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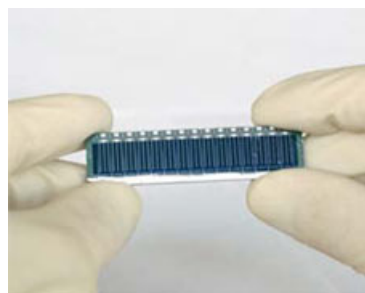
**Photovoltaics: Thin-film technology about to make its breakthrough;
crystalline silicon cells to continue their dominant role**

2009-08-07



The manufacturers of thin-film solar modules are bringing costs down and gaining in competitive strength. But classical crystalline silicon technologies will not relinquish their market positions without a fight because they still hold considerable development potential. The race to market the most successful solar energy concept is still on.

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Left: Test strip with 15 CIS solar cells by ZSW an the record breaking cell in the middle. Right: A staff member of the Berlin-based Inventux company inspecting the surface of thin-film silicon module. Sources: ZSW; Inventux.

CIS solar cells reach efficiencies of approx. 20 % in pre-industrial production

The Centre for Research into Solar energy and Hydrogen Research (ZSW) is closing the gap separating it from the world's leading institutions in the race to market the most efficient thin-film solar cell. Its copper-indium-gallium-diselenide-based CIS cells achieved efficiencies of up to 19.6 per cent in a pre-industrial production line. This means that the Stuttgart-based research workers are hot on the trail of the US-based

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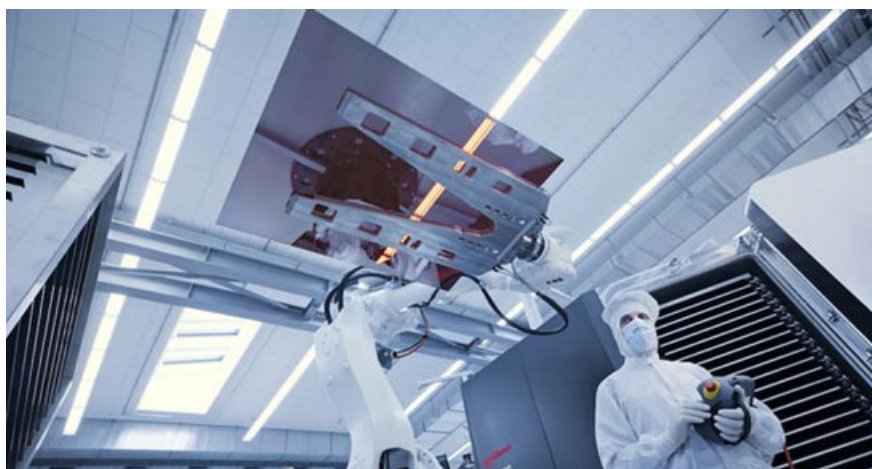
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National Renewable Energy Laboratory, scoring efficiencies of up to 19.9 per cent under the same conditions. Mr. Michael Powalla, head of the ZSW photovoltaics section, proudly announced: "We want to take the 20 per cent hurdle next". This would take the CIS technology into the efficiency ranges of available crystalline photovoltaics equipment. Multicrystalline silicon cells, taking the lion's share of the market today, have reached efficiency rates of 20.3 per cent under laboratory conditions. They are, therefore, hardly more efficient than their slimmer competitors.

The Solar Report on solarsserver.com in August 2009 publishes a contribution by the forthcoming trade fair for solar production equipment "solarpeq", to be held concurrently with the world's leading fair "glasstec" in September/October 2010 and to provide an international forum for all those interested in selling or buying machinery for producing and processing silicon, wafers, solar cells and modules. 250 exhibitors from 30 countries will present themselves and their products on the debut event: more than 55,000 trade visitors are expected for solarpeq and glasstec.



