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Transparent Conductors in Thin Film and Organic Photovoltaics-2012

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NanoMarkets, LC
PO Box 3840
Glen Allen, VA 23058
Tel: 804-270-1718
Web: www.nanomarkets.net

Transparent Conductors in Thin Film and Organic Photovoltaics – 2012" is the latest report from NanoMarkets in our ongoing coverage of materials and markets in the photovoltaics sector. In this report, NanoMarkets examines the changing opportunities for different kinds of transparent conductors in the TFPV and organic PV industry.

This report considers how transparent conductors will find markets and help create value for suppliers of leading edge PV technologies under the changed circumstances that PV faces today in which government subsidies are under threat and there are huge pressures to reduce TFPV costs to make it competitive with c-Si PV and with other sources of energy in general. Taking into account the new dynamics of the TFPV and OPV industry, this report identifies where transparent conductor firms can generate business revenues, both from the older segments of the TFPV/OPV industry and from emerging segments, such as BIPV glass.

This report is designed to help transparent conductor suppliers to understand how the overall changes in the PV industry will influence their sales. It covers the use of transparent conductors in thin-film Si, CIGS, CdTe, OPV, and DSC and includes a discussion of how both established transparent conductor technology and the latest transparent conducting nanomaterials can make money in the PV market.

As with all NanoMarkets reports, this report includes an eight-year forecast of the markets broken out by type of PV technology and type of transparent conductor material. In addition, the report discusses the strategies of key firms to watch in this important sector. The forecasts are provided in both value and volume terms.

Chapter One: Background to this Report

1.1 What Has Happened in the TFPV Market Since the Last Report?

NanoMarkets anticipates significant challenges to the *status quo* in the photovoltaics (PV) market in the coming decade. The PV sector as a whole is entering a period of flat or moderate growth in the next couple of years, and the industry remains highly cost sensitive. Meanwhile, the ongoing shift in market share toward thin-film PV (TFPV) is changing the accepted landscape of available PV technologies. This movement, in turn, is causing a shift in demand for transparent conductors (TCs) in PV applications from market-dominant crystalline silicon (c-Si) PV that uses little or no TCs to TFPV that, in most cases, requires the use of high performance TC electrodes.

1.1.1 Changes in the TFPV Market that Affect TCs

The PV market has, for the past several years, been a boon to the materials industry. Partly thanks to government subsidies, the solar industry has grown dramatically, including a significant growth spurt in 2010. NanoMarkets believes, however, that the boom days are over for the PV sector, and the outlook for the next decade is much different from that of the last. First, the success of the PV industry is closely tied to the construction industry, which is still struggling in several important markets, such as Australia, Canada, France, Sweden, Spain, and the U.K. Second, we think that, in most countries, many of the subsidies and tax incentives that have supported the PV industry for a number of years are going to be reduced significantly. Recall that when the Spanish government took this step a few years ago, the PV market in Spain declined by 75 percent.

This slow growth affects the c-Si market the most, but the TFPV market is not immune. And the penetration of TFPV will happen gradually, rather than sharply, and we are not certain it will happen rapidly enough to overcome sluggish overall growth prospects. *The end result of this analysis is that the TC industry can no longer rely on the TFPV industry to provide new business based on rapid growth.* Complicating the picture, too, is the fact that growth will occur only as long as the TFPV industry is able to keep up with the continuing cost reductions in the c-Si sector, and as long as the flood of low-cost Chinese silicon modules cause minimal disruption to the TFPV business models.

The expected trajectories of the different PV sub-sectors and their impact on the TC business are quite different:

- The success of cadmium-telluride (CdTe) PV, driven by a single firm, First Solar, has created a *de facto* entrenchment of a single TC type, namely fluorine-doped tin oxide (FTO) in this PV technology. Until now, this situation has meant that there were few opportunities for other materials (or other suppliers) to gain entry. However, with the recent entry of GE into the fray, things may be changing in CdTe PV. And since First Solar's success has proven that CdTe PV can effectively compete with c-Si PV, we expect that other panel makers may also explore implementation of CdTe PV. This new scenario could present opportunities for TC suppliers to gain entry by offering products that provide an additional efficiency, cost or other market-differentiating advantage beyond that which FTO can offer.

- The situation has not been so great at firms producing copper-indium-gallium-(di)selenide (CIGS) PV. The shuttering of Solyndra in 2011 and the exiting of Veeco in 2010 caused some concern that CIGS was headed for failure, but we think instead that the struggling industry needed the consolidation. Those that remain may be in a better position now to learn from the mistakes of the failed firms, and innovative firms will look for new ways to reduce costs and improve performance, both of which are very much tied to the choice of TC.

