NanoMarkets Report

Transparent Conductor Markets 2014–2021

Nano-735

Published August 2014

www.nanomarkets.net

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During the past year the transparent conductor (TC) market has continued to evolve. It seems that all the focus remains on the touch-panel sector, where alternatives to ITO have genuinely established themselves. As a result, this latest report in NanoMarkets' seven years of coverage of the transparent conductor market focuses heavily on the realities of the touch-sensor market for alternative TCs. Acknowledging that this is where the money is for now, we also discuss how some industry estimates of touch opportunities appear to be exaggerated and how there are serious technology challenges for touch down the road—challenges such as gestural control—that could hurt the current TC boomlet.

We also examine what other big changes are appearing in the TC opportunity space. The solar panel business is back, but with a new mix of PV technologies. What will this mean for the TC space? OLED lighting, which looked like it might go into decline in our previous report, now looks like it is back on the board as a possible mass consumer of TCs. At the same time some the great hopes for alternative TCs, such as OLED TVs and flexible displays seem increasingly fanciful and may be areas that alternative TC firms pursue at their peril.

The interest in the various alternative transparent conductors is also shifting. Metal meshes are no longer quite the "flavor of the month," that they were last year. And carbon nanotube-based TCs seem to be making a quiet comeback in Asia.

In this dynamic market environment, NanoMarkets believes that this new 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 look at what the next generation of transparent conductors will be 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, nanosilver-based TCs, metal grids and conductive polymers. We have also included 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.

TABLE OF CONTENTS

Chapter Five: Markets for Other Transparent Conducting Materials

Chapter Six: Forecasts and Markets for Transparent Conductors

RELATED REPORTS

Transparent Conductor Markets 2013

Markets for Metal Meshes as Transparent Conductors-2014

Markets for Silver Nanomaterials as Transparent Conductors

Chapter One: Introduction

1.1 Background to this Report

NanoMarkets has been covering the transparent conductor (TCs) market for just under a decade. In that period, we have seen alternative TCs emerge as a serious alternative to ITO. Not only have they improved their performance compared to ITO, but they have found a fast growing application—touch-screen sensors—that now seem willing to accept alternative TCs as much more than just a "science experiment." In 2014 10-15 percent of touch-screen sensors will use alternative TCs and that penetration number can only grow over the coming decade. Since touch sensing is expected to become increasingly common for displays over the same period, it seems that touch is a good place to be for alternative TCs right now.

1.1.1 Alternative TCs: Flavors of the Month

NanoMarkets has seen the TC opportunity change over the past few years as different materials have come to the fore and then receded in terms of the attention that they are getting. At first it seemed that carbon nanotube (CNT) coatings were a viable TC alternative, but for high performance films, they turned out to be hard to make. Then with the much-publicized rise of Cambrios, silver nanowire inks were all the rage and these turned into real shipments to real end users. We should also note that over the period that NanoMarkets has been covering TCs there has been a flurry of interest in graphene, but this is now universally acknowledged as a futuristic TC at best.

In 2012 and 2013, metal grids started to become an important topic of discussion in the TC community. This was partly because of the publicity that swirled around UniPixel for a while and partly because it seemed that grids, if made fine enough, were an especially simple and cost effective solution to the TC issue. Although mesh didn't quite take off in 2013 as expected, enough progress was made that mesh—in one form or another—could become the dominant alternative TC going forward based on what NanoMarkets is seeing today. Also, at the present time—and based on our interviews for this report—it seems that CNTs are back on the agenda.

With this history, it is hard to resist the belief that there is an element of fashion about how the alternative TC market progresses, with each alternative TC getting its 15 minutes of fame. There is something to this. However, there is also surely more, and NanoMarkets believes that the alternative TC business is starting from a somewhat different technological environment than it faced in 2013.

They're back—carbon nanotubes: There are still important companies such as Linde that plan CNT-based TCs with performance and value propositions that can beat ITO. But it has to be admitted that the whole CNT TC research program, that at various times has involved Canatu, Dow, Eikos, Linde, Toray, and Unidym doesn't have that much to show.

