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Rapid Single Cell Manufacturing of Thin-Film CIGS

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The XsunX Approach

- **Combine:**
  - **CIGS Deposition Technology , and**
    - ✓ Best Thin Film Performance
  - **Rapid Single Substrate Processing using Hard Drive (HD) Equipment**
    - ✓ Established a Joint Development Agreement with the Industrial Leader for HD Equipment → ***Intevac***
      - o Co-Located Technical Team, Deposition Systems, and Metrology Equipment
    - ✓ Production Volume Achieved Via Speed Rather Than Large Area Processing

- **Final Goal → High Volume Production of CIGS Cells that have a Similar Efficiency as Poly x-Si Produced at a Lower Cost**
  - **Module Uses Same Glass, Encapsulant (EVA, PVB), Dual Rated j-Box, and Frame as Current x-Si Modules → The Difference is a Lower Cost Cell**

Result : Equal Performance at a Lower Cost → Best $/W

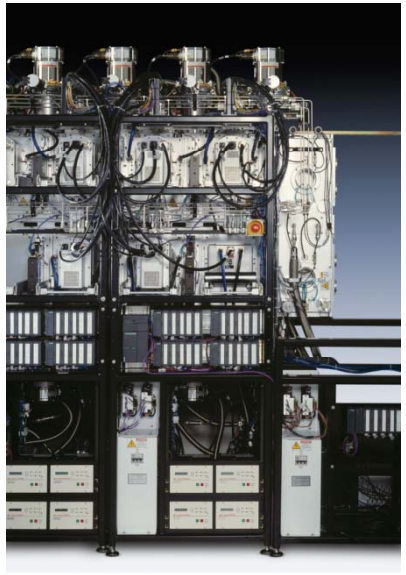
XsunX Combines Mature HDD Systems with CIGS Expertise

	Back Contact	Absorber	Buffer	Front Contact
XsunX Process Flow	Sputter: Mo	Evaporation: Cu, In, Ga, Se	Wet Bath: CdS+	Sputter: ZnO / ITO
				
	200 Lean™ (8)	Lean Vapor Deposition	Third Party	200 Lean™ (8)

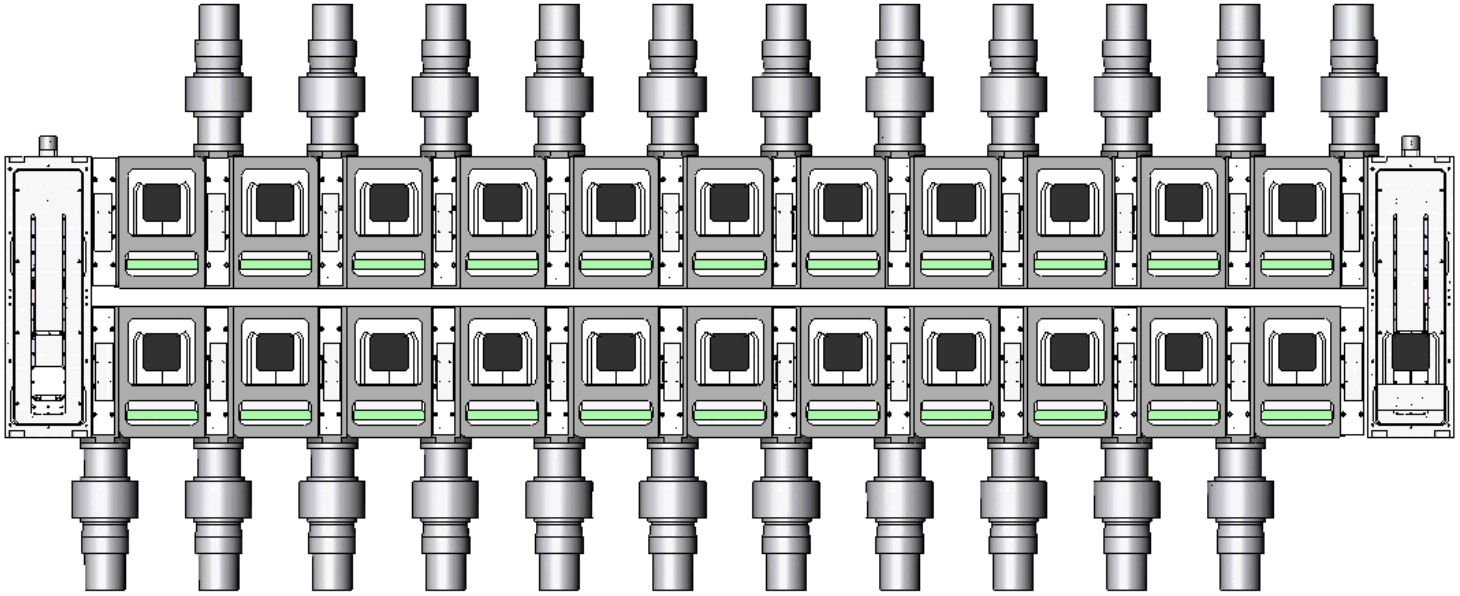
- **Better Manufacturing Technology**
  - True Single Substrate Processing
  - State-of-the-Art Control System

