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The global photovoltaic materials market – is the future bright?

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ABSTRACT

Despite the financial crisis and present credit crunch, photovoltaic materials markets experienced only a temporary slide in demand in 2009, with the overall outlook remaining optimistic. This paper presents a strategic analysis review for the materials used in photovoltaic modules, essentially materials for encapsulant, frontsheet, backsheet and anti-reflection coatings. Rising concerns about the need to reduce CO_2 emissions and increase the use of renewable energy sources worldwide will stimulate the global photovoltaic market. Feed-in tariffs and politically backed targets boosting renewable energy use will provide further impetus to the photovoltaic market. This, in turn, will have a positive ripple effect on the demand for photovoltaic materials; however, depending on the market share for technology used, i.e. crystalline or thin film for PV energy, the market for materials will be influenced, in addition to advantages and disadvantages of these materials that will influence their market share. With rising awareness about green trends, the future will lie in technologies that offer enhanced energy-efficient solutions at a low cost. Manufacturers who offer products with optimum performance while remaining price-orientated will be poised to gain substantial market share.

Introduction

The solar PV market has been booming over the last few years, despite the financial crisis. Although in 2008 the PV market experienced a temporary slump, the outlook for the industry looks positive. The market is dependent to a large extent on the political volition and subsidies with the support mechanisms being specific to a country. The introduction, modification or scraping out of such support mechanisms can have a profound effect on the PV sector. At present, the global PV market is being driven by the financial incentives offered by the federal and state governments. In addition, the optimization of production costs coupled with technological advances and research and development initiatives are also assisting in the expansion of the sector. The integration of PV systems in the grid or off grid is illustrated in Fig. 1.

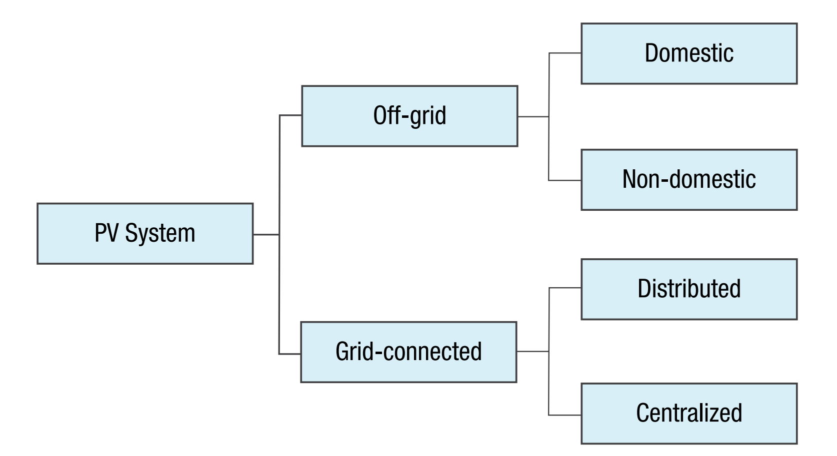

Figure 1. Schematic of a PV system integration in the electric supply chain.

Outlook for PV modules

The PV technology that is used for the production of electricity determines the usage of various materials. Crystalline silicon technology is material intensive but provides many opportunities for the material suppliers. Thin-film technology is a cost-effective solution that has a promising future scope for companies supplying polymers to the PV sector. However, the major disadvantage of thin-film technology is its efficiency. The development and supply of materials with improved efficiency at a competitive price will assist the thin-film modules market to exhibit a higher growth rate in comparison to crystalline silicon modules. Development in the use of PV modules between 2009 and 2016 is illustrated in Fig. 2.

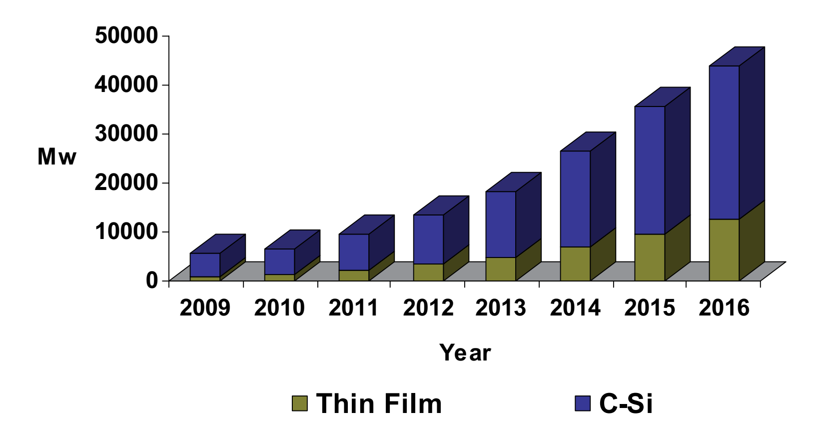

Figure 2. Outlook for photovoltaic modules (2009–2016).

