C. elegans* is a proven animal model for the study of human diseases because it utilizes many of the same proteins and molecules as humans. It also has a generation time of approximately only four days and a lifespan of about two to three weeks. This accelerates the understanding of the function of disease-related proteins.

<http://www.rdmag.com/News/2010/01/Life-Science-Electric-field-propels-worms-to-test-new-drugs/>



Palm-sized adhesive device could let humans walk on walls

Could humans one day walk on walls, like Spider-Man? A palm-sized device invented at Cornell that uses water surface tension as an adhesive bond just might make it possible. The rapid adhesion mechanism could lead to such applications as shoes or gloves that stick and unstick to walls, or Post-it-like notes that can bear loads, accord-

ing to Paul Steen, professor of chemical and biomolecular engineering, who invented the device with Michael Vogel, a former postdoctoral associate.

The device is the result of inspiration drawn from a beetle native to Florida, which can adhere to a leaf with a force 100 times its own weight, yet also instantly unstick itself. Research behind the device is published online Feb. 1 in Proceedings of the National Academy of Sciences. The device consists of a flat plate patterned with holes, each on the order of microns (one-millionth of a meter). A bottom plate holds a liquid reservoir, and in the middle is another porous layer. An electric field applied by a common 9-volt battery pumps water through the device and causes droplets to squeeze through the top layer. The surface tension of the exposed droplets makes the device grip another surface – much the way two wet glass slides stick together. "In our everyday experience, these forces are relatively weak," Steen said. "But if you make a lot of them and can control them, like the beetle does, you can get strong adhesion forces."

For example, one of the researchers' prototypes was made with about 1,000 300-micron-sized holes, and it can hold about 30 grams – more than 70 paper clips. They found that as they scaled down the holes and packed more of them onto the device, the adhesion got stronger. They estimate, then, that a one-square-inch device with millions of 1-micron-sized holes could hold more than 15 pounds. To turn the adhesion off, the electric field is simply reversed, and the water is pulled back through the pores, breaking the tiny "bridges" created between the device and the other surface by the individual droplets. The research builds on previously published work that demonstrated the efficacy of what's called electro-osmotic pumping between surface tension-held interfaces, first by using just two larger water droplets.

One of the biggest challenges in making these devices work, Steen said, was keeping the droplets from coalescing, as water droplets tend to do when they get close together. To solve this, they designed their pump to resist water flow while it's turned off.

Steen envisions future prototypes on a grander scale, once the pump mechanism is perfected, and the adhesive bond can be made even stronger. He also imagines covering the droplets with thin membranes – thin enough to be controlled by the pump but thick enough to eliminate wetting. The encapsulated liquid could exert simultaneous forces, like tiny punches. "You can think about making a credit card-sized device that you can put in a rock fissure or a door, and break it open with very little voltage," Steen said. "It's a fun thing to think about."

Current Events (cont'd.)

<http://www.rdmag.com/News/2010/02/Materials-Science-Palm-sized-adhesive-device-could-let-humans-walk-on-walls/>

Applied electric field can improve hydrogen storage properties

An international team of researchers has identified a new theoretical approach that may one day make the synthesis of hydrogen fuel storage materials less complicated and improve the thermodynamics and reversibility of the system. Many researchers have their sights set on hydrogen as an alternative energy source to fossil fuels such as oil, natural gas and coal that contain carbon, pollute the environment and contribute to global warming. Known to be the most abundant element in the universe, hydrogen is considered an ideal energy carrier—not to mention that it's clean, environmentally friendly and non-toxic. However, it has been difficult to find materials that can efficiently and safely store and release it with fast kinetics under ambient temperature and pressure.

The team of researchers from Virginia Commonwealth Univ.; Peking Univ. in Beijing; and the Chinese Academy of Science in Shanghai; have developed a process using an electric field that can significantly improve how hydrogen fuel is stored and released. "Although tremendous efforts have been devoted to experimental and theoretical research in the past years, the biggest challenge is that all the existing methods do not meet the Department of Energy targets for hydrogen storage materials. The breakthrough can only be achieved by exploring new mechanisms and new principles for materials design," said Qiang Sun, Ph.D., research associate professor with the VCU team, who led the study. "We have made such an attempt, and we have proposed a new principle for the design of hydrogen storage materials which involves materials with low-coordinated, non-metal anions that are highly polarizable in an applied electric field," he said.