Careful intermediate storage procedures after semiconductor coating. Source: Oerlikon Solar

Ambitious target: generating solar PV electricity at prices undercutting all other competitors

But CIS technology is still lagging behind its potential when it comes to practical applications. Industry-manufactured modules of this type of semi-conductor turn a maximum of 12 per cent of sunlight into electricity. Multicrystalline modules manage up to 18.5 per cent, while monocrystalline units score conversion rates of up to 20 per cent. So far, CIS panels cannot make up their efficiency backlog by lower manufacturing costs. Production costs over € 2 per watt of electricity generated, this is the same as silicon modules, requiring much more semi-conductor material. CIS, therefore, is still miles away from achieving its major objective which is to generate electricity at prices undercutting all other competitors. Other thin-film technologies, however, cannot take up this challenge either. The experts say that thin-film silicon modules, for instance, may score efficiency rates of over 15 per cent, and they be may be manufactured at less than € 0.30 per watt of electricity. Once they actually achieve this, they would put all other solar energy technology in the shade. But at present they merely manage to score efficiencies of around 9 per cent and they are about three times as expensive to make.

Double the market share by 2010

But CIS, thin-film silicon and related devices, are just preparing for a major leap in development. In the words of Mr. Arnulf Jaeger-Waldau, an energy specialist working for the European Commission: "At present



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some 200 companies are making thin-film modules or they are working on them". This leads the European PhotoVoltaics Industry Association (EPIA) to expect that manufacturing capacities for these technologies will double to over 4 gigawatt by 2010 – representing a market share of around 20 per cent. At the same time, new manufacturing technologies and advances in automation make for ever more efficient production. Mass production and technological progress bring down costs and raise market chances. Many of these innovative production processes shall be on demonstration at the solarpeq International Trade Fair for Solar Production Equipment in Düsseldorf from 28 September to 1 October 2010.

Milestone on the way to making solar-generated electricity competitive

The successes achieved by First Solar, a US-based manufacturer of cadmium telluride (CdTe) modules have kept the confidence of thin-film firms up. Based on information made available by their company, the Americans by now produce one watt of electricity at about USD 0.93 (or about € 0.67). There is no other company achieving this. But the disadvantage of these CdTe solar units is that their maximum efficiency stands at only 11.1 per cent at present. They will therefore need a greater surface area in order to generate the same amount of electricity as silicon cells marketed at present. A part of the gain in lower manufacturing costs will be eaten up by higher installing charges.

But First Solar's achievement is still considered to be a milestone on the way to making solar-generated electricity competitive. Experts had expected this network grid parity for Germany for 2015 at the very earliest. From then onwards, solar energy would no longer be more expensive than traditionally-produced electricity coming out of a socket in the wall. As Mr. Holger Krawinkel, an energy expert at Germany's Verbraucherzentrale Bundesverband e. V., noted this most recent progress brought grid parity into the foreseeable future: "First Solar modules may already generate electricity at € 0.20 to € 0.25 per kilowatt hour", the expert said. In Germany, electricity prices now stand at about € 0.20 per kilowatt hour.



Thin-film cells for American roofs: In California, before all, solar power stations are being put up everywhere. 2-MW First Solar modules being installed on a roof in Fontana. Source: First Solar.

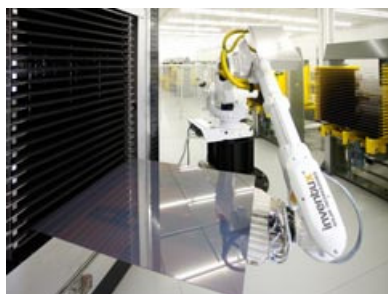
First Solar sets the tune

First Solar set the benchmark as far as cost is concerned. Other thin-film module makers which will be unable to rapidly follow suit or which do not bring down systems costs on account of higher efficiencies, will be unable to keep their share of the market. Added to this, makers of traditional crystalline technologies have continuously lowered their cost by increasing mass-manufacture and technological improvement. Thin-film technology competitors, therefore, are very ambitious now. In April 2009, Abound Solar from Fort Collins, Colorado, launched its CeTe module production

and the company wants to bring down the price of one watt on its 35 megawatt line to USD 1, the equivalent of € 0.72. Pascal Noronha, its founder and President of the Board, said that costs of around USD 0.90 (about € 0.65) per watt at a capacity of 200 MW are envisaged already for 2010.

