Printed PV: Nanosolar unveils 640MW utility-scale panel fab, high-efficiency CIGS cell production

By **Tom Cheyney**

After staying relatively quiet for much of the past year, thin-film PV manufacturer Nanosolar came out with a full docket of announcements on 9/9/09: the completion of its major panel-assembly factory near Berlin; the start of serial roll-to-roll production of its flexible copper-indium-gallium-(di)selenide cells in the company's San Jose facility; $4.1 billion in panel purchases from customers – including some of the world's largest utility companies; NREL-verified cell efficiencies up to 16.4%; and new technical details of both its printed CIGS cell technology and utility-scale panels.

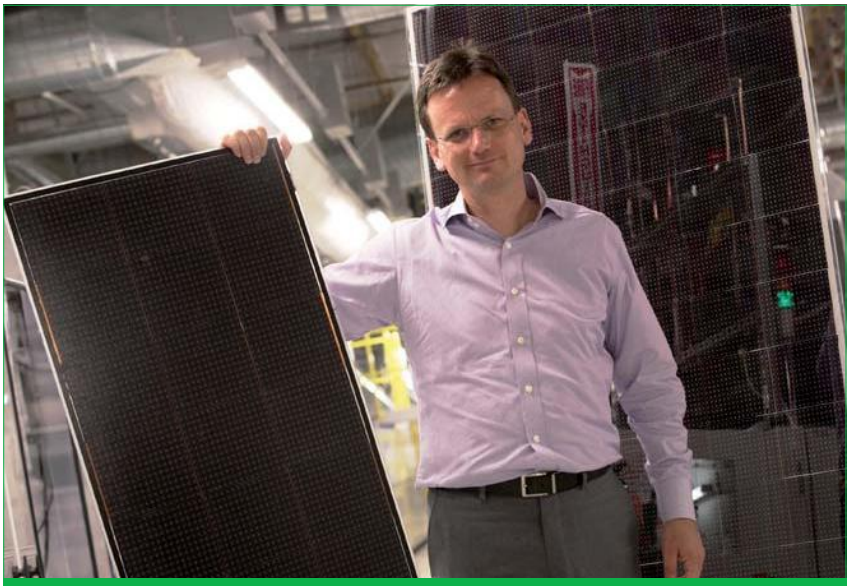
The panel-making facility, located in Luckenwalde (about 60 kilometres south of Berlin), can operate at a production rate of one panel every 10 seconds and is capable of reaching a peak capacity of 640MW when operated around the clock, according to Nanosolar.

Referred to by TÜV Rheinland inspectors as "a factory unlike any we've ever seen," the plant incorporates a fully automated robotic line integrated with a sophisticated in-line quality control measurement system to string and assemble the individually sorted and tested cells into panels. One innovative part of the production line is a high-throughput stack lamination technique developed with a "leading provider of lamination equipment."

The German panel factory is supplied with flexible aluminum-foil cells produced at the venture-backed company's fab in San Jose. Nanosolar, which prints its cells using a proprietary CIGS ink in a mostly non-vacuum, low-cost process sequence, says it began serial production on its R2R processing line earlier this year.

"Getting to the point of serial production with the unusual extent of innovation and leapfrog cost reduction involved in our technology and delivering a product that out of the gate meets and exceeds the high bar set by the industry's existing volume manufacturers on performance and reliability is an accomplishment due to the incredibly hard work and perseverance of our team," said Nanosolar president/CEO Martin Roscheisen.

"As far as process complexity, we almost never ever had a problem with the nanoparticle printing process," he elucidated. "This process basically always works. High-vacuum tools, which we still use for the electrodes, turned out [to be] more hassle than we wished for. So in a curious way, this surely validated our business plan.



Photos by Wilhelm Breuer, Courtesy of Nanosolar

Nanosolar president/CEO Martin Roscheisen stands tall next to CIGS modules.

"There's a host of R&D activities to continue to drive the agenda we have had of simplifying the manufacturing of thin-film solar cells. In fact, through the five generations of pilot tools we have developed, we have basically reinvented many processes more than once already."

