# Eye on Stion: Moduling in Mississippi makes sense for upstart CIGSSe 'layer cake' manufacturer

By **Tom Cheyney**

Source: Stion

When Stion started looking for sites to establish its first volume production plant, Mississippi was not even on its radar. After vetting some "100 different opportunities, state and local flavors and locations," the San Jose-based thin-film PV module company had "narrowed the list down to a half-dozen or so pretty quickly," including Texas, Virginia, Michigan, and California, according to CEO Chet Farris.

But then Pierre Lamond of Khosla Ventures (a VC investor in Stion) provided an introduction for Farris with the current governor of the Magnolia state and former chairman of the Republican National Committee, Haley Barbour. Less than five months after an initial meeting between the two chief execs, Stion has agreed to – and the Mississippi state legislature approved – an incentive-laden deal for the CIGSSe firm to build its factory in Hattiesburg.

During the late August meeting, "we discussed where we were at, told him [Barbour] that we were pretty far along in our process, and that they would have to do something fairly quickly," recalled Farris during a phone interview. "They jumped right on it."

The Stion CEO has nothing but praise for the efforts of the Mississippi group. "They worked very hard. It's just a whole different environment than many other places. They put together a consolidated team at the state, county, and local levels. They brought in the university [Southern Mississippi] and junior college on the workforce training programs. They put it all together and worked as a team to come to an agreement that made a lot of sense for both the state and Stion, whereas in other states, that can be a much more difficult challenge to get all those people together on one sheet of music with one common goal."

Incentives were arranged, leading to the low-interest loan of US$75 million, a sales tax exemption worth about US$10 million offered for the tools to be bought and brought in, and other perks presented as part of the package for the company. According to published reports, the company also plans an IPO in 2012 to raise US$100 million to US$150 million.

Five or six locations were scrutinized, although Hattiesburg was not initially considered. "We started closer to the proximity of the Memphis airport, for example," said Farris. Because of the "combination of the worker demographics, the local incentives from the city and county coupled with what the state was willing to do, the proximity to the university and the junior college, we found that it is the right place for us, the right city, the right infrastructure."

The actual site location is a former Sunbeam factory, about 725,000 sq ft in size, that is "very well-suited [for us] and doesn't require a major investment to use," according to Farris. "It was a manufacturing building and has a fair amount of power and infrastructure available on the site. It's a very large, open building, which is ideal for our footprint, with very high ceilings, thick concrete, a lot of basic stuff…the load ratings, the amount of water, power, and sewer that are available at the site, just happen to be a real good fit for us."

The building also "would give us the ability to continue to grow and expand for the next five or six years." Initially, Stion will occupy roughly half the space, with options to utilize more space in the future and even build additional facilities on the overall property, which is about 180 acres.

The news also means that the original major expansion plans for Stion's south San Jose base of operations – where the company has a couple hundred thousand square feet of additional space available to it – will be put on hold.

"We have the [10MW] pilot line, which we'd already started to build up, to add automation and improve the economics and our ability to produce on that line…we'll finish the work we started on the pilot," explained Farris. "The corporate headquarters, the research and development, the general and administrative functions will all stay in San Jose."

While it won't benefit from the hundreds of additional jobs now promised for the Hattiesburg facility, the home site will still hang out the "help wanted" sign for prospective new hires. More hands on deck are needed to help ramp up and operate "the pilot line to get it to be very stable and able to run four full shifts, 24 hours a day. But as we expand further, Mississippi is going to move in advance of any major expansion that we would have in California."

