P/O/E/T/S

Fall / Newsletter / 2016

1. Director's Message:

This summer saw some new faces join POETS as new students joined us at their respective universities. In addition, we completed our first round of new project selection since the center began. This led to a very busy summer and beginning of Fall 2016. The new project selections came with new POETS faculty involvement. I recently had the opportunity to give a State of the Center address during our Annual Meeting and I can reiterate here what I said there: the state of our center is strong. We've already got over 60 papers from POETS work and 80 students involved with POETS activities. This includes approximately 40 students directly supported by POETS and 40 involved in POETS-affiliated projects. Overall, year 2 of our center is shaping up to be as successful as year 1.

2. POETS News and Notes:

David Huitink is one of the new faculty who joined POETS. David is in the Mechanical Engineering department at the University of Arkansas. His technical area is reliability for electronic systems and he comes to Arkansas after a career in industry at Intel. Kiruba Haran is an Electrical Engineering professor at Illinois whose specialty is in electric machines and drives. Similar to David, Kiruba joined academia after a career in industry at GE R&D. Xiuling Li is an Electrical Engineering Professor at Illinois whose specialty is in nano- and micro-electronics design and fabrication. All three faculty bring expertise that directly maps to gaps in the Research Needs identified by POETS leadership.

In other exciting news, POETS held its first Annual Meeting in Palo Alto California on October 27-28, 2016. This was a significant success; we had initially targeted attendance at 80 people since it was an invitation only event. When all was said and done, we had over 120 attendees including government and company representatives. There were over 2 dozen different companies of varying sizes that attended. Below you can see the audience listening to Greg Salamo from the University of Arkansas during one of the research presentations.

The students also did a fabulous job during the poster presentations where they had an opportunity to interact directly with the industry and government attendees. Feedback from the company representatives was uniformly positive, reinforcing what we already knew: we have great students working on interesting research. That said, one of the key pieces of feedback from the industry representatives was the need to integrate many of the excellent pieces within POETS to create a high impact translation of our research into practice.

In addition to the poster session, the students had the chance to participate in a really interesting tour one day prior to the start of the meeting at Proterra (www.proterra.com). This is a company that makes an all-electric zero emission bus. This was an exciting visit and the CEO came to talk with the students directly during their visit.

The Annual Meeting was so much fun we can't wait to do it again next year in Washington D.C. hosted by Howard University.

3. Research Highlights:

Thermal circuitry:

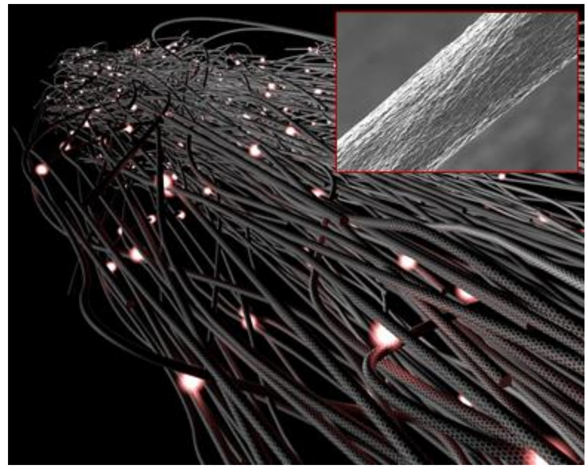
Many smartphone users can relate to feeling a slight temperature spike in their pocket as their device begins a download. With wearable electronics, such as smartwatches, this rise in temperature can become problematic if it exceeds what the skin can handle. But what if the download only took 5 to 10 seconds, and something called a thermal circuit could push the heat away from your skin for that amount of time?

"The idea is that over short timescales, it is possible to essentially control heat and to prevent even high temperatures from causing damage," said Eric Pop, an associate professor of electrical engineering at Stanford University. Pop is one of the collaborators at POETS who is working to use circuitry, which is traditionally thought of in relation to electricity, to direct and control heat. The goal of thermal circuitry is twofold: to protect humans from temperature spikes in electronics, and to protect sensitive electronics from temperature spikes in their own environment, such as if they go into outer space or a car engine.

Pop is collaborating closely with Joe Lyding at the University of Illinois, who works on atomic scale systems and is examining the application of carbon nanotubes, which are straws around one nanometer in diameter and one atom thick. They're based on a material called graphene, a one-atom-thick sheet of carbon that's very strong and flexible. Rolled into a tube and stitched together, graphene makes a seamless carbon nanotube. Lyding, who is an electrical and computer engineer, said the key issue where thermal circuitry comes into play is that components with electronic functionality generate heat, which can often limit performance and cause thermal failures. Thermal circuitry would help to get that heat out.

