Astronergy pushes toward gigawatt scale, with silicon thin film set to play a major role

By **Tom Cheyney**

Photos courtesy of Astronergy

Astronergy's 30MW line is highly automated, employing a stocker-based approach.

HANGZHOU, CHINA – Liyou Yang started in the thin-film game in 1985 with BP Solar, where he eventually ran the company's amorphous-silicon research efforts. "Once you get into it," he smiled, "you get hooked." During the course of our conversation at Astronergy's headquarters, the Rutgers-educated president/CEO would often reference his time at the old company, using his early experiences as reminders of just how far the technology and the solar industry in general have come since those pioneering days in the 1980s and '90s.

"The macroenvironment was totally different then," with no "industrial base for solar – we incubated the whole thing ourselves," he recalled. BP's in-house R&D and equipment teams were largely on their own trying to figure things out, designing the tools and the processes, and working with equipment builders to transform the concepts into functioning systems and nascent production lines.

Now running one of China's fast-growing photovoltaics enterprises, Yang and his team have aggressive plans to bring Astronergy to gigawatt production scale and beyond over the next few years. Benefitting from the support of the Chint Group, its deep-pocketed corporate parent, he told me that the not-quite-five-year-old solar company is adding or will soon be adding both crystalline-silicon and tandem-junction amorphous-silicon manufacturing capacity in four locations – Hangzhou, Shanghai, Wenzhou and Jiuquan.

As one of a handful of PV firms continuing to promulgate c-Si and a-Si product lines, Astronergy (also called Chint Solar) plans to dedicate about two-thirds of its production focused on crystalline and one-third on thin film, according to Yang.

Liyou Yang, president/CEO of Astronergy.

A new 50MW TFPV line in Hangzhou starts production in Q2 2011, supplementing the existing Oerlikon-supplied 30MW fab. Another 100–150MW is coming online by year's end at the headquarters campus and the Wenzhou site several hours drive south of the lakeside resort city, where building construction will be done in September, and the tools installed by December, he said.

Plans call for an additional several hundred megawatts of thin-film factory capability to be available by 2012 – pushing the total to 730MW – with 200MW of that coming from a new Jiuquan location in northwest China. Astronergy's crystalline capacity should increase to 800MW this year – most of that growth will come from its Shanghai facility – with a total of 1200MW ramped by 2012, he noted.

Altogether, Astronergy hopes to see its total capacity rise to almost 2GW in 2012, before continuing its expansion and passing another milestone the following year. "We want to be at two-and-a-half gigawatts by 2013," the chief executive said.

Once the Chinese factories have been built, the company will site its first production facility outside the home country – a highly automated silicon thin-film fab located in the United States. "We do believe the US market will become prominent," he added, noting the importance of putting factories close to key end-markets. (This distributed-manufacturing strategy also played a role in the decision to build the moduling plant in Jiuquan, near the 1GW of solar farms backed by a partnership of Chint and government entities planned for Gansu province.)

Written off by some as an inadequate or doomed technology with little or no future, silicon thin-film PV has been seeing a bit of a resurgence of late, thanks to companies like Sharp and Astronergy as well as the continued envelope-pushing efforts of equipment and process supplier Oerlikon.

After a couple of tough years riding out the financial crisis and fending off the blowback of Applied Materials' failed SunFab venture, the company cofounded by Yang is now capacity constrained, unable to keep pace on its single production line with the prodigious demand for its 9%-plus-efficient tandem-junction micromorph panels.

"We can't make enough panels," he said. "We're in a difficult situation: how do you turn customers down? We could take three times more orders. It feels like if we really put the squeeze on, we can win every bid. But since we don't have enough capacity, we don't go after every single deal."

Much of the business is coming from southern Asian countries like India and Thailand, including five sizeable orders from the region landed so far this year, he related.

"We are focusing on large customers, going into different markets, especially emerging ones like India, getting our name out, working on bankability. We've found that it's most efficient going through the big guys, and they really help us. We concentrate on that with the small line so far, to get the most out of it."

The combination of Astronergy's c-Si reputation, the built-in financial clout of Chint, and high-quality, low-cost, relatively efficient panels have provided the key components of what Yang sees as the company's competitive "sweet spot" with its silicon thin-film efforts.

"One of the advantages we have is that we already have 500MW of crystalline capacity, so we have some loyal customers who are also doing thin film," he underscored. "We have not seen one customer so far that we supply who specializes in thin film, so that's a plus for us."