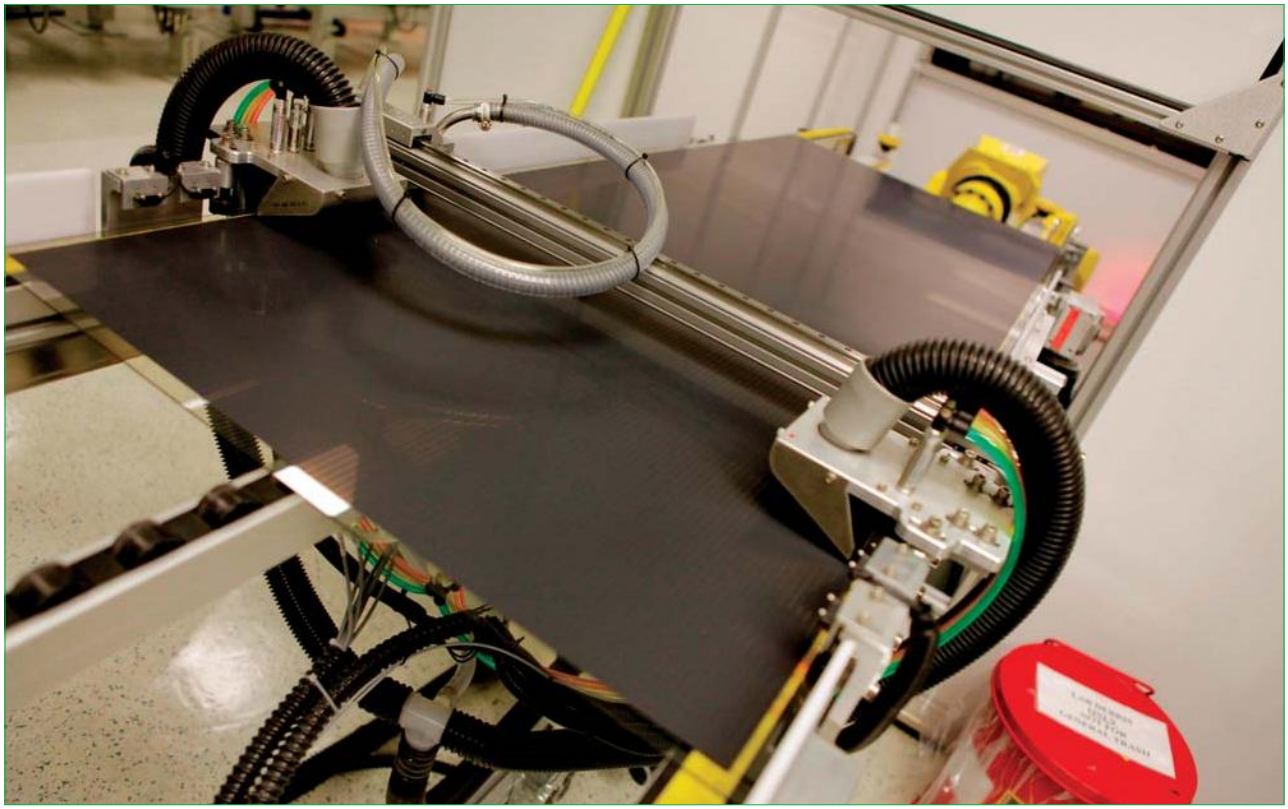
The pilot line will feature the same toolset as the planned volume production facilities. Farris said it will be used as a "training vehicle, so that when the new equipment starts arriving in Mississippi in the late May/June time-frame – we ordered all the long lead tools in the third and fourth quarters of 2010 – people will be able to hit the ground running as it comes up, so we'll have a much quicker ramp-up as a result."

Assuming no major tool shipment delays, with deliveries continuing throughout the third quarter, the company plans to be at "a full 100MW rate by the end of 2011," according to the company exec.

Since the Stion manufacturing scheme features both single- and multiple-use equipment – one sputter tool can handle molybdenum back-contact and absorber-formation duties, for example – the company can "incrementally scale" and not "have to wait for all 100 megawatts to be on the floor before you can produce."

Before manufacturing multimegawatts monthly in Mississippi, Stion will make and ship its Gen 1 65cm × 165cm panels from San Jose. The company has received the requisite UL and IEC certifications, which means that customers will start receiving more monolithically integrated modules soon.

He acknowledged that previous shipments have been "fairly modest," not only because of the size of the pilot line, but also since the company is "still doing a lot of technical work in San Jose to improve efficiency (currently



Source: Stion

averaging ~12%) and support the technology transfer with TSMC."

