Speaker 1:

Research is really important because by definition it's the only way to get new knowledge. There's so much that isn't yet known that it's just a cool time to be in science.

Speaker 2:

Well I think at the end of the day, what really gets us out of bed in the morning is just a curiosity, trying to understand things we didn't understand the day before.

Cole Cullen:

Welcome to Reach, the podcast that tells the stories of researchers, their studies, and how their work impacts you in the world you live in. I'm Cole Cullen.

Beth Bamford:

And I'm Beth Banford. Today we're going to tell you about materials. More specifically, the research being done at Penn State about materials. Have you ever seen the commercial where all the people are fighting over the electric outlets so that they can plug in their chargers to charge their devices?

Cole Cullen:

I have not seen that commercial.

Beth Bamford:

You should check it out. It's pretty entertaining.

Cole Cullen:

The world is full of gadgets, and everybody needs to charge those gadgets. When I interviewed Dr. Susan Trolier-McKinstry, she talked about technology she's working on that just might help that problem.

Susan T.:

I'm Susan Trolier-McKinstry. I'm a professor at Penn State University in the Material Science and Engineering Department. I am a Penn Stater from my undergraduate degree on. So when I was looking for schools, I wanted a school that had aeronautical engineering and ceramic science and engineering, because I was going to work on space shuttle tiles. When I got here I figured out space shuttle tiles had already been invented. And the net result was I looked around at the two departments. And in the area of electronic ceramic materials, Penn State has really been the world leader for longer than I've been alive.

My research specialty is on thin films for dielectric and piezoelectric applications. So a dielectric is an electrical insulator. A piezoelectric is a material that converts between electrical and mechanical energies. And so I've been working on piezoelectrics my whole career. Because piezoelectrics convert between mechanical and electrical energy, I can take a mechanical motion and convert it into power. And so we're very interested in developing these for applications that range from the Internet of Things.

Cole Cullen:

Expand on the Internet of Things.

Susan T.:

So the idea behind the Internet of Things is that we'll be able to put sensors and communication packages many, many places. And that could be anywhere from your refrigerator literally saying, "Your milk is about to go sour" to something that might be monitoring how much time you've sat at a desk, and your doctor needs you to get up and get moving. So we have all of these in-placed sensors that can communicate with each other. And they will all be communicating one with another.

Cole Cullen:

And they all need to be powered?

Susan T.:

And they all have to be powered. If you imagine... And this is pretty far out, so this is not a next year thing. If you imagine placing a trillion sensors and you don't provide local power. That means you're going to have to replace 500 billion batteries annually. Which means for the most part, 500 billion batteries in landfills. And 500 billion batteries, who wants that job?

About seven years ago, we started a large program with North Carolina State University, the University of Virginia, and Florida International. And we're working on being able to build self-powered health monitoring devices. Health costs in the United States are enormously high. And one of the things that might mitigate that is if people were not in the hospital, if they did not have to be in the hospital, and the people who went to the hospital actually needed medical care. And so one approach that you might consider using in such a case then is to be able to provide people individualized health monitors that are doing things like measuring their pulse, their oxidation state, and this also in providing a little information about the surroundings. Maybe the temperature, the humidity level, the pollen count, or the level of ozone that's in the atmosphere. And so it'd be incredibly helpful for people who might have a long-term medical condition to be able to provide them personalized information.

You've just walked into a room that might make you sick tomorrow. Maybe you need to go and be in a different place. And so the center that we're working on is really aimed at how do we miniaturize all of this, massively reduce the power that's required to run it, and then enable the human body or the human surroundings to provide power to that system so that a user doesn't have to think about it. They don't have to think, "I've got to charge this too. I've got to change the batteries." And in practice, the part that I'm working on is how can we take motion of the human body and be able to use that to power these medical systems.

Cole Cullen:

So how do we do that? How does the powering work?

Susan T.:

How does the powering work? There's really three steps to converting mechanical energy into electrical energy. And so the first step is, how do I take the motion of the body and couple that motion into a mechanical structure? And so the approach that we've taken is to utilize piezoelectric cantilevers. So think of a cantilever as a long thin object. In this case, we make very thin metal foils. So about 50 microns thick. It's roughly half the thickness of a human hair. And we put about five microns... three to five microns of this piezoelectric material on both sides. And then we hold it on one end, and that's the clamped end. And then we shake the material, so that the rest of the cantilever beam flexes. And as it flexes, it puts stress on the piezoelectric, and the piezoelectric converts that stress to electrical energy.

