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Market dynamics of materials supply for PV in China

Mark Thirsk, Linx Consulting LLC, Mendon, Massachusetts, USA

ABSTRACT

China has become the largest manufacturing base for crystalline silicon modules in the world, and is becoming increasingly reliant on a domestic supply base. This article discusses the emergence of local supply chains and the strategic responses of global suppliers to this domestic competition. It proceeds to review a set of conclusions from four case studies of formulated material supply within China that can apply to supply-chain participants in the PV industry, concluding with some strategic considerations for suppliers on the cusp of entering the Chinese market.

Introduction

In the last three years, China has quickly established itself as the major manufacturing site in the world for PV cells and modules. In 2011, supply from China accounted for more than 65% of the global PV demand, and total capacity installed in China came close to equalling global demand. While established manufacturing capacity in China historically relied on imported materials for support, the expansion of the manufacturing base led to purchase suppliers seeking domestic supply of high volumes of chemicals and materials that were used in cell and module manufacturing.

A domestic supply base existed in China for many chemicals and commodity materials, and these companies rapidly took advantage of the growing demand for the products in the PV industry. Materials such as inorganic acids, solvents, alkalis, silicon carbide grit and other non-formulated materials were quickly sourced from domestic supply in China. By 2007, most single-component, pure materials were sourced from domestic chemical suppliers.

Complementary to these pure chemicals – and critical to the long life of a finished module and the high efficiency of the cells – are formulated materials that must be produced with tight quality controls and product-specific compositions. Materials such as metallization pastes, encapsulant polymers and backsheets are all highly predictive of module performance and lifetime, and are specified to the appropriate level of functionality required by the module design, without incurring extra cost. The suppliers of these products have typically been Japanese, European or North American, and have enjoyed high market share because of the know-how required to produce these materials.

Over the last two to three years, domestic Chinese suppliers have developed the competencies and supply chains required to best service the domestic module supply base with formulated materials. These challenge imported materials in functionality, and can offer price advantages to the end-users. This shift has meant significant changes in strategy for global suppliers operating in the Chinese market.

In general, the manufacturing technology for crystalline silicon PV modules is little changed from that used several decades ago for the first modules. As the global PV industry has ramped up in the last decade, standardization of manufacturing equipment and module testing has led to a market largely supplied with modules with minimal differences in process and functional design. New technologies and materials competing to displace incumbent processes face a stringent selection process, and, prior to their being widely adopted, the lifetime testing process. Thus, manufacturing change occurs relatively slowly. Relentless pressure to reduce prices means that new materials and processes have to bring significant savings in manufacturing cost in order for them to be adopted.

In the last 18 months, the PV industry has continued its dramatic growth in terms of installed generating capacity coupled with similarly dramatic reductions in module cost and market price. Cost reductions have been underpinned by the slide in price of the main raw material, polysilicon, which was responsible for up to a third of a module's total cost at the end of 2010. In 2012, we are seeing that the average polysilicon price is below the cash cost of many small-volume manufacturers, and is challenging large manufacturers such as OCI, Hemlock, Wacker and GCL to further reduce their manufacturing costs while maintaining product quality.

As polysilicon prices come ever closer to manufacturing costs, price reduction pressure moves to other key materials in the module manufacturing chain. Some of this pressure is also taken on by manufacturing efficiencies and support supply-chain optimization in the tier 1 manufacturing environment.

Figure 1. Hemlock Semiconductor is among the large polysilicon manufacturers that have had to reduce manufacturing costs in order to remain competitive.

Many of the products in the bill of materials for cell and module manufacturers are commodities on global markets. A characteristic of a commodity is that the price is to some extent dependent on market supply and demand conditions, and price elasticity with increased demand is relatively weak. As the PV industry makes up a small part of the total global demand of these commodity materials, it is quite difficult to envisage the added demand for PV production yielding further cost reductions in these materials. Examples of commodity materials whose price is very independent of PV demand include silver bullion, glass, oil derivatives and energy.

We will now provide a review of the conclusions from four case studies of formulated material supply within China that can apply to supply-chain participants in the PV industry.

