Organic Electronics-Printable, Flexible, Biocompatible

[MUSIC PLAYING]

KAREN WEATHERMON: Sort of chaotic, busy, full weeks-- I hope you all had a good trip home and are ready to settle in for this last rush toward the end. I'm Karen Weathermon. I'm chair of the Common Reading Program. And on behalf of the people who work with me and of my colleagues in the Office of Undergraduate Education, I want to welcome you to this afternoon to our talk today by Dr. Collins. This talk today is one of a full year's series of speakers and events that present various topics and activities related in some way to this year's come reading book Soonish-- Ten Emerging Technologies That'll Improve and/or Ruin Everything.

So as we go through the year, we're both highlighting WSU researchers-- tonight's presentation is in that vein-- and also highlighting ways that you can propel yourself forward in your own soonish future here at WSU. I especially want to acknowledge our folks in Global Campus today, who are joining us through livestream. So it's great to have you with us wherever you may be watching this afternoon. I want to let you know there are still three Common Reading events left for this semester.

Tomorrow evening Robbie Cooper from human development will be giving a presentation and workshop from 7:00 to 8:30 in Spark G45. That's that big round lecture hall. And the title for his presentation is The Value of Self-Care. And he'll be demonstrating-- and I think it's sort of interactive in some ways-- ways to think about self-care for yourself now during this very stressful time of the semester, but also ways in which this is a new kind of venue of thinking about health care more generally, that preventative self-care is another mode of addressing serious illness. So that's tomorrow-- again, 7:00 to 8:30, Spark G45.

And then we end the semester series next week with student presentations from two different classes from HD 205 and from SOE 110. Both those classes have used Soonish as the starting point for semester long projects. And in HD 205, it will be the final film festival of short films that students in that class have created. They'll be voting for people who attend that presentation. And then the SOE, the environmental science class-- they have been doing semester long projects on sustainable cities.

So those different events occur on Tuesday. Well, Tuesday's is at 5:30-- that's the film festival-- and Thursday at 2:50 and Friday at 8:00 AM. So there are more details on that on the Common Reading website and on the CougSync Common Reading site. If you're attending for Common Reading credits, we'll be verifying attendance by swiping you into CougSync with your Cougar card at the conclusion of the event out in the hallway.

This is one that to have it show up on your CougSync involvement page, there's a required post event survey with a few questions. That will be emailed to whatever email account you have associated with CougSync. If you can't find it there, you can also get to it from your own involvement page in CougSync and their instructions on how to do that also on the Common Reading website. So we're thankful for your responses to that short survey. It helps give us and our presenters some feedback about who's attending for what classes and what kinds of things you find useful and interesting so that we can plan for within our programming.

So now I want to introduce this afternoon's speaker. Brian Collins is an assistant professor of physics and the head of the Collins Research Group. This is an interdisciplinary research lab composed of undergraduate, graduate, and postdoctoral researchers, and whose work as you'll hear today straddles physics, materials science, electrical engineering, and chemistry. I also want to point out in that list of who works in his lab, undergraduates are part of that cohort of folks who work with him.

And I will be having an event in the spring that will highlight how to get involved in undergraduate research, but I just want to put a small plug in, plant that seed if you haven't thought about that before, that working with faculty in their areas of research, it's a tremendous way of propelling forward your own experience here at WSU. For the innovative research done in his lab, Dr. Collins was awarded an Early Career Research Award from the US Department of Energy in 2017. And he was one of just 59 scientists who received the award out of 700 applicants.

Collins Lab is also notable both for their outreach to K12 students to spark the enthusiasm of youth for science at a young age and also for their collaboration with other research groups, both in the US and in other parts of the globe. He earned his bachelor's degree in physics from Gustavus Adolphus College and his masters and PhD in physics from the University of North Carolina at Chapel Hill. When I asked central folks in research and academics across the campus who are the folks doing the most exciting research, Dr. Collins was one of the first names that was forwarded to me. So it's a real pleasure to have him here today. And I hope you'll help me welcome him.

[APPLAUSE]

BRIAN COLLINS: Thank you very much for that introduction. First of all, can you guys all hear me OK? Am I coming through the mike OK? All right, so yeah, thanks again for the great introduction. And, yeah, today, I really excited to tell you a little about what really excites me in terms of the science that we do in my lab in physics.

And, in particular, I'm going to talk today about this kind of really new type of material based on organic materials. This is not biological materials necessarily. But it is a material that I think really is in line with the reading that you guys are doing, the Soonish book, where a lot of these technologies are really kind of on the verge of coming out into the marketplace and, some really exciting, possible things could happen with them in the near future.

So organic electronics has its roots a little bit in kind of what you might consider a little bit more mundane material as of late. They really start and they rooted in plastics. So what do we think of when we talk about plastic materials? We think first of all kind of cheap, think of really bad toys or cheap toys, containers. Now they're recyclable, so that's decent.

