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THIN FILM PHOTOVOLTAIC TECHNOLOGIES: STATUS AND PERSPECTIVES

ABSTRACT: *Today, the renewable energy systems have a significant impact on the environment. One of the most promising renewable energy technologies is photovoltaic (PV) energy conversion, which represents the direct conversion of sunlight into electricity. Commercial PV materials commonly used for PV systems include solar cells of silicium (Si), cadmium-telluride (CdTe), coper-indium-diselenide (CIS) and solar cells made of other thin layer materials. In this paper we will focus on the different thin film photovoltaic technologies, actual market situation and future challenges arising with growing PV demand. Also we will point out the advantages of the thin film photovoltaic technology for building integration, because the Building integrated Photovoltaic (BIPV) market is still one of the big hopes for thin film technologies.*

KEYWORDS: Thin film Photovoltaics, technology, building integration

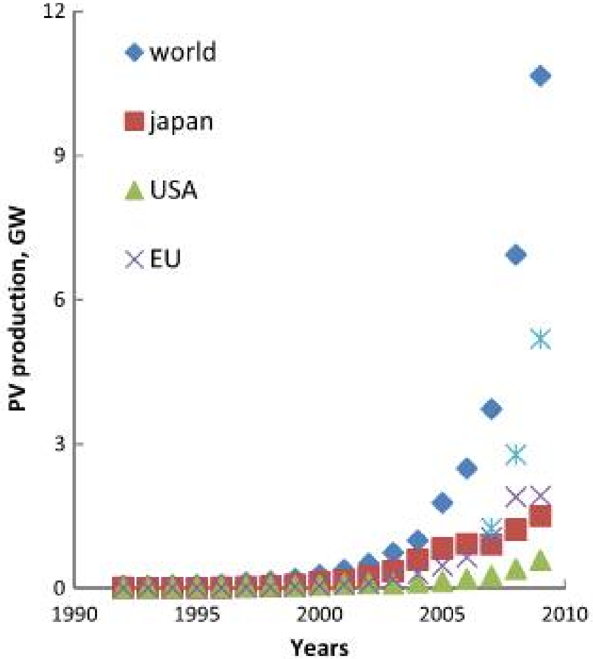
1. INTRODUCTION

Silicon is a leading technology in making solar cell, due to its high efficiency. But many researchers, due to its high cost, are trying to find new technology to reduce the material cost for production of solar cells and thin film technology can be seen as a suitable substitution. However, the efficiency of solar cells based on this technology is still low, and researchers are intensively making an effort to enhance the efficiency.

In this paper, it is analyzed the current status of the PV market and technology, and different thin film technologies, present at the market today, based upon amorphous-silicon (a-Si), cadmium telluride (CdTe), copper indium gallium selenide/copper indium selenide (CIGS/CIS), organic solar cells (OPV) and dye-sensitized solar cells (DSSC). It is expected that thin film PV technologies will play a main role in the world PV market in the future. Further the advantages and perspective of the thin film photovoltaic technology for building integration are pointed out.

2. PV MARKET

Nowadays photovoltaics enjoy quick expansion in a market. Development of the PV market began between 1980 and 1990, encouraged by changes of the policy frameworks made in some of European and worldwide countries (Japan, Germany, etc). Today, the present PV market grows at very high rates, around 30 – 50 % per year, even higher.



Nowadays, over 80% of the world PV industry is based on c-Si and pc-Si wafer technologies, so these are the main materials for the world PV industry. The CdTe technology is growing sufficiently fast, while thin film CIGS and a-Si-based PV production is still in the beginning stages. It is expected that thin film PV technologies will play a major role in the world PV market in the near future.

Fig. *Evolution of world PV cell/module production*

3. THIN FILM (TF) PHOTOVOLTAICS

Thin-film Si solar cells have few important advantages compared to crystalline cells: the thickness of Si can be drastically reduced to 50 μm, thin films can be deposited on low-cost substrates, thin films can be fabricated on module-sized substrates and in integrally interconnected structures, etc.

