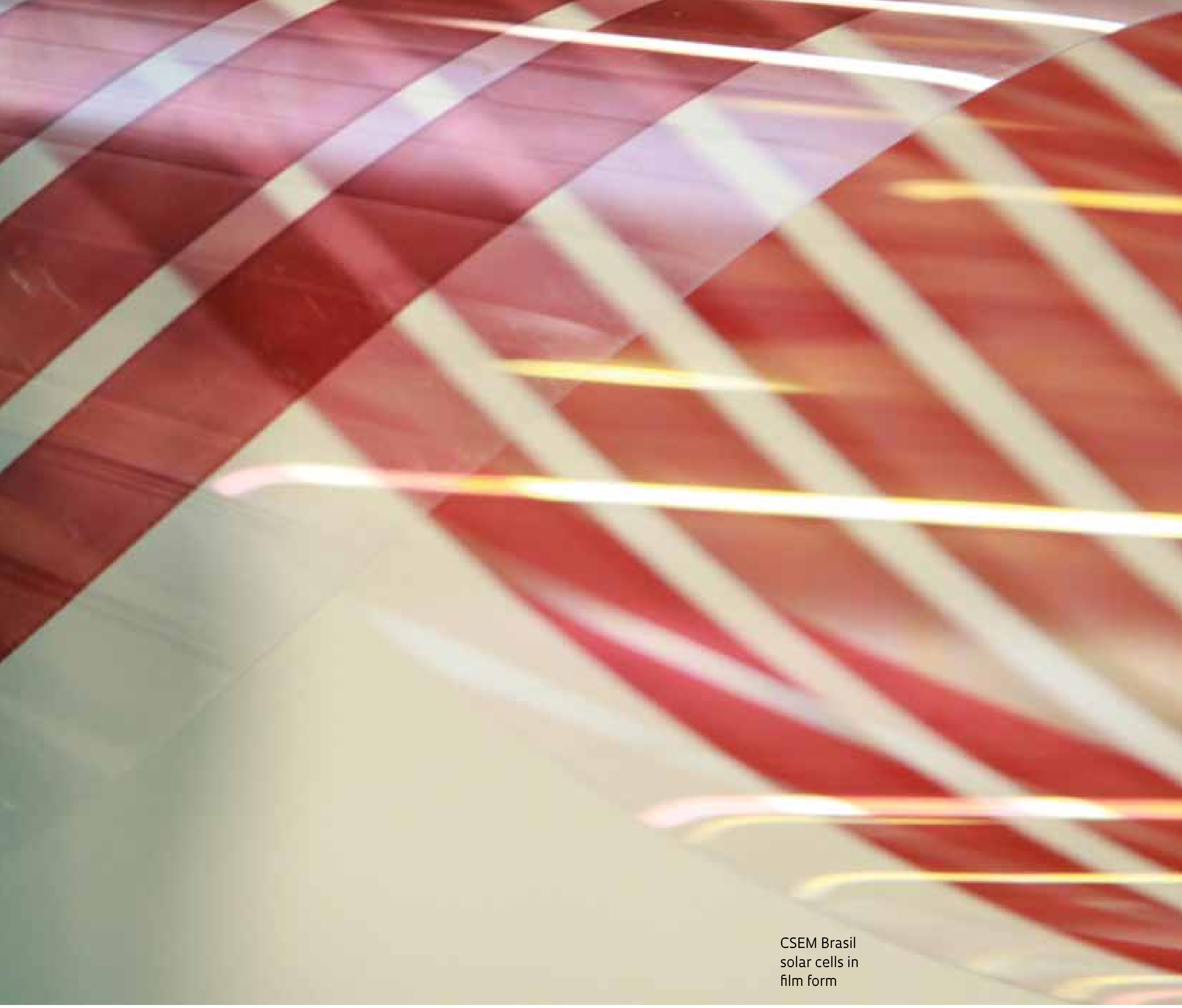
Films capture *energy from the sun*

Production of organic solar cells, flexible in comparison to traditional photovoltaic panels, is beginning on a small-scale in Brazil

Evanildo da Silveira

Each year, the earth absorbs the equivalent of 10,000 times the total energy consumed over the entire world, in the form of sunlight and heat. The problem lies in transforming all of this energy into electricity. The most efficient technology used today, employed since the 1980s, is the silicon photovoltaic cell, whose application is limited because of weight and lack of flexibility. Now the search is on for devices in the form of thin films—like organic photovoltaic (OPV) cells composed of carbon-based semiconductor material—that can be applied and tailored to a variety of surfaces, such as



CSEM Brasil solar cells in film form

CSEM BRASIL

glass windowpanes. In Brazil, a number of research groups and companies are at work developing organic cells.

