CAREERS

TURNING POINT Vision researcher earns European research award **p.559**

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COVEME

Thin-film microprocessors made from organic semiconductors could lower costs.

ELECTRONICS

Organic growth

The multifaceted field of carbon-based electronics offers options for researchers from all areas of the physical sciences.

BY NEIL SAVAGE

When Sebastian Reineke sought a postdoctoral position in organic electronics, the field offered what many science and technology graduates covet: choices. He could have marketed his skills in improving the efficiency of organic light-emitting diodes (OLEDs) and solar cells to a big manufacturer of displays, such as LG in Seoul or Toshiba in Tokyo; a lighting company, such as Philips in Amsterdam; or any number of smaller companies or university labs around the world.

Reineke, who did a PhD in physics at the Institute of Applied Photophysics at the Technical University of Dresden in Germany, prefers academic to industrial research and hopes to tackle some fundamental questions about organic electronic devices. He ended up doing his postdoc in a soft-semiconductor group at the Massachusetts Institute of Technology in Cambridge, where he is working on two of the main research areas for organic electronics — improving OLEDs to the point at which they can be used to light homes and offices, and developing organic photovoltaic devices, which can be manufactured at a fraction of the cost of standard silicon solar panels.

"I really like understanding the photophysics and how it behaves," says Reineke. But there is an added bonus to building tangible devices that produce light or electricity, rather than working on chemical formulae or nanotechnology. "You do something that you can show to your parents and your grandparents," he says, adding that seeing one's research efforts culminate in a product is "really cool".

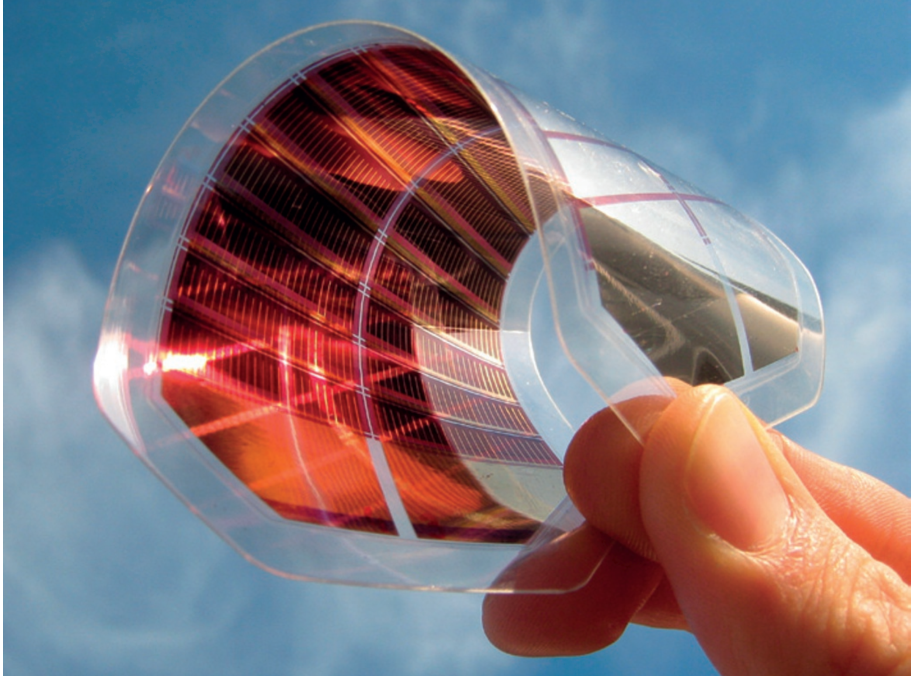
Researchers in organic electronics deal with carbon-based polymers and small molecules, and seek to replicate the functionality of inorganic semiconductors, and develop innovative devices. The field's first success was in OLEDs for displays, used in smart phones. It is now moving into large-screen televisions, led by DuPont in Wilmington, Delaware, which announced on 2 November that it has licensed its active-matrix OLED technology to an unnamed Asian manufacturer.

Within a few years, OLEDs may also penetrate the lighting market, as one of the technologies vying to replace the inefficient incandescent bulbs being phased out in the United States and the European Union, among other places. OLEDs not only use less energy, but also offer intriguing ways to illuminate buildings, with wall-sized fixtures or tunable colours.

Less far advanced are organic solar cells, which are printable, flexible, and cheap; and better batteries for electric vehicles and renewable-energy storage. Also on the horizon are flexible circuits printed on plastic or textiles, bendable batteries and sensors that bridge the divide between the inorganic and the biological, monitoring for pollution or food pathogens, for example. Organic electronics may also one day enable cheaper radio-frequency identification tags, or innovative thin-film transistors for touch screens. Governments are funding research into the field, enticed by the environmental benefits.

VARIED EXPERIENCE

Researchers come from a variety of backgrounds: chemical and electrical engineering, materials science, physics and chemistry. They develop and synthesize materials that have desirable optical and electrical properties — such as emitting or absorbing light at desired wavelengths, carrying current efficiently or operating at appropriate voltages. Researchers also design ways of using those materials in practical devices, and develop ▶


OE-A

Flexible organic photovoltaic cells will be cheaper and more environmentally friendly than silicon ones.

manufacturing methods. The materials have to be made reliably — organics are notorious for having their properties altered by contamination. And production processes have to take into account the specifics of the materials and keep costs down.