As a result for the past few years, NanoMarkets has gradually extended the timeframe within which we believe that CNT TCs could become a success. Indeed, internally, we were wondering if CNTs were simply going to miss the TC boat entirely! That is, we thought it possible, that by the time CNTs were good enough to provide serious competition to ITO, some other alternative TCs will be well enough established that CNT TCs might be a little too late to market.

What we are seeing now, however, is a new direction for CNT TCs. In Asia, CNTouch, has developed a new way to create CNT films for touch-screen sensors and is already supplying these films for low-end Chinese cell phones. Although some of the shipment data that we have heard for this company seem surprisingly high, NanoMarkets has no doubt that some CNT TC development will adopt a low-cost/lower-performance strategy in the next few years and generate some significant revenues in the meantime

Meshes march on: The old program for CNT TCs was to produce the best of the best; a TC material that could give ITO a run for the money. By contrast, what CNTouch has done, it seems, is to come to market with a low-end TC for low-end products; Chinese white box cell phones. Reportedly, touch-sensors using this kind of TC do not perform well. However, it seems that there is a substantial market for low-performance TCs even in the West where conductive polymers have found a niche role as TCs (although not in brand-name smartphones).

For the rest of the market, NanoMarkets believes that meshes are going to continue to do well. This is primarily because it is easy to see how manufacturers can get to an end point where they can beat ITO at its own game. In particular, the conductivity and flexibility advantages that meshes have over ITO are intrinsic and the potential for very high transparency is also strong with metal meshes.

However, in 2014 the mesh business is something of a zoo, with a growing number of offerings in silver and copper. Indeed, the silver nanowire products of Cambrios and Carestream and the nanosilver offering of Cima NanoTech might (at a pinch) be thought of a self-creating mesh adding to the general chaos. With this in mind, a big open question—with many possible answers—is what mesh-like solutions

will the market finally settle on. We discuss possible scenarios for meshes of all kinds in the main body of this report.

1.1.2 Beyond the Touch Screen: Solar, OLEDs, etc.

Although the points made above are true in general, most of them are made in the context of touch screens, which is where virtually all the attention for alternative TC use is directed at the present time. This is understandable because (1) at the present point only touch-sensor makers are buying alternative TCs in any quantity and (2) the use of alternative TCs for the one really large TC market—LCDs is minimal at best.

But NanoMarkets believes that the alternative TC industry should be cautious about adopting even some of the more bullish numbers for alternative TC adoption in the touch-screen sector. Many displays—including the largest—simply don't need touch and there is a general movement in the industry to design TCs out. While these facts are well known and understood, what is not much remarked on is that touch itself may not be forever—next-generation gesture recognition may well have already begun to compete with touch in cell phones and tablets. This would not be good news for TC makers.

Given this, NanoMarkets believes that alternative TC makers will within a few years have to shift their attention from touch screens to other markets. And we see three possible opportunities here, although they all come with serious limitations.

OLEDs: Today, for all practical purposes, all OLED displays and lighting make use of ITO. However, there is a growing literature that suggests alternative TCs may have better mechanical and electrical properties for OLED devices. In addition, the OLED sector—an emerging sector itself without fully mature processes—may be relatively open to adopting alternative TCs.

This is no sure thing though. There are certainly no big signs of OLEDs using non-ITO TCs; just much talk about it over the past few years. At the same time, large OLED displays continue to be hard to manufacture cost effectively, which seems to be damning the OLED TV business—a potential consumer of large amounts of TCs.

Solar: After a horrendous couple of years, the solar industry is beginning to edge back to profitability. Solar panels have been a potential market for TCs for a number of years and is the one market where TCs are used where ITO is not dominant.

However, the need for TCs is mostly in the thin-film PV (TFPV) space, which got hit harder than the solar space as a whole, so the market for TCs in the solar market depends on the uncertain resurgence of the TFPV. Secondly, the alternative TCs being used in TFPV are primarily just non-ITO, transparent conducting oxides (TCOs). The use of the more novel TCs in solar has been few and far between.

Flexible displays: Fully flexible displays would represent the ultimate market opportunity for alternative TCs, because ITO wouldn't work in them in principle. However, no such flexible displays yet exist and ITO would work well with merely curved displays, which *do* exist, but are just niche products.