"But the balance of the allocation of time on tools will shift more to the production side in the second quarter," and the production volume will be in the "hundreds of kilowatts range over the next few months, and that will continue," said Farris. "By the third quarter, we'll definitely start to see output from Mississippi, and it'll just dovetail right in."

"Making CIGS is kind of like baking a cake; they all have flour, eggs, and milk. But we don't tell you everything in the recipe," quipped Farris. In his company's case, the cinnamon and nutmeg can be found in the constituent ratios, molybdenum back-contact secret ingredients, a nontraditional approach to depositing the transparent conductive oxide, and other ways of sweetening its copper-indium-gallium-sulfur-(di)selenide thin-film photovoltaic confection. The pastry analogy doesn't end there: the upstart's roadmap calls for a tandem-junction CIGSSe device, a veritable high-efficiency layer cake.

Stion may be the only CIGS player that has been pursuing a tandem-junction architecture from day one. As I learned during a visit to the company in early December, its first-generation product is actually the bottom device of what will ultimately be a mechanically stacked dual structure.

Farris has been pleasantly surprised that the initial product, given its low bandgap (about 1.05eV), has performed "better than we had actually anticipated," with the Elevation Series modules coming off the company's 10MW pilot production line regularly hitting 12–13% conversion efficiencies.

He believes that a "rational endpoint for single-junction efficiencies from a reproducibility point of view" is about 14–15%. Not champion cells, which Farris has little use for, but "consistent, centerline, tightly distributed" +/-0.5% module efficiencies. "We have a little different strategy: first we tighten the distribution, then work on moving up the efficiency numbers."

Admitting that the "interconnect structure is pretty loose today, especially on the first rollout of the product," he explained that the design "set the P1 to P3 [scribe] spacing pretty wide, and about half of that space can be recovered, which is worth about three-tenths of an [efficiency] point all by itself."

Throw in the elimination of the interconnect card and improved doping, selenization, and sulfurization, as well as other optimization of the film stack, and the efficiency could be boosted a whole point or more. "We were being very, very conservative in that design, so we're going back and looking for ways to recoup some of that."

Although the Gen 1 and eventually Gen 1.5 single-junction modules represent the vanguard of Stion's first commercial push, the key strategic piece of the longer-term game plan hinges on the development and rollout of the tandem-junction CIGSSe panels, which will push efficiency numbers into the mid- to high teens.

"It's a mechanically stacked tandem; the device structures are built completely independent of each other," Ferris explained. "This has some advantages, like not needing tunnel junctions. It allows you to optimize the diodes independent of each other."

"The bottom circuit is built in the substrate configuration, and the top circuit is built in the superstrate configuration. This allows us to exploit and not complicate the bill of materials. We have the semiconductor layers but we don't change any [other] materials.

"We already have two sheets of glass, so we exploit the second sheet of glass for the tandem, and the EVA acts as the dielectric between the two pieces of glass. It's a four-terminal device that gets converted to a two-terminal device in the box, and the way you match currents is by physical cell dimensions rather than to try and suboptimize the diodes.

"The high-bandgap devices ( about 1.6eV) will be higher voltage, lower current than the low bandgap devices, which will be lower voltage, higher current, so you have a current-matched diode, and the best way to do that is simply to do it mechanically," he said.

Work on full-size tandem modules has recently begun at Stion. Farris told me that the final tool had arrived a few weeks before. Up to that point, development efforts used 5 × 5cm$^2$ and 20 × 20cm$^2$ test devices, on which efficiencies of 15.7% and 15.5%, respectively, had been achieved.

The "tool performed flawlessly, the very first [full-size] panel was good that came off of it. We did the absorber formation on that particular tool; it's an RTP [rapid thermal processing] tool. I'm very happy

Source: Stion

with the performance and uniformity--it did what we expected."

"We'll continue to work on that, to make sure we perfect that recipe in 2011 and get it qualified," Farris continued. "I would anticipate that the Gen 2 product would be available in early to mid 2012."