Three materials that have been given much attention under thin film technology are amorphous silicon, cadmium telluride/cadmium sulphide and copper indium gallium selenide/copper indium selenide, but researchers are continuously putting in more effort to enhance the efficiency. However, all of these materials have some bad impact on the environment. Another solution for thin film technology has been carried out by researchers by using polymer organic as a solar cell material. Polymer materials have many advantages like low cost, light weight and environmental friendly, but they have very low efficiency compared to other materials with just 4–5%.

In this chapter, we analyzed current commercial and potential future TF PV technologies, with a special focus on their related prospective and challenging manufacturing issues.

3.1 Amorphous-silicon based PV

Commercial solar cell devices based on hydrogenated amorphous silicon (a-Si:H or a-Si) are typically made of a dual-junction with micro (μc-Si) or nano-crystalline (nc-Si) Si, (micromorph tandem), [5].

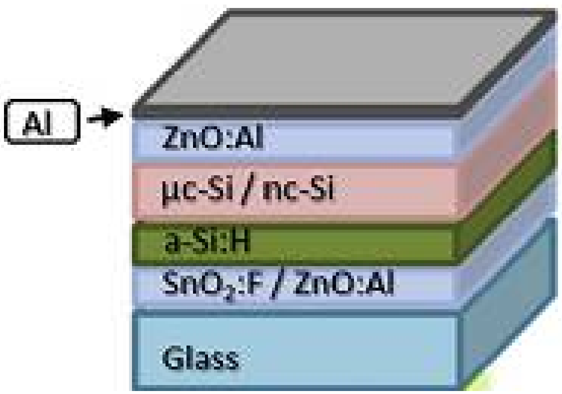


Fig. *Solar cell device based on a-Si/μ-Si*

These devices rapidly surpassed 10% efficiency, but suffered from light-induced degradation that leads to a reduction of the solar cell efficiency. The possibility to deposit a-Si at temperatures below 200^0 enables the fabrication of light-weight, flexible laminates on temperature sensitive substrates, which is a unique feature that provides a competitive advantage in markets such as consumer products and BIPV.

The best initial efficiencies of 13.7 % and 9.8 % were achieved on triple-junction cells and modules, respectively. However, stabilized efficiencies are still low, arround 6–7% for the best commercial modules. Nevertheless, at present, about 8–10% of the worldwide PV production uses a-Si technology,

3.2 Cadmium-telluride

This material can produce high efficiency, more than 15 % and is also known to give an ideal band-gap (1.45 eV) since the direct absorption coefficient is very high. A layer of cadmium sulphide is deposited from solution onto a glass sheet coated with a transparent conducting layer of thin oxide. Standard CdTe-based devices, comprising a glass substrate, the TCO, usually SnO2:F (FTO) and/or (In2O3)0.9(SnO2)0.1 (ITO), the n-type window layer (CdS), the p-type CdTe absorber, and finally the back contact (ZnTe/Cu/C or Mo), fig. [5].

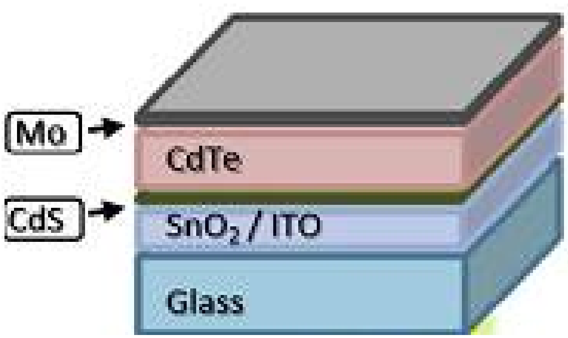


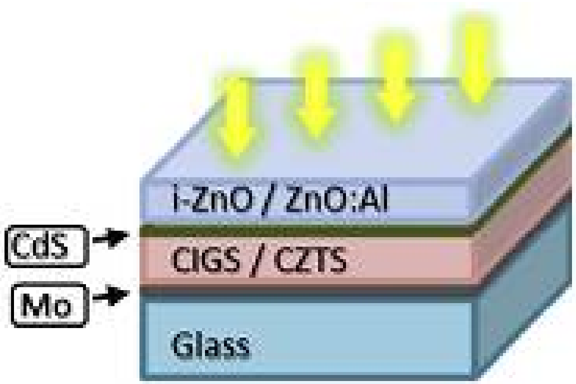
Fig. 2. *Solar cell device based on CdTe*

Laboratory CdTe cells have the efficiency of 16 %, and commercial ones around 8 %. Great toxicity of tellure and its limited natural reserves decrease the prospective development and application of these cells

The issue of Te availability will require substantial observation and fundamental research, whereas recycling may play a major role, not only regarding the toxicity of Cd but also regarding the reuse of Te.

