INFORMATION TECHNOLOGY

Bernard Kippelen of Georgia Tech, front, holds solar cell (inset). *Photos: Nicole Cappello, Georgia Tech.*

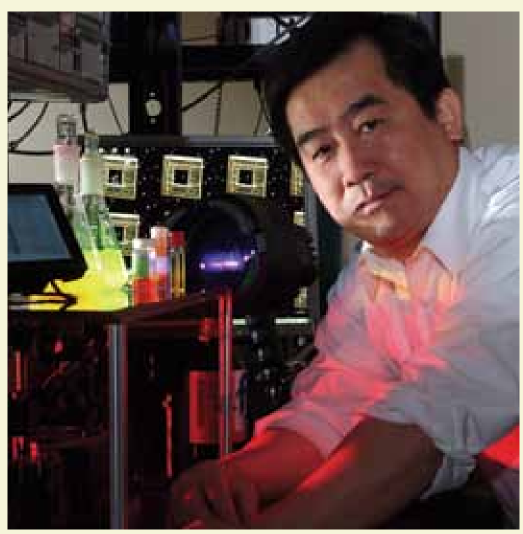
CENTER ON MATERIALS AND DEVICES FOR INFORMATION TECHNOLOGY RESEARCH CMDITR

CENTER HAS ITS "HIGH BEAMS" ON

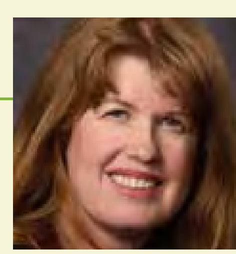
Existing electronic and photonic devices based on inorganic materials such as silicon, gallium arsenide, and lithium niobate are about to "hit the wall"—that is, they are approaching their practical limits in terms of speed, flexibility, and cost.

Researchers at the Center on Materials and Devices for Information Technology Research (CMDITR) are working on organic-materials-based technologies that may provide attractive alternatives to those based on inorganic materials. Outcomes of center research are expected to provide the technological foundation for a thousandfold increase in throughput of telecommunications and information systems.

The center's research program has helped to attract interest from federal agencies, says center researcher Larry Dalton, emeritus professor of chemistry at the University of Washington (UW) and founding director of the center. "NSF-funded technology has produced complementary interest among mission-oriented agencies to focus on translation of basic research into defense applications."



UW Professor Alex Jen; At right: Susan Ermer, Lockheed Martin Corp.



Ultimately, center researchers hope to lay the groundwork for radically new approaches to the design of computers and sensors, with a move to ultrafast "all-optical" technologies and ubiquitous, embedded systems. CMDITR research will be key to the development of next-generation radar and navigation systems that will enhance U.S. defense capabilities, transform transportation, and facilitate space exploration.

Benefits in the energy sector are also targeted, including the commercial deployment of practical, inexpensive, and lightweight solar cells.

The manufacturing operations needed to produce organic-based technologies not only will provide exquisite control of material structure on very small scales, but are also expected to employ manufacturing processes and materials that are safer, cheaper, and more environmentally benign than those employed in the silicon-based semiconductor industry.

One research area, led by Alex Jen, UW professor and Boeing/Johnson Chair of Materials Science and Engineering, concerns electro-optic (E-O) materials, used to convert information between the electronic and photonic (light) domains at ultrahigh speeds. These materials can be used in devices called electro-optic modulators that transform electrical signals into optical signals and back again as signals enter and leave the ends of a fiber-optic cable. If you've made a long-distance telephone call lately, you've likely used electro-optic modulators.

The process involves the fast and efficient manipulation of the refractive index (ability to modulate light) of a material with an applied electric field. Efforts at the center are therefore aimed at developing suitable materials with high E-O activity, a measure of a material's ability to undergo change in its refractive index with an applied field.

CMDITR researchers have developed and tested a class of novel organic materials that achieve an order of magnitude improvement in E-O activity compared to the best inorganic rivals. The new materials also are specially designed to self-assemble into a structure that facilitates fabrication for computing and communication applications, explains Jen, who is director of the UW Institute of Advanced Materials and Technology.

The new high E-O materials offer several advantages: They can be produced in thin films with much smaller size than their inorganic counterparts, offering the possibility of higher density of integration and higher speed and bandwidth for information technology applications. Devices made of these new materials also have the advantage of a lower drive voltage and therefore, lower power consumption.

This research thrust is of keen interest to Susan Ermer of Lockheed Martin, an industrial affiliate of the center since its inception. Ermer works on the research side of the organization—as she puts it, the side required to "have the high beams on."

