Dye-Sensitized Cell Markets–2012

Nano-531

Published April 2012

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In the past two years, the dye sensitized cell (DSC) market has come of age and has moved out of its R&D phase. The performance of DSCs is now comparable with amorphous silicon PV, but with much more potential than a-Si for performance improvements. DSC's also offers an ability to be deployed on flexible substrates and perform under non-peak insolation.

This report provides an in-depth market analysis of recent developments in DSCs, examining the meaning of the latest products, strategies and technical developments. We identify how performance improvements are likely to help grow addressable markets for DSC and where these new markets are to be found. Specifically, we examine the potential for DSC in the BIPV sector and how DSC is likely to do in a world in which solar energy is not the hot topic that it was a few years ago.

The report also appraises the commercial significance of the developments that have taken place in the DSC over the past year; for example, attempts to reduce the cost of dyes and electrodes. And it also includes NanoMarkets' assessments of the strategies of leading firms active in the DSC space. And, as always with NanoMarkets reports, this report also contains granular forecasts of DSC panel and materials shipments in volume and value terms.

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Chapter One: Introduction to the Dye—Sensitized Solar Cell Market

1.1 The Coming of Age of the DSC Market

NanoMarkets has covered the market for dye-sensitized (solar) cell (DSC) photovoltaics (PV) for several years, but believes that since our last report—and certainly in the last two years, the DSC PV market has come of age and has moved into the early commercialization phase:

- Pilot line-produced commercial cells are being made and shipped to customers.
- The laboratory performance of DSCs is now comparable with amorphous silicon (a-Si) (PV), but with *much more potential* than a-Si PV for performance improvements down the road.
- In addition, DSC PV is compatible with flexible modules, solution processing, and roll-to-roll (R2R) production processes, which widens its applicability beyond that of most conventional PV technologies.

But these facts, which mean that DSC can expect to start generating significant revenues in the near future, are, NanoMarkets believes, obscured in the eyes of much of the PV industry (perhaps including investors) by history.

1.1.1 A Market in Early Commercialization

In the past, the DSC market has frequently been seen as a subset of the organic PV (OPV) industry. Most superficially, this viewpoint has existed because “pure” OPV and DSC use organic materials. More significantly "pure" OPV and DSC for many years exhibited the same low performance characteristics that relegated both technologies to the same low-end addressable markets.

This association made some kind of sense a few years ago, when both “pure” OPV and DSC had very similar performance and commercialization characteristics:

- However, DSC, as we have already noted, is beginning to look more and more like a commercially viable PV technology, while OPV seems to be mired in a permanent R&D phase, and has a measurably worse efficiency performance.
- Today, the DSC industry largely consists of a handful of firms that share a common history. Most of the dyes for DSC projects, for example, have come from Dyesol technology and intellectual property, while the basic structure itself is based on the

original École Polytechnique Fédérale de Lausanne (EPFL) Grätzel/O'Regan-type cell. This kind of concentrated industrial structure has reinforced the idea that DSC is niche technology.

To the extent that DSC is amalgamated with OPV then, and seen as an industry sector made up of tiny firms, its image suffers. But NanoMarkets believes that the DSC industry will be able to break away from at least some of that negative image, based on its improving performance, which in turn will lead to broader addressable markets and a less niche-like industry structure:

- For a while DSC and OPV seemed to be suitable primarily for marginal products such as solar handbags or solar umbrellas; DSC seems to have made somewhat more progress in the building-integrated PV (BIPV) space than OPV.

  The Dyesol-Tata partnership announced achievement of several technical milestones in 2011 at their product development facility in Wales. In addition, Dyesol and U.K. glassmaker Pilkington (owned by Japanese glass firm Nippon Sheet Glass (NSG)) formed DyeTec Solar to produce and commercialize semi-transparent BIPV modules based on DSC technology. DyeTec Solar announced in August 2011 that its production facility was fully equipped and ready to start prototype production.

- Although the materials focus is still with Dyesol, several other large and mid-sized specialty chemical firms have entered the DSC materials business, including German firms BASF and Merck, as well as Japanese firms Showa Denko and Fujikura.

1.1.2 The Performance of DSC PV Continues to Improve

Today, champion cells at various key DSC firms top 12 or 13 percent, but these values are for small cells, usually of 1 square centimeter, measured in very controlled settings. Conversion efficiencies are much lower, as the realities of scale up and manufacturing keep actual peak conversion efficiencies closer to 4.5 or 5 percent:

- A-Si PV conversion efficiencies for commercial products hover around 10 percent, Furthermore, a-Si PV is a mature technology with limited potential for further efficiency improvements, while the potential improvements to be made in DSC PV over the next few years are significant.

  NanoMarkets also notes that while the a-Si industry is somewhat dispirited after ramping up for a big boom that never happened, the DSC industry is quite enthusiastic about its prospects.

Thus, DSC manufacturers are now engaged in an effort to get commercial efficiencies up to the levels obtainable in the lab setting. This effort involves optimization of materials, device fabrication techniques, module development, and various integration and connection considerations.

And the industry is making progress on this front; recently, Australia-based Dyesol announced the successful production of a 1.2 meter by 60 centimeter single-substrate DSC module for BIPV applications.

- Peak conversion efficiency is not the only measure of performance—and potential value—for DSC development. Important measures of performance for DSC also include performance under *other* lighting conditions, and comparisons such as "25 percent better" than other cells, or "more uniform power" throughout the day are commonplace in DSC marketing literature.

  For example, G24 Innovations (G24i) just announced a record-setting 26 percent *average* conversion efficiency (ambient light, 200 lux). By contrast, a-Si PV suffers from sharp drops in efficiency in low light, off-angle light, and high heat environments.

