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The Future of Thin Film Solar

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1 The Emergence of Thin Film PV

1.1 Introduction

For as long as the sun rises, the Earth will have a sustainable source of energy: solar energy. Harvesting this abundant energy source has been a dream of mankind for thousands of years. From Archimedes' experiments with solar concentrators to today's solar cells that quietly convert sunlight to electricity, the science of harvesting the sun's power has made huge strides. Yet despite the lofty dreams and scientific advances, today only 0.04% of the world's electricity is generated by solar cells[i]. What makes the power of light so elusive and difficult to capture? The answer lies not only in science, but also in economics and geo-politics. Solar power belongs to a portfolio of energy sources and access to energy is one of our society's greatest needs. As such, solar technology will always be at the whim of political events, dependent on complementary technologies and in competition with conventional sources of energy.

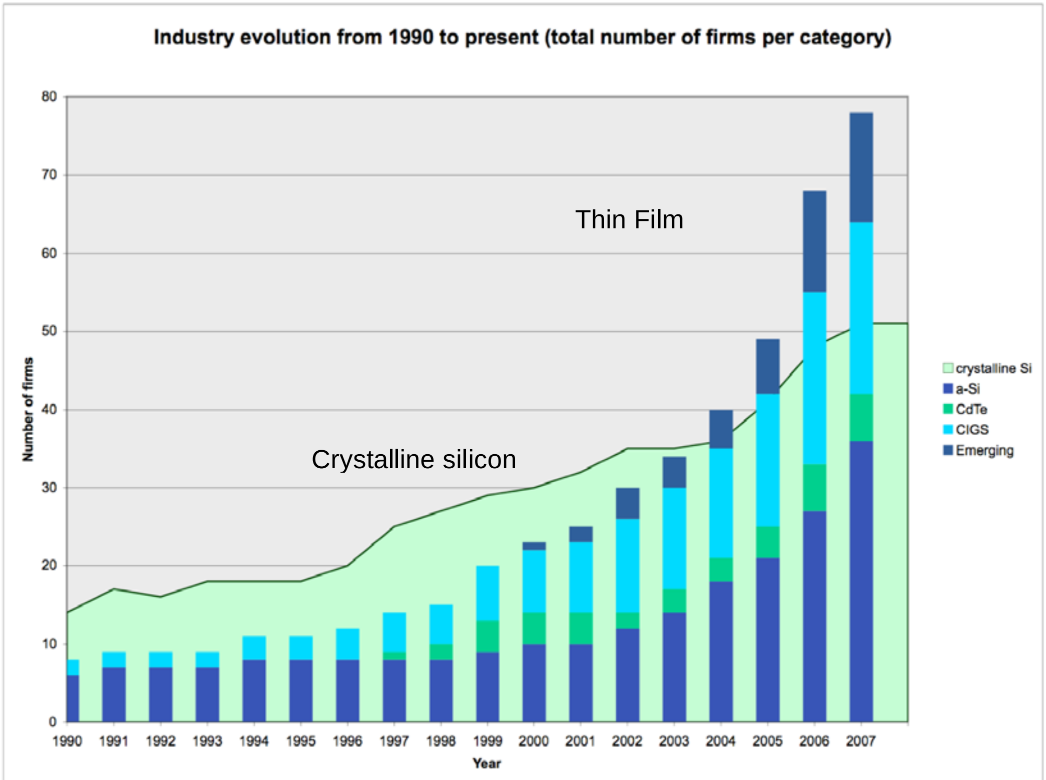
The resurgence of the solar industry has been largely driven by the sophistication of the semiconductor industry and government subsidies

However, in recent years, a number of events have changed the economic and technical potential for solar energy to make a substantial impact on the current energy architecture, particularly through the use of photovoltaic (PV) devices. Through these increasingly inexpensive, solid state, and scalable devices, solar energy today is on the threshold of becoming a surprisingly powerful tool to simultaneously address issues from universal access to vital energy to economic security to environmental damage caused by our current methods of harvesting energy.

A number of factors have driven the resurgence of the solar industry since the initial surge of economic effort in the 1970's post-oil embargo period. The two main drivers have been the increasing sophistication of the semiconductor industry and, more recently in the 1990s, the significant government subsidies, especially in Japan and Germany, creating a healthy market for solar PV. The confluence of a rising market for solar energy from an increasing demand for renewable energy, the shortage of polysilicon feedstock and a maturation of associated technology has created a perfect storm for thin film solar photovoltaic. Thin film PV's lower material cost (it uses a fraction of semiconductor material used by polysilicon PV), malleability and range of manufacturing methods and applications offer tremendous advantages in extending the range of solar electricity generation from small-scale microelectronics to utility scale electricity. Thin Film PV could not only replace silicon-based solar panels, but could also open up new markets and applications. For example, the low weight of thin film PV solar panels allows them to be fully integrated into commercial and residential building materials and components. Thin film PV's low cost and flexibility will extend the use of solar energy to many mobile and disposable applications.

