# NanoMarkets Report

## Silver Inks and Pastes Markets: 2014 – 2021

### Nano-727

Published June 2014

www.nanomarkets.net

# Silver Inks and Pastes Markets: 2014 – 2021

## SUMMARY



This is the latest in NanoMarkets' ongoing series of industry analysis reports on silver inks and pastes. In this report we analyze how the changes within the applications for silver inks and pastes have impacted the business and what this means over the coming years.

On the positive side, the solar panel industry is reviving and is much more oriented toward crystalline silicon (c-Si) panels than before the great solar crash. This is good news for the silver pastes business, because c-Si panels are major consumes of silver. Silver inks and pastes suppliers also have some reason to be hopeful about the likelihood of large OLED lighting and displays panels finally being commercialized, since silver undoubtedly has a role to play in OLED electrodes.

The negatives for the silver inks and pastes business include the fact that plasma televisions and membrane switches, both which have consumed a considerable amount of silver pastes are phasing out and printed electronics is gradually being abandoned as a viable application by many suppliers.

This report also examines the commercial implications for silver inks and paste markets. In this year's report, we place a special emphasis on the replacement of silver by copper in critical applications such as solar panels. We also re-examine the future of silver inks and pastes in the light of the rising Internet-of-Things meme and address whether or not there will there be demand for printed silver used within all those sensors and smart objects. Finally, we take one more look to see if nanosilver inks will ever make it out of the "research material" category.

In this evolving market environment, this report identifies which market opportunities for silver inks and pastes are likely to be the most important over the next decade. And as with other NanoMarkets reports, we also include detailed eight-year forecasts in both volume and value terms, with breakouts by application, type of material and type of printing process used. The report also contains an assessment of the product/market strategies of leading silver inks and pastes firms – both the traditional and the new suppliers that appearing from China and India.

## TABLE OF CONTENTS

## RELATED REPORTS

The Silver Inks and Pastes Market – 2013
Silver Inks and Pastes Markets – 2012
Markets for Silver Nanomaterials as Transparent Conductors
Silver in Photovoltaics 2012

# Chapter One: Introduction

## 1.1 Background to this Report



Printed silver inks and pastes have been in use for decades in a variety of electronics applications. Silver is valued for its high conductivity, stability, and compatibility with screen printing and other printing methods. Despite its high cost compared to alternative materials, it will continue to be used in applications that need conductive circuitry or electrodes.

The silver inks and pastes industry has always developed in more of an evolutionary than revolutionary manner. Suppliers continue to produce new versions of materials with improved properties or lower cost per gram or, perhaps more importantly, lower cost for a given conductivity. They tailor materials to shifting demands in different applications in order to take advantage of trends and bring new life into their product lines.

### 1.1.1 Changes Since the Last Report

The environment has changed since NanoMarkets last published a report on silver inks and pastes in January 2013. We think that current trends in silver inks and pastes markets will change the opportunities available to suppliers and shift their focus going forward.

**New opportunities in photovoltaics:** The crystalline silicon (C-Si) PV market became the single biggest user of conventional silver pastes in 2011, but first the rise of thin-film PV and then the bursting of the PV bubble has threatened silver paste sales in the PV market.

That situation has now changed for the better from the perspective of the silver paste suppliers. As the PV industry has emerged from its slump, c-Si has regained dominance. This is good news for printed silver suppliers because, even though we are seeing a trend toward using less silver in c-Si panels, the increased PV capacity worldwide means more revenue opportunities for companies that supply materials for panels.

Another good piece of news is that the collapse of PV prices has ended and in fact the price of c-Si panels has begun to rise a bit. This makes panel makers a little less likely to go in search of alternatives to silver. Meanwhile, silver paste suppliers are responding to opportunities in PV by expanding their offerings to this sector and tailoring materials to meet the requirements of today's cell and panel designs. The bottom line is that prospects for sales into the PV sector are reasonably good.

All this is very good news for the paste suppliers. But the renaissance of c-Si does not mean that they are home free. It seems highly likely that thin-film PV technologies (notably CIGS) will reassert itself in the next few years. And, as already noted, the solar panel industry is seeking out new ways to reduce its use of silver.



**Dropping silver prices:** Although all serious players in the silver inks and pastes market hedge by buying and selling silver futures, there is no doubt that big price changes in the silver markets can impact the silver pastes and inks markets.

Silver prices dropped dramatically in 2013, ending the year near $20 per troy ounce, and they have hovered around that range since.

Facing what looked to be an extended period of high silver prices, over $30 per troy ounce, nearly all major silver ink and paste suppliers have emphasized products with lower silver content while maintaining high (and sometimes improved) performance. So they face a marketing issue as to whether to continue to push these products in a different economic environment or revert to a more silver-centric strategy.

