NanoMarkets Report

Smart Windows Materials Markets: 2014–2021

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SUMMARY

In the past five years or so, smart (i.e. self-dimming) windows have taken off in both residential and commercial building markets. They are also increasingly used in automobiles and trucks. There are several different smart windows technologies, but all of them are materials plays in one way or another. NanoMarkets believes that, as a result, there are important opportunities for materials firms that are emerging from the smart windows "revolution."

The objective of this report is to identify and quantify these opportunities. The report contains a granular eight-year forecast in both volume and value terms as well as an assessment of the strategies being deployed in this market by notable firms.

In this report NanoMarkets discusses the opportunities for materials in smart windows and mirrors using electrochromic, photochromic, thermochromic, PDLC, SPD and microblinds. The forecasts and analysis cover not only the active smart materials used in these technologies, but also the substrate materials; both plastic and glass. We also examine changing manufacturing patterns within the smart windows sector.

In addition, this report analyzes a number of different business models being used in the smart windows sector and shows how materials play into the total smart windows value chain. We also discuss the role of technology licensing, as well as direct supply of smart coatings and other materials to glass and windows firms.

NanoMarkets has been covering the smart glass business for more than five years and has therefore acquired a deep understanding of the dynamics of the smart windows sector and of materials selection within that sector. We believe that this report will be of vital interest to specialty chemical firms, as well as both display and build glassmakers, along with windows firms.

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Chapter One: Introduction

1.1 Background to This Report

Smart windows—which we take here to mean self-dimming or self-tinting windows—are first and foremost materials plays. At every level of the value chain the business opportunities presented by smart windows are dependent on the specific smart materials on which the windows' functionality is based. For example, smart glass based on PDLC technology never quite becomes transparent; so this technology is primarily used for privacy glass.

Smart glass is already extensively used for self-dimming auto mirrors, but has not yet been found in *windows* to any great extent. OEMs in the building products and automotive sectors that have needed tinted glass for windows have mostly adopted a *non-smart (i.e., non-dynamic)* solution; either coating window glass with a tinted material or laminating a tinted film to the glass. These materials are low-cost, but have fixed performance levels; their transmission/blocking of light never changes. Eastman Chemical, which claims to be the leading manufacturing company offering retrofit window films, continues to see its film business as a source of growth, according to its recent annual report.

Smart windows may eat into the retrofit film business, but NanoMarkets has no expectations that the retrofit windows business is in any danger of going away. What we do think is that the smart windows business will grow out of its current niche-like status. And as it does so, materials selection will play a key role in determining which smart windows technologies will do best.

The reason for NanoMarkets being bullish on smart windows in this sense is primarily our belief that there are widespread consumer expectations that the real price of energy will continue to rise for years to come. This will promote the sales of products that promote energy savings; smart windows being one such product type. Buildings need smart windows to comply with LEED or zero-energy requirements. Automobiles adopt smart windows to keep interiors cool and cut down on the need for air-conditioning on sunny days, while letting as much light as possible through on gloomy ones.

We expect these novel market drivers for smart windows to combine with more traditional ones—especially the need to reduce glare in the summer while not obscuring visibility in the winter. But the new market drivers for smart windows based on energy prices, NanoMarkets believes, will help grow the smart windows business dramatically.

1.1.1 Electrochromics Rises

As NanoMarkets sees it, electrochromic materials have already staked out an enviable position in the emergent smart windows sector. What we are seeing here is a list of factors that combine to position electrochromic materials as the materials of choice for smart windows in many instances. These factors include:

- Low technological risk. Electrochromic materials are already widely used in auto mirrors, so much is already understood about their performance and capabilities
- Potentially low cost. Electrochromic windows are fabricated with such non-exotic materials such as conductive polymers and metal oxides. Nonetheless, prices of

electrochromic windows remain high at this point in time reflecting the early stage of the self-dimming windows market.

- Long product life. Metal oxides are also not easily degraded by light, adding to the life of the window; lifetimes being an obviously important factor for any building product.

- Low power requirements. Although smart windows based on electrochromic materials need to be powered, this is not a major drawback. According to NREL, powering 1,500 square feet of color-changing glass (about 100 windows) would require less power than a 75-watt light bulb.

At least four companies are actively pursuing the development of electrochromic windows, Sage, View, Chromogenics and US e-Chromic. At least two of these companies—Sage and View—are already shipping and both have access to extensive marketing and financial resources.

Sage is especially to be watched because it is now part of the Saint-Gobain group and can muster both the money and the supply channel strength that being part of a huge multinational offers it. In fact, Sage had been well funded even before it was fully acquired by Saint-Gobain and it continues to announce new customers on a frequent basis. View (which used to be Soladigm) also has some customers, as well as investment that includes money from Corning and GE. View also has an alliance with Corning that NanoMarkets believes will help View move forward both technically and at the marketing/supply chain level.