Eschewing the prevalent strategy of many companies of starting with a single-junction

A dual-source solar simulator, with carefully tuned spectral balance, tests the tandem-junction panels.

amorphous silicon turnkey line and then progressing to a tandem-junction design after that, Astronergy chose to go directly to the twin-junction architecture, with the help of its equipment partner, Oerlikon.

"Thin film with 6%-plus efficiencies was never going to make it, except maybe for a short time when polysilicon was so expensive," Yang said, highlighting how he uses the generic term regularly as shorthand for "silicon thin film." "Since I knew thin film struggled long before, because of its lower efficiency, I believe that you really can't compete ultimately."

"We decided that we wanted to go directly to tandem-junction structures at that time [2008], from 8% to 9% range," he continued. "We struggled for many quarters, but we got past the financial crisis, and right now I believe that for thin film to become sufficiently competitive with crystalline products, the efficiency needs to be around 10% and the cost structure needs to be below 75 cents US. If you can't do that, you are in a relatively weak position."

"We've held [up] the expansion of thin film for the last two years; we've not done things aggressively because we just simply couldn't. But we have been doing a lot of technology development in the meantime, and we've been building very strong teams.

"After about two years of development, I feel that we are about to make a breakthrough this year, so that we can really hit what I call that threshold for true competitive thin film at 75 cents and 10% efficiency. From there, we're working with Oerlikon to push the envelope for efficiency – 11% is pretty doable, though beyond that I don't know."

Already producing 110–135W panels achieving north of 9% aperture-area efficiency at a cost basis of about 95–98 cents US per watt on the first line, Astronergy is implementing the new process recipe into production on its second line in Hangzhou. After successfully piloting it on a single-chamber R&D tool, the 10% process "can be rolled out when the certification process is done by the middle of the year," Yang said.

The boss wouldn't say which "knobs" were turned to achieve the improvements, pointing out that he could not even share the general categories where they occurred, "because once you mention that, then people would know. Interestingly, in this tandem-junction stack, with something like 20 layers all the way down, there are a number of things that in the past people have been looking into, but to implement them in the production environment, I think this is the first time."

The yield and capacity utilization data from the initial Hangzhou line are impressive. Yang provided charts showing the yield numbers hitting in the 98–99%-plus range continuously since June 2010, with that 30MW of current manufacturing capacity sustaining run rates of about 94% since October.

"We have been running month after month at a yield level that is astonishing – not just the high nineties, it's really close to 100%!" he exulted. "I think there are some intrinsic fundamental factors that are associated with the whole process flow, but there's also the equipment reliability and so on. At BP Solar, we struggled for two years, *two years* to get 80%, so you can see how happy I am."

Yang believes by increasing panel efficiencies and improving throughputs – two areas of development focus at Astronergy and Oerlikon, individually and jointly – more capacity can be squeezed out of the 30MW line. "By achieving 10% efficiency as well as implementing other productivity enhancements, we can increase the line capacity by at least 10%. Right now, we are not even achieving nameplate, running at about 28MW. We will be above 30MW when it's done."

The high level of automation becomes quickly apparent when you walk through Astronergy's tandem-junction production factory floor. Train-like AGVs run along a central chase area and big-armed material-handling robots glide back and forth, slinging the hefty, glass panels in and out of the cassette carriers and various process tools with little or no human intervention on most of the line.

The layout is a serial-batch stocker configuration not unlike that seen in modern semiconductor and flat-panel display fabs. ""The systems are all built around the stocker, so they're pretty flexible. If an individual tool is down, the rest of the process can operate," Yang explained.

The thin-film veteran described the inner workings of the all-important plasma-enhanced chemical vapor deposition tool. "The Oerlikon line's system is built with a single vacuum chamber with 10 individual plasma boxes inside, which operate independently. There is very little interaction between the boxes, and it's pretty reproducible and uniform.

"The system takes about 20 plates at a time for simultaneous deposition, and it takes about a half hour for 20 plates to be processed," he said. The total cycle time on the line, from bare glass in to finished module out, is about 3–4 hours, although "there are some queue times between the production steps."

As the decibels of production throb and whir enveloped us, Yang talked about several aspects of Astronergy's technology and manufacturing as well as offering some teachable moments on the intricacies of certain silicon thin-film behavior and characteristics.

One element of the company's film stack that he sees as a differentiator is its use of zinc oxide rather than tin oxide as its front

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contact layer, materials he is well familiar with from his days at BP.

"Zinc oxide is the superior transparent conductive oxide, yet because of its electrical properties, you need some engineering to get around some problems. Otherwise, even though you get higher, superior light transmission, the open-circuit voltage typically will be lower. But Oerlikon has found a process that does it well. Another difference is that we use zinc oxide on the back-side as well, not using a metal back contact."