"There are fantastic physics and materials-science questions in the field," says Stephen Forrest, director of the optoelectronic components and materials group at the University of Michigan in Ann Arbor. And addressing those questions requires a diverse set of skills. Forrest insists that researchers who join his group with expertise in one area of science must have at least a passing knowledge of the other fields involved; and they should know how to build devices and analyse them from a basic physics viewpoint. "If you're a chemical engineer, it helps you if you know the physics of charge transport, say, or how a transistor works," he says. "You don't have to be an expert in everything, but you have to know about it."

Researchers often have multidisciplinary backgrounds. Noel Giebink, who is taking up an electrical-engineering post at Pennsylvania State University in University Park, has undergraduate degrees in physics and engineering science. After a PhD in electrical engineering at Princeton University in New Jersey, he "sort of fell into organic electronics" while working on photovoltaics. He is interested in increasing efficiency by combining the light-manipulating properties of some organics with the electrical properties of inorganic semiconductors, perhaps using organic materials to capture photons and convert them to wavelengths that a silicon solar cell can handle.


PNNL

"One of the enduring challenges of our generation will be how we use energy to power our society."
Dan Gaspar

Even self-teaching can provide useful background. Henning Sirringhaus, head of microelectronics and optoelectronics at the University of Cambridge, UK, trained as a semiconductor physicist. One of the first things he did when he moved into organic electronics, he says, was to buy a chemistry textbook "just to learn the language". Reineke, as a physicist, also finds it challenging to speak to chemists. When asking them to synthesize an unfamiliar molecule, "it's not just that you say, 'I need another red OLED. Please make me a red dye'", he says. He has to specify a variety of parameters, such as electrical conductance and charge transport.

But there are opportunities for researchers who can overcome such challenges, says Sirringhaus. "People who are able to combine experience in manufacturing inorganic materials with a know-how or an understanding of organic materials, those would be the people to hire," he says. "There are not many of them."

Jobseekers in other sectors may have at least some of the requisite skills. Julie Brown, chief technical officer of Universal Display in Ewing, New Jersey, has found herself trying to lure synthetic chemists away from the pharmaceutical industry, because of their experience with organic chemistry. To interest them in her company, which has concentrated on OLEDs for displays but is now tackling lighting, she has to overcome misconceptions about the field. "They hear 'organic electronics' and they think they have to be engineers", but that isn't true, she says. "They need to be able to be interested in talking to engineers."

TARGETED TRAINING

This need for an in-depth, broad skill set has inspired an interdisciplinary master's degree programme in molecular and organic electronics at the Technical University of Dresden, to start in autumn 2012. Karl Leo, an optoelectronics researcher at the university, believes that it is the first such course. The programme will be offered in English and will be available to international students, although Leo isn't yet sure how many places there will be. The plan is to cover solid-state and semiconductor physics; techniques for depositing films of organic materials, such as the layers of an OLED or a coating on a solar cell; how to measure the physical properties of materials, such as strength or electrical conductance; and modelling the function of a device such as an OLED.

The Organic and Printed Electronics Association (OE-A), an international industry group based in Frankfurt, Germany, has a working group on education that is also pushing the idea of bringing together different academic disciplines under the heading of organic electronics. It has been developing a template for master's programmes. "What the industry needs is people with a broad knowledge in chemistry, in printing, in engineering, in electronics," says Klaus Hecker, managing director of the OE-A.

Environmentalism motivates many researchers. "One of the enduring challenges of our generation and the generation to come will be how we use energy to power our society and have a limited impact on our environment, on the place where we live," says Dan Gaspar, who works on OLED lighting at the Pacific Northwest National Laboratory in Richland, Washington. A switch to OLEDs and inorganic light-emitting diodes could cut US demand for electricity used in lighting by 25%, according to the US Department of Energy (DOE). Likewise, cheaper photovoltaics could encourage the use of solar energy, reducing demand for oil and emissions of greenhouse gases. And Sirringhaus points out that organic materials, unlike some inorganic semiconductors, don't generally contain elements that are toxic or require mining in remote areas. "There are not really any environmental issues from a materials perspective," he says.

RAMPING UP

The lure of energy-efficient and renewable technologies has spurred various government-funded initiatives. The European Commission (EC) supports such work, and countries such as Germany, the Netherlands, France, Finland and the United Kingdom all have large national research programmes in lighting and photovoltaics. Last month, IMEC, a nanotechnology-research company in Leuven, Belgium, launched X10D, a three-year, €11.9-million (US$16.1-million) international research programme to develop organic solar cells that produce electricity at less than €0.70 per watt. The company has also begun a three-year, €5.12-million programme to design large, power-adjustable OLED lighting tiles. The EC is providing about two-thirds of the funding for both projects. Overall, the EC is spending more than €270 million on 90 research projects covering organic electronics and photonics.

