

## Manufacturing challenges facing CdTe and CIGS Markus Beck

NSF Workshop – Catalyzing Innovation in PV Manufacturing, May 6-7, 2010, Golden, CO





## **Our Mission**

# To create enduring value by enabling a world powered by clean, affordable solar electricity.



© Copyright 2010, First Solar, Inc.



## Outline



- Brief market overview
- Current status
- Opportunities in TF PV manufacturing
  - Technological Improvements
  - Labor force characteristics
- Conclusions



## **Global Cumulative Installed Capacity of PV**



#### **Selected IEA countries**



Source: "Trends in photovoltaic applications". IEA PVPS. September 2009.



## Long-term View of the Solar PV Industry



#### A complex marketplace









#### 2008 Technology mix





Source: "Clean Technology Primer", Jeffries Research, March 2

## "Copy Smart" Production Capacity Growth



© Copyright 2010, First Solar, Inc.

## Products & Performance



## Proven Record of Increasing Module Conversion Efficiencies





## **Conversion Efficiency Potential**





© Copyright 2010, First Solar, Inc.

## High-Confidence Roadmap to >12.5%



- 12.5% requires closing the gap between CdTe product and lab record performance
  - NREL "hero" CdTe Cell is 16.5%
  - Best module is 80% of "hero" cell
  - Production average is 90% of best module
  - 16.5% hero-cell corresponds to ~13% production

#### • Pathway is mostly improved light transmission into existing device

- NREL Jsc demonstrates upside of 1.3% absolute
- Many opportunities for improvements in current
- Technology challenge is to make these improvements manufacturable
  - Reducing thickness of CdS
  - Proprietary improvements to TCO
  - Proprietary improvements to glass transmission

#### • FSLR Leveraging current leadership for sustained competitive differentiation



## 1,000 Pathways to >16% and Beyond



- Multiple approaches to driving performance
- Renewed excitement in the technical field
- Fundamental device physics and materials science
- TF-CdTe still has enormous headroom

**Optical Engineering** 

**Contact Engineering** 

Grain-boundary Engineering

Band-Engineering

**Dopant Engineering** 



## **Opportunities in TF PV Manufacturing**



- 1. Technological Improvements
- 2. Labor Force Characteristics

### Key Criteria

- i. R&D needs to be compatible to HVM i.e. takt times, CapEx, OpEx, environmental impact (toxicity, CO<sub>2</sub> footprint)
- ii. No need to fix what isn't broken/reinvent the wheel







© Copyright 2010, First Solar, Inc.



## **Technological Improvements**



- Increased fundamental understanding of semiconductor system and interfaces
- Novel in-situ, on-line, and off-line metrology
  - compositional control
  - key opto-electronic properties
  - module scale solar simulators and QE
- Equipment engineering
  - P1 through P3 laser scribing for CIGS
  - thermal processing
- Reliability
  - fundamental understanding of device & material degradation mechanisms
  - new packaging materials
  - energy rating standards, methods and algorithms
  - accelerated stress test protocols representative of multiple climatic regions





- Novel materials for encapsulation and device stack
  - ohmic back contact
  - TCO
- Recycling methods for CIGS
- BOS optimization
  - inverters optimized for TF PV
  - NEC revision enabling > 600V system voltage



## Labor Force Characteristics



- Solid state and theoretical physicists trained in polycrystalline compound semiconductor systems
- Analytical and physical chemists as well as process engineers understanding TF deposition technologies
- Materials Scientists skilled in materials characterization and failure analysis
- Electrical engineers and physicists trained in device characterization and instrumentation
- Mechanical engineers with focus on large area, HVM deposition and automation equipment
- Computer scientists
- Sound understanding of basic principles in physics, chemistry, and engineering



## Conclusions



- PV historically too expensive; conventional electricity rising in price; PV reducing cost
- Grid parity leading to inflection in price elastic demand; exponential demand leading to continued growth of PV
- CdTe clear leader in LCOE from PV; c-Si will continue to play a major role; CIGS, if commercial scale will prove viable, can emerge as competitive on cost to c-Si
- Better understanding of fundamentals for CdTe and CIGS required
- Technology/engineering challenge is to make R&D improvements manufacturable
- Need for a wide array of experts mechanical as well as electrical engineering, physics, chemistry, materials science, and computer science

## Career Opportunities at First Solar



#### http://www.firstsolar.com/en/careers.php

G First Solar FSLR - thin film solar modules																											
< ►	] [+	- 🙆	http://t	be.taleo	.net/NA	3/ats/car	eers/jo	bSearch	.jsp?c	org=FIF	RSTSOL/	R&cws	1					¢	Q	Googl	e						
m III	Ар	ople	Yahoo!	Googl	e Maps	Wikiped	ia Ne	ws (465)	)▼ P	opular	▼ One	Block O	ff the	Grid													
			First S	Solar,	Clean. Affordabi Sustaina	le. ble.									Lar	nguage	): <b>W</b>	-		Log ir	n   Ci	ontact		1			
	CORPORATE MODULES SYSTEMS INVESTORS PRESS CENTER													(	CONTA	ст											
			Cur	rent Job	Opening	js ———																					
		Search Openings Search our positions by selecting a location below. To see all openings sorted by location select "-Any-". Each job description incl applying and submitting your resume to us online. This is the fastest and most reliable way to be considered for any of our positio												on inclu osition	ides a s.	ı link for											
			To fill out a general application form <u>click here</u>																								
					L	ocation:	– Any – Amster Berlin Blythe.	dam CA			0																
				Descr	iption Ke	eywords:																					
			Sea	arch	Updated	d Within:	Any ti	me 💲																			
Previous Applicants If you have previously applied to a position on our website, input your e-mail address and password below to login.																											
					Pa	Email:								]													
			Log	jin																							
			If yo	u do not	rememb	oer your pa	assword	d <u>click he</u>	re.																		
																						powered I Tale	<sup>by</sup>				
				lication	Details a	ind Job Be	enefits-																				
		Interested and qualified candidates can submit a resume for any open position or add it to our general database. Enter your credentials into our database today for immediate or future consideration. First Solar is an equal opportunity employer.											nto our					4 4									



## First Solar Locations



Global Headquarters Tempe, Arizona, USA

Manufacturing

Frankfurt (Oder), Germany Kulim, Malaysia Perrysburg, Ohio, USA

#### Europe

Amsterdam, Netherlands Berlin, Germany Brussels, Belgium Madrid, Spain Mainz, Germany Paris, France

#### North America

Bridgewater, New Jersey, USA Oakland, California, USA New York, New York, USA Sarnia, Ontario, Canada

Asia/Pacific

Sydney, Australia