- **Process Flexibility**
  - Easily Add Process Stations
  - Factory Efficient Small Footprint

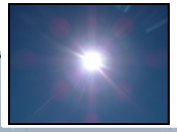
- **Low Cost of Ownership**
  - High Throughput
  - High Utilization



HD Single Cell Processing Video

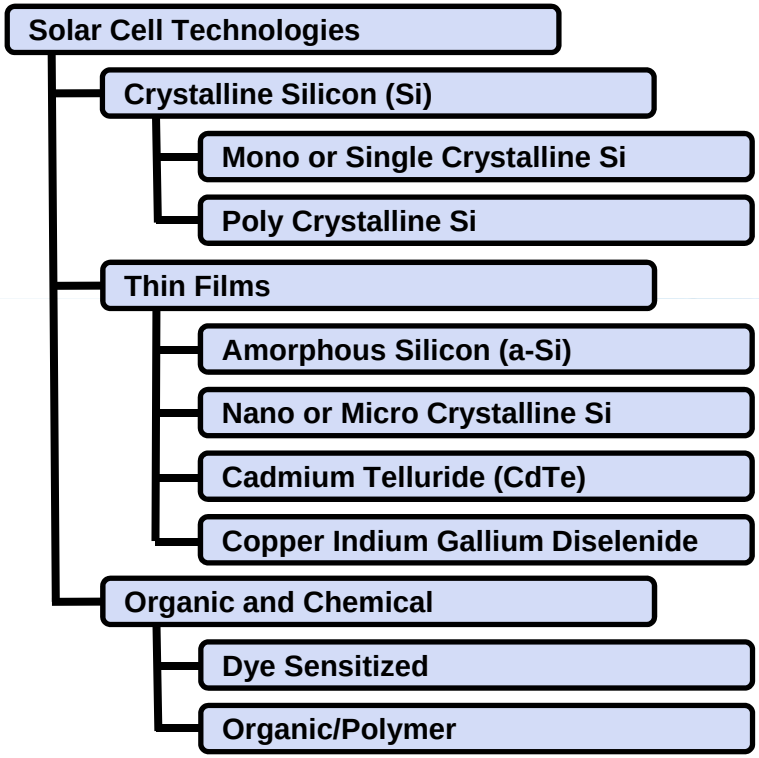


- High Throughput, Individual Cell Processing
- Tight Process Control for Uniform Morphology
- High Capital Equipment Utilization




Comparison of Solar Technologies

❖ Family of Solar Cells for Terrestrial Applications



Module Efficiency*	Record Lab Efficiency**	Efficiency Difference
15 – 18%	25%	39%
13 – 16%	20%	25%
5 – 8%	9.5%	10%
8 – 9%	10.1%	12%
8 – 10%	16.7%	67%
8 – 10%	19.9%	100%
N/A	10.4	N/A
N/A	5.1	N/A

CIGS Provides the Best Opportunity to Improve Module Efficiency (Lab vs. Production Headroom) and the Best Overall Thin Film Efficiency

*** Acquired from Published Data/Sell Sheets**

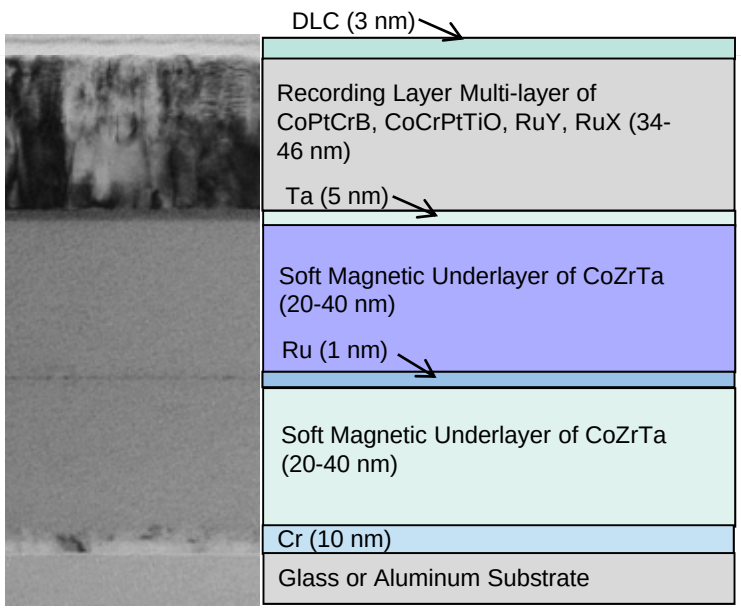
**** Green MA, Emery K, Hishikawa Y, and Warta W. Solar Cell Efficiency Tables (Version 33). *Progress in Photovoltaics: Research and Applications* 2008; 17: 85-94.**