Nanosolar has worked "strategically with production tooling partners on each tool," noted Roscheisen. "We only build pilot tools in-house. We do not find it scalable to build production tools ourselves, so we have a best-of-breed partner in each category."

Although the San Jose facility is calibrated for rapid growth, current production is running at a subcapacity baseload rate of about 1MW per month, according to Nanosolar. Web widths run up to 1500mm on the cell line, while certain process steps can attain throughputs as high as 40m/min, he explained. A full roll of processed, unsingulated PV foil is equivalent to 100KW.

"We see excellent down-web uniformity almost naturally," Roscheisen said of the R2R line. "We have also achieved sufficient cross-web uniformity but only after some tooling modifications."

The exec also spoke of the "huge amount of inline metrology in place, including things that are unprecedented. It's been a huge effort and investment area of ours. According to engineers on our team who have worked at First Solar and other leading manufacturers, what we have on that is on a completely different level, (although) I cannot comment further as this is a very proprietary area."

The San Jose plant will be ramped in sync with the company's market-introduction plan, which it says focuses on achieving "product bankability" with commercial banks and delivering on the company's $4.1 billion in contractual customer commitments.

"With almost all large solar installations credit financed, broad-based product bankability is our key next commercial goal," stated Roscheisen. "We have long prepared for this, including through the technology choices we have made, the strong balance sheet we have maintained, the quality of customers we have secured, and the local production we have built."

The product coming off those automated assembly lines in Luckenwalde is Nanosolar's initial commercial offering, the Utility Panel – what it calls the industry's first solar electricity module specifically designed as well as electrically and mechanically optimized for utility-scale solar power systems.

Nanosolar's fully automated panel assembly factory is rated at an annual capacity of 640MW.

Featuring an innovative design scheme, the company says the IEC 61646-certified panel effectively eliminates the "balance-of-system penalty" that medium-efficient thin panels from First Solar and others have conventionally carried relative to higher-efficiency, more-expensive crystalline-silicon panels.

The Utility Panel is the industry's highest-current thin module, by up to a factor of six, according to Nanosolar, and is also the first PV module certified by TÜV for a system voltage of 1500V – about 50% higher than the next highest certified device. The combination of enhanced current and voltage enables utility-scale panel array lengths and results in a host of substantial balance-of-system cost savings, the company says.

On the mechanical side, the panel package employs a dual-tempered glass/glass design housing the flex cells, which is distinctly stronger than that of conventional thin-film-on-glass modules, achieving about 70% greater mounting span, thus facilitating substantially lower mounting costs, the company states.

The full panels as well as their components and materials have been put through a wide range of rigorous indoor and outdoor reliability and performance testing, done internally and with third-party firms, in a variety of geographic and climate conditions, and are certified under various IEC, UL, and other standards, according to Nanosolar.

One of Nanosolar's customized internal testing procedures is a thermal freeze stress test, which led the company to make changes in the panel materials in order to optimize the coefficients of thermal expansion across all layers. "We don't mind others copying this test, in fact would suggest so," Roscheisen explained. "Our attitude is that if others' panels fail in the field, this only hurts everyone else too."

"We have a huge effort on testing and are in fact expanding this even further," he continued. "We believe the standard tests are limited in some ways. We are interested in looking at combinations of stresses as well as various forms of dynamic behaviour."

While the company exec said that his company has "all of the certifications we require," he did note that "we obviously need to resubmit panels on an ongoing basis for recertification as we change process or components or power ratings."

The company has run side-by-side comparisons with both First Solar's cadmium telluride units and crystalline-silicon panels. Roscheisen said the results are indicative of "the usual thing one would expect: First Solar has atypically good low-low-light efficiency, which is in part an artifact of their semiconductor and their cell series resistance not being optimized for full-sun irradiation. But given that 0.1 suns only contribute a tenth of the kilowatt-hour as a full sun, this is of limited impact. The critical zone is at 0.3 to 0.4 suns, where it gets more interesting."