PV module materials

The photovoltaic modules market has been growing rapidly on a global scale. There are several different solar cell technologies at a range of efficiency levels and various states of commercialization, as illustrated in Fig. 3.

The major goal is to get production costs down to less than \$1/Watt while maintaining long-term durability. Manufacturing technologies have to become more cost effective, including innovations in materials for module components. The required functions of key component materials in photovoltaic

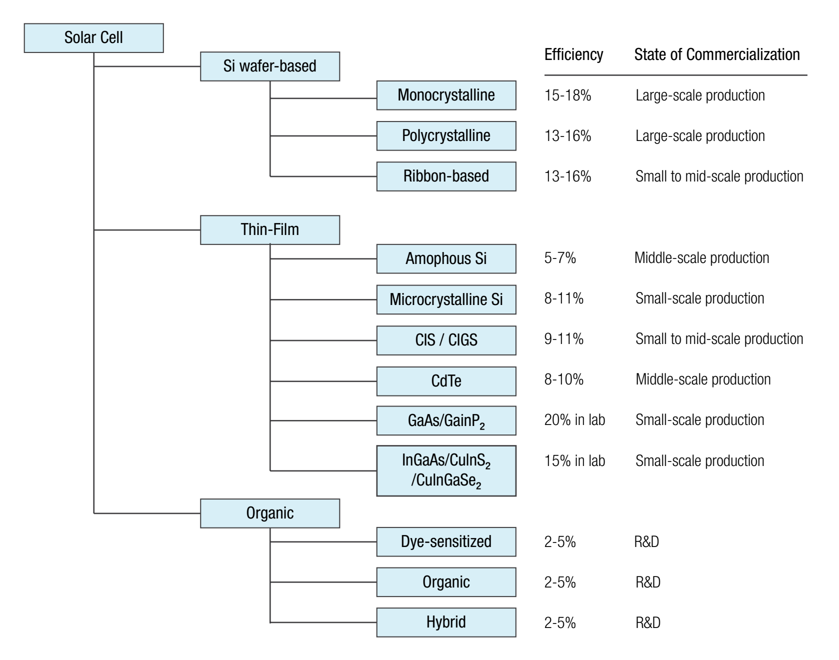

Figure 3. States of efficiency and commercialization of various solar cell technologies.

modules are to provide chemical resistance, flexibility, availability and ease of process. The four key components that largely influence the functioning, longevity and efficiency of photovoltaic modules include encapsulants, frontsheets, backsheets and anti-reflection coatings (ARCs) for cover glass.

Encapsulants

Photovoltaic devices are encapsulated in polymeric materials for mechanical support and to prevent corrosion. The encapsulant represents one of the most important materials to module manufacturers for high-volume module sealing and integration. Selecting the right material not only increases the module production, but it can significantly prolong the power-generating efficiency and module durability. As the industry expands, it is critical to provide suitable materials solutions to meet the numerous requirements including performance, price, throughput and global availability.

"The encapsulant represents one of the most important materials to module manufacturers for high-volume module sealing and integration."

The undisrupted performance necessary for photovoltaic modules to perform over a lifespan of 20–25 years requires every module component and the entire assembly to be long-lasting without substantial degradation. A testing procedure for 20–25 years is neither feasible nor economically viable when a period of 2–5 years is required for the development and launch of new encapsulation materials, processing methods, or both. As a result, artificial accelerated exposure (AET) testing plays an important role in addressing this challenge.