While silver *could* decline further in price there seems to be something of a consensus that prices will begin to rise again. If this is the case, despite temporarily lower silver prices, business conditions for materials with a lower silver content should remain excellent. Customers also probably see them as better options, especially in the long run.

**The case for nanosilver:** For many years, nanosilver inks and pastes was touted as a strategic alternative to conventional silver inks and pastes because it can deliver higher performance with lower silver content. In addition, during the big printed electronics bubble of several years back, printed nanosilver traces were seen as *the* way to create interconnects of various kinds.

These earlier hopes for nanosilver inks and pastes seem to have faded. There is some evidence that nanosilver pastes have been used in the Asian display industry, but no evidence that this has been widespread. The problem has been that the total cost of nanomaterials is not lower, because any cost savings from using less silver is offset by the higher cost of developing and producing the nanosilver inks and pastes. In addition, the original conception of printed electronics has all but gone away and no longer represents an obvious opportunity.

In the past couple of years, NanoMarkets had come to believe that nanosilver inks would find their niche as a research material and would have few other

opportunities. But we are now seeing signs that nanosilver may be on the rise. DuPont has introduced nanosilver inks specifically geared toward the OLED lighting market, but also for applications such as wearable electronics and sensors.



With an industry giant like DuPont pursuing nanosilver, the industry needs to take notice. And one possible takeaway is that the high hopes of a decade ago that nanosilver inks would be a key material for the prophesied printed electronics "revolution," may now be in the process of transferring to a future wearables and IoT revolution.

So NanoMarkets now we sees reason to be cautiously optimistic about the future of nanosilver. The future of nanosilver is in no way guaranteed, but it is looking less uncertain that it did a year ago. In order for nanosilver to move from R&D into commercial production, however, the focus needs to be on performance rather than price and therefore on applications that are not extremely cost-sensitive.

### 1.1.2 Continuing Prospects for Silver Inks and Pastes

Suppliers of printed silver have enjoyed a long period of growth due to shifting needs and the development of new applications. In fact, the silver inks and pastes business has been very fortunate in finding a new and big opportunity, each time the old and big opportunity has vanished. Thus silver paste opportunities have shifted over the past half century from membrane switches to PCs to mobile phones and then on to PV. With the decline of the PV industry, it finally looked as if the silver inks and pastes business was out of luck. However, as we discussed above, we think that he industry has been saved in this regard.

In any case, we note that, while some traditional markets for silver pastes are genuinely disappearing (e.g., plasma TVs) other traditional markets continue to offer hope for stable or even growing revenues.

**Traditional thick film applications:** Traditional consumer electronics is a mature market that still uses billions of dollars of silver pastes every year. While it is not growing, it remains a steady source of income that suppliers can rely on while they develop products for newer applications.

Even without high volume growth, most suppliers of silver inks and pastes cannot afford to ignore the thick film sector. Customers may be looking for lower cost alternatives, but many who are already using silver will continue to do so. They aren't seriously considering alternatives.

**Displays**: The market for silver in plasma display panels (PDPs) is declining rapidly along with the overall decline in the PDP market, but there are still opportunities for the printed inks and pastes in newer display applications:

- Touch displays have been around for a while, but have become much more widely commercialized over the past few years with the boom in smartphones and tablet computers. Printed silver could be used for the circuitry required for integration of the touch panels with the underlying displays.
- Similarly, although printed silver pastes are not particularly prevalent in displays today (although printed silver conductive adhesives are), we think there are opportunities for printed silver to be used in the circuitry of all types of new display formats, in both conventional LCDs and newer OLED displays.
- Printed silver could be very useful in flexible displays. Truly flexible displays are many years off, if they ever do become commercial products, but suppliers that develop materials that are compatible with flexible circuit boards could take advantage of future developments in flexible displays.

**Lighting:** Thick film silver paste has been used in electroluminescent (EL) lamps for many years, and will continue to be so. This is not, however, a growth opportunity. But the commercialization of the OLED lighting market, which seems to be accelerating could poses a real opportunity for printed silver suppliers.

We believe that large OLED lighting panels could employ printed silver as bus bars to prevent visible brightness gradients due to the significant voltage drops and resistive heat losses across long spans of less-conductive transparent electrodes. Printed silver can also serve as interconnects for concatenated OLED lighting panels. However, OLED lighting panels that are large enough for all this to matter are still a few years out.

**Demographic and economic factors:** Increased industrialization and urbanization of the developing world creates increased per capita expenditures in a variety of products that use printed silver. Also, silver inks and pastes are used in so many consumer products that increases in the world population as a whole is likely to spur increased demand for silver inks and pastes.