Thin film PV is benefiting from an influx of venture capital and customer interest in new applications for PV

This potential for thin film PV to significantly change the economics of creating electricity from sunlight has attracted much attention and considerable resources are being poured into thin film PV with the intent of capitalizing on a tantalizingly large market. A substantial influx of both venture and corporate capital has taken place in recent years creating a healthy, competitive environment with both startups and established players. Although thin film PV has been around for many years, it has recently has seen its share of the PV market grow from 4% to 8%. Additionally, manufacturers' plans and rapidity of deployment suggest that its market share will continue to grow in the next decade.



Thin film industry evolution – 1990 to present

However,

- What will be the nature of the impact of thin film PV on the solar energy industry?
- What is the potential for thin film PV technology to be disruptive to crystalline PV solar technology that currently dominates 92% of the market?
- If disruptive, which thin film technology is likely to do so?
- How will underlying shifts in supply, demand, and prices affect the relative competitiveness of different technologies?
- What challenges will thin film PV encounter as it continues to mature and penetrate markets?

Our report answers these and many questions within the larger technical and economic framework of solar technology itself.

What has emerged in the process of our research has been surprising and inspiring. We believe that thin film PV's technical and economic characteristics will make true the promise to reduce the cost of solar electricity to a level where solar power will compete effectively with power generated from fossil fuel alternatives. The amount of capital being invested, the breadth of technical approaches, and the established success of a number of companies suggest that thin films are a powerful force very likely to alter both the solar energy and larger energy industries in the next decade.

This report analyzes the technical merits of the different thin film solar technologies, their market and applications, and the dynamics of a growing industry. It also compares different thin film solar technologies against each other and against the dominant polysilicon technology, from both a technical as well as a market perspective. It examines industry characteristics and studies the different technology strategies employed by players in the industry. Finally, it highlights the manufacturers of each type of technology and presents a snapshot of the industry in terms of current production and forecasted manufacturing capacity.

The research involved an extensive interview program of all major firms in the thin film solar industry. Data collected during these interviews populated a database allowing us to perform statistical analysis and graphical presentations. The information extracted from the interview data was augmented with an in-depth research of technical literature, web sites and trade journals and discussions with industry veterans.

1.2 Breaking Out from the Shadow of Polysilicon PV

The relative advantages of crystalline PV are eroding quickly, setting the stage for a robust thin film PV market.

Thin film PV has been around for decades, always tantalizingly close to being ready to meet the world's challenge for local, clean, renewable sources of electricity. But so far, it has constantly failed to meet its potential. Over that time, thin films have had multiple rounds of financial backers and surges of interest, but remain today less than 10% of the total PV market, having watched traditional crystalline silicon (crystalline or c-Si) based PV capture the lion's share this fast growing market.

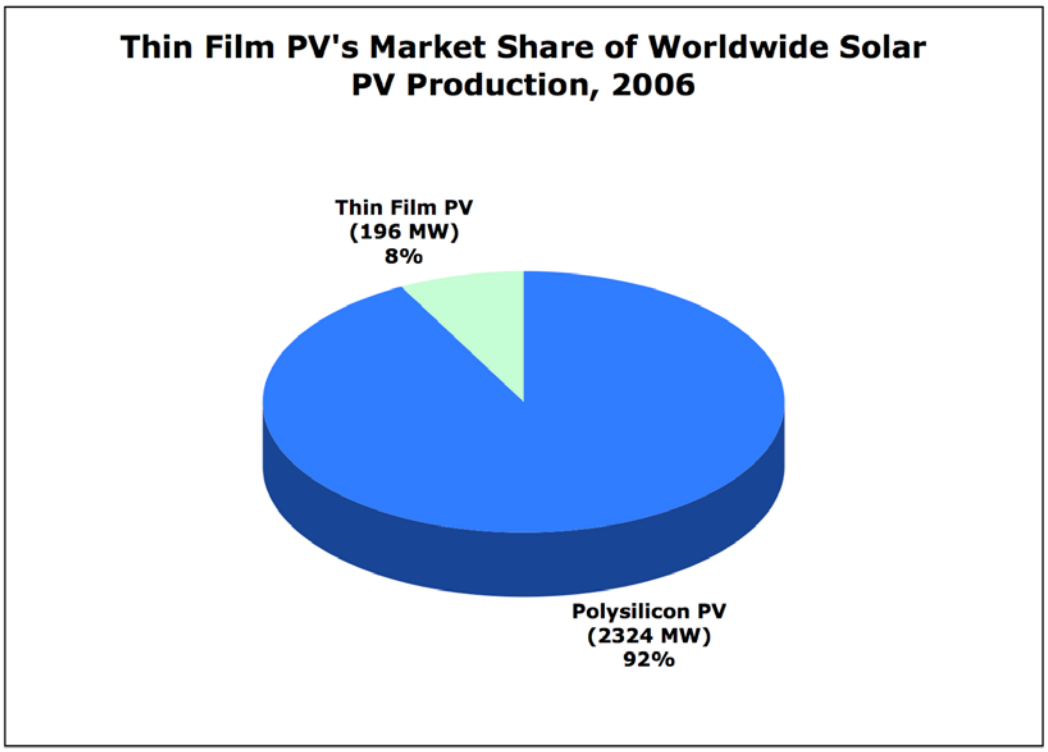
There are many reasons why crystalline PV has been so successful. In many ways, the technology's ability to use scrap material and processing equipment from the semiconductor industry has helped to reduce technical risks. The standardization of manufacturing processes and form factors of the end product has reinforced its economics. And as increasing returns to scale have been strong for these emerging technologies, the rapid deployment of investment and capital flowing as a result of the highly successful Japanese and German governments' solar energy programs of the last year reinforced its relative cost advantage.