"Using an external electric field as another variable in our search for such a material will bring a hydrogen economy closer to reality. This is a paradigm shift in the approach to store hydrogen. Thus far, the efforts have been on how to modify the composition of the storage material. Here we show that an applied electric field can do the same thing as doped metal ions," said Puru Jena, Ph.D., distinguished professor in the VCU Department of Physics.

"More importantly, it avoids many problems associated with doping metal ions such as clustering of metal atoms, poisoning of metal ions by other gases, and a complicated synthesis process. In addition, once the electric field is removed, hydrogen desorbs, making the process reversible with fast kinetics under ambient conditions," he said.

The team found that an external electric field can be used to store hydrogen just as an internal field can store hydrogen due to charge polarization caused by a metal ion. "This work will help researchers create an entirely new way to store hydrogen and find materials that are most suitable. The challenge now is to find materials that are easily polarizable under an applied electric field. This will reduce the strength of the electric field needed for efficient hydrogen storage," said Jena.

(excerpted from <http://www.rdmag.com/News/2010/02/Energy-Applied-Electric-Field-Can-Improve-Hydrogen-Storage-Properties/?wnnvz=1737,01289654737>)

A charge for freezing water at different temperatures

Lisa Grossman, Science News

A watched pot never boils, but an electrically charged pot sometimes freezes. A study in the Feb. 5 *Science* reports that water can freeze at different temperatures depending on whether the surface it rests on is positively or negatively charged. Under certain conditions, water can even freeze as it heats up. "We are very surprised by this result," says study coauthor Igor Lubomirsky of the Weizmann Institute of Science in Rehovot, Israel. "It means that by controlling surface charge, either positive or negative, you can either suppress ice formation or enhance ice formation."

Water usually begins freezing by forming an ice crystal around a particle of dust or some other impurity. Without that starting point, water can stay liquid well below its freezing point, down to about -42° Celsius. This supercooled water is useful in nature and in the lab, from frogs and fish surviving long winters to cryogenic preservation of blood and tissues.

Scientists have suspected for decades that electric fields could be used to trigger freezing in supercooled water. A molecule of water has a slight positive charge on one end and a negative charge on the other, so electric fields could snap water molecules into a rigid formation by aligning them according to charge. But previous experiments to understand whether electric fields can influence freezing were complicated by the materials used. The best materials for holding electric charge are metals, but as anyone who has tried to open a car door after a snowstorm knows, ice forms easily on metals even without a charge.

"If you try to do it with metal, you don't know what is from the electric field and what is from the metal itself," Lubomirsky says. "We wanted to know whether it is the charge that does it, or something special in metal." Instead of metal, Lubomirsky and his colleagues used a

Current Events (cont'd.)

pyroelectric material, which can form a short-lived electric field when heated or cooled. The researchers used four pyroelectric crystals, each of which was placed inside a copper cylinder. The bottom surfaces of two crystals were coated with chromium to conduct an electric charge, and the other two were coated with an aluminum oxide to keep the surface uncharged.

The researchers placed the experimental setup in a humid room and turned down the thermostat until water droplets formed on each crystal, then cooled the room further until the water froze. With no charge on the surface, the water froze at -12.5°C , on average. But on the positively charged surface, water froze at a relatively balmy -7° . And on a negatively charged surface, ice formed, on average, at a chilly -18° . "It's really dramatic, the strong effect of the charge," says physicist Gene Stanley of Boston University. He also says that the simplicity of the experiment means that "it's the kind of thing that is almost surely correct."

Lubomirsky and colleagues also managed to freeze water by heating it. Water droplets stayed liquid at -11° for up to 10 minutes on a negatively charged surface. But after the negative charge dissipated, heating the room to -8° was enough to induce a positive charge in the pyroelectric crystal and freeze the water. "That's a very intriguing behavior," comments atmospheric physicist Will Cantrell of Michigan Technological University in Houghton. "In this case, on this particular substance, if you warm it up, you can get it to freeze."