Typical polymers used in encapsulants are ethylene vinyl acetate (EVA), polyvinyl butyral (PVB), silicone, ionomers, polyethylene terephthalate (PET), polyolefins, thermoplastic polyurethane (TPU), polymethylmethacrylate (PMMA), and polycarbonate (PC). The market split of various polymers used in the manufacturing of encapsulants in 2009 is illustrated in Fig. 4. The 'others' group includes polymers such as TPU, PET, PMMA and PC.

Encapsulants for solar cells must have excellent adhesion to backsheet, cells and glass; high light transmission over the lifetime of the module; weatherability; good moisture barrier; high flexibility and fire resistance. Since the early 1980s, the encapsulant used in almost all PV modules has been made of EVA, representing the industry standard because of its transparency and refractive index, which reduces reflection. As EVA is not naturally UV stable, it has to be treated with various additives in order to make it suitable for photovoltaic applications.

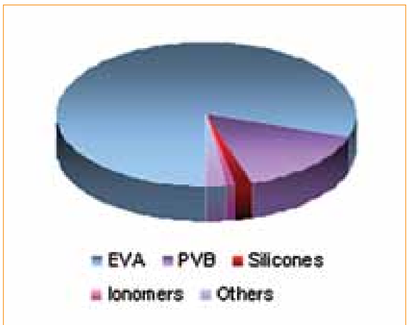

Figure 4. Market split of polymers in encapsulants.

Despite EVA's having both glass and melting phase transitions at temperatures experienced under environmental exposure, its low cost and good optical transmission made it the most preferred material for PV modules. These transitions, however, cause EVA to become brittle at low temperatures (approximately -15°C) and to be very soft at high temperatures (greater than 40°C). For modules to have a long lifespan, one would prefer a material that is relatively unchanged under a wide temperature range, as it would ultimately produce a more reliable system. These concerns are likely to become more important as silicon-based cells become thinner.

"There have been more module failures in recent years due to the use of alternative materials with limited track records."

There have been more module failures in recent years due to the use of alternative materials with limited track records. TÜV Rheinland has been looking at the IEC standards and requirements for polymers in photovoltaics including delamination, electric arc damage and local heating spots. Laboratory tests have been developed ranging from UV preconditioning and thermal cycling to damp heat tests.

Various polymers have been developed for the marketplace. However, the lack of track record and higher costs has restricted their uptake. PVB is the preferred material for thin-film technology. In addition, when high aesthetic and high durability are required, silicone and ionomer encapsulants are the preferred choice. Silicone encapsulants are UV stable, durable, increase light transmission (and therefore efficiency), and the liquid process is less labour-intensive and more cost-effective.

Building-integrated photovoltaics (BIPV) offer great potential as innovative materials. PVB has been used for many years as an interlayer in automotive glazing and more recently in thin-film PV applications, and has great potential in the BIPV market.

The global market for encapsulants was valued at over US$2 billion in 2009, a figure that includes the laminates market for all applications such as automotive, construction, solar and others. While the solar market is currently the smallest, it exhibits the fastest growth. The global market for photovoltaic encapsulants

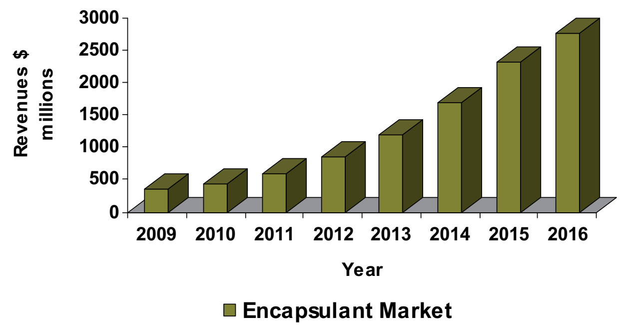

Figure 5. Revenue forecasts for PV encapsulants.

was valued at US$354.2 million in 2009 as illustrated in Fig. 5. The photovoltaic encapsulant market is mainly dominated by the EVA encapsulant that serves a larger end-user base in terms of MW value. As a result, the EVA market will continue to benefit from the increase in demand for photovoltaic energy.

Technology trends in the end-user market will directly influence the market for photovoltaic encapsulants. For instance, EVA that is preferred in the case of C-Si cells may be negatively affected if thin-film cells gain more importance. This trend can, however, positively affect the market for PVB that is traditionally preferred in thin-film cells.