LCDs: Apart from a Cambrios R&D project and some casual comments from a few other suppliers, the signs of the use of alternative TCs in the LCD space are negligible—just as they have been throughout the decade that NanoMarkets has been covering alternative TCs

Makers of LCD displays with their giant fabs are not likely to want to change materials and the impact on their BOMs of such a change is not likely to be much. However, even a small alternative TC penetration in the LCD space would represent a large revenue source by comparison with today's sales of alternative TCs. NanoMarkets therefore continues to note that the adoption of an alternative TC by a major display maker—however unlikely that might be—would make a big difference.

1.1.3 China Looming

NanoMarkets believes that the proverbial elephant in the TC room is now China. A year or so back, the Chinese government tried to control the indium/ITO supply chain, but has signally failed to so. In fact the price of both Indium and ITO has been falling. (It just started to climb again as this piece was being written.)

It seems difficult to believe that China will ever control the ITO supply—there are just too many potential alternative sources of Indium and ITO production is still located firmly in Japan. However, a very real possibility is that China will increasingly become the dominant consumer of TCs as the solar, OLED, touch-screen sensors and display industries increasingly shift to mainland China as the result of Chinese industrial policy. The recent successes of O-Film, for example, also suggests the possibility that China will play a key role in the alternative TC business in the future.

1.2 Objectives and Scope of this Report

So we are at a fairly dramatic juncture in the TC sector where fairly new alternative TCs (low-cost CNTs and meshes, in multiple forms) seem to be on the rise and alternative TCs have become a force to be reckoned with in touch panels. But plenty of uncertainties too—such as the long-term future of touch and the question marks over the resurgence of solar and the growth of OLEDs. And the presence of China looms over all.

In this dynamic phase of the development of TCs, NanoMarkets believes that this report provides important 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 2013.

We have also changed the emphasis in the applications sector. We have dropped coverage of e-paper, since this application seems currently to be in serious decline. On the other hand, we have refocused somewhat on the solar panel sector, where the opportunities for TCs seem to be on the increase.

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. The growing involvement of Chinese firms in many parts of the TC supply chain is also covered in some depth.

1.2.1 Materials Covered in this Report

The classes of materials that are considered for transparent conductive applications have not changed very much from our 2013 coverage. Apart from ITO itself, this report also covers materials based on carbon nanotubes, graphene, silver, copper, conductive polymers and non-ITO TCOs. We note that the

discussion of copper somewhat overlaps the discussion of metal mesh, since some of these meshes are fabricated from copper metal.

In forecasting the markets for such materials, certain assumptions were made regarding each class of material. What follows are a few general comments about the assumptions that we make about material classes that inform projections in all applications.

Other TCOs: It seems reasonable to assume that the closer an ITO substitute approach resembles the traditional ITO approach, the easier it will be to get a substitute accepted, if adequate performance can be proved. Alternative TCOs would also be close to passing this "familiarity" test if their major performance parameters could be proven.

TCOs are already widely used in the PV sector, but attempts to use them for displays have been mixed and some confident predictions that variants on zinc oxide would soon displace ITO have proved dramatically incorrect. Non-ITO TCOs have simply failed to reach the performance possible with ITO. And all TCOs—ITO or otherwise—fail when it comes to the necessary flexibility for flexible panels of various kinds.

Since our previous report, we have not seen any dramatic progress in the use of non-ITO TCOs outside of solar.

ITO (and other TCO) inks: ITO inks and other preparations made with powders or nanoparticles are alternative forms of ITO that aim to provide the film quality and performance of sputtered ITO, but without the sputtering. These inks have a fairly long history of trials, but almost no actual penetration of the TC market. This is principally because of their low performance compared with ITO.

There has always seemed to be enough interest in this area (there are certainly a few suppliers) for continuing coverage in NanoMarkets' TC forecasts. But there never seems to have been enough interest (except *maybe* in the antistatic area) to afford this area much attention or respect as a commercial material. At best, we think that the use of TCO inks will not start to reach significant penetrations of the commercial display/PV marketplace until later in the forecast.

Carbon nanotubes inks and films: For years, there have been high-profile demonstrations of carbon nanotubes as TCs in such applications as FPDs, touch screens, and e-paper and these demonstrations now have a long history. NanoMarkets has also been aware of major display firms that are currently working with carbon nanotube-based materials as ITO substitutes in their industrial labs.