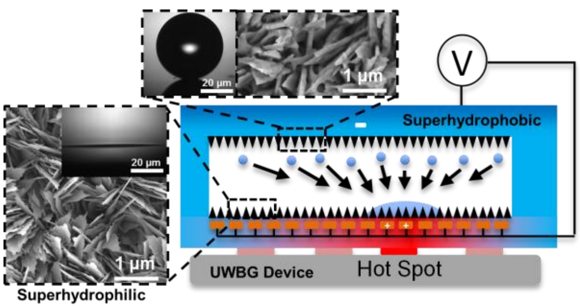
Currently, copper metallization is what's used, and while it's a good electrical and thermal conductor, Lyding said chips are running using copper thermal circuitry at its max. "So there's a technological barrier to go further," he said. "And I think that's what POETS is trying to address: Can we break through that technological barrier and come up with something that's a better thermal conductor than copper, yet be able to utilize it like copper—you know, make routing structures and perhaps even have the combined dual purpose where it's an electrical as well as a thermal conduit." The built-in thermal conductivity of carbon nanotubes and graphene can be 5 to 10 times that of copper. In addition, the process of linking carbon nanotubes together increases their strength. "We're already seeing a 70 percent increase in strength just in our very first initial experiments," Lyding said. "There's some promise in terms of making ultra-strong materials as well."

Because a single carbon nanotube is so small, alone it is not effective. What's needed is a composite made out of millions or billions of carbon nanotubes. The problem is that the crossing point where heat has to suddenly jump from one carbon nanotube to another has very low thermal conductivity, so the composite starts losing the intrinsic properties of an individual carbon nanotube. Lyding is developing techniques to make connections between the carbon nanotubes so that the intrinsic advantage isn't wasted. He's made some fibers by this process, which were sent to Pop's group for testing. The image below depicts the carbon nanotube (CNT) interconnection process used to enhance the thermal conductivity of nanotube-based thermal conduits. The inset shows a scanning electron microscope image of a CNT fiber fabricated for these experiments



Paul Braun, a materials scientist and engineer at the University of Illinois, is working to help define the areas where new materials will make an impact. "Specifically in my group, I'm very interested in materials or structures that can have strongly switchable thermal properties—in particular, things like thermal conductivity," Braun said. Currently, devices are being designed with the assumption that all the heat generated has to be extracted equally, whether or not that part of the device actually needs to be cooled. This leads to very significant over-engineering and over-designing. "Your cooling unit is 10 times bigger than it needs to be because you're cooling everything instead of just the critical component," Braun said. "So if you could reduce the power demands of cooling by a factor of 10, or you could reduce the size of the cooling device by a factor of 10, it really allows you to change the way that you design everything, from aircraft to vehicles."

Nenad Miljkovic, an assistant professor in mechanical science and engineering at the University of Illinois, works in phase change heat transfer, which involves some sort of change from liquid to solid to vapor. Enhanced heat transfer surfaces are used to cool hot spots by directing liquid to those areas and evaporating. Miljkovic said that same concept works perfectly as what's called a thermal diode. "A thermal diode, or a diode itself, is a very important concept in circuitry," he said. "It's a device that allows heat to flow in one direction, or electrons to flow in one direction, but not in the reverse direction. So it's kind of like a little valve which only moves in one direction but not backwards." Miljkovic added that controlling the direction of thermal flow is notoriously difficult, because heat and electricity are fundamentally very different forms of energy. "It's very easy to control exactly where your electrons flow," he said. "Whereas phonons, or heat, is much more notorious because it'll just sort of go wherever is the easiest path to move, and it's a very disordered form of energy." The figure below shows an early concept of such a device where electric fields and surface energy are used to control the on-off flow of heat in a microscale vapor chamber as well as the spatial concentration of heat flux using addressable electrodes.



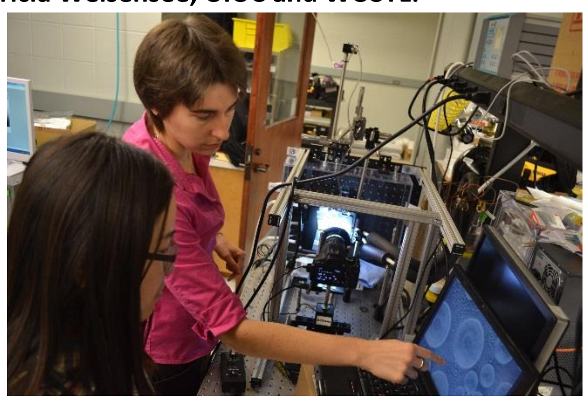
He anticipates having to overcome initial challenges with durability, whereas for the other researchers it might be scalability. "What a lot of companies often ask is, 'How long will this last before it stops working?'" he said. "The other issue is also cost. What's the cost for them to implement this in real-life situations?"