The São Carlos firm nChemi, for example, produces nanoparticles made of molybdenum oxide, iron, titanium, and zirconium, among whose numerous applications include the ability to become inserted in some of the organic solar cells. NChemi was established a year ago at a laboratory in the Chemistry Department of the Federal University of São Carlos (UFSCar), which is part of the Center for Research and Development of Functional Materials (CDFM), one of 17 Research, Innovation and Dissemination Centers (RIDCs) funded by FAPESP.

The nChemi nanoparticles are being analyzed in the research and development (R&D) phase at CSEM Brasil for future use by Sunew, a firm from the state of Minas Gerais that began producing organic photovoltaic cells in August 2016. Founded in November of 2015 as a CSEM Brasil spin-off, Sunew operates in conjunction with venture capital fund managers. CSEM Brasil is a non-profit technology research institution whose mission is to pass its findings on to industry, as it did with OPV technology licensed for production and sale by Sunew. To achieve this degree of technological maturity, CSEM received research funding from—among other public and private institutions—the Minas Gerais Research Foundation (FAPEMIG). NChemi, in turn, is funded by FAPESP's Innovative Research in Small Business Program (PIPE).

"Through the partnership we established, we're responsible for the design and production of nanoparticles, and CSEM Brasil is responsible for analyzing their performance in photovoltaic devices," says nChemi founding partner Bruno Lima. "With the active participation of our partner in developing the high-demand nanoparticles, the agree-

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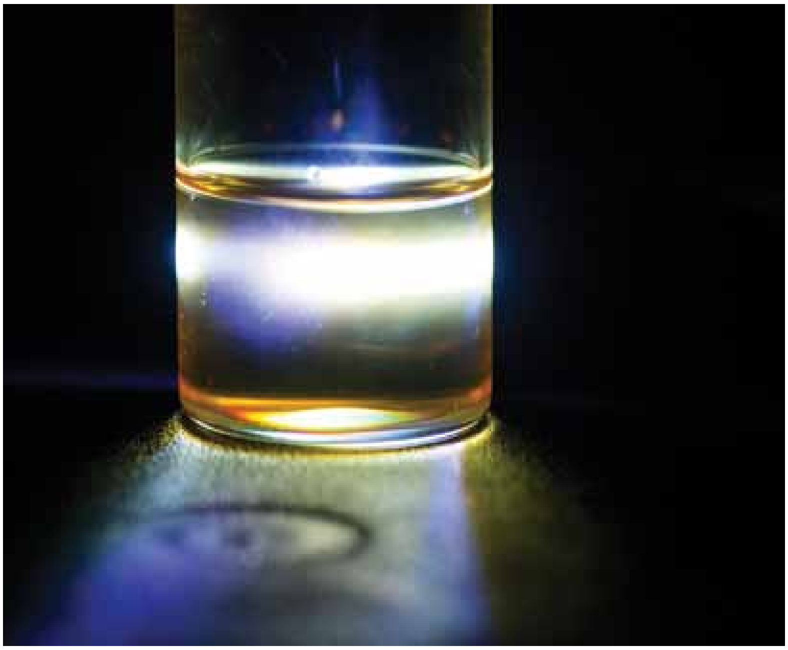

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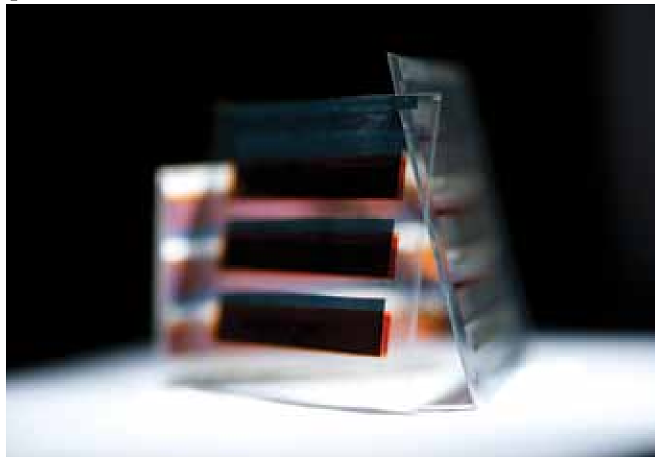