Speaking of those ubiquitous recipes, the firm's cooking process doesn't deviate that much from the standard combination of back electrode/contact–absorber–buffer (which is called the emitter in Stionese)–top contact flow and requisite isolation and interconnect scribe steps seen on other CIGS lines, but the cake does have its differentiated flavors.

Farris took me through the company's existing facility in San Jose, where he described the circuit process and module assembly flow. About US$8 million was spent on the production and R&D gear, an indication of another factor that Farris believes makes Stion "a bit different from other thin-film companies" – they don't design, develop and build their own equipment.

"We use industry standard equipment, optimized for each individual process step," he pointed out. "For virtually all the tools, there are second and third sources available. There is nothing really proprietary in the mass production line from an equipment point of view." Capital expenditures for the volume production facility are projected to be well under a dollar a watt, he added.

The manufacturing line starts with washing/drying the incoming glass and tagging each plate with a barcode. The molybdenum back electrode (along with some proprietary additives) is then sputtered on the glass, followed by a laser-scribe isolation/patterning step.

From there, the absorber layer begins to take shape, the first step consisting of copper, indium, and gallium precursor metals being sputtered (in elemental form, not as compound semiconductors, he pointed out), followed by a reactive thermal anneal process and introduction of the hydride gases to convert the stack to a semiconductor.

A "pretty standard cadmium sulfide dip" takes place next to create the buffer or emitter layer, with the wet process followed by a mechanical interconnect scribing step.

At this point, the Stion process takes a road less traveled in the CIGS community. The company has concocted its own aluminum-zinc-oxide TCO cocktail, which in and of itself is not an eyebrow raiser, but the method it uses to deposit that film does grab one's attention – metalorganic chemical vapor deposition.

MOCVD is cheaper than the usual sputtering processes used to deposit the top contacts, Farris claimed. "More importantly, the film quality on our TCO is unique in that it has a scattering effect to it…which improves the diffusion length of the junction slightly."

Although Stion uses this approach because of its lower cost and improved current characteristics, there's also what the chief exec called a "serendipitous" benefit in terms of the "superior aesthetics" of the module, since its appearance is more uniform compared to some other thin-film panels.

Eventually, because of what Farris vaguely described as "intrinsic aspects of using MOCVD for TCO," the scheme may help with another process innovation: the *elimination*, not the replacement, of the buffer step altogether. "We've already demonstrated a completely cadmium-free process, and we're doing reliability studies," he said, adding that modules made with the improved process should be released to the market in the first part of 2012.

Back on the production floor, once the P3 isolation scribe is lasered in and the leads attached, the manufacturing flow continues into a pretty standard layup/lamination/edge-seal/etc. module assembly sequence, which is semi-automated on the current pilot line but will be highly automated when the volume lines are installed and qualified in the Mississippi facility.

While walking through the line, we encountered groups of TSMC employees being trained in the Stion process. The semiconductor giant plays a major role in the young company's life, as major investor (to the tune of 21%), licensor of the single-junction technology, joint developer, and eventual supplier of modules to Stion to help fulfill its backlog of orders, which "saved us a fair amount of capital investment in order to gain access to that capacity sooner," according to Farris.

The partners are on similar production ramp paths, with both saying they should be getting their volume lines rolling by the second half of 2011. "I think the timeline we have is pretty much the same, and it's dictated by tool delivery schedule and nothing else. TSMC is also buying the same tools from the same vendor(s)," he revealed.

Stion is "very happy with the relationship with TSMC," Farris said. "Obviously, you have different cultures, different styles, that's always a little bit of a challenge to make sure you integrate with them effectively. I think the partnership is working as planned.

"They've helped us get these tools released and our procedures released, and work on maintenance procedures—they're a very good manufacturing company so we've exploited that resource. I think it's been a real win-win relationship, and I'm looking forward to continuing it."

With a reported 500MW of sales deals valued at US$700 million, the CIGSSe company and its low-cost, measured approach and differentiated technology, as well as its strategic alliance with that certain four-letter acronymed chip foundry, may make it a serious player in the photovoltaics cake-baking market in 2011 and beyond.

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