Nanosolar's gameplan includes taking on the thin-film PV market leader and pulling away from its compatriots in the CIGS sector. "We are planning to demonstrate that we are three times as capital efficient as First Solar," he explained. "By depositing thin films directly onto glass, First Solar is limited in the types and sizes of glass it can use with existing cell production investment. We believe this will be limiting."

Citing what the company believes to be the lowest-cost foil substrate, a proprietary metal wrap-through architecture, high materials utilization, and a mostly non-vacuum cell-making process among Nanosolar's differentiating advantages, Roscheisen believes that "just because it's CIGS, does not mean it's lower-cost than CdTe and First Solar specifically. In fact, according to our cost models, it takes quite a lot of innovation and effort to make CIGS actually come in at lower cost than the First Solar baseline."

"People at times forget that First Solar does have a very high throughput

Nanosolar uses a proprietary ink-based process on its roll-to-roll CIGS solar-cell production line.

semiconductor deposition process–more economic than any high-vacuum process as typically required for CIGS," he pointed out. "I don't see how high-vacuum CIGS can compete with First Solar."

Roscheisen thinks that "for solar to go to big scale at low price points, there is no way of doing so without supreme capital efficiency of production. If your price point to capex ratio is one, you can't grow even at 30% a year without being an eternal black hole for cash flows.

"We are quite pleased about the extent to which we are beating our original business plan on capital efficiency; we are on a very good track there and have many more things in the pipeline along these lines," he said.

Although Nanosolar has not as yet installed megawatt-level amounts of its panels in the field, Roscheisen does not see this as a disadvantage. "Our past installations were more focused on the quality with which we obtain accurate and independently verified data from them than their quantity and size," he said. "So in terms of watts, this doesn't add up to all that much. But it's very accurate data in many different locations."

"We are presently completing a first megawatt-scale project and have several further ones in the pipeline," he said, adding that the company has "a solution for commercial rooftops using our Utility Panel and we are planning to offer a solution for the residential market."

On the cell side, the National Renewable Energy Laboratory (NREL) has independently verified that the company's metal-wrap-through, back-contact, printed-CIGS-on-metal-foil devices produced on its Gen 3 line have reached active-area conversion efficiencies as high as 16.4% during tests conducted earlier this year. "Our lab and production teams have managed to make more progress on efficiency than we had planned on in any of our business plans," smiled Roscheisen.

Noting that "we print CIGS onto inexpensive metal foil, something that some have been skeptical can work while others have been wondering whether it can deliver cells better than 6% efficient," he explained that the latest efficiency numbers for the foil cells actually "represent two world records in one: It's the most efficient printed solar cell of any kind (all semiconductor and device technologies) as well as the most efficient cell on a truly low-cost metal foil (with a material cost of only a cent or two per square foot and mil thickness)."

Going beyond the champion cell results, Roscheisen reveals that "in terms of our current baseline production process, our best production rolls now achieve higher than 11% median efficiency measured as equivalent to panel efficiency, with very tight cross- and down-web uniformity."

Moving forward on the conversion efficiency improvement curve, the company exec said Nanosolar "obviously has some rather detailed plans and models on this," although he would not go into detail on which engineering pathways – optical, contact, grain boundary, band, and dopant – were being exploited to drive those efficiencies higher. "We believe we can gain a few more points within the existing framework through a number of known knobs."

NREL's Miguel Contreras, the senior scientist who supervises the CIGS group at the national lab, said that his team has supported Nanosolar "with official measurements, characterization, transferring the know-how we have in making 20% solar cells in the labs. We showed them what the [film] structures look like, what they should shoot for, to improve their own processes and materials – that was our strongest contribution to them."

But he gives full credit to Nanosolar, saying "truly, it's to their merit on most or all of the work that's been done. We just helped a little bit in their success, and I'm proud and honoured to be part of that effort."

This feature is an edited version of two Chip Shots blogs originally published at PV-Tech.org, where the entire exclusive interview with Nanosolar President/CEO Martin Roscheisen can be found. Free, downloadable technical white papers about the company's CIGS solar cell and Utility Panel technologies are available at www.nanosolar.com.