The second step of the conversion is actually to use the piezoelectric to do the mechanical to electrical energy transduction. And then the third part... Since when something's vibrating, if I have a layer on the top, sometimes it's in tension. Sometimes it's in compression. And that means sometimes I'm going to get a positive voltage. Sometimes I'm going to get a negative voltage. And so I need them to be able to take whatever electrical energy I produce, and convert into usable electrical energy. And so we've been working very closely with the group of Mehdi Kiani and the Electrical Engineering Department here. His group has built very, very efficient conversion circuitry. So you need to couple the mechanical energy into some structure, convert it from mechanical to electrical, and then run a second conversion that makes it kind of useful electrical energy that I can put into a supercapacitor, or put into a battery that then runs the rest of the electronic system.

Cole Cullen:

You're creating energy from motion essentially. That sounds like an electrical engineering issue. Why is a material scientist doing this?

Susan T.:

That's a great question. So in practice, engineering doesn't divide by disciplines very cleanly. And so if you really want to build a system, you're working across discipline boundaries. Piezoelectricity occurs only in certain families of materials. My real contribution to this program is to figure out how can we increase the efficiency of the electromechanical conversion. So when we started this program, if we would define the figure of merit that basically said, "What fraction of the energy can I help convert to electrical energy?" The figure of merit was about [.1 Coulomb squared per meter to the fourth 00:04:25]. And we've been able to take that up 10 times by engineering the domain structure of the piezoelectric material. And so the material scientist is working on this, because we're trying to make the material more efficient. The more efficient we can make the material, the more efficient the system becomes.

Cole Cullen:

I mean it sounds like you're creating power out of things moving?

Susan T.:

Out of things moving and-

Cole Cullen:

Why can't we just do everything that way?

Susan T.:

Well, we're not going to solve the energy crisis this way. So this is not going to generate megawatts of power, but it's a really useful way of generating microwatts, to milliwatts, to in a few cases watts of power.

Cole Cullen:

What is it about materials that kind of gets you up in the morning?

Susan T.:

What gets me up in the morning? Material Science and Engineering is a cool discipline, because I think of it as sitting kind of at the juncture between engineering, chemistry, and physics. So I get to work on all of that. So I get to go think about what are the physics that controls why material has the properties that it has? How can I engineer that? How can I change it? I get to think about how am I going to make these materials, so that I can optimize the materials that are possible? And then I get to use them. And sitting at that juncture where we get to do wonderful fundamental science and make it important from the other end, in terms of something that people manufacture and utilize. That's kind of a cool thing to do.

Cole Cullen:

So Beth, you interviewed our next researcher. What was it about that story that you were interested in?

Beth Bamford:

Our next story is interesting to me because he's working on technology that could have helped me a couple of years ago when I broke my arm. He's developing things that would have helped my arm heal faster and stronger. I interviewed Dr. Jian Yang, a professor of Biomedical Engineering at Penn State who specializes in the study of biomaterials.

Dr. Jian Yang:

Biomaterials is basically the materials going to interact with the human body... with a biological system. So this means when you deal with the biomaterials, right, it's not just only material science. It's the material that has to interact with the human body. So there's a two-way interaction. Materials can inference the biological response. That biological response can also inference-

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Dr. Jian Yang:

The biological response. The biological response can also influence material property. Just for example, so you have a material you put in the body, the materials may generate some immune response. Because the body may recognize, oh, this is a foreign body material, is something not belong to my body. So then the body recognizes this is something invading into the body then try to kick them out.

This is a normal biologic response from the body. But the biological response from the body can also affect material properties. They can make some enzymes, some proteins, some chemicals can help degrade the materials, can make the material to erode to fatigue. So this can... This is something that we have to look at this way. So in one word, in one sentence bio-materials these are the materials used in interact with biological system.

Beth Bamford:

Can you tell us a little bit about yourself?

Dr. Jian Yang:

Yeah. I'm a professor in biomedical engineering, so I do teaching, I do research. My background is more material science, chemistry. And so this is why we can make material, make new materials. And the materials, like I just mentioned, is really a foundation for many medical innovation. So for example, you can use metal to make stent for cardiovascular disease or you can make ceramic materials, then you can use that kind of material to make a bone graft.