  NanoMarkets believes that the focus on this potential advantage to DSC indicates the growing recognition that DSC PV is attacking a different kind of market than the (currently) more efficient inorganic PV technologies and that, consequently, different kinds of measures may be more appropriate. More specifically, DSC manufacturers are often marketing their products for indoor or other low-level illumination settings—or at least on total kWh output—instead of on peak watts in full sun.

  The emergence of BIPV applications is a key example of this trend, and as we stress throughout this report, NanoMarkets believes that DSC's low-light PV performance advantage will translate into a substantial commercial advantage in the BIPV market, where PV cells are often called to function in more shaded areas. It may even be the case that in some market niches, DSC may be the only PV technology that is suitable for use.

1.1.3 DSC and the PV Industry Crisis

However, prospects for DSC must be considered within the context of the overall PV market, of course. And unfortunately, the economics of the PV market in general are quite different—which is to say much gloomier—than they were the last time NanoMarkets reported on DSC:

- By all accounts, the overall PV market in 2012 is entering a period of lackluster growth, which is in stark contrast to the 2009-2010 time period that saw year-to-year doubling (or more) of the market, even in the midst of worldwide recession.

- In 2012, a glut of conventional PV modules on the market and dropping panel prices are expected to significantly slow growth rates in PV production going forward.

There has also been a big shift in the economic environment. Lingering monetary concerns in important global markets in the United States and the European Union, coupled with slow growth and high unemployment, have led governments around the world to consider serious cost-cutting measures in an effort to reduce debt:

- The subsidies, feed-in tariffs (FITs), and other tax incentives that have supported the PV industry over the last several years are now being reduced significantly. For example, Germany, currently one of the largest PV markets, recently announced sharp cuts in FITs that support its PV industry.

- The ramifications of these cuts are not yet fully known, but when the Spanish government took this step a few years ago, the PV market in Spain declined by 75 percent.

What does all of this change mean for DSC applications?

- DSC will be hit by all the negatives associated with disappearing subsidies and to the extent that cuts in PV subsidies also hurt the investment climate for new DSC firms.

- However, DSC currently primarily competes in off-grid applications, which are not impacted by a decline in PV subsidies. And DSC's future may be in BIPV, where the economics is somewhat less dependent on subsidies.

- Given DSC's status as an "emerging technology," it could also be argued that the overall problems in the PV market will have less impact on growth prospects for DSC.

In summary, we believe that the pace of growth in the DSC market *will* offset declines related to decreasing government support and slow overall economic growth, *but we also believe that 2012 will be a year in which DSC must prove itself in the market. If it does, then the growth prospects are quite substantial.*

1.2 Objectives and Scope of this Report

The purpose of this report is to examine the opportunities and challenges for DSC over the next eight years. Specifically, this report provides a market analysis of recent developments in DSC PV.

In the report, we examine the latest products, strategies and technical developments of the industry. We identify how performance improvements are likely to help grow addressable markets for DSC, and where these new markets are to be found. Specifically, we examine the potential for DSC in the BIPV sector and how DSC is likely to do in a world in which solar energy is not the hot topic that it was a few years ago.

The report also appraises the commercial significance of the developments that have taken place with DSC over the past year; for example, attempts to reduce the cost of dyes and electrodes and various breakthroughs in cell size and/or cell efficiency. In addition, it also includes NanoMarkets' assessments of the strategies of leading firms active in the DSC space. And, as always with NanoMarkets reports, this report also contains granular, eight-year forecasts of DSC panel and materials shipments in volume and value terms, broken down by application wherever possible.

Materials covered include the critical components of the cells and modules; host, dye, and electrolyte materials; transparent and nontransparent electrode materials; and encapsulation materials. To construct the materials forecasts, we focus on the DSC PV modules only; we define "module" as the unit of self-contained PV devices, consisting of one or more cells. Thus, materials used to construct auxiliary articles involved in integration of the PV modules into products are excluded from the analysis.

The DSC device markets are considered in light of the various applications they are targeted toward, which include conventional panels and BIPV (including BAPV), solar chargers, and powered bags, umbrellas, and tents.

1.3 Methodology of this Report

This report is the latest from NanoMarkets that looks closely at the PV 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 PV, PV materials, 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 the previous version of this report, *"Dye-Sensitized Cells: Materials, Applications, and Opportunities"* from April 2011. In addition, some of the more recent market information in this report comes from our most recent reports on PV, silver, and transparent conductors:

- *"Silver in Photovoltaics"* from March 2012
- *"Transparent Conductors in Thin-Film and Organic PV"* from February 2012
- *"Markets for Silver-Based Transparent Conductors"* from September 2011
- "*Markets for Indium-Based Materials in Photovoltaics"* from August 2011
- *"Transparent Conductor Markets – 2011"* from July 2011

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 markets for DSC, along with their materials needs, and the technological and market pressures that affect growth prospects for DSC modules and the mix of materials used to produce those modules. We also assess the competitive landscape to determine the suitability and likely volume of DSC devices produced over the next eight years, and we consider broader economic developments that impact DSC PV and materials development and commercialization.

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

This report 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.

1.4 Plan of This Report

In Chapter Two, we discuss the market evolution of DSC by examining DSC product and application developments. We look particularly at key applications that are expected to be revenue generators, like solar chargers, flexible PV modules, and BIPV. We also examine how

DSC compares to other types of PV with which it must compete, and we discuss the prospects for DSC in light of the overall situation in the wider PV market.

In Chapter Three, we examine the DSC products that are now entering the marketplace. We consider various levels of the DSC value chain, from key materials firms to key firms that provide value-added products—modules, solar chargers, etc.—that use DSC as their key power technology.

Chapter Four contains our eight-year forecasts of the markets for DSC devices, as well as the materials used in them. We have broken out these product types by applications in the case of DSC devices and by materials types in the case of materials.