For the most part, CNT films appear to underperform ITO and they must still be considered a work in progress. The scenario that is now being widely talked about is that CNT TCs will win in the end because of their potentially low cost. The obvious question here is, "how long will this take?"

NanoMarkets said all this in our 2013 TC report, noting at the time that "If the performance of CNT-based TCs can be improved, then their future may still be a good one." In our forecasts last year, carbon nanotubes really do not come into their own in the TC space until after 2018 or so. However, this year's forecasts reflect the sudden emergence of low-performance CNT-based TCs as a commercial possibility.

Silver nanowires and other silver nanomaterials: Nanosilver and similar approaches are now commercialized with perhaps dozens of users in the touch-screen sensor business using these materials from Cambrios, Carestream and Cima NanoTech.

NanoMarkets continues to be bullish about the progress/market penetration of such materials and we have not changed our forecasts for penetration of these materials from last year in any substantial way.

Metal meshes: In this latest NanoMarkets report on transparent conductors, we have continued to increase our coverage of metal meshes. For the most part we are talking silver meshes here, but some use copper.

Metal meshes were once seen as primarily a TC for large panels, but the addressable market for these materials seem to be increasing and this is reflected in our forecasts.

Conductive polymers: As a practical matter, conductive polymers used as TCs tend to mean PEDOT and similar polythiophenes. These polymers have done a fairly good job of penetrating certain applications where high-performance TCs aren't required.

This material seems to have attracted more TC customers than we would have expected a few years back. Conductive polymers are already used widely for transparent antistatic coatings and PEDOT is being used in a few commercial products as an ITO alternative.

NanoMarkets has been impressed by the care with which the main players in the conductive polymer space have matched the capabilities of these materials with

the requirements of various products and expect that conductive polymers will continue to enjoy good fortune.

Other materials: This sector is very much a catch-all category. It potentially includes other metals, one of which is nano-copper, although this has been tried unsuccessfully as a TC in the past. Copper meshes are included in our numbers for metal meshes. Another metal that has occasionally been referred to in the literature as a possible TC are gold nanowires; obviously cost might be a factor there.

Beyond metals, the "other" category that is getting the most attention is certainly graphene. As we discuss elsewhere in this report, we think it will take a long time before graphene is a serious contender as an ITO substitute. We said this last year too, although at the time, there seemed to be some with the opinion that graphene was a near-term TC solution. However, we are not seeing much indication of this.

Form of material forecast: There are a number of options available with regard to what is actually being forecast. For example, one might forecast sputtering targets or films. For ease of comparison between TC types, our primary forecasts—as in previous NanoMarkets TC reports, are all in the form of *material* costs on a coated substrate; this enables us to forecast using square measures. The cost of coating or printing is not included in these costs.

1.2.2 Sectors Covered in this Report

The product areas that are forecasted in this report are, for the most part, similar to those in previous NanoMarkets report on this topic, although there are some changes from last year, too.

Flat-panel LCDs: The big issue for the alternative TC business remains whether it will be able to penetrate the LCD market with its new materials; this is where most TC (i.e., ITO) is currently sold and is likely to be sold for the foreseeable future.

There seems to be a generalized belief that a shift away from ITO to the use of other TCs will eventually occur, but there doesn't seem to be much thought in the TC community between when and how this will occur. Nonetheless, the forecasts in this report reflect these expectations as the forecasts have done in previous NanoMarkets reports on TCs. We have been somewhat more bearish on this issue than in our 2013 TC report.

Touch panels: These are acknowledged as the proverbial "low-hanging fruit" for the alternative TC market at the present time. The question is whether there is

really enough of a market there to support the many alternative TC firms that are flocking into it.

As we note throughout this report, we think this is one area that has changed significantly in the past year in the sense that touch is now spreading beyond smartphones and tablets and into non-mobile computing. This is largely under the influence of Windows 8. According to some accounts, Windows 8 is not only designed with touch in mind, but actually works much better when touch is available.

