May/Jun 2017 • No. 241

# ESA Newsletter

Electrostatics Society of America - The Friendly Society

## President's Message

It is always nice to write about achievements and to review good memories of our annual meetings. This year the ESA annual meeting was held on the University of Ottawa campus, beautifully located in the city center of Ottawa. The efforts from both the technical program chair, Shubho Banerjee, and the conference general chair, Poupak Mehrani, are greatly appreciated. Thank you Poupak and Shubho for your excellent work. Thanks are due to all the support the university has rendered in order for the attendees from around the world to participate and enjoy in technical and non-technical activities. Thanks to all the authors, presenters, session chairs, judges and the audience for creating a rich scientific forum with a truly diverse international representation. Students participated in both oral and poster presentations and made the sessions very attractive and lively; keep up your enthusiasm and interest in electrostatics! As always, both Mystic Tan Inc., and Trek Inc. sponsorships were much appreciated and used towards the student paper awards.

Keynote talks on applied aspects of electrostatics covered car manufacturing, pharmaceutical aerosol production, integrated circuit protection and planetary atmosphere exploration. Thanks to all the keynote speakers for enriching the forum. It was an honor to present the ESA Lifetime Achievement Award to Wamadeva (Bala) Balachandran from Brunel University, UK for his outstanding contributions to the field of Electrostatics and the ESA Honorary Life Member Award to Shethar (Duke) Davis from the USA for his outstanding contributions to the field of Electrostatics, especially in the area of education. Bala and Duke, congratulations to both of you.

You may be looking forward to seeing the photos from this year's meeting. Fahad Chowdhury (Ph.D. student from U Ottawa) and Al Seaver have done a great job in capturing the moments and compiling the photos. Use the link *http://electrostatics.us/esa/2017/page_01.htm* to get a glimpse of what went on at the 2017 meeting. Of course, this note would be incomplete without writing about the banquet as both the banquet food and fun-filled presentation by Mark Horenstein were amazing. Thank you Poupak and Mark.

Looking ahead to next year, we will be having a Joint Conference, sponsored by ESA, IEEE IAS-EPC, FES and IESJ, held on the Boston University campus in Boston, USA. Mark and Shubho have accepted the responsibility to host the meeting. Thank you both. Also, tentatively, the venues for 2019 and 2020 have been selected as Rochester, New York, USA and Prince Edward Island (popularly known as PEI) on the east coast of Canada, respectively. Kelly Robinson and Kaz Adamiak would lead the organizations of these meetings.

Life has both sweet and bitter memories. We want to share about Charles Gallo, a longtime ESA member who passed away on June 23rd, 2017. The legacy that Chuck has left behind for us, whether it is about application or fundamental aspects of physics is a great treasure. Please see his obituary in this newsletter.

Endless efforts of Steve Cooper and Mark Zaretsky, and the council's support along with support from many ESA members are all much appreciated. Enjoy your summer.

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

# ESA Officers

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**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.

# Calendar

- 2017 IEEE/IAS Annual Meeting, Sept 29- Oct. 5, 2017, Cincinnati, Ohio *http://ias.ieee.org/2017annualmeeting.html* Contact: Maciej Noras *mnoras@uncc.edu*
- 2017 CEIDP, Oct. 22-25, 2017, Fort Worth, Texas Contact: Enis Tuncer *e-tuncer@ti.com*
- 2018 Electrostatics Joint Conference June 18-20, 2018, Boston University, Boston, MA, Contact: Mark Horenstein *mnh@bu.edu*

