NanoMarkets Report

Transparent Conductor Markets 2013

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SUMMARY

The past year has seen major changes in the world of transparent conductors (TCs). Efforts by Intel and especially Microsoft to bring touch to every laptop have suggested new opportunities for non-ITO TCs. Meanwhile, the continued rapid growth in tablet computing can only be regarded as a positive sign for TCs.

On the other hand, new ways of producing both touch panels and displays suggest that display OEMs may be using less TC material in the future. At the same time flexible displays, OLED TVs and other applications that were supposed to generate major revenues for non-ITO TCs seem just as slow to develop as they did in 2012.

In this somewhat confusing phase of the development of TCs, NanoMarkets believes that this new report provides the necessary strategic insight into how TC firms can best generate new business revenues in the in the display, solar panel and other sectors. This report also analyzes important developments on the TC materials front and it takes a peek at what the next generation of transparent conductors will look like and how these materials will extend addressable markets.

This study also contains detailed eight-year forecasts in volume (square meters) and value terms. For each of the applications covered there are breakouts of demand for ITO, other TCOs, ITO/TCO inks, carbon nanotube films, silver-based and cooper-based transparent conductors, other nanometallic transparent conductors and conductive polymers. And there is also a forecast of ITO products by type (sputtering targets, films, coated glass, etc.). Finally, the strategies of the leading TC firms are also assessed in the context of the latest market developments.

NanoMarkets has been covering the TC market for seven years and its studies in this area are widely regarded as the most reliable insider analysis publicly available.

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Chapter One: Introduction

1.1 Background to this Report

The past year has seen major changes in the world of transparent conductors (TCs). The uncertainties in the TC market are now—in the opinion of NanoMarkets—higher than they have been for many years. In summary, in the past year, we have seen three trends emerge that are currently reshaping the opportunities in the TC market.

The three trends that NanoMarkets sees as central to the potential for TCs as a business proposition are (1) the growing ubiquity of touch panels, (2) the tendency to eliminate TCs from the latest display technologies and (3) alternative TCs reaching some kind of tipping point in terms of acceptability. These trends have differing implications on the TC community.

1.1.1 Touch Everywhere: Good News for Non-ITO Transparent Conductors

For quite a few years now touch modules have been *the* battlefield in which alternative TCs have fought it out with ITO. In other markets, ITO is either too entrenched for non-ITO TCs to put up a serious fight (primarily we are talking about LCDs) *or* the market is too small at the present time to generate serious revenues (flexible displays are the case in point).

So the ubiquity of touch very largely determines the immediate addressable market for alternative TCs at the present time. Obviously, with the arrival of tablet computing and the latest generations of smart phones, touch became much more part of the general computing experience. In the year since NanoMarkets' previous report on TCs, however, the use of touch has been ramped up a notch or two.

The key event here is the arrival of Microsoft's Windows 8 OS, which became generally available in October 2012. This latest version of Windows is specifically optimized for touch and includes a new platform for developing applications using touch interfaces. Windows 8 touch capabilities—although not everything about Windows 8—have received good reviews.

The point of all this is that the installed base of Windows users is huge and most of them will eventually move to Windows 8 or higher. As this happens it will embolden the computer OEMs to use touch screens. So, at first touch-screen was for some smartphones only, then for almost all smartphones and the new tablets and now it makes sense to deploy it on most incarnations of PCs including laptops/notebooks—Intel is already pushing it for Ultrabooks—and even desktop monitors.

We note here that when a few firms tried to introduce touch on desktop machines five or six years ago, things didn't go so well for them. Windows 8 should therefore be considered a key enabler for touch.

Implications for TCs: The interesting aspect of all of this from the perspective of TCs is that the addressable market for TCs in the touch module market just got bigger; a lot bigger. But as NanoMarkets sees it, this is not just a simple change in the potential size of the market it is also a strategic sea change.

Thus, until very recently, alternative TC makers, while thinking of the touch display market as low-hanging fruit also regarded this market as no more than a place to start. To illustrate the point, an executive at a leading supplier of alternative TCs told us some time back that his (relatively small) factory had the capacity to produce all the transparent conductive film that the touch module market now needed.

In other words, in order to build a sizeable business, alternative TC suppliers have been aware for some time that they would have to break into other market areas that would not be so easy to penetrate either because of intrinsic risks or because of entrenched use of ITO. What the latest rise in the fortunes of ITO does is buy time and give the alternative TC firms more growing room for the next few years.

In other words, Microsoft has inadvertently reduced the risk for the alternative suppliers. And while Windows 8-based touch has been praised for mobile devices, it has not received the same level of praise for its use on legacy desktop machines. So Windows 8 users may be driven towards the use of a new class of desktop and notebook machines by the need for touch to make the best of windows.