For example, you can also use metal material to make hip replacement. So many medical device has to come from some kind of material. So I'm working on a field called tissue engineering and regenerative medicine. So tissue engineering means that, people suffer from the tissue loss, organ failure. So a lot of people waiting for tissue transplant or organ transplant from donors.

But the donation, the transplant is obviously not enough compared to the needs for organ transplantation. So if someday people can use materials to make your own tissue organ, you do not have to wait for tissue transplant or organ transplant, that would be huge impact to the medical field. The material has to be degradable. So that means that if you can use the materials to make some kind of template and put that in the body and use the scaffold or template to guide the tissue regeneration.

But then the scaffold kind of would be degraded and absorbed by the body. So only some left over will be your own tissue organ. There's no immune rejection. So if this can be successful, there's going to be a huge impact to the medical field. I think our ultimate goal is can we build a human parts factory? Now in the future, if somebody needs a tissue or needs a organ replacement, just grab the tissue organ from the shelf and then implant into the human body.

So now the challenge, one of the significant challenge is, how can we generate the right bio materials for this purpose? We can use this kind of materials to make a bone screw, bone plate, pins with different kinds of things. So we can use this kind of medical device for let's say in the orthopedic fixation. We have licensed this technique to a company it's called Acuitive Technologies. This is a company located in New Jersey.

They're expecting to get FDA approval very soon to make bio-degradable bone screw based on our materials. Now they are hopefully the end of this year, this product is going to be all over the world. It's going to generate huge impact. So this is I think to me this is a perfect story about fundamental study, yield very nice optimum materials for medical vocation.

Beth Bamford:

So this is really great. I didn't realize how relevant this interview would be to me because I have a plate in my arm that has screws, and you can feel the one screw. There's like a bump on my arm where you can feel a screw a little bit higher than the rest of the plate or other screws. And so if that technology or bio materials was available seven years ago, are you saying I could have had the surgery and had a different type of material put in my arm?

Dr. Jian Yang:

Yeah.

Beth Bamford:

That would dissolve.

Dr. Jian Yang:

I think these is very likely. Because the metal screw, I mean been a standard in orthopedic fixation surgery. They may have to take the bone screw out and do a second surgery to fix your bone. So this can possibly happen, I'm not saying this is going to happen to you, so yeah, but nowadays with the concept of biodegradable screws, so the idea you don't need the second surgery, right? So why this is put in your bone, fix a broken bone for example, and then eventually degrade it, absorb it. There's nothing that's left over, then you do not need a second surgery to take it out. So that's the ideal situation.

Beth Bamford:

So it's not only a short term solution to a broken bone, but also it will help the bone heal faster?

Dr. Jian Yang:

Yeah, that is also another very good question. So because there are some biodegradable bone screw in the market already, but our materials that the nice thing for our material is that how much it can help bone regeneration, can speed up bone healing because we can provide the signals, provide the molecules that cell need.

Our materials when the material degrade they can release citrate. Citrate that can regulate the bone stem cells differentiate into bone cells to make bone tissue. So I think this is kind of at a second level of kind of the innovation that we're not just using the materials, just the materials, and the material can bring a lot of biological benefits.

So in general, my field is basically, I'm a biomaterial scientists. So my job is that we understand the biological needs, the medical needs, and use that as a guidance to design bio materials to address the medical problems. So all what we do is not just only the material scientist, we combine medicine, biology and material science together to address the medical problems.

I think that this field is rapid growing. People are not necessarily to work in biomedical engineering department. They can work in material science department, work in material in chemistry department, they can work in mechanical engineering or electrical engineering. So bio-materials has become very a broad field. People can benefit from making materials or from using materials to do what they need to do.

Beth Bamford:

That's fascinating to think that in the future there could be that possibility of not waiting on a list for an organ transplant.

Dr. Jian Yang:

That's the goal.

Beth Bamford:

But that's like growing or?

Dr. Jian Yang:

Yeah, you can say growing your own organ because ultimately the goal is that you build your own organ and tissue not from donor. If we can develop technology, we can address some medical problems. Now people are dying, people are waiting for the suitable technology to cure the disease. If we can do something like that, that's the ultimate impact I would say. My goal is that I hope that all I do can benefit the society and the patients.