# Obituary - Charles “Chuck” Gallo

We note with sadness – and yet with fond recollections – the passing of longtime ESA member Charles F. Gallo, Jr. on June 23, 2017. Referred to as Chuck by his many friends, he received the ESA Lifetime Achievement Award in 2008 for his many contributions to the understanding of corona and corona generation behavior. Chuck was born on July 22, 1935 in Mount Vernon, NY and received his BS in physics from Rensselaer Polytechnic Institute (RPI) in 1957. While at RPI he was in a cooperative program between RPI and the General Electric Company where he was engaged in new material process deposition techniques. After graduation he joined Westinghouse Research Laboratories where he worked on theoretical and experimental studies related to the transport properties of solids with a goal of developing a practical thermoelectric generator. In 1964 he joined Xerox Research Labs where for the next 17 years he helped develop xerography by working on the many aspects of corona discharge and gas breakdown. His studies of the work function of metals and insulators, his studies of surface properties and charge exchange phenomena, and his studies of surface and transport properties of photoconductors, led eventually to many publications and patents (US and foreign). Much of his work is found throughout R. M. Schaffert’s classic book titled **Electrophotography**. During his stay at Xerox Chuck also interacted with Dr. John Bardeen on the quantum mechanical treatment of the work function of metals. From 1981 to 1988 Chuck worked for the 3M Company at their Corporate Research Labs. When IBM researchers discovered high temperature (HiTc) superconductors in 1986, Chuck again interacted with Bardeen, attempting to develop a theory applicable to HiTc superconductors; but the effort was terminated after Bardeen’s death in 1991. Following Bardeen’s suggestion, Chuck left 3M in 1988 and founded Superconix Inc., where he produced and sold HiTc superconductors (primarily single crystals, materials, wires and magnets) to the growing global HiTc superconductor research community that had developed. Over time, as others entered the market, he stopped producing and moved into buying and selling single crystals from around the world, although primarily from China.

While noted for his contributions to electrostatics and HiTc superconductors, Chuck also had a long history of contributions in astrophysics, especially active in applications of the red shift to analysis of astrophysical problems, including dark matter. Starting in 1967, and for the next 50 years, Chuck published his works and attended APS conferences, where he presented papers on a variety of subjects including developing the thermodynamic laws of neutrino and photo emission. Chuck was active in IEEE, APS and ESA and remained an active and dedicated scientist until the time of his death. Over his scientific career Chuck obtained 18 US Patents and published over 50 papers. An example of the potpourri of Chuck’s interests can be found in his paper (D2) at the ESA 2008 Annual Meeting (*http://www.electrostatics.org/images/ESA_2008_D2.pdf*) where he compared a classical treatment to a quantum mechanical treatment of the work function of metals. Chuck was a strong believer in Occam’s razor and always looked for the simplest explanation of physical phenomena. Rarely do you find a researcher involved in so many diverse fields of study as Chuck. Chuck Gallo was a polymath, and he will be missed.

*(contributed by Al Seaver)*

# New ESA Awards

The ESA is pleased to announce creation of two new awards:

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.

These awards were created in response to inquiries from some of the ESA members. The intent of the "Rising Star" recognition is to show appreciation to researchers and engineers who already carry on their work and fulfill their professional dreams, but are still at the early stages of their career. The ESA would like to acknowledge their accomplishments and show that the ESA cares about their achievements and supports them. It may even be helpful with sustaining their efforts by assuring them of the value of their work, perhaps even assisting in getting the next grant or that desired promotion.

Similarly, the "Entrepreneur" award is to put a spotlight on people who were able to take ideas to the commercial and industrial world and succeed. It is not an easy task and not a small accomplishment, and it deserves to be recognized. After all, they were able to show that electrostatics is not just equations in an abstract world, but something real and useful.

As in past years, a call for award nominations will be issued in the newsletter in the late winter and early spring issues. But you don't need to wait until then to submit a nomination. For reference, you may find a description of the other awards on our website (*http://electrostatics.org/esaawards1.html*).