1.1.2 But the Latest Tech Trends from the Display Industry Should Worry the Transparent Conductor Sector

The fly in the ointment is that while—all things being equal—the addressable market for the alternative TCs is expanding thanks to Microsoft, all things are not at all equal. The point here is that there are two trends in the display industry that seem to be working towards the use of TCs in general. The two trends that we are talking about here are the rise of the OLEDs and the in-cell/on-cell touch technology.

OLED displays are emissive, which is to say they don't need backlighting, which is to say they only need one layer of TC. Thus, consider a thought experiment in which LCD displays give way to OLED displays over a period of time; this would essentially halve the effective demand for TCs of both the ITO and non-ITO variety.

Something very similar can be said about the arrival on the scene of in-cell and on-cell touch technology. Both of these newer touch technologies integrate touch directly into LCD display and eliminate the need for TCs for the touch module either partly or completely.

OLED displays have a lot going for them; they are ultra-thin and offer bright glowing colors. They could also be flexible. The business case for in-cell and on-cell can also be easily made. Not only do they squeeze cost out of the BOM of conventional displays, but they enable the main display makers to begin to control the value embedded in touch; formerly this value flowed to the major touch vendors.

So in-cell, and on-cell and OLEDs are all technologies that have made decent progress in the past year and they are all in their way TC eliminators, so NanoMarkets believes that these areas all represent things for TC manufacturers of all stripes to worry about.

But they shouldn't worry *too* much. OLEDs are doing well in the mobile display space, but in TVs, not so much. And it is quite possible that LCDs may be able to compete with OLED TVs using quantum dot-enhanced back lighting. And OLEDs may actually lead to a new market for TCs as they start to be used more widely in the lighting sector. Meanwhile, while NanoMarkets sees in-

cell and on-cell touch as an unstoppable force, current market shares for these two technologies remain low.

1.1.3 Non-ITO TCs are at a Tipping Point

NanoMarkets has been watching the alternative (i.e., non-ITO) TCs emerge since almost ten years ago when carbon-nanotube coatings were first being proposed as an alternative to ITO. As is often the case with such new technologies, it has taken much longer than anyone predicted for TCs to get commercialized. In the case of TCs specifically this seems to have something to do with the market focus gradually switching from carbon to metal solutions, although carbon nanotubes and graphene remain part of the mix.

However, we think that in the past year, non-ITO TCs have reached a point where it is impossible deny that they are a serious alternative to ITO for a number of applications. As we discussed in last year's report many of the alternative TC makers have been working hard at business development for their products and NanoMarkets' sense of the market is that these efforts are beginning to bear fruit in a significant way.

For perhaps three years now it has been possible to point to alternative transparent conductor firms that have delivered their products for use in commercial products; almost exclusively in touch modules. However, what seems to have happened in the past year is that these occasional successes have turned into a trend. We think that this may not be obvious to the casual observer, because most deals of this kind aren't announced. However, insiders are seeing some real signs of commercialization.

As a result of this, we think that certain non-ITO TCs should now be considered serious alternatives to ITO and we would expect to see them spreading out of the touch segment and into other areas. LCD firms are very conservative about new materials choice, but if they start to see these materials succeed in touch, they are almost certainly going to start to experiment with them in main ITO layers in standard LCDs. Indeed, to a limited extent, this is already happening.

ITO suppliers currently seem very unthreatened by all of this. But NanoMarkets wonders whether they should be!

1.1.4 Same Old, Same Old

These newer trends should not be allowed to obscure the hardy perennials: flexible displays and the advantage that metal grids and nanomaterials have over ITO for that application; solar panels and what the real opportunities are there for novel TCs; and LCDs and whether their manufacturers will ever embrace something other than ITOs,

Most alternative TCs firms still trot out the story that their products are much more suitable for R2R manufacturing and intrinsically flexible displays. This is almost certainly true, but R2R and flexible displays remain as niche-like as ever. Their future is increasingly tied to that of OLEDs, because the first R2R displays will most probably be large OLED displays and the market now seems to be suggesting that if intrinsically flexible displays ever appear, they are most likely to be OLED displays and not the e-paper displays that were associated with flexibility just a couple of years back.

Then there is the matter of solar panels. Thin-film solar panels are the one product that already uses non-ITO TCs, and may well be open to new materials if they can prove in at acceptable prices. However, the devastation that has struck the solar industry in the past few years or so, has meant that manufacturers of the newer TCs have not paid that much attention to solar for a while.

