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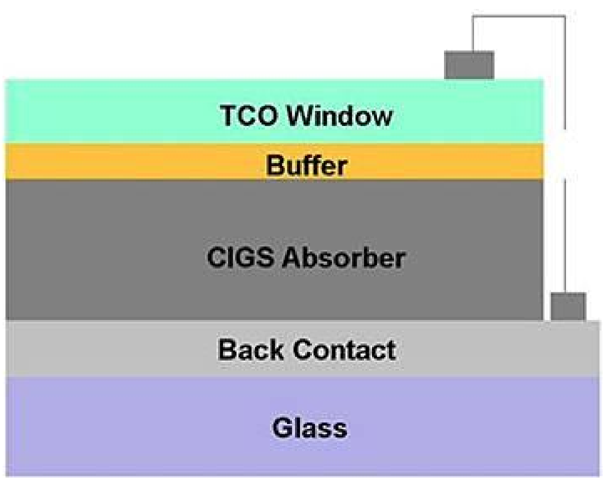
Thin-Film Photovoltaic Cells: When Less is More

Written by Kathy Li Dessau | 27 July 2010

The global PV cell market has grown tremendously with a five-year compound annual growth rate, CAGR, through 2008 of 56% ("2008 Solar Technologies Market Report," US Department of Energy, Energy Efficiency & Renewable Energy). While crystalline silicon (c-Si) PV has approximately 80% of the market share, developers are working hard to lower costs. And, since c-Si wafers make up 40-50% of the final cost of the finished cell module, the industry is turning to alternative materials and technologies. One of the new technologies—thin-film photovoltaics (TFPV)—has grown faster than c-Si with an impressive five-year CAGR of 87%.

TFPV cells use a much smaller amount of semiconductor material—just 1-2 microns thick versus several hundreds of microns for c-Si. And, they use direct band gap semiconductors that have stronger absorption bands, enabling TFPV cells to achieve similar efficiencies of c-Si PV that have 24% cell or 12-18% module efficiencies. Moreover, TFPV may be less costly to manufacture because it lends itself to automated processing and better scalability.

TFPV cells typically consist of three layers deposited on a large glass or metal substrate: a transparent conductive oxide (ITO or SnO_2) layer, a middle semiconductor photovoltaic layer, and a thin metal layer (Al, Au, Cu or Mo). Typical semiconductor materials for thin-film solar cells include cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous silicon (a-Si) layer. The best laboratory CdTe cells have achieved efficiencies of more than 15%, and CIGS, almost 20%. (From the report "Opportunities and Challenges for the Development of a Mature Concentrating Photovoltaic Power Industry" from the National Renewable Energy Laboratory [NREL].) However, when produced in high volumes and fully packaged, actual module efficiencies are much lower than published cell efficiencies.



Cross-sectional schematic of a typical CIGS TFPV solar cell

Although the US ranked 5th in the global 2008 PV market, the US was the global leader in TFPV cell production. The top two manufacturers were First Solar, the world's largest manufacturer of CdTe TFPV cells, and United Solar Ovonics or Uni-Solar, the world's leader in flexible solar modules. Uni-Solar makes a-Si based TFPV that have achieved 12.5% cell efficiencies (5-8% module efficiencies) with their high-volume roll-to-roll solar cell deposition process. Uni-Solar's lightweight, durable and flexible panels are ideal for building-integrated applications because they are easy to install (and remove) and require no roof penetrations.