- Thin-film silicon (TF Si) is still around, and still accounts for the biggest chunk of the TFPV market. We expect this sector to remain large throughout the period covered by this report, but we also anticipate that its market share will continue to shrink as other more cost-effective PV technologies take hold. In this market, we think that cost cutting, rather than innovation, will rule the day, which means that low-cost alternatives that require minimal changes to implement—*i.e.* principally transparent conductive oxides (TCOs)—will see opportunities to expand or gain entry.

- Meanwhile, organic PV (OPV) and dye-sensitized cell (DSC) PV have struggled to take off as quickly as expected, and the outlook for these sectors, although promising, remains somewhat uncertain. OPV and DSC have thus far mostly used ITO TCs based on legacy rather than strategy, while these technologies have developed. However, OPV and DSC are now entering a do-or-die commercialization period during which the realities of scale-up are front and center, and where the need to keep costs down and performance high will favor evaluation of many different TCs, including those like nanosilver and conductive polymers that promise low-cost, sputter-free processing.

Optimistically, we think that internal technology transitions in the PV industry will yield new opportunities for those coatings firms that know where to look for them. *TC materials used in thin-film PV are not a settled matter across the sector*. New suppliers entering the TC space in PV are often not battling entrenched materials and entrenched suppliers. And, in NanoMarkets opinion, this opportunity can only get better over time, since with subsidies removed firms are more likely to come up with innovative new types of solar panels with even more uncertain TC requirements.

The importance of flexible PV to opportunities for TCs: TFPV and organic PV are also diversifying, with increasing proportions of flexible products and new approaches to reducing costs. These trends include the increasing importance of building-integrated PV (BIPV) types, which are at least partially flexible, and of flexible versions of OPV and/or DSC PV.

As these changes in the industry occur, there will be new opportunities for suppliers of other transparent conductors. Flexible products will take their toll on ITO and the other TCOs, and additional opportunities for more flexible materials—conductive polymers and nanomaterial-based films—will emerge. Similarly, the high cost of vacuum deposition for even relatively cheap, indium-free TCO materials will support the development of printed or coated alternatives—using the same conductive polymers and nanomaterials—simply to enable reductions in manufacturing costs and to enable production of low-end/low-cost "disposable" PV cells for use in the growing, ubiquitous printed electronics industry.

1.1.2 Why Cost is So Important in PV

Cost has always been important in PV applications; a central thesis, after all, is that PV can be a more eco-friendly alternative to carbon-based fuels. And PV technology has a way to go to meet its goal of parity with conventional energy generation technologies for on-grid applications. Note, for example, that the U.S. Department of Energy (DOE) says that thin-film solar production costs need to be reduced by as much as 75 percent—down to under $50 per square meter or less than 5 cents per watt—before cost-effective distributed power and utility-scale production of electricity from TFPV can be realized on a widespread basis.

The pressures for low cost exist throughout the PV industry, but are arguably most intense in TF-Si PV. As a mature technology, TF-Si has already exhausted many of its options for cost reduction through economies of scale, and hence panel makers are now left to target bill of materials (BOM) and manufacturing cost reductions. For this reason, ITO is disappearing in favor of lower-cost TCOs.

As noted above, the CdTe PV industry already uses FTO as a low-cost alternative to ITO. And cost pressures across the PV industry may now encourage those panel makers that are still using ITO in CIGS, OPV, and DSC PV to make the switch toward lower-cost TCOs.

Eventually, even alternative TCOs will be seen in some cases as too costly. When this occurs, manufacturers will thus renew their interest in *other* materials, particularly if they don't involve the costly vacuum deposition equipment used for TCOs. And this opportunity applies not only to TF-Si, but across the other TFPV types as well.

In summary, overall, the TFPV sector is still far from mature. In many sub-categories, it has yet to settle on TC materials. For example, the struggling (but still big) thin-film Si PV sector has turned toward FTO, CIGS PV uses mostly AZO, and FTO is already standard in CdTe PV. These sectors have turned to different TC options not solely because of performance, but also because of the need to reduce costs. This fact, in turn, indicates that there are real opportunities for suppliers of alternative TCs to make the case for their materials on a cost-savings basis.

Even with this potential, however, NanoMarkets believes that capitalizing on the opportunities will require a serious rethinking of how money is going to be made in TCs for PV applications. A more active business development program is required—one that is designed to convince TFPV players that costs can be reduced without sacrificing performance using a particular TC material. In the near- to mid-term, this means alternative, indium-free TCOs, and in the long-term less expensive nanomaterial-based alternatives make sense.