Chemical and material market segmentation

At a high level, materials required for crystalline silicon cell and module manufacture can be separated into pure

Pure chemicals	Formulated chemicals and materials, and specialty materials
Poly	Polysilicon
SiC	Specialty texturization mixes
Wet chemicals (HF, KOH, ethylene glycol, Nitric acid, etc.)	Specialty cleaning mixes
$POCL_3$	Metal pastes (Ag and Al based)
Process gases (silane, nitrogen, ammonia, etc.)	Silicon inks and dopant pastes
Encapsulants	Backsheets

Table 1. Pure chemicals and formulated chemicals, materials and specialty materials required for crystalline silicon cell and module manufacture.

chemicals, and formulated chemicals and materials; most of the key PV-relevant materials can fall into these two segments, as illustrated in Table 1.

Case studies

Polysilicon

Polysilicon is a key raw material for crystalline silicon modules. Generally sold either as chunks produced from a modified Siemens CVD process or as granules from a fluidized bed reactor, the supply of polysilicon is concentrated in the hands of a few of large producers. However, on a global scale, there are upwards of 50 smaller producers capable of manufacturing between tens and thousands of tons of polysilicon per year. In 2011, polycrystalline prices crashed, driven partly by significant overcapacity in the industry and partly because of strong competition among leading suppliers to supply the available market. Reductions in the selling price of polysilicon translated into significant price reductions of finished modules, which have maintained end-market demand even as government subsidies have declined or are withdrawn completely.

In China, approximately 40 suppliers have been established in the polysilicon space. A select few, such as LDK and Yingli, are captive, but most offer polysilicon on the merchant market. The largest, GCL Polysilicon, has focused on only selling wafers that for the most part are manufactured with internally produced polysilicon.

> "In China, approximately 40 suppliers have been established in the polysilicon space."

In the latest five-year plan for renewable energy, published in 2012, the National Development and Reform Commission (NDRC) has made it clear that, while it expects an increase in domestic capacity to approximately 50,000 metric tons this year, it will also concentrate its support on the top 20 suppliers, leaving others to fend for themselves. The imbalance between domestic supply and demand has led to volatility in polysilicon imports, and suppliers from Korea and the USA have been able to meet the added demand from their expanded capacities as this domestic supply is ramping up.

The high value and relative ease of transport of polysilicon means that local supply does not always carry an advantage. Additionally, a stable high-quality production plant may take many quarters to ramp up production, and require a highly trained staff to run the capital-intensive equipment. Such suppliers seek long-term supply contracts with their customers that include an element of price indexing to ensure plant loading and consequent high-quality production. Once a wafer maker has selected a polysilicon supplier, change will only be made on the basis of price and supply capability for equivalent quality.

Sawing wire

Wafer production is dominated by the use of multiple wire slurry sawing (MWSS), which uses brass-plated steel wire and silicon carbide abrasive. Wafer sawing requires between 50,000 and 150,000km of wire per megawatt of wafers produced, depending on saw loading and desired wafer quality. The wire used for wafer sawing must be of exceptional quality, with no defects that could cause breakage during a cut. Suppliers of sawing wire have historically been based in Europe, Japan and the USA; however, in the last few years, competitive Chinese suppliers of sawing wire have emerged.

Cost-reduction efforts also favour migration to diamond wire cutting, which eliminates the need for slurry and slurry recycling. In addition to new steel wire suppliers, multiple diamond wire suppliers are beginning to compete for business in this emerging application.

In the case of MWSS and diamond wire, the basis of competition is primarily that of technical performance, with yield and sawing performance driving supplier selection. Chinese suppliers have been able to develop high-quality sources of steel and wire-drawing processes capable of matching those of leading global suppliers. As a result, these Chinese suppliers are gaining market share in competition with foreign suppliers.

Metallization pastes

Metallization pastes are considered to be among the most complex materials used in the manufacture of solar cells. The silver pastes used in forming front grids and busbars are the most difficult to produce, with the rear-side silver pastes somewhat easier. Back-surface field aluminium pastes are usually considered the least technically challenging to manufacture within this group.

The supply of front-side silver pastes continues to be quite a niche market and is concentrated among a small number of suppliers who have significant experience and know-how in formulating pastes for low contact resistance, high conductivity, reliability and consistent supply. In contrast, aluminium pastes are somewhat easier to formulate and have fewer performance requirements.

