
Silver in Photovoltaics:2010

Nano-216

Published September 2010

© NanoMarkets, LC

NanoMarkets, LC
PO Box 3840
Glen Allen, VA 23058
Tel: 804-360-2967
Web: www.nanomarkets.net

Silver in Photovoltaics: 2010

Nano-216

This report identifies and quantifies the opportunities for silver and silver products in the rapidly changing photovoltaics (PV) industry. The report consider silver inks and pastes and various hybrid materials that are used in PV; materials such as transparent conductive silver-containing composites.

Page | 1

With the end of the silicon shortage, crystalline silicon, for which silver is the dominant electrode material, seems less threatened by thin film PV (TFPV) than it did a year or so back. How good is this news for silver? TFPV, in its various forms, is still expected to gain share in the PV market and has yet to firm up on the electrode materials that it will use going forward. As TFPV technologies mature, will silver be a winner or loser?

This report answers these questions and many more. It also examines the potential revenues for silver in PV in the light of NanoMarkets' revised PV projections given the current economic situation and prospects for renewable energy worldwide.

Table of Contents

Executive Summary

- E.1 Why silver will continue to be used in photovoltaics
- E.2 New approaches to controlling the costs of silver in the PV industry
- E.3 Opportunities for silver alternatives in the PV industry
- E.4 PV-related opportunities for the silver production and distribution industry
- E.5 Opportunities for silver paint and ink firms
- E.6 Silver-related opportunities for solar panel firms
- E.7 Important development and changes since last year's report
 - E.7.1 What the decline in the prospects for the PV industry means for silver sales
 - E.7.2 Recent silver-related pricing trends and other changes impacting the PV industry
 - E.7.3 Impact of worldwide economic conditions
- E.8 Summary of eight-year forecasts of silver sales into the PV industry

Chapter One: Introduction

- 1.1 Background to this report
- 1.2 Objectives and scope of this report
- 1.3 Methodology of this report
- 1.4 Plan of this report

Chapter Two: Current and Future Utilization of Silver by the Photovoltaics Industry

- 2.1 Traditional applications for silver in crystalline silicon PV

- 2.2 Thin-film PV: New uses for silver
 - 2.2.1 Applications for silver in amorphous silicon and other forms of thin-film silicon
 - 2.2.2 Applications for silver in CdTe PV
 - 2.2.3 Applications for silver in CIGS PV
- 2.3 Silver, organic PV and dye sensitive cells
- 2.4 Are there uses for nanosilver in the PV industry?
- 2.5 Silver in transparent conductors for the PV industry
- 2.6 Production trends impacting silver use in the PV industry
- 2.7 Regulation issues for nanosilver
- 2.6 Key points made in this chapter

Chapter Three: Markets for Silver in the Photovoltaics Industry

- 3.1 Front electrodes
 - 3.1.1 Fingers: Balancing electrical coverage with light obstruction
 - 3.1.2 Transparent electrodes: Balancing conductivity with light transmission
 - 3.1.3 Tabbing
- 3.2 Back electrodes
 - 3.2.1 Silver as a reflector
 - 3.2.2 The drive to lower cost materials
- 3.3 Alternatives to silver in PV
- 3.4 Key points made in this chapter

Chapter Four: Eight-Year Forecasts of Silver in Photovoltaics

- 4.1 Forecasting methodology
 - 4.1.1 Data sources
 - 4.1.2 Scope of forecast
 - 4.1.3 Alternative scenarios
 - 4.1.4 Some notes on pricing
- 4.2 Forecasts of silver consumption by PV technology
 - 4.2.1 c-Si
 - 4.2.2 Thin-film silicon
 - 4.2.3 CdTe
 - 4.2.4 CIGS
 - 4.2.5 DSC
 - 4.2.6 OPV
- 4.3 Forecasts of silver consumption by PV cell component
- 4.4 Forecasts of silver consumption by silver material type
- 4.5 Summary of forecasts

Chapter One: Introduction

1.1 Background to this Report

In serving the applications for silver inks and pastes, manufacturers and distributors face a quandary: most of the high-growth markets for silver are relatively small, while the larger markets are already mature and generally offer only modest growth prospects. But the photovoltaics market for silver inks and pastes offers the best of both worlds. This segment is already approaching a billion dollars in annual revenues, but it will grow faster—in absolute terms—than any of the other silver ink categories, and it will challenge traditional thick-film applications for dominance of the overall silver electronics market by the end of the period covered by this report. *With all this in mind, this report specifically analyzes the photovoltaics-related markets for silver inks and pastes, in order to provide a comprehensive analysis of the revenue opportunities for firms in this space.*

This growth in the use of silver for PV is driven primarily by the growth of PV itself, which is still growing quite rapidly even though it has slowed—and at times faltered—in the last few years. While PV is certainly not immune to the undulations of the economy—as we saw in the contraction of PV shipments in 2009—it is still one of the stronger components of that economy. In part because this because PV has been spurred by government subsidies, which in turn were put into place because of concerns (valid or not) about the availability and accessibility of fossil fuels and the environmental impacts of extracting and burning them. As an aside, however, we note that without such subsidies, the PV industry has a hard job surviving as the ending of some subsidies in Spain and Japan have proved. In some cases, subsidies are being supported with renewable energy mandates, but there are no guarantees that these mandates will be successful in achieving their goals in the long run and a strong probability that they will not.