However, those relative advantages are eroding very quickly. Polysilicon, the primary ingredient for crystalline PV, is in short supply and its price has exploded with the rapid growth of the overall solar energy industry. Companies developing thin film are finally beginning to realize on investments made to transition lab technologies to economic production, with 25 MW to 100MW production lines becoming standard. Also, major equipment producers, who spent billions on factories to produce high-speed deposition lines for electronics equipment to make large-area devices like LCD screens, are now looking to adapt that knowledge base to thin film manufacturing.

There are four basic categories of thin film PV based on the materials used to convert light into electricity:

- Amorphous Silicon (α-Si)
- Cadmium Telluride (CdTe)
- Copper Indium (Gallium) di-Selenide (CIS/CIGS)
- Emerging (Dye-sensitized, Organic or Nano-materials)

Not only can different materials be used to create the PV effect, but they can also be deposited on different substrates. Currently, most production technologies use glass as the substrate, as in the case of all CdTe technologies, and many emerging α-Si technologies. But some α-Si solutions, including those from United Solar, use a flexible metal foil as the substrate, and many emerging and CIGS technologies can be deposited on glass or metal foil as well as lower temperature substrates like plastic.



Thin Film Market Share of Worldwide Solar PV Production, 2006

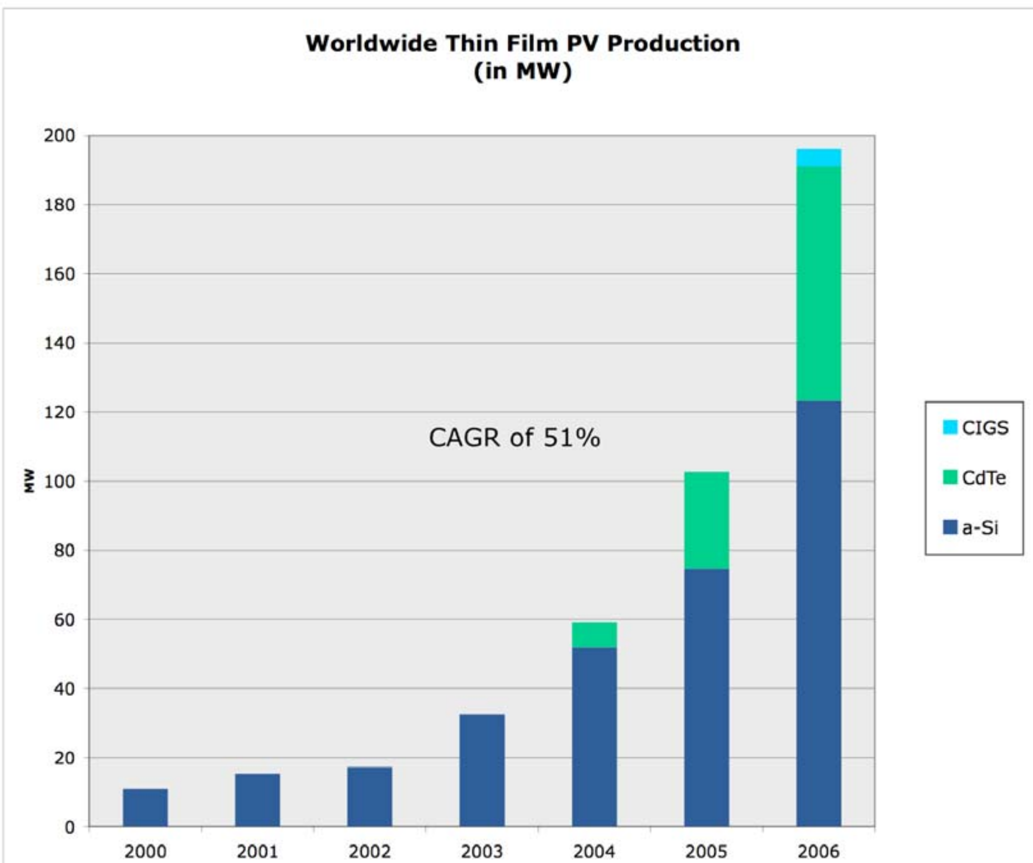
Thin film then offers three key technological advantages:

1. Unlike today's traditional solar photovoltaic (crystalline PV) technology, thin film PV uses very little or no silicon and other material to build a solid state electricity generation device.
2. A whole new range of applications otherwise not possible using traditional solar cells are enabled because thin film

materials can be applied to a multitude of surfaces such as glass, plastic and flexible metal foils.

3. Thin film PV can be manufactured using various deposition and packaging methods that offer flexibility in scaling production and addressing applications. For example, the most common method uses glass as both the substrate and the superstrate, as in the case of CdTe or some α-Si modules that batch deposit (using sputtering, vapor, or plasma methods) the layers onto the front pane of module glass. Other methods that can increase production throughput include deposition in roll-to-roll processing on flexible metal or plastic substrates that can then be converted into modules using either standard glass-packaged rigid modules or flexible encapsulated modules.

While thin films will for many years be less efficient than crystalline PV, their ability to create electricity at a substantially lower cost (even when efficiency issues are accounted for) and in a much wider range of products and form factors will allow thin films to gain market share, rising to 20% of the PV market in 2010 and potentially dominate the industry within a decade after that. The ability to deliver electricity inexpensively and ubiquitously will place thin film PV in the front rank among all energy technologies in the surprisingly near future.



Worldwide Thin Film PV Production 2000 - 2006

1.3 Key Findings

We forecast the thin film PV market to grow rapidly, and begin to reshape the PV market worldwide.

Thin film achieved a rapid growth from 5.8% of the total worldwide production solar PV to 7.5% (module sales of between $500 million and $600 million) in 2006. Furthermore, it achieved its increase of market share in a growing solar PV market driven by a need for renewable energy sources. A rising market for solar energy, the shortage of polysilicon feedstock and a maturation of thin film technology have been the prime drivers for this growth, and multiple factors and applications will continue to remain in place to support the uninhibited growth of thin film.

Thin film, though technically challenging, is commercially viable.

The commercial economics of thin film PV were proven in early 2007 as First Solar, a Cadmium-Telluride cell manufacturer completed a successful IPO and launched a rapid ramp up to 300 MW of production across three continents with a healthy 50% gross profit margin on sales, proving that that thin films could be made faster, cheaper and ready for full scale market adoption.

Over the next decade thin film will remain competitive with crystalline PV.

The ability to deliver electricity cheaply and ubiquitously will put thin film solar in a position to threaten existing solar manufacturers who rely solely on polysilicon

Expected energy-conversion efficiencies and production costs show that even after adjusting for its lower energy-conversion efficiency, thin film will remain competitive with crystalline PV, and under most scenarios should provide substantial margins for producers. Thin film is today, and will likely be for the next decade, a lower efficiency and lower cost technology. PV technologies that have such characteristics require more physical space and more Balance-of-Systems components (like racks and cabling) and installation labor. When standardized to cost per Watt, this lower efficiency should be accounted for by a lower market price per Watt. Given the conversion factors today (about 10 cents per Watt per point of efficiency loss), thin film is still very competitive at expected price levels.

Thin film PV will be a major player in new electricity generation.

Our analysis shows that under almost all possible economic states of the world that may emerge in the next decade, thin film PV will be a powerful force in deploying new electricity generation capacity. It will add to the supply of new sources, provide the ability to rapidly scale to meet growth in energy demand, circumvent many production bottlenecks in today's PV industry, and bring down costs and prices.

More in the full report.....

1.4 Report Structure

The Future of Thin Film PV is structured as follows:

Section 2 introduces thin film PV technologies and covers basic concepts, pros and cons, production equipment manufacturers, feedstock and raw materials and energy conversion efficiencies.

Section 3 provides an overview of the market and applications for thin film technologies.

Section 4 covers thin film PV manufacturing production and capacity, costs and their evolution for the different technologies.

Section 5 presents market projections and various scenario analyses for market dynamics.

Section 6 offers brief individual profiles of leading thin film manufacturers and an overview of venture capital investments in thin film PV.

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