We think that another company worth watching is Gentex, which dominates the electrochromic self-dimming *mirror* space. Gentex's electrochromic technology is not completely suited to smart *windows.* But Gentex is a large company that has already made windows for airliners. So, if the smart windows market grows fast, Gentex's entry would not be a complete surprise.

1.1.2 And the Others: Thermochromic and Photochromic Materials, SPD and PDLC

When NanoMarkets conducted an online survey on the topic of smart windows materials, we found that the vast majority of respondents saw electrochromic materials as *the* smart material that would compete with retrofit window films. To us this suggests a familiarity with and acceptance of electrochromic materials by the windows/glass industry and perhaps by OEMs in the automotive and construction sectors too. Add to this the big names (GE, Corning, Saint-Gobain) and one has to ask whether alternatives to electrochromic materials have a chance at commercial success.

NanoMarkets believes that the jury is still out on this, but we note that there are several firms that are using materials platforms for their smart windows that are completely different from electrochromic materials. At the very least, alternatives to electrochromic materials may give firms some protection from patent squabbles that have troubled the electrochromic sector.

That said, it seems unlikely to us that any firm is going to go full force against electrochromic materials across the full range of smart windows. Instead, they are out looking for spaces where electrochromic materials may not be entirely well suited.

Thus, Switch Materials has developed a smart windows technology using a class of photochromic materials, developed at Simon Fraser University in Canada. This firm is pitching its smart windows at the automotive window business where it believes that high switching speeds, low cost and the ability to fit in with curved surfaces will give it an advantage over electrochromic materials. Research Frontiers (RFI) has also identified automotive smart windows as an important opportunity for its suspended particle (SPD) materials technology.

Picking a niche in which a novel smart windows materials platform has clear advantages obviously makes strategic sense. But as NanoMarkets sees it, more may be needed. To the materials/technology platforms that we have already mentioned, we should also add thermochromic materials and polymer dispersed liquid crystals (PDLC), although the latter is mostly for privacy glass. There are also smart windows based on microblinds, but these aren't so much a materials play.

But the point is that, as NanoMarkets sees it, the smart windows business is getting quite crowded and we think that it will take more than just a strong materials platform to win in the smart windows sector going forward. It will take money and strong partnerships, we believe.

As far as we can tell, there does not seem to be high levels of investment in the smart windows space today, which NanoMarkets sees as a problem. But we note that the big glass companies seem to be interested enough in non-electrochromic smart windows materials to give these smart windows their blessing. For example, PPG and Pleotint jointly market a commercial window glass system that combines Pleotint's thermochromic technology with PPG glass. RFI has also been able to draw the attention of important players in the auto glass industry, notably Nippon Sheet Glass.

This kind of interest by big glass firms may well be enough to let a variety of firms find profitability in a few years. But at some time—and in the not too distant future—we think there will need to be some notable investments in the non-electrochromic sector; tens of millions of dollars, at least.

Where is this money going to come from? Our best guess is the big glass firms will be the source. But perhaps venture capitalists, too. There is also the off chance that specialty chemical firms—principally those involved with coatings—might get in on the smart windows act, both in the form of a visible part of a business ecosystem and as a source of finance. At the present time, coatings/chemical firms are visibly absent from the smart windows space.

1.2 Objective and Scope of This Report

The objective of this report is to identify and quantify opportunities that have emerged for advanced materials from the advent of smart windows. In the process of achieving this goal, the report examines the strategies of leading firms marketing materials into the smart windows sector, as well as a granular eight-year forecast in both volume and value terms.

The main focus of this report is on the markets for the core materials used in self-dimming windows and mirrors using electrochromic, photochromic, thermochromic, PDLC, SPD and microblinds. However, the scope of our analysis and forecasts also includes the electrode materials used by the various types of smart windows technologies. In this report, we also cover substrate materials for smart windows: both plastic and glass.

In addition, we examine changing manufacturing patterns within the smart windows sector and other aspects of the smart windows business as it impacts materials. Thus, this report analyzes a number of different business models being used in the smart windows sector and shows how materials play into the total smart windows value chain. We discuss the role of technology licensing, as well as direct supply of smart coatings and other materials to glass and windows firms.

Although conventional retrofit window film is not—almost by definition—a smart window material, we include a forecast of this film by way of comparison, since it is the material that smart windows are mostly directly in competition with.

Smart windows are today used in residential and commercial buildings, as well as transportation of various kinds. With regard to transportation, we note that dimmable mirrors using electrochromic technology are the only part of the smart windows market that has achieved any significant market value at the present time. However, in this report, we are not focusing on end user markets for smart windows.

This aspect of the smart windows business is more fully covered in other NanoMarkets reports. And, as we have already noted, we have not tried to include materials that are used—or could be used—in self-cleaning, self-repairing windows or other kind of windows that are sometimes called smart.