Backsheets

Photovoltaic modules comprise a transparent protective superstrate and rear sheet called backsheet. In the case of crystalline silicon technology, the front panel and backsheet encapsulate solar cells and protect them from adverse weather conditions. In the case of thin-film technology, amorphous silica may be deposited on a rigid transparent layer, such as glass, and bonded to a backsheet with a transparent adhesive.

Photovoltaic backsheet materials protect photovoltaic modules from ultraviolet rays, moisture and adverse weather conditions, while also insulating the electrical load of modules. These functions are essential for the functionality and longevity of photovoltaic modules as well as the safety of people who work with and near these modules.

The backsheet comprises a laminated structure based on glass or a thermoplastic polymer, such as polyvinyl fluoride, ethylene vinyl acetate, polyvinylidene fluoride and other. The backsheet laminates are highly customizable. However, this laminated structure is not fully impervious to moisture. As a result, over time, the power output and/or useful life of photovoltaic modules made with this kind of backsheet material is reduced, due to electrical shorting resulting from absorbed moisture.

The prime requirement of a backsheet laminate is to have excellent adhesion with the encapsulant when the components are laminated together in a thermoforming process.

PET is the most preferred material with excellent water vapour resistance and relatively lower cost, but is vulnerable to degradation from exposure to environmental influences, such as UV radiation, IR radiation, and ozone. PET is mostly protected by the use of Tedlar polyvinyl fluoride (PVF) films, which are tough, photo-stable, chemically resistant and enduring against moisture exposure. They also adhere well to encapsulants and have good resistance to water vapour. As a result, the lamination of Tedlar film and PET provides an excellent backsheet material.

Polyvinylidene fluoride (PVDF) can also be used in place of PVF and is gaining more market share because of its relatively lower cost and good adhesion to PET in comparison to PVF. Other polymers used for this purpose include EVA and ethylene propylene diene monomer (EPDM); however, these polymers are rarely used because they lack some of the physical properties that are required in harsh environments.

These constructions can suffer from the drawback of poor adhesion of the PVF to PET. Backsheets formed from PVDF and

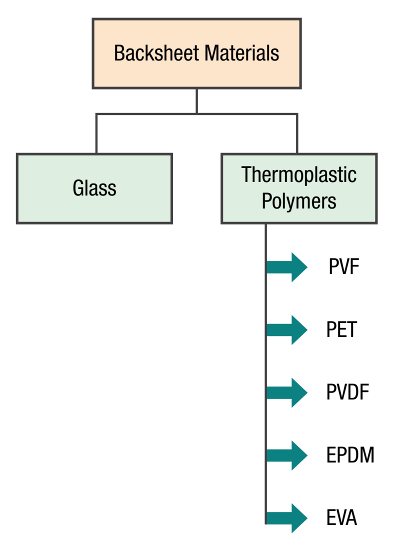

Figure 6. Types of backsheet materials.

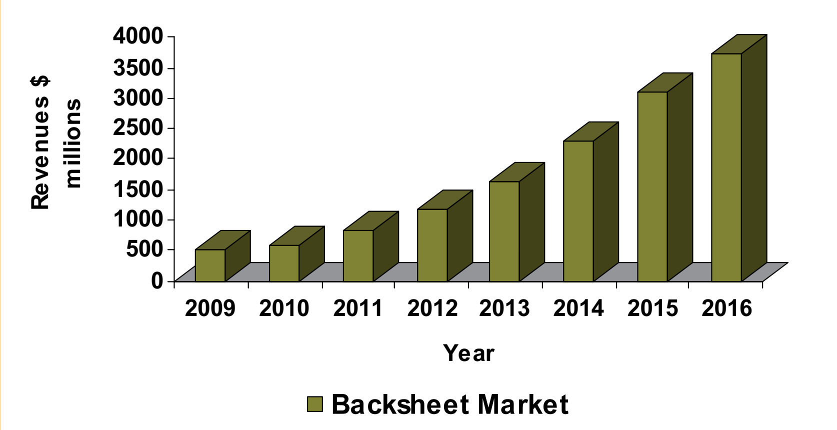

Figure 7. Revenue forecasts for PV backsheets.

PVF copolymers and PVF blends can take advantage of the properties of PVDF to overcome this issue of harsh environments.