There are some negative aspects of the evolution of touch technology too, from the perspective of TCs. The market now seems to be drifting towards using touch technologies that use less TC material. Overall, we continue to be quite bullish in our TC-for-touch forecasts this year. But we note again that there are limits to how far touch displays can be deployed and the possibility that touch itself will be replaced by better technologies

OLED displays and lighting: We continue to be reasonably enthusiastic about the use of non-ITO TCs in the OLED space, but there are plenty of ifs, ands and buts.

Since last year we have become more skeptical about OLED TVs, which just never seem to make much of a splash in the market. We are, however, much more optimistic about the future of OLED lighting, now that Konica Minolta has built its production-level plant.

E-paper: We have dropped coverage of e-paper in any significant way because this technology seems to be on the wane.

Photovoltaics: Compared to last year, the PV sector seems a lot more stable but not in a way that is especially favorable to TCs. Crystalline silicon panels seem to be in growth mode again.

However, these c-Si panels do not make much use of TCs. Instead, the TC sector will have to rely on the TFPV, DSC and OPV markets, all of which will continue to grow, but not at the same rate as we had expected a few years ago. It is still uncertain what role TFPV will have in the new solar panel market. But we are encouraged by the recent surge of commercialization in the DSC sector, which may have some minor impact on the TC business.

TCs in smart glass: As with last year's report, we are giving some attention to the use of TCs in smart glass. That is, in addition to the use of TCs for infrared

radiation protection and for ESD, we have also added forecasts of the use of TCs in "smart windows."

As we discuss in a later chapter, these TCs would add a number of additional functionalities. And while smart windows should not be considered as a major opportunity for TC makers in the near-term, we think they will be an interesting niche going forward. The forecasts for TCs in the smart windows sector are based on NanoMarkets' latest projections for smart windows, which we have revised considerably in the past year.

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 business development managers and technologists 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.

1.3.1 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 2013 report in line with the discussion above. As in the 2013 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, which seem to have only increased in the past year. 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.

1.3.2 Assumptions About Materials Utilization, Wastage and Yields

Another part of our forecasting approach is that in turning our volume (area covered) forecasts into value ($ millions) forecasts we use the *actual cost* of materials used to cover the area. This means that we are dealing with "cost of materials" and *not* "prices of materials," with the (often quite considerable) wastage built into the costs.

Among other advantages, this approach has the methodological advantage that there is no need for an additional layer of calculations to account for deposition efficiency, and other factors, these factors are simply built in. It also enables direct comparisons to be made between the various materials considered in this report with regard to materials costs. However, it is important to remember that the numbers used are costs that include wastage and not the price of the material actually utilized.

There is really no good source of pricing for many of the newer TCs, which, at this point in time are usually quoted on a case-by-case basis. We have, therefore, based the pricing for these materials on previous NanoMarkets' transparent conductors reports, which have been widely quoted in the industry.

Costs of ITO sputtering: This takes on a special importance in the context of ITO sputtering, which is known to have a very low efficiency, routinely reported as 30 percent. Rotary sputtering is a lot more efficient, but the targets are more expensive and so is equipment depreciation. So there is plenty of room for differences of opinion in this regard. Readers are therefore invited to replace our pricing estimates by their own, if they believe that this is appropriate. That said,

we have taken a second look at the proportion of rotary/planar sputtering in the industry.

By way of comparison between rotary and planar sputtering, we cite some data provided by Umicore in one of its brochures which gives utilization by planar targets as 25.5 percent and by rotary targets as 85 percent. However, according to Umicore, the relative ITO target cost is 1.9 x the cost of a planar target for the rotary target. So the relative cost of the materials for rotary is less than planar by a factor of 1.7 (= 85/(25.5*1.9)).

We suspect that these numbers were chosen to highlight the advantages of rotary, so this differential may not be as great as shown here. We think it might be closer to 1.3. This is still a big number when one is actually considering the costs of production. However, for the purposes of market forecasts, which have to gloss over such things as quantity discounts and so on, such differentials are not all that great.

Yields: We have not made any special adjustment for differences in yields across the applications covered in this report. Essentially what we are assuming here is that these yields are very high in most applications and yield variations are insignificant when considered in the context of the forecasts contained in this report as a whole. In practice, the reader of this report might want to consider that there may be a few exceptions to this rule. One possible exception might be the OLED lighting market, which is only just getting underway.