Beth Bamford:

This type of technologies would really impact patient care, faster healing times, shorter hospital stays.

Cole Cullen:

Shorter waits for organ transplants.

Beth Bamford:

I can't wait to see what these developments lead to in the next couple of years for patient care.

Cole Cullen:

Our final story for this episode is with Dr.Tak-Sing Wong. He gave me the opportunity to say the words camouflage poop.

Beth Bamford:

You've been waiting all your life for that moment.

Cole Cullen:

All my life, and that was the end of the Reach Podcast.

Beth Bamford:

You had a good run

Tak-Sing Wong:

My name is Tak-Sing Wong. I'm assistant professor of mechanical engineering and biomedical engineering at Penn state. I'm currently directing a laboratory called the Laboratory for Nature Inspired Engineering. As the name implies, we study nature, we look into biological system. We are interested to look at all kinds of natural system including insects, plants and animals and try to extract some of the clever strategy they use to deal with their everyday life. And we have particular interest in the materials aspect of the systems.

Cole Cullen:

What is it about nature that you look to nature for kind of your motivation, I guess?

Tak-Sing Wong:

Yeah, that's a great question, why do we look into nature? So if you look at the lateral history of biological system, it has close to 3.95 billion years of history, evolution history. So with such a long history, many of the solutions that are developed by nature are highly optimized. So it's right there, we can treat it as an encyclopedia, all the knowledge are really there. So why don't we just go into look at the lateral world carefully and take some of this concept and use them to solve our own human problems.

Pretty much everything we see in this physical world is made of some kind of materials. All the way from the water that we drink, from the chair that we sit on, even for the materials for this microphone, we are really living in the materials well. So understanding the science of how this material is made of is very important because sometimes we want to solve problem by modifying the mechanical property of the materials. So we use advanced micro and nano manufacturing to try to recreate this materials and try to find applications for those materials.

Cole Cullen:

What are some of the projects that you guys are doing?

Tak-Sing Wong:

Right yeah, our lab are interested in multiple aspects of the biological system all the way from plants to insects to animals. Starting from the plant, many plant leaves they are really water repellent. And one of the key reason behind that was because of the micro and nano structures that are present on the surfaces. So I was very intrigued by this phenomenon that just micro nano structures can give out microscopic phenomenon of water repellency.

Cole Cullen:

In layman's terms, can you kind of give a description of what micro nano structures are?

Tak-Sing Wong:

Yeah. So give you an example. The diameter of a hair is about 100 micron. A thousand times of that it will be one nanometer.

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Tak-Sing Wong:

...micron. A thousand times of that it will be one nanometer. So, that will be a size of a molecule. That give you a sense of the size of different... From molecule all the way to a diameter of hair, it's from one nanometer to about a hundred micron. Our group are interested in [inaudible 00:22:19] pitcher plant, which is a carnivorous that capture insects for its food source.

We are very interested to look at why this plant can capture insects. And one of the reason is because they have this very slippery surface that is evolved on top of this plant. So our group try to understand the mechanism and replicate this slippery coating and use this coating for different scenario. For example, if you have a super slippery long sticky coating, you can think of using it, a biomedical device, that bacteria doesn't stick on it, you can put it on a airplane so that ice or frost won't accumulate on it.

Same for a automobile, windshield, camera lens. So, those are some of the area that my group has look at before. So that's in the area of plants. In the area of insects, two years ago our group has look into this insect called a leafhopper. Leafhopper is actually really interesting in a sense that they excrete or feces or poop. It's actually very advanced. Their poop looks like a micro scale soccer ball and on this micro scale soccer ball it has some nano scale cavities are surrounding the the micro scale soccer ball.

And actually there's a name for this micro scale soccer ball it's called brochosome and we study them. We try to understand why leafhopper excrete this brochosome. One thing that biologists has find was that this brochosome the excretion they actually rubbed this brochosome on the lily laid eggs, on the leaves for some purposes.

And our group have been interested to look at why and to do that we use advanced micro and nano manufacturing method to recreate this micro scale soccer ball. I mean as you can imagine it's micro scale soccer ball, very sophisticated geometry and we have to use a specialized way to make them. And what we find is that this soccer ball can absorb light all the way from UV light to visible light to infrared light.