That's something that is a positive about them. They're flexible, so that's kind of interesting compared to say metals and other types of technologies that we have out there, so that could be a potential positive thing. Often we make too much of them. And so we have to deal with pollution and that sort of aspect that has to do with the manufacturing of plastics. But on the other hand, there's some interesting things coming up.

So there's 3D printing that's kind of coming out now, and we have a lot of those in kind of the art studios and even in the engineering, manufacturing. So that's kind of an interesting aspect too to plastics. And in terms of electronics, we think of them as kind of not very interesting. They think of them as insulators. So they're the stuff that we coat all of our wires and our components so we don't get shocked ourselves.

So we often consider them not to be very interesting in terms of electronics. They're more kind of structural materials and may be interesting in terms of their flexibility and printability. But where do they come from? Down to the atomic or molecular level, what do they look like?

So they all are basically what we call polymers or the science committee likes to call them polymers. These are basically big molecules that are all very stringy. They're chains of carbon atoms that maybe are wound up, or are long, or just kind of do whatever they want to do. And they're coming from basically small molecules usually based on carbon that we bond together into long chains. And you can think of all plastics as like a lot of spaghetti just kind of thrown together, and it's solidified in that shape.

And that kind of helps to give it the flexibility that we know about these materials, allows them to be flexible at the macro scale. But it also allows a lot of other possibilities. Some examples-- Styrofoam is one example, as well as Teflon. This is actually Teflon here where you have carbon atoms in the middle.

They're the black blobs, and the green ones are actually fluorines. But you can use basically any atom you want and kind of chaining together into these plastic materials. Most of the time they're made out of carbon or they're based in carbon. And, actually, we didn't kind of come up with these ideas ourselves. This was something that we got ideas actually from living organisms.

Actually, it turns out we are all composed of polymers of some sort. And, of course, the most well-known polymer out there is the DNA molecule. It itself is a polymer in fact. So if you come down here, you see these are the DNA molecule. Here we have a polymer made up of, again, these monomers, which are just the individual links.

We link them up, or the body actually in this case links them up. And then we have four possible monomers. Now Teflon is a little bit simpler because it's just got one thing that we going to repeat all the time, whereas DNA is something that the body changes up. It has four possibilities. But we've actually synthesized or chemists have synthesized stuff like this where there's four possible monomers-- adenine, thyamine, guanine, and cytosine.

But that's kind of cool because it actually encodes all of life, and that is itself a polymer. And, in fact, the rest of your body is also made out of polymers, basically what we call proteins. Proteins are just long chains. There's a couple more types of monomers you can have. There's 21 amino acids, and those are all the monomers that chain together into these long stringy molecules that we call proteins and basically make up all of our bodies and all of living things.

And so we kind of got this idea of what plastics could be from what we already are made out of ourselves. So that's pretty cool. But I don't see any electronic applications here. So what does this have to do with electronics, and how can we mesh that together? So, first of all, way back in the day we had the transistor invented.

And that was a really big revolution in terms of what kind of technologies we can have as a society. And, of course, naturally, Bardeen, Brattain, and Shockley were awarded that prize in 1956, which was really well deserved because that has come from that invention of that electronic device. We get all of our laptops and of course all our cellphones. And that has really revolutionized society as a whole over the past several decades.

So how does this relate to plastics though? And really the thing that makes all of this, all the electronics possible really is electronic connectivity. And what does that really mean? We know this idea. We have wires, and you can have electric charges jumping across something and making a lightning bolt type of cool pattern.

But really what this is are how the atoms are constructed. We have this nucleus at the center of each atom. And, of course, we have the electrons of swirling around it, and those electrons are the things that could potentially move around and give us the ability to do what we can do with our cell phones. So how does this work? I mean, so in a metal, we basically end up with atoms, and it's kind of crystal lattice or a repeated pattern like this.

And every atom has a whole bunch of electrons around it of course. And as we know, basically, opposite charges attract each other. So we have a positive nucleus and a negative electron, and they attract each other. And so these ones in the middle-- they're kind of bound to the atom pretty tightly.

But as you get further and further out, you start having these electrons that don't really feel that electric field or feel the attraction of the nucleus so much. And they become a little bit freer to go around and kind of swim around in kind of this quasi sea of electrons that kind of surround these atoms. And if you put a little voltage on them, they will flow from atom to atom and eventually down the wire. And so that's kind of what makes all of the electronics possible is the ability for these electrons to flow. And you see those in of course metals.

So what makes an insulator of course is the inability to flow. So if you have an example of a carbon bond in these polymer molecules, what will happen is these two carbon nuclei or atoms really want that electron. And they share it when they bond together. But that electron has to stay kind of between those two. And I've kind of drawn a little region where they have to be confined to.