He commented on how far the laser technology used in the trio of scribing tools deployed in the fab had come since the old days, when the crystals used in the UV lasers needed to scribe the TCO film were expensive and the process difficult. Now the quartet of tunable-wavelength parallel beams sweep across the glass, quickly separating the films into serially connected cells.

Applied bursts of concentrated photonic energy will also play an increased role on future Astronergy lines, as the trimming of excess material from the panels' edges now done by what he called "sandblasting" will be replaced with laser ablation.

When the subject of one of the banes of amorphous-silicon PV performance – light-induced degradation – came up, Yang took on a professorial air, noting he had written some 10 papers on that very subject. He informed me that tandem-junction structures have intrinsic advantages in reducing LID.

"One factor that influences the LID is material quality," he explained. "If you do a very fast deposition, you can have very strong degradations. Second is the film stack. If you make the junction thinner, so the electrical field within the junction is much stronger; it's not as sensitive to the light-induced defects."

"With tandem junction, for one thing, the junction gets thinner, especially the top junction, where it's more the silicon that is subject to light degradation, while the microcrystalline material on the back-side is mostly stable. Also, that front junction is very, very thin, only about <1000 angstroms. So the total degradation of a panel's junction device is limited to 10-15%, rather than for single junction, where you can have around 25% or more."

Once Astronergy has exhausted the various knobs it can turn to get the most out of its current tandem-junction design, the addition of a third junction to the stack – which would decrease the LID effect even more – is squarely on the company's roadmap. But don't expect a fourth or fifth junction down the proverbial road.

"The general understanding is that triple junction is the most you want to go to; even with the trouble you have, it's still worth doing," he said. Because of diminishing performance returns and increasingly complex engineering challenges, "four-junction is not."

The depth of Oerlikon's involvement in Astronergy's ambitious technology development and capacity ramp plans remains an open question. The new 50MW line entering production status features a different mix of equipment suppliers than the initial, more turnkey line.

"We want to have our own capability of integrating, because that's the way the semiconductor industry has developed, where nobody buys turnkey lines, and eventually solar will go that direction as well. We will continue to work with Oerlikon, all the way from pieces of equipment to a fully integrated fab, depending on the timing, what makes sense at the time, speed, cost, all of that."

A different configuration will help boost the new line's nameplate to 50MW to go along with the targeted 10% efficiencies and 75 cents per watt cost basis, he said.

"If you look at the technology mix that you can bring in, Oerlikon is one configuration, and we have looked at other options. We are very confident we can reach 75 cents by Q2 this year, and that's been done by opening up all of the technology options. You can look at various suppliers and can significantly reduce costs, even though the line is still mostly imported equipment.

"I think our cost structure is still much better compared to an Oerlikon turnkey line, from a capex point of view. We're looking at domestically-produced equipment, which is also still in its infancy stage, yet it has some potential to further reduce capex. We are working with European, US, Taiwanese and domestic equipment on the new line. It's an interesting choice of vendors but it's a painful process of qualifying all of them."

Despite the growing pains experienced by Astronergy, the presence of its flush parent company makes its future prospects trend toward the brighter portions of the spectrum. Yang laid out several advantages of having a "big daddy."

"At the development stage with a big parent company behind you, it really helps in terms of financing. Another reason is that setting up a factory here in China is not an easy thing, even for regular Chinese. When I came back and got a group of technologists together and tried to start a company, it was not as easy. In that regard, the parent company has helped quite a bit in terms of getting the right government support and so forth. Third, there is some access to the parent's global sales network.

"Fourth, there is the synergistic advantage of having complimentary products (Chint is a major player in the power transmission and distribution industry), so we are now pushing in the direction of a total solution together with the parent company," he continued. "Eventually it's the total system that counts; with lower costs you really have to consider everything. Together we can not only optimize the system design and the solution path, but also really leverage the low-cost manufacturing infrastructure in China, with scale and expertise, to really make the PV systems as inexpensive as they could be."

Another not-to-be-discounted factor is what Yang calls the "top level of connections" enjoyed by Chint company head Cunhui Nan, who he describes as "charismatic" and "visionary."

"Our chairman is a member of the People's Congress. He's one of the most well-known businesspersons in China. There are seven guys in the Politburo, and very few businesspeople that all seven would know. And our chairman is one of them. In terms of connections, we probably enjoy one of the best."

This article is the original version of a two-part blog that appears on PV-Tech.

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