Ready to roll

**Flexible solar cells featuring Empa tech
near Zurich. The pilot plant of the spin
This is the culmination of eighteen yea**

TEXT: Rainer Klose / PICTURES: Heidi Hostettler

Protective clothing was the order of the day at the inauguration of the Flisom pilot production plant on 11 June. Not to protect the visitors, but rather the sensitive machinery, which will manufacture the first flexible solar cells on a large scale by the end of the year. No dust particles are allowed to get into the equipment. The young company's production plant is a world first: rolls of flexible solar cells measuring up to one meter in width and based on the CIGS technology developed at Empa are to be produced in large vacuum evaporation machines.

The acronym CIGS stands for "copper indium gallium selenide", the semiconductor mixture used to convert sunlight into electricity. Unlike in conventional solar cells made of crystalline silicon, the CIGS absorber layer is merely a thousandth of a millimeter thick – and therefore supple, which enables flexible solar cells to be produced for the first time. Instead of a large-scale "window factory", a space-saving "film factory" is sufficient to produce solar modules in series. As a result, a major step towards the mass distribution of solar technology has been achieved: the low-cost modules can inexpensively be mounted on roofs or incorporated into the sheet metal body of cars, busses and trucks.

Much like potato chip bags

"What we do here has a lot to do with packaging for potato chips," says Ayodhya N. Tiwari. The company founder is both its current Chairman and Head of Empa's Laboratory for Thin Films and Photovoltaics. "The metallized foil bags that potato chips come in are also produced in vacuum machines using similar roll-to-roll methods," he explains. While the structure of the CIGS layers is considerably more complicated than the simple aluminum layer needed to protect food, the vision is the same: produced in large quantities, low-price films stand a chance of worldwide distribution.

K.R.S. Jamwal, Executive Director of the Indian multi-industry group Tata Industries, hopes to conquer the global market with the technology developed in Niederhasli.

Production hall at the Flisom pilot plant in Niederhasli. Flexible solar modules are mass-produced on the roll machines. Every year, solar cells with an output of 15 megawatts can be built.

nology will soon be rolling off the production line at a brand new factory in Niederhasli
-off Flisom is the first step towards serial production and could slash the costs for solar modules.
rs of research and development, the majority of which took place in Empa's labs.

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Jamwal is also responsible for the promotion of start-ups at Tata. The global giant already invested several million Swiss francs in the Swiss company in recent years. “We’re involved in high-tech companies in Silicon Valley, Boston, Great Britain – and now here in Greater Zurich, where the start-up conditions are at least as good as in the US,” said Jamwal at the opening. “I’m glad I came across top-class scientists here, with whom you can talk about revenues as well as about research. That’s a great combination.”

However, there is still a long way to go before the first sales revenue from solar cell production comes rolling in. Production is to be launched and increased in the next nine to twelve months. Even then, however, the first CIGS cells from Flisom still won’t be freely available; instead, they will be reserved for research purposes, durability tests and experimental buildings such as NEST on the Empa campus in Dübendorf. Once the production process is fully up and running, the factory in Niederhasli will churn out solar cells with a total output of 15 megawatts (MW) every year. The pilot plant serves as a kind of blueprint for commercial factories with a total annual output of 100 MW. This is equivalent to the output from the new hydroelectric power plant in Rheinfelden, which opened in 2010.

Good things come to those who wait…

While the plant in Niederhasli produces solar cells that are one meter wide, Flisom’s somewhat older facility on the Empa campus will also carry on working. Innovative production methods for the solar cells of the next generation are already under development at this smaller plant. In parallel, Tiwari’s group at Empa is conducting further research into the basics of thin-film technology, such as increasing their efficiency in energy transformation – a field where his lab has already broken world records (see box at p 07).

It is not always possible, though, to transfer what works well in the lab to industrial production. It took the supple CIGS technology almost two decades to be ready for mass production. “A long way, which wouldn’t have been possible without the support and expertise of Empa,” Tiwari is convinced. As important as private investors are for the development of market-ready products and technologies, this is clearly too long for them. “This example illustrates the key role that Empa plays as a bridge between research and practical application,” says Empa CEO Gian-Luca Bona. “All the years of hard work we put into researching renewable energy have now finally paid off.”

In the meantime, Flisom’s experts are already working on their business model for marketing the CIGS cells. “We’re competing against Asian manufacturers, who also produce inexpensive solar cells – albeit on glass plates at present,” says Stephan Stutterheim, who is responsible for business development. “We offer pioneering prospects and new business models for solar module production and integration. The advantage we’ve got is that we can provide customized and inexpensive solutions for our international customers.”

One of the first results from this close interaction with customers was already evident at the inauguration: Roland Kern, who is responsible for product development at Flisom, showcased ready-to-mount rooftop modules, complete with solar cells and electrical wiring. “We’re able to integrate our flexible cells directly in sheet aluminum or steel. The sheet metal can subsequently be bent into a metal roof tile or façade element,” says Kern. “This makes our light and semi-flexible solar modules just as easy to install as a normal tin roof, which saves time – and therefore money – as the roof and solar technology come in one piece.” However, not only are particularly inexpensive solar roofs feasible; special aesthetic solutions can also be discussed at Flisom. “Many architects like the uniform black color of the Flisom modules,” says Kern. //

Researchers neck and neck

While production gets underway at the Flisom pilot production plant, research in the lab mustn't grind to a halt. For a reasonably priced, competitive solar cell, efficiency is key – i.e. the proportion of light that is converted into electricity. Over the years, Empa researchers have managed to keep increasing the efficiency for flexible CIGS solar cells: from 12.8% in 1999 to 14.1% (2005), 17.6% (2010) and 18.7% (2011). And in 2013 a team headed by Ayodhya N. Tiwari succeeded in achieving a world record value of 20.4%. The secret to this success was a new production method for CIGS solar cells, where tiny amounts of sodium and potassium are incorporated into the CIGS layer. This special treatment alters the chemical composition of the complicated sandwich structure changes – and thus its electronic properties, as detailed electron-microscopic studies revealed.
With an efficiency level of 20.4%, the CIGS cells can (finally) keep up with the best polycrystalline silicon solar cells. This makes Empa CIGS cells some of the most efficient in the world. The research projects are funded by the Swiss National Science Foundation (SNSF), the Commission for Technology and Innovation (CTI), the Swiss Federal Office of Energy (SFOE) and the EU Framework Programs.

Top: Inauguration of the Flisom pilot plant in Niederhasli (ZH) on 11 June 2015. Seated: K.R.S. Jamwal from Tata Industries; behind him, Empa scientist and company founder Ayodhya N. Tiwari.
Bottom right: Flisom product developer Roland Kern demonstrates how the flexible Flisom solar modules can be turned into ready-to-fit roof tiles.