And they can't really get out of that. And so because of that, those electrons are not able to flow, and we have insulators. And that's why, of course, we coat all of our wires with these materials in order to keep us from getting shocked with the electric flow that's occurring in the metal. But that's what kind of makes the big difference between a metal and an insulator and how we get our electronics to work.

So, typically, you think that, OK, so polymers are probably not going to be able to do this type of thing because carbon atoms have these bonds like this versus metals. So that was true until someone realized that if you bond them in certain ways, you could actually make them act like metals, and that's called conjugation. And these folks here, MacDiarmid and Shirakawa, in 2000 won the Nobel Prize for literally quote, "the discovery and development of conductive polymers." And it was kind of interesting because as how a lot of science goes, this happened by accident.

They weren't actually trying to make conductive polymers. They just made a mistake in the lab, and they were working with polyacetylene. And, typically, the way you make polyacetylene-- it actually comes from an oxy-acetylene torch, I don't know if anybody's played with one of those things. It's used a lot in welding, and a lot of soot is created, a lot of black soot. And what comes out of this is polymers as black polyacetylene.

And when they were trying to prepare this stuff, it got really shiny. And they were surprised at this because usually soot is not very shiny. And they tested, and it turns out it was very conductive. And they found the way that they prepared this-- technically, called by doping-- they could actually change the conductivity all the way from being insulating through semiconductors into being metallic-like just through this process.

And so that's kind of pretty cool because now just by changing the way that you make this polymer, you can make it an insulator. You can make it a semiconductor, or you can make it a metal. And then you can make any type of device you want. So the way it works really is actually the second bond between two carbon atoms. That's the key to how these things become conductive or metallic-like.

So here's two carbon atoms. Here's the nuclei, the red nuclei there. And like I said, the first bond-- the electrons-- they're stuck between those two atoms. They can't actually go anywhere, and they're stuck right there.

The second bond though-- it's called a pi bond. Actually, there's already an electron here. So they have to exist over here or down here. And so now there's basically nothing to stop them if there is a chain of these things to keep marching down the line here. And that's exactly what you see in this line.

Every other one of these bonds is a second bond. And in this sketch, you can kind of see here's those sigma bonds that are trapped. And then here are these what they call pi bonds, the second bond. And that actually can hop along this chain. So now you have basically molecular little wires that can transport electrons down the line and you can use for your electronics.

So that was pretty cool. And on top of that, we can tune those properties. Like I said, we can go from an insulator to a semiconductor. We can do a conductor, but we can also change its optical properties this way. We can change how it's sensitive to light, how it emits lights, and all that sort of thing by changing kind of the organic chemistry of how these molecules are constructed together.

So for example, we can connect them into ring structures. We can use other atoms like oxygen and nitrogen and really completely fine tune the properties of these molecules and basically tune them to exactly the types of devices we want. So, currently, the kind of way that our technology works is it basically involves certain elements in the periodic table. So, mainly, most of the technology that makes your computers or cell phone work is silicon.

And then we add to it a little bit maybe of copper, and we add to it some gold contacts, some things like that. But we're really kind of stuck with whatever properties that silicon has. And so that doesn't give us a lot of tunability. And so silicon can do some things really great like maybe do a calculation in the calculator on your computer. But it's not good at other things.

It's not great at necessarily emitting light or absorbing light, for example. And so it doesn't have that tunability. Now with the ability to basically change the molecular structure of these molecules, we have the capability to tune whatever property that we want to be the best at that thing that it's going to do. And so that really has led to a real explosion in the research in terms of how to control this new capability to make materials with whatever properties that we want or need.

So it sounds really great, but there are a lot of challenges that have come up to make this possible. One of them is that their properties are not just dependent on the way that these atoms are bonded together into molecules. It's also how they organize at the molecular level next to each other. And so it turns out their properties are really dependent on their nanostructure.

And what that really means-- a nanometer is like a billionth of a meter. It's really small, but it's basically the size of these molecules. And so the structure that occurs when these molecules, say these stringy polymer molecules-- maybe there's like other molecules that are spherical or something like that. They're typically called fullerenes. I won't really get into them. But they can organize differently like mixing.

They can crystallize into nice packed regions. The way that they kind of make and generate these structures on the molecular level really also impacts their properties, and that's something a chemist can't control. So a chemist is more focused on making a ring structure like a benzene ring structure. And so here we come in as physicists and try to like see how can we control these nanostructures and how does that affect their properties too. And so, basically, teaming together between chemists, and physicists, and engineers, we kind of learn how to control these properties and are learning how to control them in a way that we can put them into products so that they have devices that are actually better than the ones that you currently have today.