In the United States, the National Science Foundation (NSF) and the DOE fund research into lighting and cheaper photovoltaics. For instance, the NSF this year made a three-year, $1.25-million grant to the University of Denver in Colorado and the University of Colorado at Boulder to study innovative materials for organic photovoltaics. Much of the DOE's funding goes through its laboratories, in particular the National Renewable Energy Laboratory in Golden, Colorado, and Oak Ridge National Laboratory in Tennessee, which administers DOE postdoc fellowships. The department is also running the SunShot Initiative, which has budgeted $457 million to cut the cost of solar cells by 75% within ten years — researchers are looking at all photovoltaic technologies, including organics. SunShot offers two-year fellowships, based in Washington DC, with rolling application deadlines.

Industrial efforts are also generating job opportunities. Philips, for instance, announced this year that it would spend €40 million to expand its pilot production line in Aachen, Germany, to make OLEDs for lighting under the brand name Lumiblade. Dietmar Thomas, a spokesman for Lumiblade, says that the company will start mass production by the end of next year, and expects OLEDs to penetrate household lighting within two or three years. Thomas says that the company plans to hire researchers in Aachen, as well as others to study OLED production processes at its research centre in Eindhoven, the Netherlands. "We are really talking about a huge group of people that we are going to get into the company," says Thomas, although he declines to provide specific numbers.

Scientists have also been starting their own companies for years. Sirringhaus and his colleagues, for instance, founded Plastic Logic in Mountain View, California, which makes an e-reader based on flexible electronics, and Eight19 in Cambridge, UK, which is developing printed plastic solar cells. Forrest has been involved with several start-ups, including Universal Display. He says that the field is rich enough for budding entrepreneurs to follow the path that fits them best, from striking off on their own to spinning out technologies developed in university labs.

The same goes for the field as a whole, says Giebink: researchers are constantly creating molecules with properties to be deciphered, and seeking applications for them. "It's a great place to be," he says, "if you're curious, if you're motivated to explore things and if you like to tinker." ■

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TURNING POINT
John Nolan

John Nolan, a vision scientist at Waterford Institute of Technology in Ireland, was awarded a €1.5-million (US$2-million), five-year starting grant by the European Research Council (ERC) in September — a first for a researcher from an institute of technology.

S. O'NEILL

Describe your PhD experience.
I graduated from Waterford Institute of Technology in 2002 and applied to do a PhD there, looking for links between nutrition and age-related macular degeneration, the leading cause of blindness. I was also interested in conducting population studies that might help us to understand what makes someone fit or healthy. At the time, Ireland's economy was quite strong, so it was a big decision to turn down better-paid positions. But it was the right decision. My graduate adviser and I had an exceptional experience — publishing our observations of the link between macular pigment and age-related macular degeneration in more than 800 people in just two years.

What has been your biggest turning point so far?
Without a doubt, it was winning a Fulbright scholarship to spend a year at the Medical College of Georgia in Augusta. It forced me to survive on my own. During that year, I churned out publications on how the shape and architecture of the eye affects performance of the pigment. Once I returned to Ireland, I was appointed as a deputy director of the macular-pigment research group.

How much of a long shot was it to apply for the ERC award?
It is a very prestigious award given for excellence in science. Awardees have to have a track record that shows they are capable of achieving their proposed blue-sky research idea. Typically, no more than 10% of applicants get funding across the whole of Europe. With such a low probability of success, some faculty members at Waterford were concerned that the effort would be for naught.

How did you approach the ERC application?
I promised myself when I started the application that I was going to get it. I proposed a study to find ways to optimize and enrich eye nutrition by dietary means, producing a direct impact on vision in the young normal population — by reducing issues of either glare or bad contrast through diet — and protecting vision in older people. I had to give myself enough time to write and critique the proposal — roughly a year — and prioritize and sacrifice some things. For example, I changed some of the methodology and extended our study to young as well as older people. And I got external experts to assess and be critical of the proposal, which some scientists can find difficult.

You could take the ERC funding anywhere. Why stay at Waterford?
If you have the right ideas, people and expertise, it doesn't matter whether you are at the Massachusetts Institute of Technology or at Waterford. I want to add to what we have achieved here. You always have to keep your options open to change. But for now, I've agreed with the institute to represent them, and I'm very proud to do that.

What's the single best thing you've done to establish your standing in the field?
The one strength that I have is staying focused on what I'm good at. There's always a danger, maybe even a temptation, for scientists to keep moving into different fields. Ideas can get fragmented. I think it's great to collaborate, but sometimes, in big cooperative projects, nobody takes responsibility.

How will you use this money?
My colleagues and I will be able to update our infrastructure, hire five researchers and help to raise the profile of our group, which will be important so that we can continue to bring in funds. The idea is to use all the capital we have to generate a centre of excellence for vision research. Our ultimate goal is to identify ways to prevent blindness resulting from age-related macular degeneration, and to identify ways to optimize vision and visual performance for everyone — perhaps even helping footballers to see the ball better. ■

INTERVIEW BY VIRGINIA GEWIN