An important aspect of POETS's work is that it takes a system-level approach. Braun said, "By just engineering a better material without understanding all of the other parts of the system and how they come into play, you will end up optimizing down sort of the wrong path, and then you have no chance of impact because something about the material system doesn't fit into the rest of the device." Lyding also said this project is ideally suited for the cooperative environment of POETS. "We've got people needed from different disciplines, like chemists, materials scientists, electrical engineers, all working together in a very tight manner. It's a very collaborative unit that really focuses on a wide variety of problems."

4. Personnel Highlights:

In this section, we'd like to take a deeper dive and get to know some of our people in POETS a bit better. We profile two of our contributors to get a better sense of what they do and how they got to be where they are.

Patricia Weisensee, UIUC and WUSTL:



When Patricia Weisensee was a child growing up in Germany, she used to spend the summer days with her grandfather in his wood workshop. "We would go down to the basement and just build stuff," she said. She credits that experience, at least in part, to her future love of engineering. She also credits—not surprisingly—being good at math and physics, a skill beneficial to any engineer.

Weisensee is a Ph.D. candidate in mechanical engineering at the University of Illinois and a member of POETS. Her research centers on heat transfer in electronic systems—specifically, droplet-based heat transfer. "Right now, I'm doing a project that looks at the condensation of water droplets and how to effectively remove them so we can increase the heat transfer—so, basically make the cooling more efficient that what it would usually be," Weisensee said.

Because her research calls for collaboration with people on the electrical side of things, her involvement with POETS is useful because of its interdisciplinary nature. "It's really interesting to be able to get input from other disciplines—for example, from the electrical engineers—but also from people who do kind of a system view of it. So, people who are able to integrate what I'm doing on the fundamental side into a real project or into a real system." At POETS's semi-annual meetings, Weisensee is also able to talk with students from all four member universities about their respective projects and get ideas for her own research. Because the other schools have expertise in areas different than Illinois, she said, it's a good opportunity to learn about how they deal with problems or approach their research.

While Weisensee's love of engineering started at a young age, she hadn't always set out to be a mechanical engineer. When she began her undergraduate studies in Munich in 2007, she was planning to go into aerospace engineering. But after the first two years of her program, she realized those lectures weren't what had attracted her to engineering. She found she was more interested in heat transfer lectures, and she made the switch.

After she graduates this fall, Weisensee will start a tenure-track faculty position at Washington University in St. Louis in January. "I'm hoping to continue work on heat transfer—droplet-based heat transfer—but also go a bit into renewable energies, maybe energy storage," she said. "So, expand my research area." What Weisensee loves about her work is that she gets to use her brain a lot, which she says is fun. "But then again, research is so slow. There are so many times when you're just stuck, which is frustrating, obviously. But then when you finally get through and find the resolution—if finally my experiments get to work and I see some exciting results that no one else has seen before, that's really rewarding, and that's what drives me."

In her new position as a professor, Weisensee is looking forward to working with students. It won't be her first time; last spring, she taught a class in heat transfer and thoroughly enjoyed the experience. She found the teacher-student interactions to be very rewarding.

But Weisensee hasn't gone without challenges in her career path. Her undergraduate program in Munich had a system in which a large number of students were admitted—she was one of 1,200 freshmen just in mechanical engineering. But after two or three years, students were, as Weisensee put it, "weeded out" until there were only 350 students left. "And you don't have the interactions with the professors that you have here," she said. "So that was certainly a challenge. You're really on your own."

Through each struggle, Weisensee has learned a valuable lesson that she feels applies to people of all fields, professions and experiences. "I think perseverance is one thing that's super important not only for a Ph.D., but just in general. It's not so much (intelligence) or cleverness, it's really that you just stick with it and fight for what you really want to do," she said. "That counts for everything in life."

There are several things Weisensee likes about living in Champaign-Urbana. It's calm, there's no traffic, it's very green and the people are nice. She loves that it's an educated town, which she said is certainly due to the university being a central part of it. She also loves classical music, so Krannert Center for the Performing Arts is the perfect place for her to spend her time off. "We'll see how St. Louis is. It's going to be much, much bigger and I'm not so sure how that'll be. But except for mountains and maybe food, I really like it here. I mean, plus it's far from home, but anywhere in the U.S. would be far from home."

Debbie Senesky, Stanford University:

There were several "almosts" early on in Debbie Senesky's career. She almost didn't become an engineer, and she almost didn't go into academia after completing her studies. As an undergraduate at the University of Southern California, she had enjoyed her introductory psychology course so much she considered switching fields. As she juggled her options, she sought the guidance of her adviser. "She immediately told me, 'No, you're an engineer!'" Senesky laughed. "So I just listened to her. I said, 'OK,' and continued with my studies in engineering."