In the early days of PV production, Chinese paste suppliers attempted to

Figure 2. DuPont's Solamet thick-film metallization paste is among the materials imported by Chinese PV manufacturers.

formulate full lines of metallization pastes. However, early silver formulations were variable, and customers saw yield problems, leading to their favouring the import of silver pastes from foreign suppliers such as DuPont, Ferro and Heraeus.

Domestic aluminium paste manufacture, however, has continued to go from strength to strength in China. In fact, foreign suppliers such as Ferro have built and are operating aluminium paste manufacturing facilities in China to compete with domestic suppliers such as GRTC.

As GRTC has grown, it has devoted resources to R&D, and has recently introduced silver pastes for front- and back-side metallization. Moreover, although not strictly a mainland Chinese company, Gigasolar of Taiwan has also joined the fray to compete with a silver paste range of its own. The entry of these two domestic competitors is a significant change in the last preserve of technically differentiated materials.

Challenges	Pure chemicals	Formulated chemicals
Unique segment challenges	Cost leadership Localization	Technical differentiation
Common challenges	Price leadership and scale	
Long-term challenge	Adequate returns to meet reinvestment requirements	

Table 2. Summary of strategic challenges for the different materials segment suppliers.

Module encapsulant

A key component in module encapsulation is the adhesive that is layered on both sides of the strings of a cell. This material, usually ethyl vinyl acetate (EVA), is cured on module lamination to produce a hard, continuous encapsulation around the cells. Typically two sheets are used per module, extending across the full size of the module. A large proportion of modules are still finished in China, and the domestic consumption of EVA is significant. We estimate Chinese consumption of EVA to be well in excess of 100,000,000m^2.

EVA is a globally supplied commodity that is manufactured by large chemical suppliers and supplied as resin granules. These granules are converted into film and supplied to module makers for lamination. Major EVA film suppliers include DuPont, SKC, Mitsui and Bridgestone. All of these companies, with the exception of DuPont, are vertically integrated suppliers of film to the PV industry.

In China, EVA film was also historically supplied through import from foreign suppliers. Although domestic supply of film was established as early as 2003, in the last three to four years the domestic supply has ramped up dramatically; we estimate that greater than 60% of demand for EVA film is satisfied by domestic production. The largest supplier of solar-grade EVA film in China is now Hangzhou First PV Material Co.

Drivers for supplier selection of EVA film include price, quality, ease of doing business and end-product yield.

- Price: locally produced products are usually competitive on price, quoted in RMB and import duty exempt.
- Quality: although domestic film suppliers often source polymer from global producers, film quality can be dependent on the local manufacturing capability. While domestic producers are often not perceived to be of the highest quality, acceptable final product quality can indeed be achieved.
- Ease of doing business: all suppliers are expected to have a domestic presence, although local product support is not

always perceived as absolutely necessary.

- Product yield: EVA film quality has a significant input in final product yield, and higher quality films can support the price premium. This can offset cost penalties incurred by foreign suppliers.

Since manufacturing scale is critical for tier 1 suppliers, it is difficult for market entrants to start small, which in effect favours large incumbent suppliers that are recognized by the module producers. Some large global suppliers do not have significant brand recognition among tier 1 and tier 2 module makers, which can present quite a challenge in terms of gaining market acceptance.

Lessons to be learned when supplying in China

There are several important lessons for chemical and material suppliers that derive from the case studies outlined in the previous section. Apart from having to be identified by the NDRC as a key strategic supplier, critical dimensions for competitive differentiation include cost leadership, technical differentiation, localization, customer intimacy and scale (see Table 2).

In today's cost-driven environment, cost leadership – be it derived from load factor costs, cheap capital or superior technology – is critical to being chosen as a key supplier to leading PV companies. In the area of pure chemicals, Chinese companies can compete almost entirely on price and have largely succeeded in closing out foreign competition. As domestic suppliers gain technical and manufacturing experience, they have also been able to challenge importers on technical capabilities for most formulated materials.

In the case of a few formulated materials – silver pastes and diamond wire in particular – foreign competitors in China have been able to protect premium pricing with technically superior products. However, as the market expands, domestic suppliers are finding that they are able to invest returns into R&D and develop competitive technologies to compete against imported materials.

