

# Nanotechnology to the rescue of capital efficiency

**S**ilicon wafer technology is king in solar today. Yet the fact is – the emperor is naked. How is this? Efficiency? Feedstock supply? Lack of a 50-year warranty? As is so often the case, understanding the problem is half the battle.



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So what is the problem? The defining problem the PV industry has yet to address is the dirty truth of the most important metric driving any manufacturing business: how much additional yearly revenue one can achieve relative to the capital expenditure required for it, or the revenue/capital expenditure (CapEx) ratio. This metric is about one for silicon cell manufacturers. A ratio of one is painful, and particularly so in any growth market. Profitable manufacturers in the storage-disk industry such as Seagate have a ratio of 1.3 – and the capital markets value them at one times revenue. These are superb management teams performing Herculean tasks every day in their businesses, yet the capital markets reward employees and investors very little with such poor capital efficiency. As soon as the present solar exuberance settles down a bit, being valued at one times revenue is the predictable future of the present silicon manufacturers too. To anyone who feels confident about silicon technology today – let's talk again when that time comes.

Once we understand the problem, we can work on the solution. The solution has to be technology with radically superior intrinsic process throughput, or throughput [MW output] per CapEx. How can one do this? This is not clear with silicon wafer technology. And this is not clear with vacuum-deposited thin films either (given the square meter economics that solar requires). Then how? Nanosolar is focusing on leveraging the technology

that has seen the most radical advances in recent years: nanotechnology. »Nano« is surely a bit hyped; but the reality is that there have been phenomenal advances in the engineering-focused community that works across materials science, chemistry, and physics, and connects under that name.

Nanotechnology can be applied in a variety of ways. Many utilize it in PV to develop new device technology. In our own view, nanotechnology is best applied to improve the process technology that underlies proven PV device technology (proven in the sense of high efficiency and long lifetime). The reality is that modifying anything in a cell stack (new device technology) very quickly becomes basic materials research, let alone basic PV research. We at Nanosolar are focused on utilizing fundamentally new nanocomponents and processes to make a proven device technology (CIGS) with high throughputs. One key aspect to this is to make the semiconductor printable. In terms of intrinsic process throughput (and yield too), there's nothing like printing. There was lots of pioneering R&D in printed CIGS – good early work, but commercially insufficient in many dimensions. Nanosolar has revisited much of this work and developed fundamentally superior approaches over several years of singularly focused, start-up-intense R&D. Nanocomponents? How about 20 nm sized crystals created inexpensively in bulk. Throughput? The dispersions we have really want to be printed at 1,000 feet per minute. One-hour anneal? How about doing it in seconds instead. Bandgap

grading? How about a printing process that gets you just the same bandgap grading as in an NREL 19.6 percent CIGS lab cell-pixel. Materials utilization? How about printing material just where one wants it to be instead of sputtering one's entire operating profit onto the walls of a vacuum chamber. Encapsulation? How about a nanolaminate composed of 1,000 layers self-assembled in a single printing step. These are just a few of the topics that our team could probably fill an entire PVSEC conference with. Most importantly though, the result is efficient and durable cells that are able to be manufactured with an order of magnitude better throughput/CapEx.

So how quickly will the industry move from silicon to high-throughput thin films, and who will be the most decisive driver behind this: the customers, the system integrators? Think again. It will be the capital markets. They will act very quickly and decisively (overnight) – as soon as the reality of a revenue/CapEx of one versus 10 or even 25 sinks in. The capital will move very quickly; the talent and capacity will follow; and, in this warranty-intense industry, everyone else will follow the most investment-worthy and solidly financed. The future will disproportionately reward high-throughput/CapEx companies.

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