Nanoparticles in a solution at nChemi (*left*). Solar cell prototypes at CTI Renato Archer (*top*). São Paulo building with CSEM Brasil organic films (*facing page*)

ment adheres to the model we want to follow." Edson Leite, CDFM researcher and professor to Lima and his business partner Tiago de Goes Conti, advised the two on the application of nanoparticles in OPVs and the establishment of nChemi. "Electrons are generated in the cell's active material—a semiconductor polymer," Leite explains. "They emerge when the polymer absorbs sunlight, and are responsible for generating electrical energy." The nanoparticles are currently imported by CSEM Brasil, but the main idea behind the work of the São Carlos company is to become a domestic supplier, offering advantages in terms of cost and logistics. "This development also seeks to obtain better-performing material," adds Leite.

"Nanoparticles can have various functions, such as increasing mechanical properties, serving as a barrier to external moisture, or even improving the electrical properties of organic photovoltaic cells," explains CSEM Brasil researcher Luiza Correa. "Depending on where they are used, they offer great potential for increasing the efficiency and lifetime of the modules." Correa goes on to explain that an OPV cell is composed of conjugated polymer layers, solution-processed and inserted onto a substrate that can be rigid like glass or flexible, like plastic.

According to Filipe Ivo, new businesses manager at CSEM Brasil, one of the first projects developed using OPV was the glass façade of the new building for Brazilian software company Totvs in São Paulo, scheduled for completion in November 2016. "It's the installation of Brazil's first glass-encased organic cell façade for generating electrical energy," says Ivo. "The new building's external glass structures will generate electrical energy for its own use." CSEM Brasil is also engaged in research and development (R&D) projects with such companies as: Fiat, to place OPVs on the roofs of automobiles; Votorantim, for OPV use on floating structures in hydroelectric plants; and Medabil, for OPV use in metal shingles.

SEMICONDUCTOR NANOPARTICLES

Since 2007, researcher Fernando Ely has been At the Renato Archer Information Technology Center (CTI) in Campinas working on the development of OPVs, which are produced from semiconductor nanoparticle inks on the active layer. "The cells we produce in the lab have, on average, five layers—each of which exercises a specific function in gener-

China ranks first in installed capacity

The use of solar energy is growing the world over. According to the report *Solar energy in Brazil and the World, 2015*, published in July 2016 by the Ministry of Mines and Energy (MME), the world's installed capacity last year was 234 Gigawatts (GW), the equivalent of 16.7 Itaipu hydroelectric plants. At 43.4 GW, China ranks first in terms of installed capacity, followed by Germany with 39.6 GW and Japan with 35.4 GW. As of July, Brazil had a mere 51 Megawatts (MW) in installed capacity from solar generation from 3,851 facilities (three times the capacity that was present only eight months before), chiefly residences, businesses and factories. According to the MME bulletin, the 10-Year Energy Expansion Plan hopes to increase installed capacity from solar generation to 1% of Brazil's total energy production by 2024. Installed capacity as of July measured just 0.01%, according to the Generation Database of Brazil's Electricity Regulatory Agency.

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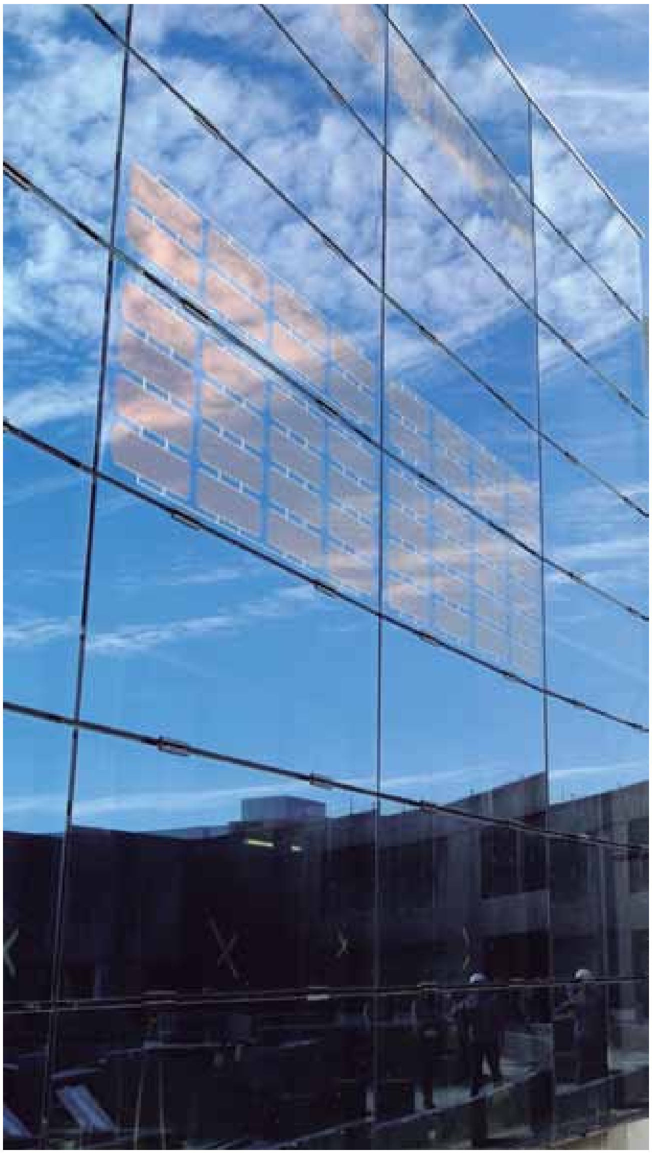