The photovoltaic industry, which has been focusing on crystalline silicon solar cells, has recently experienced an increased interest in the field of thin-film cells. Therefore, glass, which is predominantly used as the backsheet material in thin films, is likely to witness a high growth rate in the future. While the market for glass as a backsheet material was valued at US$47.5 million in 2009, the global market for PV backsheets was valued at US$493.3 million in 2009 as illustrated in Fig. 7. This market size represents backsheets provided after laminating the individual polymer layer.

The PV industry is seeking non petroleum-based chemicals for use in photovoltaic modules. Resins from renewable sources have been developed over the past as substitutes for conventional resins due to the fluctuating prices and availability of petroleum feedstock and concerns for the environment. Some resins like polylactic acid (PLA) resins, which are produced from corn or other renewable feedstock, have been considered for use in backsheets. However, these resins from renewable or sustainable resources have not been previously considered for such applications, either because of relatively poor material properties or processing challenges. Nevertheless, there is a need to provide a useful laminate film for use as a photovoltaic module backsheet from a renewable or sustainable source.

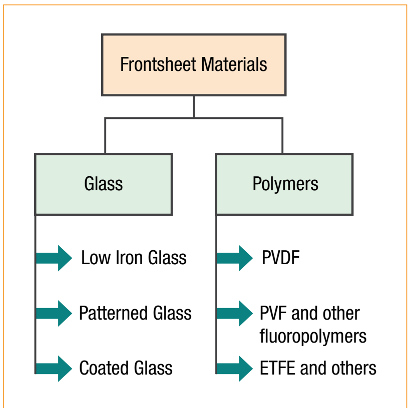

Figure 8. Types of PV frontsheet materials.

Frontsheet

The primary role of a frontsheet in PV modules is to ensure their structural stability. In addition, frontsheets are designed to facilitate the lamination process (adhesion of encapsulant on frontsheet), maximum transmission of light into the module as well as to improve the aesthetic parameters of a module. Recent growth in the solar market has created a good demand for frontsheet materials. While an array of materials is used in solar module manufacturing (see Fig. 8), certain end-user groups prefer specific types of frontsheet materials. The main criteria include cost and efficiency, which are directly related to the spectrum of light transmitted.

Glass is the most commonly used frontsheet material, and several types of glass are used for this purpose. With changes in solar technology and a growing demand for flexible photovoltaics, the need has arisen for non-glass materials, such as polymers. Fluoropolymers and ethylene tetrafluoroethylene (ETFE) cater for the need for flexible photovoltaic modules.

Tempered glass is the basic glass type used in the solar market. Tempering involves toughening the glass in order to provide maximum strength and stability to the solar module, with the resulting glass used in most module types (with the exception of a-Si because of the high temperatures involved during the deposition process).

Patterned glass currently accounts for the highest revenue share in the photovoltaic frontsheets market as it presents the best mix of key functionalities. Some of its key advantages are durability, transmission capabilities and cost. Patterned glass is an extension of low-iron glass that is used in solar applications offers, besides functionality, aesthetic appeal. This factor has gained the material more importance in recent years.

> "In 2009, the market for frontsheet materials used in the photovoltaic industry was valued at US$426.7 million."

The favourable cost of low-iron glass allows it to be used largely in applications that involve low investment. Coated glass, which is sold at a premium, currently has the highest transmission rating and looks set to be a significant product in the future.

Polymers such as ETFE and PVDF are mainly used in improving efficiency and offering structural integrity to thin-film cells. At present, they are not commonly used, unless the photovoltaic module has to be made flexible in nature.

In 2009, the market for frontsheet materials used in the photovoltaic industry was valued at US$426.7 million (see Fig. 9), with glass representing by far the largest market segment. Among the various glass types, patterned glass will continue to dominate the market, as it offers an ideal mix of cost, performance and aesthetics.

Changing end-user requirements need to be addressed through improvements in technology. End users demand a product with improved efficiency and reduced cost per Watt. Various technologies such as low-iron coated glass (anti-reflection coating (ARC) for c-Si and transparent conductive oxide (TCO) for thin films) are being evaluated to facilitate these improvements.