"We have ongoing projects in the area of electro-optic materials and devices and we know that this center has creative expertise and depth of knowledge and extensive networks. We've got a long-standing interest in this very specific area, but beyond that, we also see that this interdisciplinary group of people who have been brought together in the center are the ones that have the headlights on into the future," she says.

"In industry, you often have many people who have no choice but to be putting out brushfires, and that's what keeps the enterprise going," says Ermer. "As a research site, though, we should be looking to the future, but very frequently we're tied up in day-to-day things. The relationship with the center allows us to have these pioneers scouting out there and we get the benefit of that." □

VIEWPOINT

A CONVERSATION WITH
Phil Reid

When you recently took the helm as center director, what were your main challenges?

After you get your second five years of funding, you start thinking about transitioning things. What's next, how are you going to take the science and the technology you've got going right now and make sure it lives past the end of the center. This has been our strategy all along—basically take the individual components and spin them off to self-sustaining centers in their own right. We have really talented researchers throughout the center who can provide leadership for these spinoffs—it was just a matter of going out and getting those new grants.

One such effort, located at the University of Arizona (UA) is an NSF Engineering Research Center founded in 2008 and led by Nasser Peyghambarian. It's taking the kinds of information technologies we've worked with and turning them into integrated networks–so it's kind of the next level of engineering beyond the individual device. Called the Center for Integrated Access Networks, or CIAN, it aims to create an advanced optical access network capable of delivering data more than a thousand times faster to users at lower cost than they now pay to connect to information data bases and communication networks.

On another front at UA, Neal Armstrong is leading a new Energy Frontier Research Center involved with charge transport and interfacial aspects of photovoltaic systems, again, building on work that was part of the STC. The Center for Interface Science: Hybrid Solar-Electric Materials was established in 2009 with a $15-million grant from the Department of Energy. That research is aimed at "Generation III" photovoltaic materials that are thin, flexible, and inexpensive enough to go in many applications–from rooftops to windows, awnings, even clothing.

As you near graduation from NSF STC support, how do you view the outcomes of the center?

One of the basic ideas the center was founded on was to develop techniques and approaches that allow the rational design of materials; that goal required a significant theoretical undertaking. The theoretical work we've done in order to predict the performance of materials has been substantial. We've realized that accomplishment and the work has been featured on a couple of journal covers–so there is fundamental science that we are definitely very proud of.

We've also seen organic materials come a long way. At the beginning, they had so much promise, but the fact of the matter was that people were not convinced they were robust enough thermally or photochemically to serve in a device over the long term. Just recently, the first organic materials for electro-optic switches met Telecordia standards–the industrial standard that devices have to pass in order to be commercially viable. So we've come all the way from ten years ago, when people were saying, "well, organic materials should be good for these applications, let's give it a shot," to today, with organic materials that are now recognized by the industry as being robust enough to put in applications. That's a pretty substantial accomplishment.

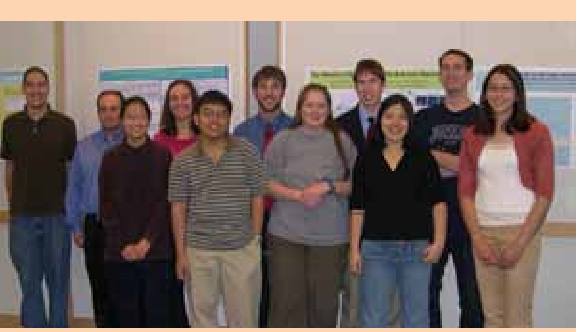
What's next?

You have this conversation about the center sunseting, but I just don't see this as an end; I see it as a new beginning, we're just moving forward. Now instead of just one center doing all these things, we've got centers on our various campuses all going after these activities, and I think the infrastructure we built to pursue nanophotonics and information technologies is really exciting–I see that as "CMDITR 2.0."

NEWS WATCH

HOOKED ON PHOTONICS

The center is trying to promote the interest of undergraduates in research with its program of summer research experiences, called "Hooked on Photonics." The program has a particular focus on lower-division undergraduates from community colleges and small four-year colleges—the so-called "gateway" undergraduates, or students with no exposure to research at their home institutions.



Left: Chemistry professor Phil Reid leads Hooked on Phonics.

OPSIS AIMS TO LOWER THE BARRIER TO MAKING SILICON PHOTONIC CHIPS

The University of Washington (UW) recently launched a program, co-funded by Intel Corp., that aims to make it dramatically easier and cheaper to manufacture silicon chips that combine light and electronics. This program will provide access to high-end semiconductor manufacturing capabilities, enabling any researcher in the world to build integrated electronic-photonic circuits in silicon.