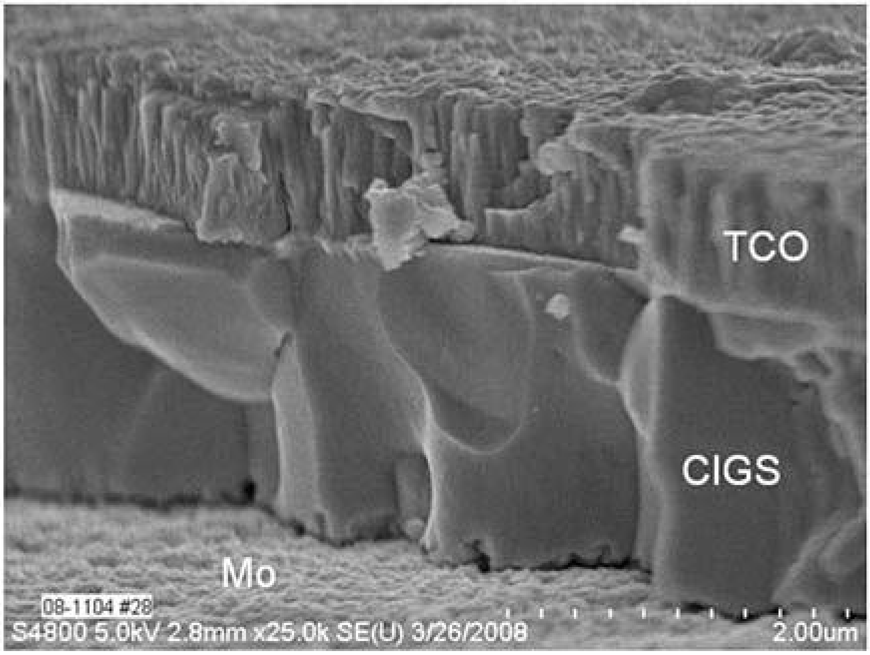
While Uni-Solar panels are reaching a cost of less than $2.50 per Watt, First Solar just recently claimed it started manufacturing solar cells for less than $1 per Watt and with cell efficiencies of 16.5% (6-10.5% module efficiencies). Their CdTe cells use both tellurium, one of the rarest substances on earth—an occurence similar to platinum— and cadmium, a heavy metal that is one of the six metals controlled by the EU in their RoHS directive.

If the demand for tellurium increases, or the EU extends a law to prohibit the use of Cd in electronics to include solar panels, First Solar's TFPV will suffer. Thus, other manufacturers are exploring other active layer materials such as CIGS. While CIGS cell efficiencies in the laboratory have reached almost 20% (NREL), actual module efficiencies are closer to 10-13.5%, similar to that of c-Si PV.

Nanosolar uses a non-vacuum manufacturing method composed of an ink containing nanoparticles of cadmium, indium, gallium and diselenide that has been deposited via a process similar to offset printing, in open air and on rolls of aluminum foil which act both as the substrate and bottom electrode of the cells. Nanosolar claims that its manufacturing process and revolutionary semiconducting ink can potentially reduce the cost to 30 cents per Watt, which would make solar competitive with coal. According to Brian Sager, Nanosolar's Vice President of Corporate Development, Nanosolar was "founded on the premise that cost-efficiency would be king in solar. While incremental increases in performance do provide value, there was an open window through which Nanosolar moved to substantially drive down costs, ultimately enabling grid-parity economics in solar." Their first commercial product is optimized for use in large-scale deployments, such as multiple MW utility-scale power plants and large commercial rooftop systems, in the MWs to tens of MWs range.

Brian Sager, Vice President of Corporate Development, shown with a TFPV panel from Nanosolar

Rival Heliovolt manufactures commercial CIGS TFPV via a proprietary, low-cost, highly scalable, vacuum-deposition manufacturing method, similar to that used in the manufacture of flat screen TVs. Their process, as Iga Hallberg, HelioVolt's Vice President of Business Development says, "is a more robust, better understood and mature technology. There are also material limitations why [Heliovolt] deposits on glass, and that has to do with product applications and 20+ year warranties." While their manufacturing process could be applied to a variety of substrates, including flexible substrates, the glass laminate platform results in the most cost effective and reliable product. They are also developing an "ink-based" process that will have the potential to be a simpler, faster, lower cost process for printing high quality TFPV systems in the future.



SEM cross-sectional image of a reactive transfer CIGS device

In the laboratory, research continues in developing the next-generation TFPV that would eliminate cadmium, tellurium, and Indium completely. In February of this year, IBM announced a TFPV made from copper, tin, zinc, sulfur, and/or selenium—all earth abundant materials. The measured cell efficiency was 9.6%. More information can be found in the IBM press release.

What technology will win in the end is unknown, but with all the competition, it is certain that PV costs will be driven closer and closer to that of fossil fuels. And, with iSuppli raising its global solar installations forecast for 2010 to 13.6 GW, the need for TFPV will certainly only increase.

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