1.3.3 Cost Assumptions

That said, there is no acknowledged definitive and accurate source of information on costs that can be used in forecasts of the kind that are presented here. The task of coming up with such costs is rendered even harder by:

- The early stage of development of many of the materials that we consider in this report; cost of novel materials once they have scaled up are hard to predict and can be (at least) an order of magnitude lower than prices of research materials.

- There are seldom any price lists that one can consult in this area and prices of even purely conventional TC materials can vary by very large amounts depending on the size of orders. And order sizes can vary a lot; consider the amount of TC material required by a large LCD maker compared with the amount required by a touch-sensor maker.

1.3.4 General Economic Assumptions

The forecasts in this report do not directly depend on economic growth rates. However, assumptions about such growth rates are in effect tacitly assumed. If the world was going through a crushing depression, for example, one might not expect lots of displays to be sold and this would impact sales of TCs for obvious reasons.

Traditionally, reports of this kind and firms such as NanoMarkets have not troubled much about such matters. They have tended to assume that worldwide economic growth would be quite strong throughout the forecasting period being considered and that it also wouldn't vary that much from year to year. If there were recessions—as there inevitably would be—these would be of short duration and would not have much impact on the long-term expectations for the markets and technologies being forecast.

In current economic conditions—and, again even though the forecasts presented here, are not derived directly from economic data, it seems as well to set out here the kind of economic growth rates that were at the back of the mind of the NanoMarkets analyst producing the projections in this report.

It seemed appropriate to assume a middle-of-the-road growth scenario for the purposes of this report. For the U.S. this means approximately a 2 percent annual rise in real GDP for the next two years or more, although how long these historically low rates of growth will persist is anyone's guess at the present time. The expectations for Europe are much lower. Because Europe's current problems are structural in a way that the U.S.'s problems are not, it is hard to resist the temptation to predict Europe as being a very low growth area for many years to come, although there will be some countries—Germany and the U.K., spring to mind—where this may not be the case.

In Asia, China is still expected to be at the forefront of world growth, but the numbers will be much less than for the past decade or so. An average growth rate of 4.0 to 5.0 percent or so would not be a big surprise. Japanese growth is expected to be in the 1.5 – 2 percent growth rate league for the next few years, but we note that, as this report goes to press, Japan had experienced a fairly good quarter and some economic analysts are fairly bullish about Japan's future.

One cannot quite assume that the better the economic growth the better the prospects for the materials considered in this report, or vice versa. To illustrate this, it seems likely that a China growing at around 6-7 percent but with a strong focus on growth for consumer markets is more of an attractive market for the products

considered in this report than a much faster growing China with its growth mostly coming from infrastructure products. Indeed, a slower growing China that is trying to build a domestic display industry could represent an exciting opportunity for suppliers of new types of TC.

One must also take into consideration the fact that existing economic problems tend to present themselves to people who live in the middle of them as if they are permanent, but in practice, of course, they never are. On the positive side, recessions don't last forever and most of the industrialized regions can be expected to return to historically normal growth by the end of the forecast period considered in this report. China is the exception here, because it never really had "historically normal growth."

1.3.5 Sources of Data

The underlying data for these forecasts have come from a wide variety of sources including the World Wide Web and various interviews with suppliers and users of transparent conductors. Information has been derived from corporate financials of firms that are major suppliers of materials for transparent electrodes of various kinds.

The projections are also based in part on earlier NanoMarkets forecasts and are designed to be consistent with NanoMarkets' forecasts in other areas of thin-film, organic and printable electronics. In some cases, the data have been taken directly from these earlier forecasts; for example, it contains a detailed analysis of device markets and volumes, which are not directly the subject of this report but which are critical to forecasting materials and revenues and have been estimated for recent NanoMarkets reports. Where necessary, we have updated and adapted the earlier forecasts based on current information and used new product categories where this seemed appropriate.

1.4 Plan of this Report

In Chapter Two, we consider the market for ITO and in Chapter Three we provide a similar analysis on the market for other TCOs being used as transparent conductors. In Chapter Four we examine and forecast the market for metallic materials used as TCs. Chapter Five covers other TC materials, especially carbon nanotubes and conductive polymers.

Finally, in Chapter Six, we analyze the main markets for transparent conductors including displays, solar panels, and transparent conductive coatings for glass.