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Solar Energy Technologies Program

National Solar Technology Roadmap:

CdTe PV

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National Solar Technology Roadmap: CdTe PV

Scope

This roadmap addresses thin-film cadmium telluride (CdTe) photovoltaics (PV) technology.

Technology development stage: Commercial.

Target applications: One current commercial thin-film CdTe manufacturing company has introduced thin-film CdTe products at >9% efficiency, with attractive pricing and availability for commercial rooftop and large-scale utility, ground-mounted systems. This is likely to remain the dominant market through 2012. This company and other emerging companies are expected to address other opportunities such as residential rooftop applications. In the near term, all forms are expected to be rigid products fabricated on low-cost, soda-lime glass substrates.

Background

Thin-film photovoltaic technologies for flat-plate modules are attractive because they consume much lower amounts of expensive semiconductors and are more amenable to much higher levels of production automation than wafered silicon. First Solar, Inc., reports production costs of $1.21 per watt (including substantial costs for take-back and warranties), corresponding to about $\$100/m^2$. Comparable values for wafer-silicon modules are in the range of $3.00–3.25 per watt and $\$250–400/m^2$. This comparison is even more remarkable when calibrated by the fact that these economies were achieved with about one-tenth the production volume. As manufacturing volumes increases, the cost advantage can expand even more significantly.

Roadmap Overview

The superstrate geometry provides some cost advantage relative to substrate designs. Several cost analyses place the area-related costs of the balance of the thin-film CdTe PV module for an entry-level plant of 25 MW annual capacity at about $\$50/m^2$. These costs include the glass, encapsulation, assembly, and operating expenses. The cost of the materials used in the cell and depreciation of manufacturing equipment will add another $\$20/m^2$ and $\$10/m^2$, respectively, while labor and utilities add another $\$10/m^2$. The remaining amount is the take-back and warranty costs. With a 90% production yield, this corresponds to about $\$100/m^2$. As the deposition process matures, yields should rise to better than 95% and efficiency to 13% by 2015 to deliver product at a cost of $ 0.70/W.

Clearly, the dominant opportunity for the thin-film CdTe industry is to raise power module conversion efficiency. This provides the best opportunity for increasing the lead that thin-film CdTe has in large PV systems, and then allowing CdTe to enter the residential rooftop markets. Open-circuit voltage (V_{oc}) in CdTe solar cells is 20% below that of III-V solar cells with similar bandgaps. This shortfall has many contributing causes, starting with a lack of clear understanding of precisely how the device works, the inability to model predicted device performance, the lack of control of carrier concentrations in the absorber layer, no well-defined and robust back contacts, the need for a better understanding of the conditions of $CdCl_2$ treatments, and a dearth of research in the family of pseudo-binary alloys that could be tapped to add latitude to device design and development. Enhanced V_{oc} with some improvements from short-circuit current density (J_{sc}) in the thin-film CdTe devices will most likely be the pathway to higher cell and module efficiency. Also, factors limiting fill factor (FF) should be analyzed and evaluated to improve solar cell and module performance.

The deposition processes used for CdTe solar cells have the distinct advantage of rapidly transferring the material needed to compose the cells. Unfortunately, these strengths also limit the ability to introduce and control constituents to modify the electro-optical properties of the materials. It is possible that some new absorber-layer process will be needed to implement the growing body of knowledge pointing to conversion efficiency improvements.

After an early shakeout of disappointing products, the reliability of the current glass-glass encapsulated thin-film CdTe modules appears to be comparable to conventional Si-based technology. As new technologies are added to boost efficiency, tests are needed to ensure that reliability is not sacrificed. Continued testing, identification of degradation mechanisms, and development of reliable accelerated tests are valuable for the continued market acceptance of CdTe. Environmental, safety, and health (ES&H) continues to be an important aspect of the technology development and should be constantly updated and studied. Efforts should be made to increase public awareness of the perceived Cd issue.

Metrics

Parameter	Present Status (2007)	Future Goal (2015)
Commercial module efficiency	>9%	13%
Champion device efficiency	16.5%	18%–20%
Module cost ($/W)	1.21	0.70
$/watt installed system cost	$4–5/W	$2/W
Levelized cost of electricity (LCOE)	18–22 ¢/kWh	7–8 ¢/kWh
Overall process yield	90%	95%
Identify relevant degradation mechanisms and develop appropriate accelerated lifetime tests (ALTs) for device and mini-modules metric	1.2% per year	0.75% per year

Identified Needs

Need	Significance	University	Nat'l Lab			Industry		
			NREL	Sandia	Other	TPP	Incubator	Other
Improve Device Efficiency • Understand and demonstrate control over key parameters that presently limit device efficiency and reliability. • Address fundamental understanding of defects, grain boundaries, and new materials. • Develop methods and metrics to address process potential. • Reduce absorber-layer thickness to 0.7 µm.	Sets technology benchmark and potential Develops firm foundations and test logical pathways toward improved module efficiency and reliability Less material needed in manufacturing	X	X			X	X	
Reduce Module and Device Efficiency Gap • Develop and test production-consistent processes and materials to improve module efficiency. • Superstrates (glass, transparent conducting oxide, buffer, antireflective coating)	Increases watt/m^2 Increases module efficiency from >9% to 13%	X	X			X	X	
Reduce Module Cost • Develop and test production-consistent processes and materials to reduce module cost. • Advance encapsulation • In-line process control	Reduces $\$/m^2$ costs Reduces LCOE to 2015 targets Improves yield	X	X			X	X	
Improve Reliability • Test completed devices to identify degradation mechanisms and establish specific ALT's.	Meets 0.75% module degradation target for 2015 Reduces reliability risk for new technologies	X	X			X	X	
Alternative Processes • Develop and test promising materials, device designs, and process steps that are not a part of present module production.	Expands market potential beyond current products New alloys/materials may significantly improve module performance over present-generation	X	X					

	technology							
ES&H	Safety at work place and environment, increase public awareness					x	x	x