Coauthor Meir Lahav, also of the Weizmann Institute, says water's response to charge probably depends on how the water molecules line up against the surface they're freezing to, though more work is needed to figure out exactly what is happening. "The water molecules should be aligned differently, so I anticipated that this difference should affect the freezing temperature of ice," Lahav says. "But I didn't expect such a large difference. I'm very much delighted to see that."

Although he has no specific plans to harness the effect for applications such as cryogenic freezing or cloud seeding, Lahav says his team has already filed a patent. Ice nucleation, "is a very fundamental problem," he says. "The moment you understand better — have a new understanding of a new effect — the applications always come afterwards."

http://www.sciencenews.org/view/genericid/56134/title/A_charge_for_freezing_water_at_different_temperatures

New fiber nanogenerators could lead to electric clothing

Sarah Yang, *UC Berkeley News*

In research that gives literal meaning to the term "power suit," University of California, Berkeley, engineers have created energy-scavenging nanofibers that could one day be woven into clothing and textiles. These nano-sized generators have "piezoelectric" properties that allow them to convert into electricity the energy created through mechanical stress, stretches and twists.

"This technology could eventually lead to wearable 'smart clothes' that can power hand-held electronics through ordinary body movements," said Liwei Lin, UC Berkeley professor of mechanical engineering and head of the international research team that developed the fiber nanogenerators. Because the nanofibers are made from organic polyvinylidene fluoride, or PVDF, they are flexible and relatively easy and cheap to manufacture.

Although they are still working out the exact calculations, the researchers noted that more vigorous movements, such as the kind one would create while dancing the electric boogaloo, should theoretically generate more power. "And because the nanofibers are so small, we could weave them right into clothes with no perceptible change in comfort for the user," said Lin, who is also co-director of the Berkeley Sensor and Actuator Center at UC Berkeley. The fiber nanogenerators are described in this month's issue of *Nano Letters*, a peer-reviewed journal published by the American Chemical Society.

The goal of harvesting energy from mechanical movements through wearable nanogenerators is not new. Other research teams have previously made nanogenerators out of inorganic semiconducting materials, such as zinc oxide or barium titanate. "Inorganic nanogenerators — in contrast to the organic nanogenerators we created — are more brittle and harder to grow in significant quantities," Lin said.

The tiny nanogenerators have diameters as small as 500 nanometers, or about 100 times thinner than a human hair and one-tenth the width of common cloth fibers. The researchers repeatedly tugged and tweaked the nanofibers, generating electrical outputs ranging from 5 to 30 millivolts and 0.5 to 3 nanoamps. Furthermore, the researchers report no noticeable degradation after stretching and releasing the nanofibers for 100 minutes at a frequency of 0.5 hertz (cycles per second).

Lin's team at UC Berkeley pioneered the near-field electrospinning technique used to create and position the polymeric nanogenerators 50 micrometers apart in a grid pattern. The technology enables greater control of the

Current Events (cont'd.)

placement of the nanofibers onto a surface, allowing researchers to properly align the fiber nanogenerators so that positive and negative poles are on opposite ends, similar to the poles on a battery. Without this control, the researchers explained, the negative and positive poles might cancel each other out and reducing energy efficiency. The researchers demonstrated energy conversion efficiencies as high as 21.8 percent, with an average of 12.5 percent.

"Surprisingly, the energy efficiency ratings of the nanofibers are much greater than the 0.5 to 4 percent achieved in typical power generators made from experimental piezoelectric PVDF thin films, and the 6.8 percent in nanogenerators made from zinc oxide fine wires," said the study's lead author, Chieh Chang, who conducted the experiments while he was a graduate student in mechanical engineering at UC Berkeley.

"We think the efficiency likely could be raised further," Lin said. "For our preliminary results, we see a trend that the smaller the fiber we have, the better the energy efficiency. We don't know what the limit is."

Other co-authors of the study are Yiin-Kuen Fuh, a UC Berkeley graduate student in mechanical engineering; Van H. Tran, a graduate student at the Technische Universität München (Technical University of Munich) in Germany; and Junbo Wang, a researcher at the Institute of Electronics at the Chinese Academy of Sciences in Beijing, China.

http://www.berkeley.edu/news/media/releases/2010/02/12_electric_nanofibers.shtml

Spherical cows help to dump metabolism law

(editor's note: though not related to electrostatics, cow geometry played an important role in a memorable banquet talk given by Glenn Schmieg at Boston University in 1999).