ESA Vice-President and Awards Chair,

Maciej Noras, *mnoras@uncc.edu*

# Current Events

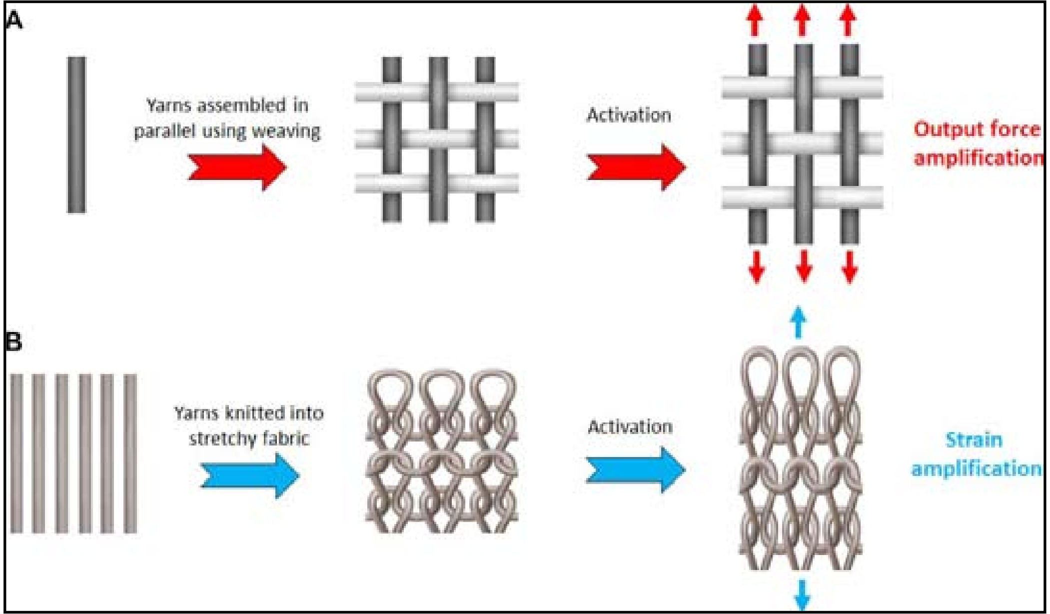
## Artificial muscles using textiles for assisted mobility and soft robotics

*Umair Hussaini*

Human muscles are an intertwined collection of muscle fibers. In a nutshell, when you want to lift something, your brain sends an electrical signal via the spinal cord to the muscle which needs to be activated, calcium is secreted, energy is obtained from ATP, and various layers of muscles get to work to cause the muscle to contract. Inspired by this process, a team of researchers at the Linköping University in Sweden have combined traditional textile processes and electrochemistry to create a material that works as an artificial muscle in response to subtle electrical signals.

The team refers to this material as a textuator (a combination of textile and actuator). Like conventional actuators, they convert electrical energy to force. An application of this technology is the ability to create clothes that would help injured or disabled people get some assistance to move or even regain mobility.

Currently, people undergoing physiotherapy after an accident to restore the functioning of their limbs; or seniors with impaired movement; or even regular people who lift a lot of weight during their jobs can use battery powered mechanical exoskeletons to move. These exoskeletons respond quickly and are very powerful. But a better option would be small, soft, smooth and easy to mass produce textile actuators that can be worn inside normal clothing and work in harmony with the natural movements of the muscle.



"Our dream is suits you can wear under your clothing—hidden exoskeletons to help the elderly, help those recovering from injury, maybe one day make disabled people walk again," said Edwin Jager, an associate professor of applied physics who led the research.

The team behind this study have created two types of actuators using different textile manufacturing processes. The woven version of the textile exerts more force whereas the knitted version is more flexible. They can combine these two and tweak them to obtain a proper balance of stretch and force.

To create these artificial muscles the team first fabricated cellulose yarn, which is renewable and biocompatible, into the two different forms stated above. The next step involved coating the fabrics with electroactive materials, using a process similar to the ones used in traditional textile fabrication. The primary electroactive material here, the one that would respond to the electrical stimuli, was a conductive polymer called polypyrrole (PPy).

Polypyrrole is an interesting material and has been widely for similar purposes because of the following main reason - it changes its size due to electrochemical reactions on the application of voltages. Expands when a negative voltage is applied. And contracts when a positive voltage is applied.

It does this due to the movement of ions and solvents through the polymer. This means that an electrolyte is required.

Let's recall the working of the human muscle, an electrical trigger, followed by a chemical reaction in the presence of an electrolyte. Biomimicry!

The team then tested the effect of the electroactive coatings on the structure of the 'artificial muscles' using scanning electron microscopy (SEM) and found that the structure maintained its physical form.

After the various stress and strain tests, they were successful in lifting a LEGO lever arm weighing 2 grams.

When can I get a sweater made up of artificial muscles for myself?