Some of the challenges, though, are in measuring this nanostructure. First of all, these materials are really delicate. You can think of biological materials, which are also carbon based, also polymers. We typically look at the nanostructure of the chips and devices in your computers through electron microscopies, and X-ray diffraction, and things like this, which are fine for those types of materials for like gold materials or silicone.

But they really basically obliterates organic matter. And so really it's hard-- this is a real challenge of measuring the nanostructure of these molecules and how they organize. They also don't like to be crystals. So if you think of all the technology that you have today, all the atoms look like this. They're all kind of in this nice pattern.

That's what we call a crystal. Molecular organic materials don't do that. They look very fundamentally different. And so the challenge really is to understand how nanostructure can affect the properties, as well as what about this nanostructure is important. I mean, it looks like a mess, right?

So the question becomes what is important about the way that those things are organized that give us the properties that we want? And so kind of just as a side effect, what we do in our lab is to use novel kind of resonant X-ray techniques with these molecules. Basically, the X-rays come in, and they resonate with the molecules. And we can actually tell one from another, how they're oriented, how they're organized, and stuff like that. And so we look at how the nanostructure, therefore, is going to affect their properties-- more on that a little bit later though.

So let's review here a little bit in terms of what are the opportunities for organic electronics. We know that they're flexible. These material in general are flexible. So that's one possible opportunity that is different than our current technology, which is, of course, based on rigid materials. They're printable, so something to the likes of cheap manufacturing.

Right now, the way that they make any of these devices and the reason why your cell phone costs $1,000 is because it literally costs a lot of money to produce one tiny little chip. They have to basically put silicon and melt it done in these giant kilns that go to about 4,000 degrees. And then they have to do everything in a clean room environment, the bunny suits that you see from Intel and IBM. Nothing like this where you can just stick it on your desk and print something out. And so this is a potential advantage of these materials that really dwarf what we currently can do with our technology.

Another aspect is that they're earth abundant. So right now the key elements that make our technology work basically reside in these elements down here. These are the lanthanides and actinides on the periodic table. Those are called rare earth elements because there's very little of those elements on the planet. And worse even is almost all of them are found only in China.

And so the only way to be able to make your iPhone or your laptop is actually to mine something in China and have it shipped over here. And so that's another aspect of not strategically having enough access to these materials. So we want to get away from that and instead go to something like this range of the area the periodic table with carbon, nitrogen, and, oxygen, those types of elements where basically that's just everywhere, and we don't have to worry about a supply chain issue. And, finally, they're biocompatible.

So they're made out of the same materials, and they're polymers. We're made out of polymers. There's some potential advantages there also in terms of what technologies you might create from this. And so really what we want to try to answer here today is really what's possible. We have this type of material that has these qualities.

How could that change society? So the first thing I would talk about is basically how what kind of technologies in general could we see from these materials that could actually change our daily lives. So coming up with these organic electronics, what could we make from them that could replace some of what you have today? So does anybody know? There's actually some products out there made from these small molecules, these organic molecules.

Anybody know of any products that have these types of devices in them? None? All right, how about the iPhone? The new iPhone has these molecules in them. The screen of the X or the next generation iPhones-- those all went to what's called OLED screens.

They're actually manufactured by Samsung. So Samsung's had them in their phones for a while or LG-- I think they also make them. They have all their TVs, the their big screen-- now they have curved TVs, and that's only made possible because of the flexible capabilities of these displays from the molecules themselves. So they're are coming into the industry. In fact, they're already a multibillion dollar industry for a number of reasons.

One is that they're simpler than the old LCD screens. The way that they used to work was in fact-- actually, my iPhone currently works where you have basically a white backlighting. And then you have several layers of filters. You have to get just the red colors, the green colors, and the blue colors, RGB. They have to have a red filter, or a green filter, and a blue color subtracting out those lights so that you have just red, green, and blue pixels.

And then they have a bunch of different filters here to improve upon that until you get out here. So you're subtracting off all the white light from the back, whereas on an OLED screen, it actually just has red pixels, blue pixels like little LEDs that are red, that are blue, or green. And just there's no filters. There's no subtraction of the light in order to get the screen that you want.

And so they're simpler. They're thinner. They actually have better color because you're not just subtracting all the colors with filters. You're just producing red, green, and blue. They can actually be turned completely off to give you really good black pixels.

So when an LCD screen or powered by an LED in the back, to give you black, they have little shutters that close off the red pixel, the green filter, and the blue filter and try to just mask all that white light that's behind it. Well, all of that stuff still bleeds through. You can only shutter off the light so well. And so you end up with kind of a gray background when you're trying to get black, whereas these can completely turn off and give you much deeper blacks.

And, of course, that also saves energy because you can just turn off the LED. Here you actually don't save any light by showing a black picture because you always have your white lamp on behind it. OK, so that's pretty cool. That's what we're using. That's what we're going to already.