And with that, because they can absorb all the light when they covered this brochosome onto the newly laid eggs, insects and birds because they see a visual spectrum that are very different from human, they wouldn't be able to identify or wouldn't be able to discover the lily laid eggs because they had covered a layer of this particles on top of the surface. So in a sense it's kind of like a camouflage coating.

Cole Cullen:

So it's camouflaged poop.

Tak-Sing Wong:

It's like a camouflage poop. Exactly. Yeah, that's right. That's right.

And let's go into, or even a smaller scale to the world of micro organism. So fairly recently our group has discovered this new material, a self healing material that is replicating the self healing property of biological cell membrane.

We call it self healing liquid membrane. What it allows you to do is to let large particle to go through, but blocking small particle. And this is very different from the regular filter all the way from seeving coffee filter to water desalination. Right. Those filter let small particle go through, but blocking large one, but this membrane we develop it's like a reverse filter.

Cole Cullen:

So what kind of applications could this reverse filter be used for?

Tak-Sing Wong:

Yeah, it can use in a lot of applications that previously weren't achievable using regular filter. For example, imagine in a battlefield or in a developing world where they do not have high quality surgical facility. If a doctor wants to perform surgery on an open wound without worrying about infection, they can put this reverse filter onto the open wound so that there's a filter that can block out all the dust and bacteria. But at the same time, the doctor can push through the surgical tools such as scalpel or tweezer into the the membrane to do surgery. So it can be used as a surgical film. Yeah.

Cole Cullen:

That's amazing.

Tak-Sing Wong:

Yeah. So that's one application. And there are many more applications. For example, in agriculture. So in California there's some kind of summer berry that they do not want insects such as fruit flies to contaminate a fruit, but at the same time they want bees to fly over this berry to pollinate. Right. But then in the past there weren't any mechanism to filter out smaller insects while allowing bigger insects to fly through. So with this membrane, this will be possible because fruit fly is smaller in size that it will be filtered out by the membrane, but then fruit fly, which is larger in size it can fly through the membrane and do the pollination with the summer berry.

Cole Cullen:

So as you're creating the membrane, you can adjust the size of things that are allowed and not allowed through the membrane?

Tak-Sing Wong:

You can tune the size selectivity, you can tune at what size of the particle it can pass through and at what size it cannot.

Cole Cullen:

So is this membrane, is it in the real world yet? Is it being used or is it still in the lab?

Tak-Sing Wong:

We publish our really first paper two, three months ago and it is still in the laboratory scale yet because with different application we need to look at... For example, if we use it for surgery, we need to look at the antibacterial fouling property, so different application require different study and that is something that we are still working on in our lab.

I have a very high hope for the reverse filtration. For the regular filtration as I mentioned, seeving and coffee filter. It has been used for many years particularly for seeving. Rice paper people use it for hundreds of years for different industrial applications and now we have proposed this new concept of reverse filtration. I think there's so many applications that can be derived from reverse filtration concept that I think many people haven't explored yet. I'm really excited to learn more about what this can be used for in the future.

Cole Cullen:

The work you're doing, you're finding new things, you're discovering things. What's it like to be in a field where you are creating and discovering new things?

Tak-Sing Wong:

It's really exciting. Every day we feel that the work that we do will someday, will help people. I think that feeling is motivating, is important and because of that, not only myself, my students are really enjoying the whole process of developing the technology. It's been a great experience knowing that some of the work that if we work hard enough it will be on people's hand one day.

Cole Cullen:

What's the most rewarding thing that you've done?

Tak-Sing Wong:

I would say when people recognize the importance of our work, when they see a video, maybe after a presentation they would just come to you to see, like thank you for doing this. This is very important and things like that. Those are very rewarding because when you do research it's a long process. It's not a easy process. And sometimes when we do our research, we don't know whether this is something important and people find it useful. I think getting that validation from the people is one of the most rewarding aspect of our work.

Beth Bamford:

Thank you for listening to Reach and a special thank you to doctors Susan Trolier-McKinstry, John Yang and [Tak-Sing Wong 00:29:57] .

Cole Cullen:

And don't forget, all the episodes of Reach can be found on our website. Please consider making a contribution to WPSU, so that we can bring you content like this. Visit: wpsu.org/donate. Thanks.

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