Not soon. Note that this is in no way a finished product. There are many variations of textile fabrication, add to that the types of material that can be used. As a result, the number of tests that can be done to establish different possible outcomes becomes exhaustive. And this permutation is without even approaching the possibility to trying variations in the electroactive polymers' section.

Polypyrrole (Ppy) has its limitations. It doesn't react quickly to an electrical signal. It can take several seconds to expand or contract. Also, this experiment was carried out in a liquid electrolyte to activate the Ppy.

The team is currently working on ways to embed the electrolyte in a way that would make it feasible to work in the air. They are also working on reducing the diameter of the yarn to increase response times. The team also plans to use metallic embeds to improve conductivity and feedback loops to self-start the actuators.

(excerpted from *http://www.technobyte.org/interesting-facts/artificial-muscles-using-textiles/*)

### 'Persistent Photoconductivity' Offers New Tool for Bioelectronics

Researchers at North Carolina State University have developed a new approach for manipulating the behavior of cells on semiconductor materials, using light to alter the conductivity of the material itself.

"There's a great deal of interest in being able to control cell behavior in relation to semiconductors – that's the underlying idea behind bioelectronics," says Albena Ivanisevic, a professor of materials science and engineering at NC State and corresponding author of a paper on the work. "Our work here effectively adds another tool to the toolbox for the development of new bioelectronic devices."

The new approach makes use of a phenomenon called persistent photoconductivity. Materials that exhibit persistent photoconductivity become much more conductive when you shine a light on them. When the light is removed, it takes the material a long time to return to its original conductivity.

When conductivity is elevated, the charge at the surface of the material increases. And that increased surface charge can be used to direct cells to adhere to the surface. "This is only one way to control the adhesion of cells to the surface of a material," Ivanisevic says. "But it can be used in conjunction with others, such as engineering the roughness of the material's surface or chemically modifying the material."

For this study, the researchers demonstrated that all three characteristics can be used together, working with a gallium nitride substrate and PC12 cells – a line of model cells used widely in bioelectronics testing. The researchers tested two groups of gallium nitride substrates that were identical, except that one group was exposed to UV light – triggering its persistent photoconductivity properties – while the second group was not.

"There was a clear, quantitative difference between the two groups – more cells adhered to the materials that had been exposed to light," Ivanisevic says. "This is a proof-of-concept paper," Ivanisevic says. "We now need to explore how to engineer the topography and thickness of the semiconductor material in order to influence the persistent photoconductivity and roughness of the material. Ultimately, we want to provide better control of cell adhesion and behavior."

(excerpted from *https://news.ncsu.edu/2017/05/persistent-photoconductivity-bioelectronics-2017/*)

## How Scientists Turned a Flag into a Loudspeaker

A paper-thin, flexible device created at Michigan State University not only can generate energy from human motion, it can act as a loudspeaker and microphone as well, nanotechnology researchers report today in Nature Communications. The audio breakthrough could eventually lead to such consumer products as a foldable loudspeaker, a voice-activated security patch for computers and even a talking newspaper.

"Every technology starts with a breakthrough and this is a breakthrough for this particular technology," said Nelson Sepulveda, MSU associate professor of electrical and computer engineering and primary investigator of the federally funded project. "This is the first transducer that is ultrathin, flexible, scalable and bidirectional, meaning it can convert mechanical energy to electrical energy and electrical energy to mechanical energy."

In late 2016, Sepulveda and his team successfully demonstrated their sheet-like device – known as a ferroelectret nanogenerator, or FENG – by using it to power a keyboard, LED lights and an LCD touchscreen. That process worked with a finger swipe or a light pressing motion to activate the devices – converting mechanical energy to electrical energy.

The current breakthrough extends the FENG's usability. The researchers discovered the high-tech material can act as a microphone (by capturing the vibrations from sound, or mechanical energy, and converting it to electrical energy) as well as a loudspeaker (by operating the opposite way: converting electrical energy to mechanical energy).

To demonstrate the microphone effect, the researchers developed a FENG security patch that uses voice recognition to access a computer. The patch was successful in protecting an individual's computer from outside users. "The device is so sensitive to the vibrations that it catches the frequency components of your voice," Sepulveda said.