Equipment producers Oerlikon Solar and Applied Materials to bisect the costs

The Berlin-based Inventux company also intends to score costs of below USD 1 rapidly. This firm has made so-called micro-morphous silicon modules since late 2008. This technology represents a development based on the thin-film panels made of ordinary amorphous silicon marketed at present. By depositing an additional absorber layer made of micro crystalline silicon on the amorphous layer, Inventux managed to raise the electricity yield to 9 per cent. This reduced cost perspective is to generate efficiencies of scale by larger output quantities and additional improvements to generate higher efficiency. Company spokesman Mr. Thorsten Ronge said: "We want to reach ten per cent of efficiency by 2010". To bring this about, Inventux works on process optimisation but the company also benefits from innovation results of Oerlikon Solar, its component suppliers, from which Inventux buys its coating equipment. Ms. Jeannine Sargent, the CEO of Oerlikon Solar, promises that by the end of 2010 Oerlikon-made machinery shall be in a position to manufacture these new tandem modules at USD 0.70 (about € 0.50), halving present costs.



High-level automation: Robots in an integrated production line are playing a major part in thin-film module production. Pictures: Inventux; Applied Materials

Applied Materials, a US-based equipment builder comes with similar plans. This company also offers complete turnkey production lines for making modules out of thin-film silicon. Mr. Christopher Beitel, head of its thin-film division said: "We are optimistic that we can present solutions with manufacturing costs of below USD 1 very shortly". The Americans will present their product portfolio at solarpeq 2010 and the concurrently held glasstec, the world's leading trade fair of the glass-making sector at which firms will also exhibit solar applications. These products will also include its SunFab thin-film line.

Nanosolar striving for USD 0.30 up to USD 0.35 per watt

Nanosolar, another US-based company, comes with even more ambitious plans. This firm developed a manufacturing technology in the process of which minute nano particles of copper, indium, gallium, selenium and probably sulphur will be printed on sheeting material using the roll-to-roll process. Using this innovative printing technology, the Americans want to bring down costs to USD 0.30 up to USD 0.35 (€ 0.22 up to € 0.25) – which is about one third of the manufacturing cost of First Solar, the leading company in the sector. Mr. Erik Oldekop, the spokesman of Nanosolar said: "We are capable of coating large areas within very short cycle times". The factories have already been built and series production is about to take off. Nanosolar wants to manufacture its cells in a 430 MW plant in San José, California. These will then be processed into circuit modules at Luckenwalde near Berlin.

Crystalline modules shining with efficiency

All signs are then switched to growth in the thin-film sector. But is quite open how many manufacturers will reach their ambitious extension and manufacturing targets within the time schedules quoted. Delays are quite frequent: It very often takes many years for a technology to be transferred into series production. It calls for the development of appropriate industrial processes for manufacturing and much money must be invested into research and testing. First Solar, for instance, needed exactly ten years to commercialise its modules. CIS manufacturer Wuerth Solar worked for seven years on optimising its technology on a pilot line, before being able of launching series production in 2007.

Newcomers in the thin-film sector do not have much time to present their products for series production. This is because their competitors from the crystalline sector are also spending great efforts on developing new technologies: efficiencies go up and costs are falling. It is because of this that scientists are of the opinion that also in future there will be no way of bypassing conventional solar techniques. As Mr. Stefan Glunz, head of the division of development and research into the properties of silicon solar cells of the Fraunhofer Institute for Solar Energy Systems ISE at Freiburg (Germany), puts it: "Crystalline silicon cells will continue playing their dominant role.



Left: Semi conductor checkup: A member of staff of China's Suntech Power company preparing a wafer for cell processing. Right: Ready for dispatch: After manufacturing, crystalline silicon modules of the Chinese Suntech company are taken into storage rooms. Source: Suntech Power.

High efficiency cells made in China and in the USA

This means that there is intense competition at the high end of the efficiency scales. Research workers from the University of New South Wales, Sydney, Australia, managed 24.7 per cent efficiency under laboratory conditions using a monocrystalline cell, and industry is moving closer and closer to this world record. Suntech Power, for instance, a Chinese solar energy company, this summer offers a module generating seven per cent more electricity than its most highly performing panel before. The core elements of their new technology are what they call Pluto cells, innovative elements, absorbing more light at their frontal sections because of a specially treated surface and thinner electric contacts. This brings up efficiency from 15.2 to 17.5 per cent for multicrystalline cells and from 17.2 to 19 per cent for monocrystalline makes. Their manufacturing process builds on German know how: in 2008 Suntech took over KSL Kuttler, a Black Forest equipment maker. The latter supplies equipment and automation sets for making Pluto cells.