Apparently, the mysterious "3/4 law of metabolism"—proposed by Max Kleiber in 1932, printed in biology textbooks for decades, explained theoretically in *Science* in 1997 and described in a 2000 essay in *Nature* as "extended to all life forms" from bacteria to whales—is just plain wrong. "Actually, it's two-thirds," says University of Vermont mathematician Peter Dodds. His paper in the January 29 edition of *Physical Review Letters* helps overturn almost eighty years of near-mystical belief in a 3/4 exponent used to describe the relationship between the size of animals and their resting metabolism.

To understand the debate between 2/3 and 3/4, assume a spherical cow. "That's what a physicist would do," Dodds says, laughing. Basic geometry shows that the surface area

of this difficult-to-milk creature would increase as the square of its radius while the volume would increase as the cube of the radius. In other words, the exponent that describes the ratio of surface area to volume is 2/3.

Next, assume a spherical mouse. OK, now compare the resting metabolic rates of these sorry animals. Since the point of resting metabolism is to keep a warm-blooded animal warm (and alive!) with the lowest necessary energy use, both geometry and common sense suggest that the cow would have a lower rate of metabolism per cell than the mouse: the mouse, with more surface area relative to its volume, would lose heat faster than our cartoon cow.

And what about in real animals? In 1883, a German physiologist named Max Rubner measured the heat output of some dogs ranging from a few pounds to nearly seventy. He plotted these numbers to show that the dog's metabolic rates were proportional to their mass with an exponent of 2/3—just like the geometry of an imaginary spherical beast would suggest. But, in 1932, Swiss agricultural chemist Max Kleiber presented a paper with a now-famous graph. It plotted, on a logarithmic scale, the body weight of 13 mammals, ranging from rats to cows, against their resting metabolism. Strangely, the line traced through the data points did not conform to Rubner's observation nor common sense. Instead, it hewed to a line with a somewhat steeper slope of about .73. To make it easier for slide rule use, he rounded the exponent to a neat .75. Kleiber's 3/4-power law was born. "Kleiber's original data is a mess, a complete mess," says Dodds, "but it became something everyone believed in. The idea of quarter-powers begins to take on this spooky, magical quality. Nobody can explain it, but it's a secret law of the universe. It's quarterology!"

Over the next decades, hundreds of animals' resting metabolisms were measured or estimated, from microbes to whales. The results in various groups of animals ranged from slopes of less than 2/3 to greater than 1. But as Vaclav Smil wrote in a sweeping "millennium essay" for *Nature* they were "close enough to the 0.75 line," and concluded that "the 3/4 slope is representative for all" animals. "Some data seems to fit this 3/4 line—if you're looking for it!" says Dodds. "It was pre-supposed to be true—and became a universal overarching law that somebody needs to explain."

Instead of explaining it, in the 1960s a Scottish conference on energy metabolism simply voted, 29-0, to enshrine 3/4 as the official exponent. Then, in 1997, an elegant, though controversial, paper by Geoffrey West and colleagues was published in *Science* that claimed to derive 3/4 from first

Current Events (cont'd.)

principles, drawing on ideas about fractals in networks and the growing length of tubes.

"The problem is their paper fell to pieces mathematically. It just didn't work. Unfortunately, I showed that and published a paper with my advisor and a fellow student in 2001," Dodds says. They also reanalyzed data from Kleiber and six other scientists and concluded that there is little empirical evidence for rejecting $2/3$ in favor of $3/4$. "But we didn't have a better theory," Dodds says, "or some way to clean it all up."

Until now. Dodds's new paper explores the geometry of branching networks -- like blood supply -- to show how a material, like blood, can be most efficiently delivered. "If you're going to build organisms with a central source, like a heart, that places physical constraints that evolution has to run up against," he says. "These constraints won't let the ratio be too far away from $2/3$." "My new paper follows the argument that was put forth in 1997 -- that, somehow, networks give rise to the $3/4$ law. They were right that supply networks are key to understanding the metabolic limitations of animals. Except my paper shows that networks give rise to the $2/3$ law, actually," Dodds says, "If you do the math properly."