ating, transporting and absorbing material," explains Ely. "The use of inks facilitates manufacturing using low-cost techniques that employ graphics-industry printing processes, thereby reducing production costs and increasing potential applications through the use of light, flexible materials."

Besides the greater variety of applications, organic photovoltaic cells have other advantages. "Unlike crystalline silicon cells, which are rigid and layered, most OPV cells are composed of films measuring a few hundred nanometers in thickness, placed over a glass or plastic substrate," Ely explains. "Therefore, while manufacturing a silicon panel requires soldering individual cells, OPV panels are placed directly on the substrate according to a predetermined design." Ely says that this procedure simplifies the fabrication process. Therefore, less energy is required (both electrical and thermal) in the fabrication of OPV panels than in that of conventional silicon panels, which consume more energy, especially during the raw materials purification step.

The CDFM's Leite adds that unlike flexible organic cells, conventional silicon cells, lacking flexibility, are mechanically fragile. On the other hand, they are more efficient in terms of solar energy conversion (more than 15%, as compared to 4% to 8% for OPVs). These figures indicate how much total energy absorbed from the sun is converted into electricity. Besides being less energy efficient, OPVs present the serious disadvantage of having a shorter operating life than the silicon variety. "On transitioning to nanoparticles, our objective was to increase their life-cycle," says Leite. "This is what nChemi has been working on in partnership with CSEM and CDFM. Organic cells today last from five to 10 years, while silicon cells have a lifetime of 10 years or more."

Flexible solar cells are still less energy efficient than the traditional silicon cells, which are rigid

As far as the lower energy efficiency of organic cells, CSEM Brasil's Filipe Ivo points out that the new technology considers other variables, such as the physical characteristics of the materials themselves: lightness, transparency, flexibility, small carbon footprint, and recyclability, among other factors. "For these reasons, OPVs are the best option for use in a number of application scenarios, such as automobile roofs and glass façades," says Ivo. "It's important to point out that silicon technology is a mature industry that has been in existence for more than 40 years. Organic printed electronics, on the other hand, are recent and just now making headway." For Ivo, large-scale production will lead to improvements in manufacturing techniques, with benefits in terms of efficiency and durability.

Ely of CTI is more cautious when it comes to the advancement of OPVs. "For these cells to be economically viable, it's still necessary to meet important challenges, such as increased reliability, durability, and efficiency," he explains. "There's also an economic problem common to most renewable energy sources, as they carry a price disadvantage when compared to more traditional sources, like hydroelectric or thermal." ■

Projects

1. *Nanostructured inks for organic photovoltaics (No. 2015/15921-0)*; **Grant Mechanism**: Innovative Research in Small Business Program (PIPE); **Principal Investigator**: Tiago de Goes Conti (nChemi); **Investment**: R$124,450.00.

2. *Synthesis of functionalized nanoparticles in pilot scale (No. 2014/21682-5)*; **Grant Mechanism**: Innovative Research in Small Business Program (PIPE); **Principal Investigator**: Bruno Henrique Ramos de Lima (nChemi); **Investment**: R$113,157.00.

PHOTOS 1 AND 2 LÉO RAMOS CHAVES 3 CSEM