1.2 Objectives and Scope of this Report

The objective of this report is to analyze the opportunities available in the PV market for suppliers of TCs. In this analysis, we consider the factors that affect the overall TC markets, such as the price of indium and/or ITO and the performance *vs.* cost characteristics of non-ITO alternatives. We include an assessment of each of the major thin-film and organic-based PV technologies, and the unique aspects of their transparent conductor usage and needs, as well as an assessment of the types of transparent conductive materials available or in development and how they could fit those needs. We are principally concerned with the transparent conductive materials themselves and the PV technologies that employ TCs, but we also consider and discuss both companies producing and developing TCs as well as the end-users in the various PV segments.

The classes of materials that are used as transparent conductors in PV applications are as follows:

- ITO,
- Other transparent conductive oxides,
- Nanosilver (and other nanometal) based transparent conductive coatings
- Carbon nanomaterial-based transparent conductors, and
- Transparent conductive polymer coatings.

Thin-film and organic PV end-use markets considered are:

- CdTe PV,
- CIS/CIGS PV,
- Thin-film Si PV,
- OPV, and
- DSC.

Through a review of each of the various market segments, we show where new business revenues will be created in the next eight years, and we provide detailed eight-year market forecasts for the use of TCs in PV applications broken out by material type and PV application. The forecasts are in terms of the materials required *per square meter of transparent conductive film and in dollars of revenue*. This choice of units makes the data meaningful to suppliers of the transparent conductor materials that may provide bulk materials like sputtering targets, inks or coatings products, or pre-coated glass and/or plastic substrates.

These forecasts are based on a foundation of NanoMarkets' forecasts of both the PV industry itself and the transparent conductors industry. These are further developed and customized with our extensive technical expertise concerning the physical and materials needs of PV manufacturing and products.

This report is international in scope. The forecasts are worldwide forecasts and we have not been geographically selective in the firms that we have covered in the report or interviewed in order to collect information.

1.3 Methodology

This is the latest report from NanoMarkets that looks closely at materials used in the photovoltaics industry, which is a key area of expertise of NanoMarkets. The information for this report is derived from a variety of sources, but principally comes from primary sources, including NanoMarkets' ongoing interview program of entrepreneurs, business development and marketing managers, and technologists involved with photovoltaics, transparent conductors, and emerging electronics of all kinds. We also use information from secondary sources, such as relevant company and industry organization websites, commercial databases, trade press articles, technical literature, SEC filings and other corporate literature.

Some background information for this report has been taken from last year's version, *"Transparent Conductors in Photovoltaics: Market Opportunities"* from January 2011. In addition, some of the market information in this report comes from our most recent reports on photovoltaics and on transparent conductors:

- *"Emerging Markets for non-ITO Transparent Conductive Oxides"* from October 2011
- *"Markets for Silver-Based Transparent Conductors"* from September 2011
- *"Markets for Indium-Based Materials in Photovoltaics"* from September 2011
- *"Nanosilver Markets"* from August 2011
- *"Transparent Conductor Markets - 2011"* from July 2011, and
- *"Thin-Film Photovoltaics Materials Markets, 2011 and Beyond"* from December 2010.

Where information has been used in an earlier report, it has been reconsidered in light of current developments and updated accordingly.

The basic forecasting approach is to identify and quantify the underlying photovoltaics markets, the materials needs for the transparent conductors that are required, and the technological and market pressures that affect the mix of materials used in these markets. We consider the specific materials needs of the various PV technologies that are or can be served by different kinds of TCs, and the technological and market pressures that affect penetration of these TCs into the different PV markets. We also consider broader economic developments that impact photovoltaics and materials development and commercialization.

This report on transparent conductors forms part of a series of reports published by NanoMarkets covering new directions in the commercialization of PV and for materials used in PV applications. Other related areas covered by NanoMarkets' reports include analyses of the markets for silver and nanosilver, transparent conductors in general (ITO, alternative TCOs, and non-TCO types), and other materials markets for photovoltaics.

1.4 Plan of this Report

In Chapter Two, we examine the types of transparent conductors that are used in thin-film photovoltaic markets, including the advantages and disadvantages of each class of materials and how we expect them to succeed (or fail) in the TFPV industry. The goal is to identify key opportunities for TC firms in PV. We pay particular attention to changes in the market over the last year, as well as anticipated trends over the next 18 months. As part of this analysis, and to illustrate important trends and developments, we briefly examine the focus and strategies of some of the key suppliers and end users of transparent conductors in TFPV applications.

Chapter Three contains our eight-year forecasts for transparent conductive materials used in photovoltaics. Our forecasts are broken out by PV technology and by type of transparent conductor.