Experts also view so-called back contact cells as offering great potential. Bus bars and contacts are no longer to be found at the front but rather at the back side of solar cells, thus enlarging the solar-active surface of these modules. A US-based company, Sunpower, the leading manufacturer of backside collectors, already produces cells with efficiencies of more than 20 per cent. Modules using these cells reach efficiency levels of 19.6 per cent and generate 315 watt of electricity.

There is no stronger module.

Falling silicon prices

The drop in silicon prices is a boon for companies in this sector. Semiconductor demand had increased so strongly over the past few years that manufacturers could hardly keep pace with their output. In 2008 this brought spot market prices up to USD 400 (about € 285) a kilo. Now, silicon prices are dropping significantly below that as the solar energy sector does not longer grow that rapidly because of the crisis. According to iSupply, a market researcher, the price stood at only USD 75 (about € 53) in June this year and there is a tendency for that price to drop even further.

Thin films on large industrial and commercial roofs or in free-range areas

Manufacturers of thin-film modules will therefore face fierce battles to retain or conquer market shares. To begin with, their technology may face difficulties where large outputs are to be generated from a small surface area, because of fairly low efficiencies. House owners in countries, where solar energy enjoys active promotion, such as Germany, will instead prefer putting crystalline silicon panels on their roofs, because these simply generate more electricity per square metre of roof area and also result in higher compensation for electricity fed into the grid. The latter will be more than enough to offset the pricing disadvantage as compared to thin-film collectors. These, however, will find short-term chances on large industrial and commercial roofs or in free-range areas offering plenty of space and where there is less pressure on generating maximum output from a limited surface. Also, and because of their flexibility and low weight, thin-film modules may be more easily integrated into the walls or roofs of a building when compared to electricity-generating windows or façades. Thus they do not only improve the energy balance of a building but they also make for more creative freedom of architects and planners. Numerous creative solutions for building-integrated photovoltaics were already on demonstration at the latest glasstec trade fair held in Düsseldorf in 2008.



Solar energy knows no frontiers: This Vidana-based open space unit of the German aleo Solar company with its output of 4 MW is just one of many solar power stations in Spain. Source: aleo Solar.

Manufacturing capacities fo thin films to be extended

CIS, CdTe and similar products will emerge to be more than niche products once their manufacturers live up to their announcements and drastically reduce manufacturing cost within very short time frames. When their slim electricity generators then close the gap separating them from

efficiency rates scored by the crystalline competition, they might even take over as the leading solar energy technology. In theory, therefore, thin-film cells may bring about much, but companies manufacturing them will first have to turn their ideas into capacities. Their plants just brought out 800 MW in 2008, of which 500 MW alone came from the lines of first Solar. According to information provided by EPIA, conventional photovoltaics cell manufacturers produced seven times as much. Trade fairs, such as solarpeq and glasstec 2010, will be pointers to the way developments will go, because there hardly is any other sector depending to such a degree on the influence of innovations to revolutionise manufacturing technologies by reducing cost.

Efficiency and cost potential of solar modules

	c-Si	mc-Si	CdTe	CIS	a-Si	a-Si/ μ c-Si
Efficiency achieved by industry (per cent)	19.6	18.5	11.1	12	7	9
Efficiency achievable (per cent)	>20	20	18	18	10	15
Manufacturing cost per watt (€)	2	1.50-2	0.67	2	1	1
Expected costs as from 2020 (€)	<0.5					
	<0.5	<0.5	<0.3	<0.3	<0.3	<0.3

Sources: EU PV Platform, research by solarpeq

Caption:

c-Si = monocrystalline silicon

mc-Si = multicrystalline silicon

CdTe = cadmium telluride

CIS = copper – indium - diselenide (CIS is also used as a generic term to embrace other copper-based semiconductor compounds), a-Si = amorphous silicon

a-Si/ μ c-Si = micromorphous silicon

Thin-film technologies have the potential to score similarly high efficiencies as crystalline silicon modules. To bring this about, silicon panels will have to be offered at such favourable prices in the long term as their slim-line competitors. But thin-film modules are still lagging behind crystalline technologies. Efficiency is considerably lower and only CdTe modules have gained a clear advantage on cost so far.

Material: solarpeq. Solarsserver.com thanks the Düsseldorf trade fair for publication rights. Solarsserver editor: Rolf Hug.

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