But there are still issues with this. First of all, it's very expensive. Again, the new iPhones are $1,000 or more, and they're rigid. So these aren't flexible or anything like that. So what's going on with that?

Well, firstly, there's still kind of made in the traditional old school fabrication methods where you have these big high temperature things and special clean room fabs. They even have big huge chambers where they suck out all the air from it, the big vacuum chambers where they have to make these in. It's really hard to make. What we're working on now is trying to switch to processing with inks, so making these screens in a principal way that will give you the flexibility and keep it inexpensive.

So one of the things that we're doing in our lab is trying to simplify the process further and, again, try and understand how we can print these devices. So here's a zoom in of one of your displays. OK, if you really look closely into it, you would actually see individual red, green, and blue pixels here rather than a color. And so when all three of them are on, you eye mixes them together and you see white.

But if you want a red-- this R, of course, is going to look red-- you just turn off the green and the blue pixels. But it turns out for every single pixel, you have to have several sub pixels, and you have to have a whole bunch of electronics below each of those in order to control each individual red, green, and blue pixels. And so it's still fairly complicated even for the new displays. So what we thought is, well, can you make a pixel that itself just can emit any color you want, rather than having separate pixels for each little bit of screen that you have?

And that would potentially actually reduce the complexity of these things. On top of that, can you make these from an ink? Can you basically print these things? And so what we thought of is to try to look at maybe if we mix a blue emitter polymer molecule and a green emitter and we print them from inks-- this is a first step to maybe simplifying the process and making these things a little bit cheaper.

So these are kind of nice molecules here. I won't get into the details of the molecules, but, basically, it turns out this F8 molecule emits a blue color. And the BT molecule we know emits green. Can we mix them together in a way that we can use a voltage signal to control which one's emitting? And so what we did as we basically have this kind of blade coating ink process, which is basically how a lot of the manufacturers use to print stuff.

And we make our own devices. So here we have basically-- the pink area is one electrode, is the first electrode. The second electrode is this white L-shaped thing. And where they cross together, they're going to emit light. And so we're going to have basically four pixels on here.

It's pretty simple. We're a pretty fundamental lab, but we still can make our own devices and test them. And so what we found is that we could actually successfully do this. And what's really interesting as they were-- the people who did this were actually undergraduates. This is Keith Hillaire who graduated two springs ago, and Zack Croft, who graduated last spring.

Both of them worked on this project and series. Keith's now in grad school at NC State University. And Zack's at Berkeley National Lab as a graduate student. And basically what they did is we mixed these things together, and we find that we can make these nanocrystals of the blue emitter surrounded by the green emitter. And without going too much into details, we could control which one was emitting through the voltage.

And the way we did this was through electroluminescent spectroscopy. So what you're doing here is you have your LED here, and you hook it up to a voltage source. And so it starts to emit some light, but you want to quantify what color is in the light. So you let that come through into a spectrometer. It's basically got a little prism in there.

It spreads out the light onto a CCD. And then you can measure which colors are being emitted in a quantitative fashion, but you don't really need that to see if a pixels blue or green. And so we are able to just use a simple webcam to show that as you change the voltage signal on your LED, you can go from a blue LED to a green one. And so this is kind of cool because, again, these are printed from an ink. They're one pixel that can make at least two different colors.

It's working on getting them to produce red as well. But that's kind of a start. So here's I guess quantifying a little bit more with this setup. We can basically go from 1 to 4 basically-- one being basically all green and 4 being all blue just to quantify how much is blue and green, but that's kind of cool.

And the cool thing here is that undergraduates did this. This is physics majors in my lab. OK, so where are we going with this. It's a principal. We want to get to flexible.

What is out there? What's coming up next because we already have the iPhone having these? So we want to look for basically in the next couple of years lighting that's flexible. These are kind of the prototype OLED displays that are coming out now that are foldable or flexible. They're already in prototypes.

We're still working on getting them be printable, so there's still a little bit pricey the way that they're making them. But that's coming out. Even sooner actually are going to be organic radio frequency ID tags, RFID tags. Basically, the way these work-- and we already have them. But, basically, now what you can do is you can print these out into sticker form.

And what's going to happen is they pass through maybe kind of like a metal detector, and the information gets read from them. And you don't have to really scan them. OK, so already there's prototypes out there putting these stickers-- you can barely see it-- on avocado. And how this might impact your life is that they all have them on the product, and then you don't have to check out anymore at the grocery store.

You just have to walk through this little measurement reader, and it just charges your account, and you're gone. Some of this is actually already happening. I'll see if I can make this happen here.

[VIDEO PLAYBACK]

[MUSIC PLAYING]

BRIAN COLLINS: This is happening. I think [INAUDIBLE].

- In order to use this checkout system, you need to use this special basket. All you need to do is put in the items that you marked. Each item is affixed with an RFID tag.