We expect that growth in the solar panel market will be fairly respectable over the next few years, since the main players in this space no longer have their fingers on the self-destruct button. So it seems likely that some of the TC firms will start investigating solar again, if they aren't already. However, they clearly need to be cautious; growth in the sector is going to be nowhere near as fast as they might remember from a few years back.

Perhaps more important, to a much greater extent than in the display sector, materials sold into the PV sector are price sensitive. It is never fun to compete on price and in this case, there is the added conundrum for TC makers that they may have to find a pricing policy that sells more or less the same materials into the PV sector and display sector, but at different prices.

Finally, the penetration of the LCD market by non-ITO TCs will not be easy to achieve, but TC makers from here on out can at least imagine a prosperous future in which there are some reasons to suppose that eventually non-ITO TCs will be adopted in the LCD market.

1.2 Objectives and Scope of this Report

In this somewhat confusing phase of the development of TCs, NanoMarkets believes that this report provides the necessary strategic insight into how TC firms can best generate new business revenues in the display, solar panel, and other sectors. This report also analyzes important developments on the TC materials front and it takes a peek at what the next generation of transparent conductors will look like and how these materials will extend addressable markets.

This report analyzes the revenue potential for each relevant application area in terms of using ITO or other transparent conductors and how the TC requirements of these sectors are changing. As this is a new version of a report NanoMarkets has been publishing for several years, there is an emphasis in this particular report on what has changed since the last version was published in 2012.

The classes of materials that are considered for transparent conductive applications have not changed very much from our 2012 coverage. However, the accepted industry categorization of the materials now seems to include "metal mesh" and "metal nanoparticles," which were more or less lumped to together for analysis purpose before. Apart from ITO itself, this report also covers materials based on carbon nanotubes, graphene, silver, copper, conductive polymers and non-ITO TCs.

In this report we have dropped much of the tutorial explanations of the advantages and disadvantages of these materials, since we believe that most of these will be well known by the readers of the report. What we have focused on primarily is an analysis and forecast of the latest developments—both technical and business—in the TC sector.

We have also changed the emphasis in the applications sector. Waiting for flexible displays to appear seems increasingly like "waiting for Godot," and as a result, we have somewhat lessened the coverage in this year's report. On the other hand, we have taken a more serious look than

last year at the renewed prospects in the solar panel sector and tried to seek out some niche applications outside of the display and PV sectors.

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. Where there are markets and opportunities that are oriented in one way or another to one particular region we note this. For example, many of the important OEMs for TCs are in the display industry, which is strongly focused in Asia, while thin-film PV makers tend to be in the U.S. and Europe.

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 technologists, business development managers, and academics involved with emerging electronics of all kinds, including the application areas covered in this report.

In addition, this NanoMarkets study 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 historical and background information came from the various specialist reports that NanoMarkets has published on the applications in which TCs are used. However, where information has been used in an earlier report, it has been reinvestigated, reanalyzed, and reconsidered in light of current developments and updated accordingly.

Finally, we have collected insider opinions and views of the evolving TC market through attendance at relevant trade shows/conferences including some where NanoMarkets researchers were featured as speakers.

Forecasting Methodology: The forecasting approach taken in this report is explained in more detail where each of the applications is forecast, but the basic approach taken here is to identify and quantify the underlying needs and markets that are served by transparent conductors; consider the specifics of the applications and the types of products available or under development; and assess the competitive landscape to determine the suitability and likely volume of each of the transparent conductor types over the next eight years. 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.

In each of the chapters devoted to applications, we have included detailed eight-year market forecasts and we have expanded these from the forecasts in the 2011 report in line with discussion above. As in the 2012 report, we have also included forecasts of the ITO value chain, noting how the market is broken out by coated glass, films and sputtering targets.

Forecasting for the materials covered in this report is especially difficult at the present time, because of the many economic and other risks that seem to be present in the marketplace. As we discussed to some degree above, uncertainty extends not only to the quantities of the devices that will be shipped but also to the pricing of ITO and the other materials and the impact that broader market events will have on all of these variables. To this must be added considerable levels of technological uncertainty associated with many of the materials covered in this report.

1.4 Plan of this Report

In Chapter Two, we consider ITO and the other transparent conductor materials including their relative strengths and weaknesses, recent developments that are relevant to the market, and the strategies and prospects for achieving significant market penetrations. We also include assessments of the strategies in these areas being pursued by major firms active with each of the materials being considered.

In Chapters Three, Four and Five, we analyze and forecast the applications that use ITO and other transparent conductors, covering the competitive landscape between ITO and the other materials, the unique needs of each of the application areas, and the strategies that will produce the greatest opportunities for growth and new revenues.

Finally, in Chapter Six we aggregate the market forecasts and provide summary forecasts both for applications and for specific TCs.