There is no reason why foreign companies cannot develop a localized presence that takes advantage of low factor costs in China and allows them to compete on an equal footing. This has occurred in several industries, and will continue in the PV industry as manufacturing scale increases. Closely linked to this local presence is the customer intimacy that a supplier must develop with its customer base. Domestic companies arguably have an advantage in this respect, although new entrants with recognizable brand names and well-trained local employees can certainly challenge domestic suppliers in this regard.

A daunting aspect of the solar industry is the speed at which manufacturing scale has grown. Suppliers that cannot offer manufacturing scale to match demand are at a severe disadvantage when competing for business with tier 1 module manufacturers. Any strategic plan to grow in this market must address scale of manufacture, as well as quality and consistency of supply.

In addition to these strategic elements there is a structural concern that suppliers must address. The pricing of most of the pure chemicals and many of the formulated chemicals used in module manufacture are approaching their cash costs. As a result, the end-market price of these materials will start to resemble commodities, and external factors will impact suppliers' capability to maintain a particular price level. This has already been seen in the case of silver paste because of the volatility of silver bullion pricing in the recession, but recent history has shown us that materials such as HF (hydrogen fluoride) and oil-derived polymers can experience significant high price spikes due to market volatility. In the supply chain, operating on narrow margins, some of these price spikes will be passed on to the end customer, which will run contrary to the expectation of continued price reductions for economically viable PV power.

A final consideration of competing at low prices with narrow margins is the need for reinvestment and capacity addition (particularly in polysilicon). As returns reduce, the attractiveness of upgrading or adding capital to a business with low IRR plummets, leading to possible demand tightness and price increases in the long term.

Strategic alternatives for material suppliers

For many current suppliers of chemicals and materials, participating in China is a must. While technical advantage can be sustained and domestic product exported to China with local representation may be a viable business model, in the long term, suppliers must expect the Chinese competition not only to start offering competitive products but also to have structural cost advantages. Setting up domestic manufacturing is not an uncomplicated business by any means, but it has been successfully achieved by many companies in this and other industries. This may well be the best approach to share gains in the Chinese market.

In order to maintain a differentiated technical advantage, a supplier can also pursue material reduction strategies. Major paste suppliers already offer silver pastes with reduced precious metal content or formulations tuned for double printing, and ultra-fast-cure EVA has the ability to reduce lamination time for enhanced productivity.

> "Addressing scale requirements as part of a strategic plan is vital to gaining share with tier 1 suppliers."

Addressing scale requirements as part of a strategic plan is vital to gaining share with tier 1 suppliers. On the flip side, however, using manufacturing scale as both a competitive and a cost advantage has proved to be an effective defence against smaller competitors; this makes Hangzhou First PV a difficult competitor to contend with in the encapsulant market.

The final strategic consideration from suppliers giving consideration to entering the Chinese market is that as demand for PV modules grows in other regions of the world, localized manufacture will be the most economic approach. An example of this is Suntech assembling its modules in the USA. Chemical and material suppliers can bid for business as and when such manufacturing is established. While such a "wait and see" strategy may be attractive to some, it is worth considering that domestic Chinese suppliers may well be considering expansion in foreign markets at that point, as GRTC is already doing.

About the Author

Mark Thirsk is a managing partner and co-founder of Linx Consulting, which provides market-defining analysis and strategic insights across major markets in electronic materials. He has over 25 years' experience in economic and business forecasting, strategic planning, technical marketing, product management and M&A, spanning many segments and processes in electronic materials. Mark has served on the SEMI Chemicals and Gases Manufacturers Group (CGMG) since 1999, acting as chairman between 2001 and 2003. He holds a B.Sc. (Hons.) in metallurgy and materials science from Birmingham University and an MBA from The Open Business School, and has authored multiple publications in both academic and trade publications, as well as contributing to several patents.

Enquiries

Mark Thirsk
Managing Partner
Linx Consulting LLC
PO Box 384
Mendon, MA 01756-0384
USA

Tel: +1 617 273 8837
Email: mthirsk@linx-consulting.com
Website: www.linx-consulting.com