3.3 Copper–indium–gallium–selenide/sulphide

The basic structure of CIGS devices fabricated by current manufacturing schemes begins with the deposition of a Mo back contact followed by the p-type CIGS absorber (1–3μm), a thin buffer layer (50–100 nm), and a doped ZnO serving as the transparent front contact, Fig. [5].



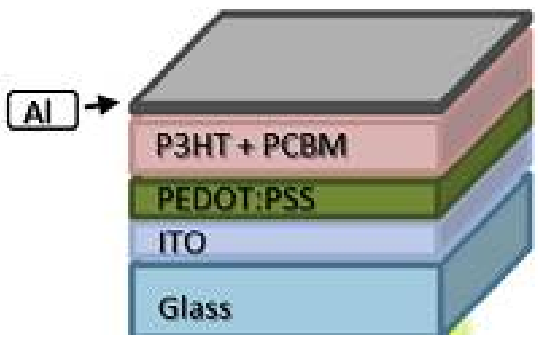
CIGS is the only commercial TF technology that has continually reported efficiency improvements of its record cells during the last decade, with efficiency at present of 13 % for modules and 20 % for cell.

Fig. *Solar cell device based on CIGS/CZTS*

Today, several companies are producing commercial CIGS modules in the range of 10–50 MW/year with Japanese manufacturer Solar Frontier on the forefront selling 14.5% efficient modules from GW-scale production. Substrates include soda lime glass, metal foils, or high temperature polyimide that aroused substantial interest for BIPV and portable power applications.

3.4 Organic solar cells

Single-junction OPV devices are generally comprised of a hetero-junction between an electron donor molecule and an electron acceptor molecule, Fig. [5]. Similar to CIGS, OPV has made great leaps in terms of performance in the past decade, with German company Heliatekbeing the first taking the 10% hurdle, reporting a 10.7% efficient organic tandem cell.



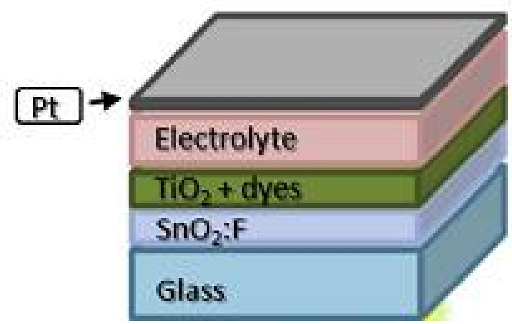
Candidates for organic semiconductor materials may be categorized as either solution-processed (polymers, dendrimers, oligomers, or small molecules) or vacuum deposited (small molecules or oligomers).

Fig. *Solar cell device based on OPV*

Since organic PV (OPV) relies on carbon based semiconductors, low cost high volume manufacturing of flexible solar modules without any raw-material concern appears feasible

3.5 Dye-sensitized solar cells

A device is typically composed of organometallic dye molecules adsorbed to a mesoporous titania nanoparticle film, with the pore space filled by an electrolyte. In such a structure light is absorbed by the dyes injecting electrons into the TiO2 network, which transports these to the front contact. If connected to an external load, the electrons return to the platinized back contact, where they reduce redox couples, which in turn diffuse through the electrolyte and regenerate dye molecules to complete the cycle.



The device is rapidly optimized the to more than 10% efficiency, a few years after of its introduction, [5].