"What's good here is that the network supplying to the inside of this system matches with the $2/3$ exponent you'd expect from surface area," he says. And recent statistical analyses continue to show that the $2/3$ exponent fits well empirically with large data sets for both mammals and birds. It seems that Rubner got it right in the 1880's after all.

Of course, it may be that biologists—who delight in detail, local mechanisms and exceptions—will win out over statistical physicists—who look for evidence of universal patterns in nature: there may be no single exponent to describe the scaling of metabolism. A line drawn through a confounding scatter of data about specific animals across orders of magnitude may be just a line, not a law. But a confluence of facts—greater understanding about how a network best minimizes volume, as evolution would favor in the costly production of blood supply; surface area geometry; and re-analysis of Kleiber's and other data—seem to be pummeling the once-beguiling $3/4$ law into dust. "Especially for smaller guys," Dodds says, "like birds, it's just absolutely, stone-cold $2/3$."

<http://www.rdmag.com/News/2010/02/General-Science-Spherical-cows-help-to-dump-metabolism-law/?wnvz=1737.01289654737>

Sources and Sinks

From Prof. Stuart Hoenig, Ariz. State Univ.

I looked at the Sept./Oct Newsletter again and noticed the article by John Johnson on a "physicist solving a lunar mystery". I think the members should know THAT ALL DUST PARTICLES ARE CHARGED. The sign of the charge is shown in the attached fig. 1, the charge can be used as part of the general problem of dust control. You use water for that is charged oppositely to the dust, fog is drawn to the dust and down it comes, fig. 2. If you put 1% of oil in the dust the fog never comes up again.

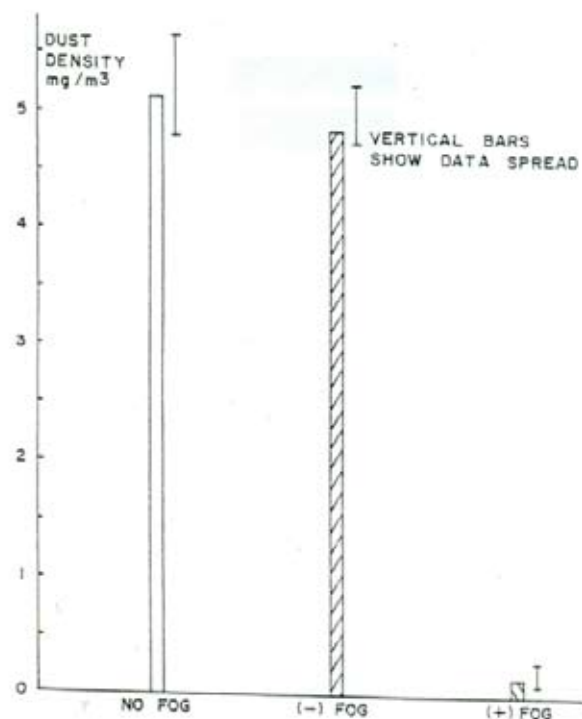
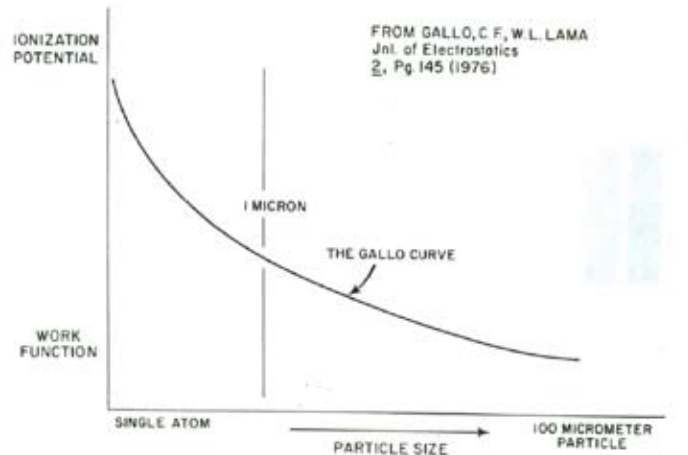


Figure 36. Coking coal (Pittsburgh Seam 8-OHio), dust density with and without fogging. Laboratory test data with GCA Corporation RDM-101 Beta Ray dust monitor; respirable fraction only. Fog water flow 30 ml/min.; air flow 100 SCFH.

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