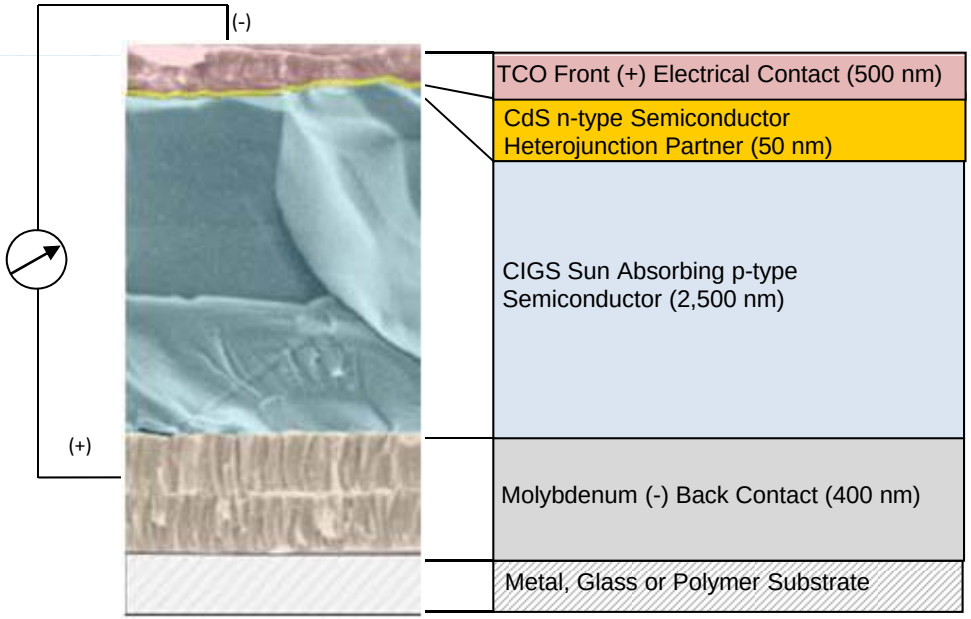
Why CIGS? Demonstrated Attributes

- ***High Efficiency*** → Highest of the Thin Films and Equivalent to Poly Crystalline Si (Laboratory Scale)
- ***Tolerant Chemistry*** → Good Performance Achieved with a Wide Range of Cu/(In+Ga) and Ga/(In +Ga) Composition Ratios
- ***Thin-Film Nature*** → CIGS absorber is ~2.5 um compared to ~170 to 250 um for Si
  - CIGS Less Susceptible to Commodity Pricing of Raw Materials or to Material Shortages
- ***Stability*** → CIGS Does ***NOT*** Exhibit Light-Induced Instability Found with Some Thin-Film Solar Devices
- ***Manufacturing Technology Advancements*** → CIGS Benefits from the Manufacturing Technology and Equipment Developed in other Thin Film Arenas
  - Hard Disk Drive, Flat Panel Display, Architectural Plate Glass

Hard Disk vs. CIGS Structure

- **HD Structure is a Similar Multi-Layer Stack as CIGS**
  - **The CIGS Structure is About 20X Thicker than an HD Structure**
    - ✓ HD Equipment Provides Precise Control of Very Thin Layers
    - ✓ Question: ***CAN*** HD Equipment Provide High Volume Production Throughput of the Much Thicker CIGS Layers