BRIAN COLLINS: I'll try to see right now.

- And this RFID tag is the key to this checkout system.

[MUSIC PLAYING]

Now we place the basket in the robotic checkout system. The bottom of the basket opens, and the items go down below. There, the items are placed into a plastic bag. And the RFID tags are read. The total is displayed here. All that's left is to pay.

[MUSIC PLAYING]

BRIAN COLLINS: So that's kind of the first example.

- Your items are ready.

[MUSIC PLAYING]

[END PLAYBACK]

BRIAN COLLINS: And this video was put out by IBM a little bit ago.

[VIDEO PLAYBACK]

BRIAN COLLINS: Is their vision of how this could eventually happen with printable RFID tags.

[MUSIC PLAYING]

- Excuse me, sir.

[MUSIC PLAYING]

Forgot your receipt.

- Checkout lines-- who needs them?

BRIAN COLLINS: So that's coming around next couple years.

- This is the future of e-business.

[END PLAYBACK]

BRIAN COLLINS: What time we got? All right, so where else this is going? A little bit further into the future, there's already a lot of these like I showed you-- this flexible display. They're working on prototypes of what could be coming out in the future. These are kind of examples of-- I don't know if you've ever had those slap bracelets.

They were big when I was growing up. With the idea of converting that, basically combining of a cell phone with a smartwatch where you have your touch screen kind of as an arm band-- and when you want a cell phone, you just pull it off. And you have a little bit more rigid cell phone there. It's just one device. And so those are some of the things that are coming down the pipeline with these.

Military is very interested in incorporating these devices into textiles and uniforms, for example, to help to diagnose if you get shot, like what happened, and even have cameras worked into this clothing, and eventually even putting these things in contact lenses in terms of augmented reality, so you think of as the next gen Google glasses where the electronics are all embedded into the contact lens. And, therefore, whatever you see kind of pops up information about something like where you see it with the cell phones where they have information popping up about the restaurants and reviews of that or even just for military purposes like what are their IDs and if they're felons or something like that. So that's what's kind of further into the future there.

And I want to switch gears from tech into energy here to see how it might impact that. And so think of this as clean energy is kind of coming about. It's getting cheaper, and, potentially, we'll see it kind of overcoming fossil fuels in your future. But the real question is could solar power actually provide all the electricity that we need? OK, so that's a real question because from a solar panel, you're not going to get nearly as much energy as you do from a natural gas power plant or a coal fire power plant for sure on the individual basis.

However, you do a little bit of calculation, and people have. It turns out that to power the entire country, the US right now, you'd basically need panels that are about 100 by 100 miles, and that translates to about 10K or 10,000 square miles of panel total. So to look at that in terms of how big that is, that's about right there. So it's a corner of a state.

But, basically, if you made a solar panel something like that size or equivalence if you added up all the solar panels, that would be enough to power the entire country just off of solar. And if you think about how we use our land currently, we actually have more than that, about four times that land use currently owned or leased by oil and gas companies right now. In fact, most of that land is not even used because it's mainly just so they have the rights to it so they can drill for their oil, and most of it is open land. Also, for example, the amount of land set aside just to grow corn for ethanol right now is about three times that amount of land.

And, for example, also the Mojave Desert itself is about twice that needed land area. So, sure, it sounds like we got this solved, right? Well, unfortunately, there's a lot of problems that we still need-- it's not just area. OK so, first of all, the first biggest hurdle is cost and speed of production of solar panels. So, like I said, these are based on silicon.

It takes a lot of time, money, and energy to make each individual cell, and then all have to be wired together into these panels and then installed. Everything is very expensive and slow. In fact, we don't have enough infrastructure to actually even service that size of a solar panel. To even replace the ones that break-- eventually, they do-- we don't even have enough production capabilities to make the ones that would replace them, let alone make the entire one in the first place.

Another problem is distribution and storage. We couldn't make them all in one spot because if we do, we have a lot of losses trying to transmit all that power to everybody who's using it. On top of that, we have to use it right when we make it. We don't have any capacity to store power in our current power grid. As soon as it's made, it's got to be used.

In fact, if we don't, then all those nice power stations basically explode. So you have to be careful about how you're making the power and when you're using it. And solar energy is not very good at that. OK, so there are these four main kind of drawbacks, or difficulties, or problems that we have to overcome if we want to see solar power get up there.

So, first of all, what about this distribution problem? So we currently have this distribution problem even now with the type of power that we have. So we have basically a few major centralized hubs that control all the power grid in our country. And, first of all, we have a lot of distribution losses. So we lose a lot of the power that we make just by transporting it.

And, secondly, all of these, again, have to be just fine tuned. So they're producing power just the right moment when somebody is using the power. And if that doesn't happen, you have brownouts, blackouts. You have, again, some of these power surges that kind of blow out some of the transfer stations. And all that is very finely tuned via the internet currently.