For better or worse this means that the markets and opportunities that we discuss in this report are highly dependent

### 1.2 Objectives and Scope of this Report

The objective of this report is to identify opportunities—primarily new opportunities—for silver inks and pastes in electronic and photovoltaic applications. The report also provides detailed eight-year forecasts of the materials and markets that make up the silver inks and pastes business.

This report covers silver-based inks and pastes for functional (non-jewelry or graphics) applications, an area that NanoMarkets has been covering for more than six years, and this report is the latest in our ongoing series of industry analyses of silver materials used in various applications.

This report specifically focuses on silver inks and pastes with high loading of silver that can be printed using various printing methods. The category of silver pastes includes formulations made for traditional thick-film applications such as printed circuit boards and crystalline PV panels. Silver pastes are most always applied using screen printing, but there are some silver inks that are often formulated for flexographic, gravure, or inkjet printing, with the ink viscosity and other properties tailored to the printing method. Although these are a fairly small part of the market, we also discuss these products.

Note that we have specifically excluded certain classes of silver-based materials from the analysis. In particular, we do not cover transparent nanosilver inks, which are covered in other NanoMarkets reports and primarily involve different players and markets than the materials covered here; printed antimicrobial silver, which is more appropriately covered as part of a broader consideration of antimicrobial silver; silver-based (usually two-part epoxy) conductive adhesives; and silver pastes used in jewelry.

The silver inks and pastes discussed in this report can be used in a wide variety of applications, so we evaluate the market for these materials and identify the applications in which printed silver will generate revenue for the industry in the near- and mid-term. Thus the applications covered:

- PV panels, including both conventional c-Si PV panels and various thin film PV technologies
- Thick-film electronic circuitry, such as found in membrane switches, printed circuit boards, keyboards, surface mounted components, and resistive heaters
- OLEDs, including both displays and lighting
- Plasma display panels and LCD panels

- Sensors, including biosensors
- RFID chips and antennas

This analysis does not necessarily cover all possible applications that may use printed silver, but it does address the most important applications for revenue generation in the next eight years. It is certainly possible that other applications will use silver inks and pastes in the future, especially in the case of nanosilver materials, which are still in a fairly early stage of commercialization.



### 1.3 Methodology of this Report

#### 1.3.1 Data Sources

To determine where the opportunities lie, we have based this report on both primary and secondary research:

- Primary information is gathered largely through NanoMarkets' analysis of relevant applications markets and market trends based on ongoing discussions with key players in the silver inks and pastes community, as well as in the electronics, display, PV, and lighting sectors, including entrepreneurs, business development and marketing managers, and technologists.
- Secondary research is drawn from the technical literature, relevant company websites, trade journals and press articles, and various collateral items from trade shows and conferences.

Some of the applications-related market information in this report, particularly that related to the underlying addressable markets (displays, OLEDs, sensors, RFIDs, PV, etc.), comes from our own most recent reports. Specifically, we have examined data from the following reports:

- *"CIGS Photovoltaics Markets – 2014 and Beyond"*
- *"Dye Sensitized Cell Markets—2014"*
- *"Markets and Opportunities for Transparent Displays– 2014 to 2021"*
- *"The Market for Sensors in the Internet-of-Things Market : 2013-to-2020"*
- *"OLED Lighting Markets – 2014"*
- *"Transparent Conductor Markets 2013"*

In addition, some background information was taken from last year's silver inks and pastes report, *"Silver Inks and Pastes Markets – 2013."*

Where data has been used from another report, it has been reinvestigated, reanalyzed, and reconsidered in light of current information and updated accordingly.

### 1.3.2 Forecasting Methodology



The forecasting method used in this report is the similar to that used for all NanoMarkets reports. We start with the anticipated production volumes for each of the applications that are expected to use printed silver for circuitry, electrodes, or both. Many of these data come from recent NanoMarkets reports related to these applications, as listed above.

The basic forecasting approach is to identify and quantify the underlying electronics markets for printed silver over the next eight years, and then to quantify the volumes and revenues for silver inks and pastes in those applications, taking into consideration the technological and market pressures that affect silver ink/paste use rates.

As part of the analysis, we also assess the competitive landscape for printable silver in order to determine the likely level of competition from alternative conductive materials in the different addressable markets. We also consider broader economic developments that may influence the general electronics, display, PV, and lighting markets.

In order to estimate silver content for each application, we converted the display, device, or panel counts of the underlying forecasts to area shipped, using an appropriate average product size for each application. Next, to determine the total volume of printed silver used in each application, we made assumptions about ink densities, printed layer thicknesses, and coverage areas, which differed depending on the application under consideration. Finally, we estimated penetration rates and growth patterns for printed silver in each application.