This is a worldwide market study and the numbers that we present in the forecasts are intended to represent worldwide forecasts.

1.3 Methodology of this Report

1.3.1 Data Collection

The methodology employed in this report is three pronged in terms of data collection. It includes interviews, an online survey and secondary research of various kinds.

With regard to primary research we have collected data through interviews conducted as part of NanoMarkets' ongoing coverage of the smart windows space, as well as interviews conducted specifically for this report. Interviews were held with executives deeply embedded in the smart windows space and included representatives of glass firms and specialist smart windows firms.

For this NanoMarkets report, we also collected useful data through the medium of a "SurveyMonkey" survey. While we don't claim that this survey is scientific in a way that a statistician might recognize, we do think that it is suggestive of thinking with regards to materials use in the smart windows space. We have used the results of this survey throughout this report as indicative of where sentiment in the smart windows market is with regard to materials issues.

Finally, we have made extensive use of secondary sources, many of these came from the Internet. These include trade press and technical articles as well as government documents and the publicly available financials of leading public companies in the smart windows space. In some cases we have been able to locate in-depth journalistic accounts of manufacturing and marketing activities by leading firms, although these are hard to come by.

1.3.2 Forecasting Methodology

NanoMarkets has been covering the smart glass business for more than five years and has therefore acquired a deep understanding of the dynamics of the smart windows sector and of materials selection within that sector. We have, therefore, been able to bring to this report considerable experience of just how the smart windows sector operates.

In particular, the forecasts presented in this report are based on previous reports published by NanoMarkets that deal with smart windows. These reports were, in turn, based on a general methodology in which we assessed the size of the available market and then used some plausible assumptions about penetrations and prices to come up with volume and value forecasts.

We have taken the volume forecasts from NanoMarkets' latest report on smart windows as the basis for this report and focused more strongly on the breakouts by technology type. Here we have constructed further breakouts of materials within a specific technology class and, specifically, have included separate forecasts for active smart window materials, electrodes and substrates.

Pricing: The pricing used in the forecasts in this report are significantly different to that used in previous NanoMarkets reports. While these earlier reports were intended to provide forecasts that would be associated with complete forecasts, here we are concerned with pricing much higher up the value chain; namely at the level of the prices paid by firms that actually construct the smart windows.

We are not, however, talking about "raw materials" here, but rather of intermediary products, such as coated film. In many, but not all, cases smart windows do not make use of intrinsically expensive materials. Most of the value embedded in the pricing we use in the forecasts in this report reflect processing done by glass or specialty smart windows firms; processing that turns commodity raw materials into intermediaries.

Finally, we note that it is very hard to arrive at definitive numbers for prices in this area. There are a huge range of prices quoted for smart windows materials both in the commercial literature and at Internet stores. These prices reflect differences in performance, quality, volumes, supplier origins, etc. For the purposes of this report it is impossible to make such distinctions in our forecasts; the prices used in these forecasts are intended to be averages that are in some sense plausible, although we accept that the deviations from such averages may be quite large.

Economic assumptions: The forecasts presented in this report do not depend on economic conditions directly. That is to say, the forecasting model used here does not contain GDP or some other important macroeconomic time series as a variable.

Nonetheless, it is obviously important to any assessment of smart windows what the underlying economic conditions look like. Thus in very poor economic conditions, the construction industry would most likely be experiencing a downturn and this in turn would hurt the windows business, including the smart windows business. The converse is also true.

With all this in mind, we note that we have appraised the opportunities for smart windows materials and constructed our forecasts in an era of slow growth that does not seem likely to change any time soon. There are, however, differences among economists with regard to what the future holds with regard to economic growth. Some economists believe that slow growth is

here to stay for various structural reasons. Others think that we will be back on track within a short period of time.

For the record—although NanoMarkets makes no claim to be an economic forecaster—we take the second (more optimistic) view. However, we do not claim that there will be any economic booms during the forecasting period that we consider in this report.

1.4 Plan of this Report

This report consists of eight chapters plus an Executive Summary. The Executive Summary is intended to capture and profile the opportunities that we identify in most of the rest of the report.

Of the eight main chapters, six of them cover the main smart windows technologies from a specifically materials-related aspect. That is to say, each chapter discusses what materials are used to create a specific smart windows technology and how the performance and capabilities of these materials fit with the market needs for smart materials.

These chapters also contain eight-year forecasts of materials used and where appropriate discussions of the strategies of leading suppliers of specialist materials in the smart windows space.

The remaining two chapters are this one—Chapter One—and Chapter Eight. This chapter provides an introductory essay and explains what the purpose of the report is and the way it was compiled. In the final chapter—Chapter Eight—we summarize all the projections created earlier in the report.