So all the power grid is basically controlled through the same internet that you get YouTube on, the same internet that you get your malware on, and everything like that. It's all open for possible attacks and is really quite dangerous. So one way around that is to decentralize the production of power. And one way to do that is simply to have basically home power grown from the solar panels in your home. And so people have been trying to do this as a proof of principle.

There's plenty of roof area in fact already in the country to come up with that area that we talked about, the 10,000 mile square area. We also have this issue of storage. And there's now battery technology that's been improving to help this to store when we're producing it and then wait for us to use it. And on this scale, this is something that is doable, whereas on a national scale, we don't have any capacity to build batteries of that size or scale to do it at say a megawatt type of storage.

The problem still though is that the production is way too slow and too expensive. Like I said, you don't have enough materials or infrastructure to make enough panels to actually allow us to power any amount of the electrical grid. So we really need something that's basically massively scalable sort of solar power to go, something from this. We're making one cell at a time with a lot of energy to something that's more massively scalable like principal organic solar cells. So can we go from something like this to something like this where we're making the sheer huge amounts of area of these panels?

And to think about the answer to that, we can see how basically we make that amount of plastic material all the time. Every year Saran company, Saran wrap-- we make about a third of what we would need to make one of these solar power facilities just every year. And that's just Saran. I mean, there's all these knockoff brands, who probably make five times as much of this stuff. It's just clogging up everything.

So there's already companies kind of going with this idea. There's a company called Heliatek. There's infinityPV where they basically use the same ideas as you might use for a printing press to go through and just print off huge areas of solar panels, and they're all completely flexible. You can see a larger grid made out here. And, in fact, they're extremely cheap.

Not this company, but another called infinityPV-- they sell some of these demonstrator panels, so I have one here that I bought. Basically, it's just like a little film that they print off on something like a printing press. In fact, the first ones were made out of old Kodak company buildings, where they still had those film press. They just converted them to make these things. And so the cool thing here is that they send these things with a postcard stamp postage.

They don't even package these things because the postcard postage costs more to send it than it costs to make this solar panel. And so, basically, you can go out in the sun and put leads on this. And you get like six volts off of it and a couple watts. And I'll just pass this through. Here, why don't you take that and kind of check it out? Hopefully, it gets through everybody.

So they're on production. They're scaling up, and this is definitely something that's possible. One drawback right now is we're only at about half the efficiency that we need on these things. So these only generate about half the power that we would need to actually make these things feasible. So really there's still some R&D that needs to go into these things to understand this.

And that's what we work on in the Collins Lab. We make our own kind of organic solar cells, similar process. We're ink coating these things and making these devices. They look fairly similar to the LEDs because, of course, the LEDs run in reverse honestly. You put in a light, and you get out power, instead of you putting in power and getting out light.

We look at them with a variety of optical tests and measurements in our lab. And then we measure how charges are made from the light and how they're made and molecular interfaces. We look at kind of the quantum states that occurred to make these things, and we've watched them happen at these interfaces between polymers of different types. And I don't want to go into much detail here and stay kind of aspirational. But, essentially, a lot of these, again, are done by undergraduates.

So this is Kyle Norbert and Jacob Hastings in my lab, who do these experiments currently actually. I'm going to skip this for time. We do this with a really powerful X-ray machines called synchrotron. It's pretty neat. X-rays are important because they are able to probe atoms and molecules.

We've gotten a lot of great results from them, but I'm going to skip that to kind of keep on time here. So, yeah, in other words, disruptive kind of power generation from solar panels is really coming soon. Currently, we have the cost of fossil fuel power is about $0.12 per kilowatt hour. That's about how much you're charged at the electric meter. The idea is that these panels are so cheap that they would be able to produce this power for far less than what that they currently can produce it for.

And so here's an example of a silicon-based ones. It used to be $76 per kilowatt hour just to do silicon. We've gotten that down about $0.30. That's still about three times the cost of producing power from fossil fuels. So we have a ways to go, but the idea is if we can get these efficiencies up to the similar efficiencies-- 18% efficient is what silicon PV is.

These things cost basically 100 times less to produce. And we are getting up there. So this is a kind of record research cells over the years. And we're getting them to starting at 2% efficient now to 14.2%, so it's getting close to that kind of point where they start to actually be able to be used. And, in fact, in Europe where power is a little bit more expensive, they already are cheaper than fossil fuels.

And so a lot of these printed solar panels are now being placed on rooftops in Europe. Another idea that people are working on are smart windows. So here's the solar spectrum. And you can divide it kind of into three sections. You got UV, visible, and infrared sections.

And for windows, all you need to see through is the visible section. You actually don't want the UV. That's the stuff that gives you skin cancer or whatever. And infrared actually is literally heat. So when you feel heat from the sun, what you're really feeling is infrared light.