All of this suggests that the opportunities available for suppliers of silver and silver products into the PV space are highly dependent on policy consideration, which should be judged a significant risk factor in view the current worldwide financial problems.

We also note that silver itself is a commodity and its price depends on much more than its photovoltaic-related use, or even the whole of the market for silver inks and pastes used in the electronics industry as whole. Besides the industrial uses of silver, silver is also used for decorative purposes (jewelry) and as a store of value in bullion. The economic turmoil of the last few years has increased investment in “hard” assets like precious metals, and silver’s price has been affected by it even as the struggling economy has caused overall industrial silver consumption to be less than robust. This naturally increases the cost of silver for use in

photovoltaics and other electronics. Since PV is a cost sensitive factor, these apparently exogenous factors – exogenous from the perspective of the PV industry, anyway – are likely to have a great deal of impact on how silver is used in PV over the next few years.

In particular, higher prices for silver would obviously be a strong signal for PV firms to look for silver substitutes. This is not an especially easy task, since silver is the most conductive material known to mankind. There are sometimes alternatives to the use of pure silver that might not be as good as silver, but are good enough performance-wise and much better than silver cost-wise. However, for most of the electronics applications of silver, including many photovoltaics-related ones, there really is no substitute, and the demand for silver is quite inelastic.

But high and uncertain silver prices do lead silver ink and paste manufacturers to seek to create greater value, in the hope of gaining better margins, or at least preserving their margins. And there is certainly room for innovation here. PV is adopting both novel cell architectures and new materials for the absorber layer and this profoundly affects the materials that are used/required for electrodes and reflector layers; the areas where silver is used in traditional cells. Consequently, new silver ink and paste formulations are needed to match the materials and devices on which they are applied, to improve durability, to lower contact resistance, and to reduce costs. The needs of the PV industry produce a fertile field for silver ink and paste product development.

1.1.1 Crystalline Silicon PV: Old Guard, New Developments

Crystalline silicon (c-Si) PV still makes up the largest share of the PV market and since the end of the (crystalline) silicon shortage, it seems likely to retain its strong position. From the silver perspective, this is surely good news because silver is the main electrode material for c-Si PV, forming both the front and the back electrode in most cells. More specifically, silver products for crystalline silicon PV fall into three general categories: those for front electrodes, those for back electrodes, and tabbing pastes.

This reduction in the risks associated with c-Si as an addressable market is unlikely, however, to be associated with complacency on the part of the silver industry. PV of all kinds is very sensitive to materials costs and new approaches and innovations to reduce the cost of the silver electrodes are coming into play. These innovations include not only ways of making silver more effective as a conductor (nanosilver, platelets and other particle shapes) but also ways of using less silver.

In addition, silver product suppliers who adopt high pricing strategies will have to compete with competitors who come up with non-silver approaches that do not use silver at all; copper and aluminum based replacement of silver are often possibilities. The back electrode is already in the process of substituting silver with other materials, since it is typically less demanding than the other cell parts that use silver. Aluminum-containing materials are being substituted, here.

Nonetheless, there is no getting away from the fact that silver is still more conductive than any other metal—a fact that will not change—and the particles from which silver inks are made maintain their conductivity even when ambient conditions would form non-conducting oxides on other metals. So, *silver's high conductivity, combined with the wide range of physical characteristics producible in formulating inks, will ensure that silver remains dominant for crystalline silicon PV front electrodes as well as competitive for back electrodes.*

1.1.2 Thin-film PV: Newer Technologies, Newest Products

Thin-film PV (TFPV) technology made great strides forward at the height of the great PV run-up of the mid-2000s, and continues to grow more quickly than crystalline silicon. But the rapid growth of the mid-2000s was in large part—and perhaps almost entirely—due to the silicon shortage, which prevented crystalline silicon PV from meeting demand. The silicon shortage is over now, though, and so is the age of runaway PV demand. As a result, thin-film PV has been dealt a setback and must compete now on its own merits.

Still, some varieties of thin-film PV have become established enough and efficient enough that they can continue to grow more rapidly than crystalline silicon PV. NanoMarkets expects thin-film PV to become comparable to crystalline silicon PV in both volume and revenue within the forecast period, and, from the silver perspective, this is important, because TFPV uses silver in different ways and in different amounts to c-Si. *In general, it is probably fair to say that TFPV uses less silver, so the growing share of the PV market that is represented by TFPV may be seen as a negative by the silver industry to some extent.*

In fact, TFPV uses much less silver than crystalline silicon PV. The front electrodes of thin-film PV are typically made of transparent conductors rather than fine silver fingers, although silver grids are sometimes applied on top of the transparent electrodes. Tabbing is virtually nonexistent among thin-film PV, since nearly all cells are monolithically interconnected on a common substrate. And for the back electrodes, the largest manufacturer and technology—First Solar with its CdTe PV—forgo silver entirely in favor of a carbon-based paste containing copper, for reasons of chemical doping. CIGS, on the other hand, uses molybdenum for the

back electrode for most cells, for ease of sputtering directly on glass substrates and for good adhesion of the CIGS layer.