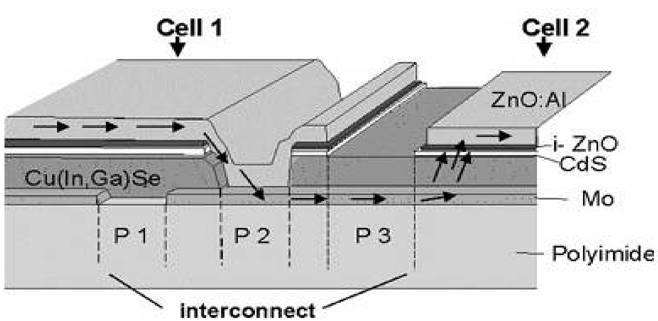
Fig. *Solar cell device based on DSSC*

In combination with the feature that devices can be fabricated in a number of colors and levels of transparency, this makes them an attractive applicant for BIPV applications. Fortunately, cell efficiencies are stagnant at about 11% since more than 15 years and further optimization of any main component of DSSC devices is not likely to yield significant efficiency improvements.

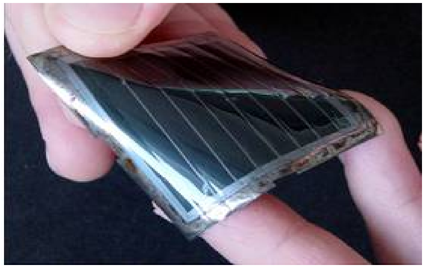
4. PERSPECTIVE FOR THIN FILM PV USE

The Building integrated Photovoltaics (BIPV) market, which got increased political support during the last years is still one of the big hopes for TF technologies. In this context, these modules have many advantages compared to c-Si ones: strongly reduced weight for the application to the building stock, see through property, adjustable optical transmittance, excellent building appearance, potential capability for applying flexible substrates, and less sensitivity to the degradation of light intensity and increasing temperature of the module.

Very important perspective of thin film PV technology is flexible modules.The basic schematic cross-section of a monolithic module on a polyimide substrate and flexible prototype mini-module developed on polymer foil are shown in next figure.



a)



b)

Fig. *a) Patterning scheme for monolithic cell integration on a polyimide substrate*

b) Flexible monolithic CIGS modules showing a prototype mini-module on a polymer foil, [3].

Table 1 gives an overview of different flexible solar cell technologies, including the organic and TiO_2 dye-sensitized PV technologies, [3]. High cell efficiency and inherent stability advantages indicate a promising potential for these technologies. The best thin-film CIGS module efficiency is 11.0%.

Table 1. *Overview of different flexible solar cell technologies.*

CIGS		CdTe	Amorphous silicon	Organic and titanium oxide
Lab efficiency on plastic foil	14.1% (single-junction cell)	11.4% (singlejunction cell)	8%*–12%* (multi-junction cell) 5	5–8%
Lab efficiency on metal foil	17.5% (single-junction cell)	8% (single-junction cell)	14.6% /13%* (multi-junction cell)	
Industrial efficiency (typical values)	6–11% (On steel foil, not yet available on plastic foil)	Not yet demonstrated	4–8% * (available on plastic and metal foils	Not yet demonstrated
Stability under light	Material stable	Material stable	Degrades	Stability not proven

5. CONCLUSION

In this paper the current commercial and potential future of TF PV technologies is analyzed, with a special focus on their related prospective and challenging manufacturing issues. Commercial c-Si cells have efficiencies in the range of 15–22%, so any TF PV still have to compete with this technology. Also TF PV will also have to make use of its potential advantages, such as reduced use of material, larger production units, and integrated cell/module fabrication, and particularly the application of thin, flexible and light-weight substrates. The use of flexible substrates offers new possibilities for the application of solar cells, for example for building integration. In addition, flexible cells are very thin and lightweight, which makes them also more flexible in use than rigid cells. One of the most important advantage of flexible solar cells, is the potential to reduce production costs. Development of photovoltaic thin film modules ensures a satisfying flexibility of the surface, and the possibility to design appropriate shapes. The future for efficient, lightweight, flexible and cost-effective thin film modules looks very promising.

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Acknowledgment: This paper is a result of two projects: (1) **TR33015**, Investigation and development of Serbian zero-net energy house, supported by the Ministry of Science and Technological Development of Republic of Serbia and (2) **COST action TU1205-BISTS,** Building Integration of Solar Thermal Systems, supported by EU. The authors thank to the all institutions for their financial support.

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