It's called Optoelectronics Systems Integration in Silicon, or OpSIS, and it is hosted by the UW's new Institute for Photonic Integration, led by CMDITR researcher Michael Hochberg, an electrical engineering professor.

OpSIS is loosely based on the model pioneered by MOSIS, the original and highly successful foundry service for electronic integrated circuits. Founded in 1981 at the University of Southern California, MOSIS helped combine many different circuits onto a single silicon wafer.

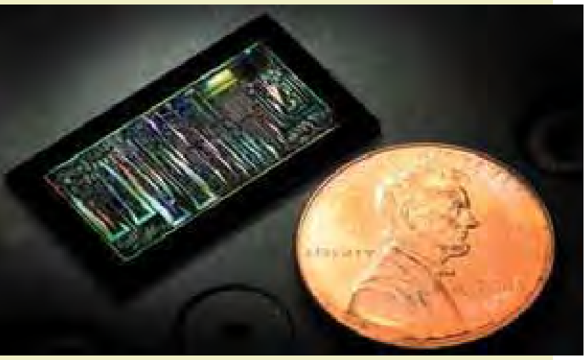
The OpSIS project will permit "shuttle runs" in which researchers cut costs by sharing silicon wafers between multiple projects. A single circuit design might use only a few square millimeters. Enabling shuttle runs, Hochberg said, can reduce costs by more than 100 times.

"OpSIS will enhance the education of U.S. engineering students, giving them the opportunity to learn the new optical design paradigm," says Justin Rattner, chief technology officer at Intel Corp. "The ability to produce such low-cost silicon chips that manipulate photons, instead of electrons, will lead to new inventions and new industries beyond just data communications, including low-cost sensors, new biomedical devices, and ultra-fast signal processors."

BUILDING A LEGACY: SUPPORT FROM SOLVAY FOR GEORGIA TECH ON ORGANIC LIGHT EMITTING DIODES AND PHOTOVOLTAICS

The Center for Organic Photonics and Electronics (COPE) was established at Georgia Tech as a vehicle to help provide a legacy for the STC so that center research at GT could continue once the STC funding was over, explains COPE founding director and CMDITR researcher Seth Marder.

An initial grant from industrial sponsor Solvay of over $4 million in 2007 was aimed at research on organic light-emitting diodes (OLEDs) and photovoltaic materials. OLEDs are thin films of organic molecules that give off light when electricity is applied. The devices could be used in everything from television and computer monitors to household lighting and handheld computing devices.



A photonic circuit next to a penny.
Photo: University of Washington

Solvay, an international chemical and pharmaceutical group headquartered in Belgium with units in many countries and a strong presence in Georgia, was looking to build a strong knowledge and innovation base in advanced materials for organic electronics, according to Léopold Demiddeleer of Solvay Corporate R&D and New Business Development. "COPE was right on target, at the right time and at the right location for us," said Demiddeleer in the grant announcement at that time. "This winning partnership will take advantage of the world-class expertise of COPE and the industrial potential of Solvay in this highly challenging field. I consider this as the first critical step of a major long-term program for the company."

And indeed, over a 5 year period, the Solvay-funded program at COPE expanded to cover surface modification of conductive oxide electrodes to improve charge injection properties and to include organic field effect transistors (OFETs).

As of 2011, Solvay had invested well over $10 million in the research at Georgia Tech, and in addition, helped to create new state-of-the-art facilities for organic electronic materials development. In January of 2011, Bernard Kippelen, a professor in GT's School of Electrical and Computer Engineering and CMDITR researcher, took the helm as director.

Marder, a professor of chemistry and biochemistry who was recently named Regents' Professor at Georga Tech, says the STC provided a "launching pad for us to get a lot of the research going that enabled us to attract Solvay as a sponsor. It is consistent with the STC's philosophy to get work going and to inspire industrial support that both enhances the work going on within the STC and potentially, a vehicle to transition that work into industry."

In 2008, Solvay created the Solvay Global Discovery Program, which now includes not only Georgia Tech faculty, but also researchers at the Chinese Academy of Sciences, (Beijing), Princeton University, University of Washington, and Imperial College London.

The collaboration has led to numerous patent applications and the creation of the Solvay-COPE Symposium, which includes both academic talks on cutting-edge research and an industrial forum to focus on issues related to transitioning new materials into commercial products. Industrial participants in the symposium have included companies such as Plextronics, Polyera, Cambridge Display Technology, Solamer, and Lockheed Martin Corporation, in addition to Solvay and others.