Then, after earning her Ph.D. in mechanical engineering from UC Berkeley, she initially wasn't interested in going into academia, so she worked for a company developing sensors for automotive and healthcare applications. When she later left her industry job to work on a post-doctoral, Senesky began to explore the idea of becoming a faculty member. "My big inspiration was actually my Ph.D. adviser at UC Berkeley," she said. "He was critical in really helping me make that career decision. And I was also inspired by his work as a professor and I learned a lot from him, so he was really instrumental in my trajectory to academia."

Now, Senesky is an assistant professor at Stanford University's School of Engineering. She said that decision-making moment in her undergraduate education really stuck with her—the challenge of choosing a profession with the uncertainty of where it would lead her, or if she would even like it. "At the end of the day, I'm really happy I made that decision," she said. "Because I love engineering, and there's a little bit of psychology that comes in from time to time as I'm mentoring students and also trying to write convincing proposals."

Senesky's research is in harsh-environment sensing technology, and the development of instrumentation that can collect information in high-temperature, high-radiation and chemically-corrosive environments through leveraging wide bandgap semiconductor materials, such as gallium nitride and silicon carbide, which are inherently tolerant to harsh environments. She said her work fits perfectly into POETS because both share a multidisciplinary nature. "(POETS) is a center that brings together electrical engineers, material scientists, mechanical engineers. My work…involves all of those disciplines, which are science, electrical engineering, aerospace engineering as well. I joined POETS because it brings together this nice set of expertise. "Also," she added, "my work in sensing technology fits in with the scope of POETS because it's interested in making next-generation electro-thermal systems more intelligent. So the sensors that my group is developing are helping with creating the ability to collect information within these new types of electro-thermal systems."

Senesky enjoys the mentorship aspect of her job and working with the students in her group, who she describes as creative, intelligent and passionate. She said the most exciting part of her day is having meetings with them and discussing new ideas. Her colleagues also make her work enjoyable, as she works with renowned professors in their fields at Stanford and also through POETS. "It's been really fun to learn from my peers and interact with them," she said. "That's the most exciting part of my profession."

Senesky's goal is to develop technology that moves from the research environment to the real-world environment; she wants to take the sensors, devices and materials being developed in her laboratory and see them in cars, satellites, space rovers and space probes. She said that's very challenging to do, but she works with students, industry and other professors in POETS to work toward success.

A challenge Senesky currently faces is finding a work-life balance. With a two-and-a-half-year-old daughter at home and a career as an assistant professor, finding the time and ability to balance those two things can be difficult. She reads books and blogs about time management and being more productive, but it's not easy, especially with the multifaceted nature of her work; she travels, gives presentations, teaches classes and performs research. "Learning how to juggle these things effectively is something that I am currently working on," she said. "And everyone's in the same boat."

Based on her own experiences and challenges, Senesky offers a piece of advice: "Follow your passion. You're not going to know where your life will lead you, so I think learn what you can to really hone in on what your passion is." She said people should get involved in activities within and outside of school and explore their interests, which will help them find their life's mission. Also, they should try to identify mentors that might help shape their careers and assist them in making decisions. "Good mentors can really be fantastic for your career, and also your personal life as well. And at the end of the day, you have to follow your heart and follow your passion. Have fun with what you do and have fun learning."

5. Educational Highlights:

Fifth grade students visit University of Illinois, engage in POETS activity:

70 students from Kenwood Elementary School in Champaign, Illinois were guests of POETS as they came to the Illinois campus for a fieldtrip to encourage the students to start thinking of college, and STEM in particular, as part of their future plans. They met with 16 graduate students in the POETS headquarters where they engaged in an activity inspired by POETS professor Dr. Miljkovic's work on super-hydrophobic surfaces and their application to thermal regulation of devices. The students learned about POETS research, explored a piece of super-hydrophobic aluminum foil, and then used it to build a "roller coaster" for water drops. Several of the students noted that this was the best field trip they have ever taken. Below we see two 5th graders exploring the behavior of a piece of aluminum foil coated with a super-hydrophobic surface.

6. Alumni News and Notes

While there are no alumni news and notes, it with great sadness that we announce the passing of Dr. Michael Dalan Glover. Michael was a key piece of the University of Arkansas team within POETS.

He passed away October 28, 2016. Michael graduated from Watson Chapel in 1989 and then attended the University of Arkansas, where after many years of hard work he received his Doctorate of Philosophy in Electrical Engineering. He worked for the University of Arkansas as a Research Assistant Professor in Electrical Engineering. He received the William D. and Margaret A. Brown Staff Excellence Award in 2011. Michael was active in the Farmington Cub Scouts and enjoyed spending time with his family. He was also a member of the Amateur Radio Club of the University of Arkansas and enjoyed Ham Radio where he made contacts all over the world.