And so we don't really want that coming through because that heats up these buildings, which are mostly windows anyway. And you have to use a lot of energy to cool the building then because of that. And so what people are actually working also are solar panels that just absorb in the UV and the infrared but are clear in the visible. And here's some prototypes of that where you actually have solar panels coating the windows, and the only way you can really do this is through these kind of flexible printing processes, but they are semi-transparent or fully transparent.

And, in fact, some of the technology is going into trying to learn how to switch them to be opaque or transparent even in the visible, allowing you to basically have these smart windows where you can basically close the window with a switch by making it opaque. It's self-powered because it's powered by the UV light or the infrared light. At the same time, it blocks all the heat coming into the building so you don't have to cool it in the first place. So these are some of the ideas people are working on a little bit further down into the future. I'm going to skip this for time so we can get out of here pretty soon.

And I'm going to skip this little bit. This is talking about basically the issue of storage. You make most of your power in the middle of the day when we don't use it. There is morning and evening demand. And you have to somehow find a way to store this.

Currently, the batteries are very expensive and actually, in fact, pretty dangerous. Lithium ion batteries are nice, but they also tend to explode and catch fire, so that's not so great. So if we could go to kind of polymer-based printable batteries, that would save a lot of our headaches. And, in fact, the Katie Zhong Group at WSU is really a big group at the forefront there. They actually have been making batteries from soy-based polymers.

And you can see kind of a sticky gummy material that actually performs just as well as our lithium technology today. However, they don't have this runaway explosion problem. And so The Economist was pretty excited about this. And they did a piece on her group. So a lot of work done here is very relevant to these organic electronics.

And the final thing that I want to kind of touch on and mention before the end here is how it might affect medicine. So a couple of years ago this was demonstrated that they could actually-- this guy-- he had a back injury and was paralyzed in his arm. And what they did was they put electrodes in his brain to measure neurons firing, and that converted that signal for a computer. The computer interpreted it, and then they had another electrode into his arm that connected to the neurons in his arm that told his muscles to flex. And, actually, they got it to the point where just by thinking about what he wanted to do he could actually control his fingers again.

And so this was a demonstration of him actually playing Guitar Hero even though he was paralyzed within that arm. So this is pretty cool. There's a nice quote of him of just the amazing stuff that happened there. And the way that that works is-- well, nerves don't really use electrons to do stuff. They use ions like potassium ions, sodium ions.

They tell you to eat your bananas. But computers, of course, use electrons. So we have to make a way to make the ion signals from neurons converting electrons. And that's really the fundamental challenge in doing this.

So what people have been trying to do are make these brain sensors to sense when neurons are firing and then to actually convert that into a signal that a computer can measure. The problem here is that it's very invasive. They use these grids of sharp needles, metal needles to get the measurement from the neurons. And it's also temporary. So what this guy could do is not actually permanent because eventually your body rejects it.

Bio rejection is a big problem with these types of things. Eventually, your body develops scar tissue around these electrodes, and they become useless again. And so this is only currently a temporary possible solution. However, with organic materials, this is not a problem. This is actually something that's biocompatible.

It's already been shown by a colleague of mine that they are more sensitive than inorganic gold-based kind of electrodes. So this is an example of polymer electrode signals. All these spikes are neuron-action potentials firing and the same thing happening with the gold electrodes, which clearly have much less signal. They're also less invasive because of the fact that they can be put on the surface, rather than being shoved as needles into the brain. And there's also not this issue of bio rejection.

So they could also potentially become permanent. So we've been working on that with this group here to establish how the different nanostructures of these are able to control the electron and ion type of motion. The questions of where do ions and electrons go and move in a polymer matrix and how to optimize that interaction is something that we've been focusing on. So hopefully in the future, we might be able to see-- actually, people are, in fact, working on synthetic skin, which actually can have sensing capabilities to actually end up with prosthetics that you could actually connect back to the brain and have the sense of feel on top of the motor capabilities of these prosthetics. And, eventually, who knows?

Maybe we'll eventually have actual androids that look and feel like real humans. So just to summarize, I hope this has been enlightening to you. Organic electronic materials are really, I think, a future technology that's really going to happen in the next few years. It's already been projected to be an $80 billion industry through 2020. And so there's a lot of possible ways it could change our lives.

Work is currently being done by undergraduate students at WSU. And there is other possible ways that you could go with this too. It's not just all the things that one could envision in terms of controlling bio molecules and the like too with these things. So, anyway, thanks for your attention, and I'm happy to answer any questions you might have.

[APPLAUSE]

KAREN WEATHERMON: [INAUDIBLE] have you stay and ask Dr. Collins [INAUDIBLE].

[MUSIC PLAYING]