Moreover, in the thin-film segment, the need for portable/flexible PV modules has resulted in an increasing demand for fluoropolymers. As transparency affects transmission, companies have developed an efficient fluoropolymer (mainly PVF/PVDF) that can match the efficiency and lifetime of glass frontsheets. However, the

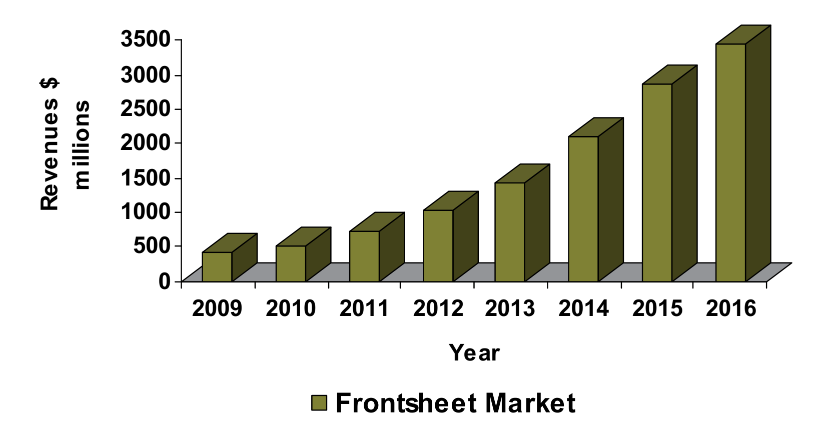

Figure 9. Revenue forecasts for PV frontsheets.

market for value-added glass is poised to dominate the photovoltaic frontsheets market in the next 10 years.

Anti-reflection coatings for cover glass

ARCs are used on the surface of glass and other optical devices to reduce reflection. These coatings are predominantly used to improve the efficiency of the system by reducing the amount of light lost due to reflection.

Conversion efficiency of a PV module is the measure of the amount of sunlight converted into electrical energy. Typically, front glass cover reflects some of the sunlight before it reaches the solar cell, thereby reducing the photovoltaic module's conversion efficiency. On a daily basis, between 4% and 15% of sunlight is lost due to reflection from the cover glass, resulting in a reduced conversion efficiency of the module. To increase the transmission at cover glass, an anti-reflection coating is applied, which increases the amount of sunlight absorbed by the cells as well as the power generated by the module. Commercially-available photovoltaic modules convert 12–20% of the absorbed sunlight into electricity; using an anti-reflection coating can increase the efficiency of PV modules by 0.4–0.7%.

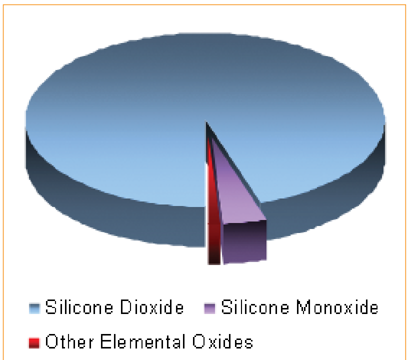

Figure 10. Market split of anti-reflective coatings.

The application of ARCs over cover glass is a relatively new concept, and its success will largely depend on the efficiency gained. The changing dynamics in the energy market will play a major role in determining the extent and pace of developments related to ARCs.

Considering the cost component, glass manufacturers have already started producing ARCs in order to accelerate development in this area and manufacture new products. The market for ARC is dominated by silicone dioxide, as shown in Fig. 10.

The market for ARC is segmented into merchant markets, comprising those companies that supply ARC to module manufacturers and cover glass manufacturers as a value addition, and the captive market, namely, glass companies that have in-house manufacturing capabilities to produce ARC and use it in their products.

The market for the ARC merchant market sector was valued at US$12.6 million in 2009, which presents a huge potential for market penetration in frontsheets by 2016.

Conclusion

The photovoltaic sector witnessed a temporary slow-down during the global financial crisis. The deceleration in the demand for photovoltaic energy made material suppliers wary of increasing their manufacturing capacities. However, the future of the photovoltaic industry is very promising. Innovation in photovoltaic materials will continue to drive the market as improvements made in the efficiency of photovoltaic modules must involve direct improvement of the efficiency of materials used. Material suppliers understand this requirement, and are continuously pursuing innovation in order to remain competitive. The future lies in new technologies that offer energy-efficient solutions at a low cost.

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