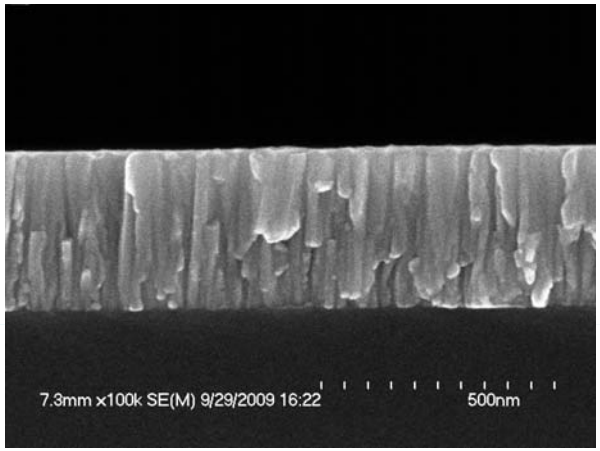




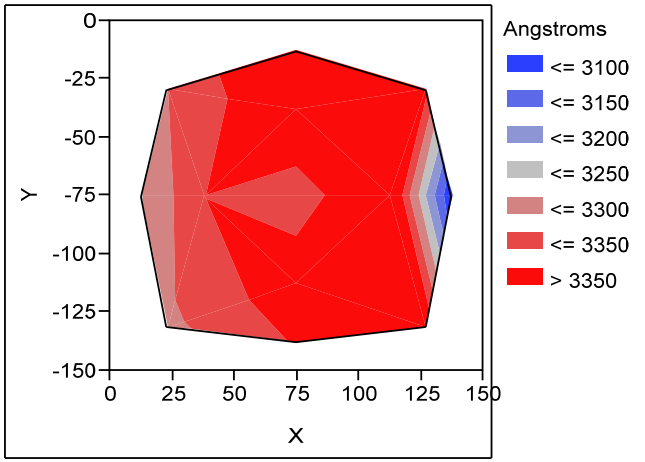
  - ***Preliminary Results → Yes***

Current Results – Molybdenum Back Contact

- ***Demonstrated Back Contact Sputtering at High Throughput Rates Similar to HD***



- **Deposited In Sequential Fashion in 4 Separate Stations**
  - **4 sec Dwell Time Per Station**
  - **Results in ~17,000 Cells/Day**
    - ✓ ~35kW/Day
  - **Rate 35 nm/s-kW**
  - **Uniformity ~+/- 3%**
  - **Demonstrated >10% Efficiency CIGS Cells on High Rate Sputtered Mo**



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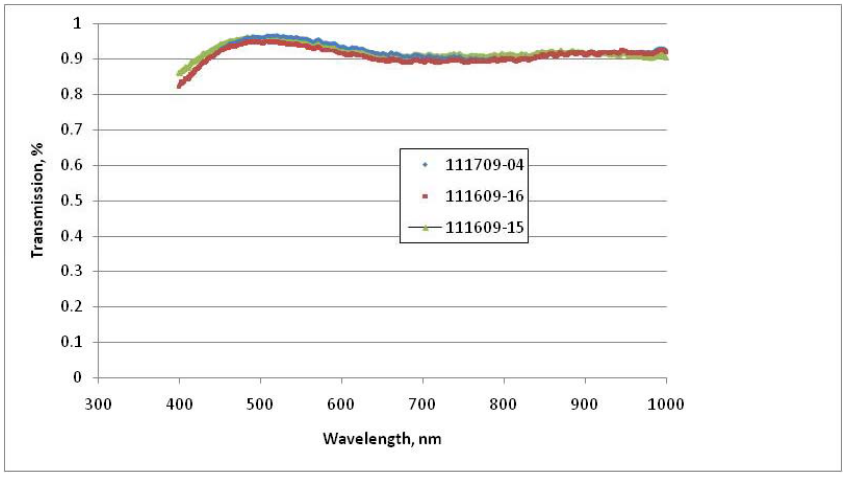
Current Results – TCO Front Contact

- ***Demonstrated TCO Sputtering at High Throughput Rates Similar to HD***
  - **Transmission (500-1000nm) > 90%**
  - **Resistance < 10 - 15 ohms/square**
  - **Rate up to 50 Ang/kW-sec**
  - **Dwell Time of 2.5 sec/station (4 Stations)**
  - **Crystalline Structure At Room Temperature**



Conclusions

- **Technology Development Progressing According to Schedule**
- **Initial Results Demonstrated that the HDD Equipment Can be Adapted for High Throughput Production of the CIGS Layers**
  - **Tools Are Capable of Meeting The ~13 MW/year Objective**
    - ✓ **Substrate Every 4-5 Seconds**
- **Molybdenum and Transparent Conductive Oxide Nearly Complete and Require Minor Optimization**
- **Metal Source Preliminary Evaporation Results Are Encouraging**

XsunX Approach → Low Risk, Speed to Market, Economically Viable

- **Small Area Wafers→** Similar to Techniques Successfully Employed in Laboratories
  - Smaller areas, about 5” squares, provide controlled deposition zones and improve solar cell performance by statistically reducing process variation and defects.
- **Technological Experience →** XsunX Staff has Previously Developed CIGS Evaporation Technology and Front and Back Contact Sputtering Used in Commercial Production
- **Not New Science →** Better Engineering, Processing Methods, and Use of Well Known Science
- **HD Operation Know-How →** High Factory Throughput and Yield, Low Down Time and Mean Time Between Failure, Low Capital Costs

Result: Revolutionizing the Thin Film Solar Cell Manufacturing Industry

Thank You!!