

Catalyzing Innovation in PV Manufacturing



An NSF Workshop

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Highlights and Summary of Facilitated Discussion

Session I: Inorganic Photovoltaics

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[Research Challenges for CIGS and CdTe](#)

Critical R & D Issues in CIGS (in no particular order)

- Moisture resistance- TCO sensitivity
- Efficiency improvements, particularly at the module level
- Fundamental understanding of relationship between film and device properties
- Decreased sensitivity to In cost

Critical R & D Issues in CdTe

- Key Issue - Close Efficiency Gap. Strategy: Improved Minority Carrier Lifetime through increased Carrier Density
- Secondary Issue: Better Understanding of the Role of Grain Boundaries
- Secondary Issue: Improved Back Contact

Dr. Markus Beck, First Solar

[Manufacturing Challenges for CIGS and CdTe](#)

Overview of PV Marketplace

- c-Silicon: Dominates market (~85%)
- CdTe: Fastest growing segment: 8% (2008) to 15% (2009)
- a-Si: 5% in 2008, but possibly losing ground
- CIGS: Yet to make break through, but could potentially compete with c-Si

Strategies to Improve CdTe Module efficiency beyond current level of 11.1%

- Continued Improvements in Manufacturing/Integration: 12.5%
- Improved Optical Transmission (glass, front contact): 13.5%, 2012
- Research – Issues Ingrid touched on: 15.3%, 2014
- Practical Potential: 18%

Manufacturing Needs

- Fundamental Understanding of Semiconductor Systems & Interfaces
- Improved Metrology: *in situ*, online, *ex situ*
- Equipment Engineering: Laser Scribing
- Reliability: Understanding degradation, new packaging, improved testing
- BOS Optimization, Inverters designed for TF PV, Higher Voltage

Dr. Chandan Das, University of Delaware

Critical Issues in Thin Film Si

Current Status

- 5% of market (2008) and cost-competitive with CdTe
- Main goals include the need for higher efficiency and improved stability
- Solution appears to be multijunction devices and the use of nc-Si, respectively
- Downside of nc-Si: Low absorption which requires thicker films

Manufacturing Issues

- VHF increases rate, but at expense of large area uniformity
- New plasma sources needed to address above: linear sources appear promising
- Better understanding of the role of ion bombardment, surface passivation
- Optical trapping/plasmonics, etc. important to maximize photon capture, particularly in nc material

Dr. Juanita Kurtin, Spectrawatt

Advanced Photon Management

Overview

- Improved texturization, rear reflectors, AR coatings are being pursued
- Downshifting: nanoparticles absorb blue, luminescence in red
- Downconversion: 1 photon = 2 e⁻, need 2X bandgap. More challenging.
- Waveguiding, luminescent lateral concentrators
- All techniques are heavily materials dependent
- Opportunity: Multi-junction performance with single junction

Dr. Andrew Gabor, 1366 Technologies

In Defense of Silicon - A Manufacturer's Manifesto

Current Status

- 84% of market (2009), possibly greater in 2010
- High efficiencies, proven stability, American manufacturing base
- No material limits – Si most abundant semiconductor
- Much feed stock produced in US, need to capture more of the downstream market

Manufacturing Issues/Opportunities

- Thinner wafers: Thickness reduction, Kerfless wafers, Handling
- Improve architectures: selective emitters, surface passivation
- Improved complementary materials (pastes, powders, thermal processing)
- Replace Ag with Cu - numerous issues involved

Session I: Inorganic Photovoltaics – Panel Discussion

Comment #1: The Efficiency vs. Production Costs scheme presented by Green (1st, 2nd, 3rd generation) is outdated. Neither 1st (c-Si) nor 2nd (CdTe) generation is stagnant or bound. Both have moved relatively rapidly toward or into what was classically defined as 3rd generation territory (< \$1/W). Moreover further reductions can be expected with improvements in production costs for Si (thinner wafers) and higher efficiency for CdTe Modules.

Comment #2: Landscape has changed dramatically In 10 years: PV now compatible with peak power costs (i.e. CA). Barrier for entry for new companies/attaining financing is much greater today than 10 years ago. PV plants do not look like fabs, particularly for thin film technologies.

Comment #3: Will CIGS make it? Heavy investment, many companies, but limited product to date. ~10 strategies to manufacturing, which may be part of the problem. CdTe is deposited by vapor transport controlled by diffusion (close space sublimation) or convection (First solar). Simplicity an advantage for manufacturing. Is the CIGS substrate configuration an Achilles heel?

Comment #4: Manufacturing Base: PV is a commodity product with negligible brand identity. As a commodity the market will be driven by relatively low margins and high volumes. General consensus was that the issue of keeping manufacturing in the US was a business one (i.e. question of tax structure, incentives), and that R&D was going to do have little impact on this issue. Best driver to keep manufacturing in the US is to further develop the US PV market, as shipping costs can be substantial.

Comment #5: Future of a-Si?: Was argued that issues related to Staebler-Wronski degradation are now better understood and can be mitigated through chemical (H atom) annealing strategies. Triple junction should deliver 15% efficiency. Appears that photon management will be critical to this system. These issues need to be addressed for a-Si to keep up with CdTe. Advantages in low temperature, flexible substrate processing may be a path for differentiation.

Comment #5: Don't bet against the rock!: c-Si dominates the market and still has substantial headroom. Opportunities lie in the value chain (wafer preparation, handling, contacts, etc.). Most abundant material. Limited toxicity issues.



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