To demonstrate the loudspeaker effect, the FENG fabric was embedded into an MSU Spartan flag. Music was piped from an iPad through an amplifier and into the flag, which then reproduced the sound flawlessly. "The flag itself became the loudspeaker," Sepulveda said. "So we could use it in the future by taking traditional speakers, which are big, bulky and use a lot of power, and replacing them with this very flexible, thin, small device."

The innovative process of creating the FENG starts with a silicone wafer, which is then fabricated with several layers, or thin sheets, of environmentally friendly substances including silver, polyimide and polypropylene ferroelectret. Ions are added so that each layer in the device contains charged particles. Electrical energy is created when the device is compressed by human motion, or mechanical energy.

(excerpted from *http://msutoday.msu.edu/news/2017/how-scientists-turned-a-flag-into-a-loudspeaker/*)

## Researchers Find New Way to Control Light with Electric Fields

Researchers from North Carolina State University have discovered a technique for controlling light with electric fields. "Our method is similar to the technique used to provide the computing capabilities of computers," says Linyou Cao, an assistant professor of materials science and engineering at NC State and corresponding author of a paper on the work. "In computers, an electric field is used to turn electric current on or off, which corresponds to logic 1 and logic 0, the basis of binary code. With this new discovery, a light may be controlled to be strong or weak, spread or focused, pointing one direction or others by an electric field. We think that, just as computers have changed our way of thinking, this new technique will likely change our way of watching. For instance, it may shape a light into arbitrary patterns, which may find applications in goggle-free virtual reality lenses and projectors, the animation movie industry or camouflage."

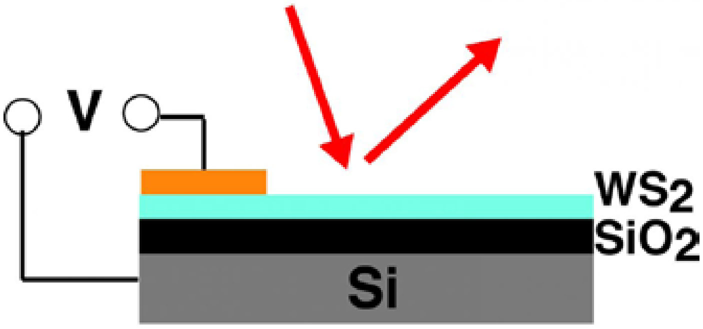
Controlling light with electric fields is difficult. Photons, the basic units of light, are neutral – they have no charge, so they usually do not respond to electric fields. Instead, light may be controlled by tuning the refractive index of materials. Refractive index refers to the way materials reflect, transmit, scatter and absorb light. The more one can control a material's refractive index, the more control you have over the light that interacts with that material. "Unfortunately, it is very difficult to tune refractive index with electric fields," Cao says. "Previous techniques could only change the index for visible light by between 0.1 and 1 percent at the maximum."

Cao and his collaborators have developed a technique that allows them to change the refractive index for visible light in some semiconductor materials by 60 percent – two orders of magnitude better than previous results. The researchers worked with a class of atomically thin semiconductor materials called transition metal dichalcogenide monolayers. Specifically, they worked with thin films of molybdenum sulfide, tungsten sulfide and tungsten selenide.

"We changed the refractive index by applying charge to two-dimensional semiconductor materials in the same way one would apply charge to transistors in a computer chip," Cao says. "Using this technique, we achieved significant, tunable changes in the index within the red range of the visible spectrum."

Currently, the new technique allows researchers to tune the refractive index by any amount up to 60 percent – the greater the voltage applied to the material, the greater the degree of change in the index. And, because the researchers are using the same techniques found in existing computational transistor technologies, these changes are dynamic and can be made billions of times per second.

"This technique may provide capabilities to control the amplitude and phase of light pixel by pixel in a way as fast as modern computers," says Yiling Yu, a recent graduate of NC State and lead author of the paper. "This is only a first step," Cao says. "We think we can optimize the technique to achieve even larger changes in the refractive index. And we also plan to explore whether this could work at other wavelengths in the visual spectrum."