For the back electrode of thin-film PV cells, silver plays a different role. It can be used as a reflector, to send unabsorbed light back through the cell's active layer for a second pass, in addition to serving as the back electrode. Silver's superior reflectivity combined with its high conductivity makes it a natural choice for this role, and it has been used extensively for thin-film silicon and OPV cells. *The cost pressures on CIGS and CdTe are pushing strongly for substitution of other metals—mainly aluminum—for this reflector. However, this is balanced by the increasing use of reflector layers in TFPV, as it moves toward thinner and thinner absorber layers to save costs.*

Also, while the quantities of silver used for thin-film PV are smaller than those used for crystalline silicon PV, silver inks manufacturers have developed products specifically for thin-film PV. For example, the fine silver grids on top of thin-film PV's transparent electrodes are both finer than those used as crystalline silicon PV front electrodes and more difficult to adhere because of the underlying transparent conductors. Special ink formulations are produced to address these challenges.

The bottom line is that both the growth and changes in the PV industry continue to present opportunities for the silver and silver products industries and will continue to do so for the next decade.

1.2 Objectives and Scope of this Report

This report analyzes the use of silver in the photovoltaics industry. This analysis is carried out taking consideration of the forces that shape the silver market -- and specifically the silver inks and pastes market -- and also those that shape the photovoltaics markets. We include an assessment of each of the major PV technologies and their use of silver as well as an assessment of the silver-based products that are on the market, in development, or potentially able to fill needs or market niches. We are principally concerned with the silver materials, but we also consider and discuss the companies producing and using these materials and the PV technologies as they produce unique requirements for silver or alternative materials to fulfill.

In this report we also provide detailed forecasts for the markets for the silver materials used in photovoltaics. These forecasts are based on a foundation of NanoMarkets' forecasts of the photovoltaics industry itself and of the silver inks and pastes industry. These are further developed and customized with our extensive technical expertise concerning the physical and

materials needs of PV manufacturing and products. The recent and ongoing economic turmoil that impacts nearly all aspects of global industry certainly affects both the photovoltaics markets and the choices of silver and other materials used for PV cells, and these factors are also taken into consideration.

The measures used in the analysis and in the forecasts contained in this report are in terms of quantities of silver (grams or troy ounces) and in dollars of revenue. In order to provide a consistent measure between different kinds of silver materials, the revenues are measured at the level of the silver itself, in the grade and purity required for producing the materials used in photovoltaics. In some cases as appropriate, we have also reported and analyzed revenues at the level of silver ink and paste materials.

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 of this Report

The information for this work 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, silver materials, and emerging electronics of all kinds. We also drew on an extensive search of the technical literature, relevant company Web sites, trade journals, government resources, and various collateral items from trade shows and conferences.

Some of the market information in this report comes from our most recent reports on photovoltaics and on silver materials, "*Materials Markets for Inorganic Thin-Film Photovoltaics: 2010*" from December 2009; "*Organic and Dye-Sensitized Cell Photovoltaics: Materials, Applications, and Opportunities 2010*," from May 2010; and "*Silver Inks and Pastes: 2009 to 2016*," from November 2009. Where information has been used in an earlier report, it has been reinvestigated, reanalyzed, and reconsidered in light of current developments and updated accordingly.

The forecasting approach taken in this report is explained in more detail in Chapter Four, but the basic approach taken here is to identify and quantify the underlying photovoltaics markets, the materials needs that are or can be served by silver, and the technological and market pressures that affect silver's penetration into these markets. We consider the specific needs of the various photovoltaic technologies and the types of products that are available or under development, in addition to broader economic developments that impact photovoltaics

and silver markets. The stated plans of the key firms are of course of special interest, although NanoMarkets critically considers these claims in light of all available data.

1.4 Plan of this Report

In Chapter Two, we examine how silver is used in photovoltaics, both at the current time and as we project the industry to develop. This Chapter considers the various photovoltaic technologies, the silver products that are available and used, and the trends—in photovoltaics as well as in silver materials—that will impact the use of silver in photovoltaics.

In Chapter Three we drill deeper into the specific cell features that use silver and the market trends that will impact both the nature of those features and the suitability of silver materials for building them over the course of the next eight years. Finally, Chapter Four contains our eight-year forecasts of silver use in photovoltaics, broken out by PV technology, by cell component, and by silver material type.

For additional details about this and other NanoMarkets reports, please visit us on the web at www.nanomarkets.net or contact us at sales@nanomarkets.net or via telephone at (804) 360-2967.