We have considered each of the major electronic/PV applications for printable silver inks and pastes and the different kinds of materials used. We have also considered both current and anticipated future economic factors likely to have major implications for silver in the applications that we have covered.

When constructing the forecasts, we have also taken into consideration:

- The potential for changes in silver content over time in each application; for example, if there is a significant chance that a new lower-cost material will be substituted for silver in a particular application.

- Changes in deposition rates and/or layer thicknesses in various applications that change the amount of silver ink/paste consumed, as well as shifts in product design that affect the amount of printed silver used.

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.



### 1.3.3 Pricing Assumptions and Pricing Trends for Silver Inks and Pastes

Silver prices have been somewhat volatile over the past few years, but ink and paste prices do not reflect the same volatility. Our forecasts therefore include a conservative estimate on silver volatility, providing an average price for silver each year. We are not in the business of predicting silver prices, but information suggests they may not go much lower.

While some pundits recommend buying silver, saying the price will skyrocket over the next one to two years, others believe it will not rise substantially until at least 2016. We therefore take a middle-of-the-road approach and assume an initial value of $20 per troy ounce for 2014, gradually returning to $30 per ounce (near the 2012 average) by 2021. Reality could be quite different than this, but unless we see extremely high prices it shouldn't have a huge effect on the overall market for silver inks and pastes.

Our forecasts assign a mark-up for printed silver products as a multiplier to calculate a price per weight of silver ink or paste. Although prices can vary widely based on the type of ink or paste formulation, silver loading, end-use application, manufacturing process, and other factors, we have attempted to estimate average silver ink and paste prices.

Although silver prices dropped considerably from 2012 to 2014, ink and paste prices did not experience the same price reduction. We therefore adjusted the initial mark up over the constituent silver to 3.0 for 2014 to reflect this reality. We have shown this number declining over the period under consideration in this report reflecting what we believe will be rising prices for inks and pastes.

Nanosilver inks have a much greater mark-up than conventional silver inks and pastes because of the cost involved in producing them and the relatively early stage of development of these materials. We assigned a mark-up of 12 times the cost of silver in 2014. However, we allow for a fairly steep drop-off in mark-up of 15 percent per year over the duration of the forecast period, based on recent

announcements that lead us to believe that nanosilver will begin to see economies of scale.

*It is important to keep in mind that our average prices are just that—averages. In reality, many different grades of inks and pastes are available, and pricing for different products varies greatly among grades, suppliers, and end-use applications.*



#### 1.3.4 General Economic and Policy Assumptions

The forecasts in this report do not directly depend on economic growth rates. However, assumptions about growth rates and economic conditions do have an impact on the market for end products that use printed silver, and on R&D spending. Silver prices are also related to the general economic climate. Given the broad range of applications into which silver inks and pastes are sold, we think that most of the silver paste markets that we discuss in this report will be strongly impacted by the economy worldwide.

As we see things, this is a major source of uncertainty in the forecasts that we provide in this report. While we note that many economists have expected that the U.S. would return to historical rates of growth this year, the first quarter of 2014 actually saw a decline in the U.S. GDP. There are also major political uncertainties in Europe and perhaps China to throw into the mix.

To the extent that silver inks and pastes are sold into the PV sector, government policies with regard to solar energy are also relevant. Here we note that the subsidies that were once ubiquitous in this area are slowly disappearing in key markets and ongoing slow growth has led to governments gradually deemphasizing alternative energy as part of short-term considerations.

### 1.4 Plan of this Report

In Chapter Two we discuss materials and processes, including trends in printing methods and strategies and revenue potential for key silver ink and paste suppliers. The chapter also includes an evaluation of risks posed by competing materials, including copper, carbon, and other options.

Chapters Three through Six cover important applications. Each chapter provides an analysis of current and future uses of printed silver for the given application and includes granular eight-year forecasts of revenues for silver inks and pastes. We break down forecasts by type of ink or paste and printing process for each application.

Chapter Three examines PV panels, looking at how changes in PV technologies and shifts in the overall PV market affect the market for silver pastes.

In Chapter Four we cover displays and lighting. This includes plasma, LCD, and OLED displays and OLED lighting. The chapter provides forecasts for each application separately.



Opportunities for silver in printed electronics are primarily restricted to sensors and RFID antennas, which we cover in Chapter Five. Chapter Six covers traditional thick film applications, including membrane switches and printed circuit boards.

In Chapter Seven we summarize the revenue forecasts for printed silver for the various applications. The chapter includes granular forecasts for each material type (silver paste, silver ink, and nanosilver) and printing method (screen printing, inkjet, and flexographic or gravure).