Researchers develop technique to electrically manipulate light through interaction with an atomically thin semiconductor.

(from *https://news.ncsu.edu/2017/05/electric-fields-control-light-2017/*)

### Printed Sensors Monitor Tire Wear in Real Time

*Ken Kingery*

Electrical engineers at Duke University have invented an inexpensive printed sensor that can monitor the tread of car tires in real time, warning drivers when the rubber meeting the road has grown dangerously thin. If adopted, the device will increase safety, improve vehicle performance and reduce fuel consumption. The group hopes that the tire wear sensor will be the first of many that could disrupt the $2 billion tire and wheel control sensor market.

In collaboration with Fetch Automotive Design Group, the Duke researchers have demonstrated a design using metallic carbon nanotubes (tiny cylinders of carbon atoms just one-billionth of a meter in diameter) that can track millimeter-scale changes in tread depth with 99 percent accuracy. With two patents pending, the researchers are in the process of establishing industry collaborations to bring the technology to a tire near you.

"With all of the technology and sensors that are in today's cars, it's kind of crazy to think that there's almost no data being gathered from the only part of the vehicle that is actually touching the road," said Aaron Franklin, associate professor of electrical and computer engineering at Duke. "Our tire tread sensor is the perfect marriage between high-end technology and a simple solution."

The technology relies on the well-understood mechanics of how electric fields interact with metallic conductors. The core of the sensor is formed by placing two small, electrically conductive electrodes very close to each other. By applying an oscillating electrical voltage to one and grounding the other, an electric field forms between the electrodes.

While most of this electric field passes directly between the two electrodes, some of the field arcs between them. When a material is placed on top of the electrodes, it interferes with this so-called "fringing field." By measuring this interference through the electrical response of the grounded electrode, it is possible to determine the thickness of the material covering the sensor.

While there is a limit to how thick a material this setup can detect, it is more than enough to encompass the several millimeters of tread found in today's tires. And with evidence of sub-millimeter resolution, the technology could easily tell drivers when it's time to buy a new set of tires or give information about uneven and often dangerous tire wear by connecting many sensors in a grid to cover the width of the tire. Tests also proved that the metal mesh embedded within tires does not disrupt the operation of the new sensors.

"When we pitch this idea to industry experts, they say to each other, 'Why haven't we tried that before?'" said Franklin. "It seems so obvious once you see it, but that's the way it is with most good inventions."

While the sensor could be made from a variety of materials and methods, the paper explains how the researchers optimized performance by exploring different variables from sensor size and structure to substrate and ink materials. The best results were obtained by printing electrodes made of metallic carbon nanotubes on a flexible polyimide film. Besides providing the best results, the metallic carbon nanotubes are durable enough to survive the harsh environment inside a tire.

The sensors can be printed on most anything using an aerosol jet printer -- even on the inside of the tires themselves. And, while it is not yet certain that direct printing will be the best manufacturing approach, whatever approach is ultimately used, Franklin said the sensors should cost far less than a penny apiece once they're being made in quantity.

Franklin's group also wants to explore other automotive applications for the printed sensors, such as keeping tabs on the thickness of brake pads or the air pressure within tires. This is consistent with a key trend in the automotive sector toward using embedded nanosensors.

Other tire tracking products have recently hit the market. For example, the tire company Pirelli recently unveiled a system to electronically track each tire -- when it was installed, how many miles it has gone, when it was last serviced, etc. -- and use an algorithm to estimate its wear and tear. While not the same thing as actively, physically measuring tire tread, it shows that the market is there for this type of information.

But the technology isn't limited to cars.

"This setup could be used with just about anything that isn't metallic or too thick," said Franklin. "Right now we're focusing on tires, but really anything you'd rather not have to cut apart to determine its thickness could be monitored by this technology in real time.

(excerpted from *https://pratt.duke.edu/news/tread-sensor*)

An illustration of how the novel tread sensor works. The sensor is placed on the inside of the tire, where the tire wall and tread interferes with an electric field that arcs between two electrodes. That interference can be measured to determine the thickness of the rubber with millimeter accuracy.

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