Enabling Utility Scale PV: Challenges for Glass Makers

Romain Beau de Lomenie
Director, Module Materials Management
Thin Film Products, Solar Business Group
Applied Materials

International Workshop on Glass for Harvesting, Storage & Efficient Usage of Solar Energy
Nov 16th-18th 2008

think it. apply it.™

APPLIED MATERIALS®

External Use

Safe Harbor Statement

This presentation contains forward-looking statements, including those relating to Applied Materials' growth opportunities, product capabilities. acquired businesses, cost-per-watt-reduction strategy, efficiency roadmap, solar contracts, and financial goals. These statements are subject to known and unknown risks and uncertainties that could cause actual results to differ materially from those expressed or implied by such statements, including but not limited to: demand for solar products, which is subject to many factors, including global economic and market conditions, government policies and incentives relating to renewable energy, technological innovations, the cost of competing sources of energy, and evolving industry standards; the performance of acquired businesses; Applied's ability to (i) successfully develop, deliver and support its broad range of products and expand its markets and develop new markets, (ii) effectively manage its resources and production capability, (iv) accurately predict the characteristics of, and capitalize on opportunities in, emerging markets, and (v) attract and retain key employees; and other risks described in Applied's SEC filings. All forward-looking statements are based on management's estimates, projections and assumptions as of February 20, 2008, and Applied undertakes no obligation to update any such statements.

External Use

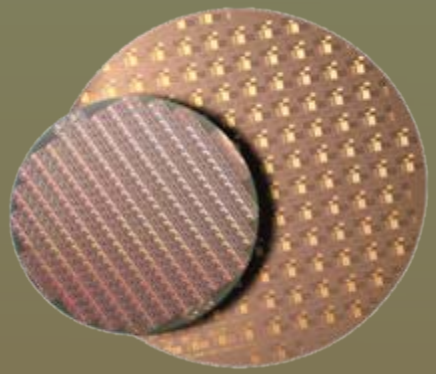
Applied Materials' Overview

- **Founded**
  - Oct 1967 in Mountain View, California
- **Revenue (Fiscal 2007)**
  - $9.73 Billion
- **Worldwide Employees**
  - ~ 14,000
- **Worldwide Locations**
  - 18 countries, over 100 locations
  - Owned manufacturing in Germany, Israel, Switzerland, Taiwan, US
  - Development in North America, Asia, Europe and Israel
- **RD&E Investment (FY'03 – FY'07)**
  - $5.1 Billion
- **Service**
  - ~ 3,500 field engineers
- **Installed Base**
  - > 19,000 Silicon IC systems
  - > 600 Flat Panel Display systems
  - > 500 Glass and Web Coating Systems

External Use

Extending Cost Reduction Focus to Solar

FIRST



Cost per transistor

1974	2004
4 trillion	1,400,000 trillion
10 cents	5 nano-dollars

20,000,000x Cost Reduction

Source: SIA, IC Knowledge LLC

THEN

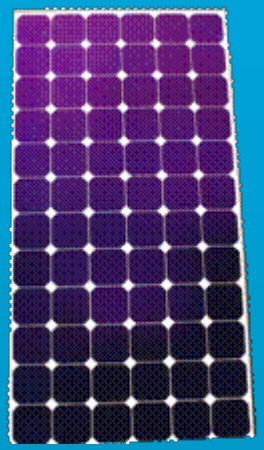
Cost per area

1995	2005
0.3 million/m^2	25 million /m^2
\$30,000/m^2	\$1,500/m^2

20x Cost Reduction

Source: Display Search, Nikkei BP, Applied Materials

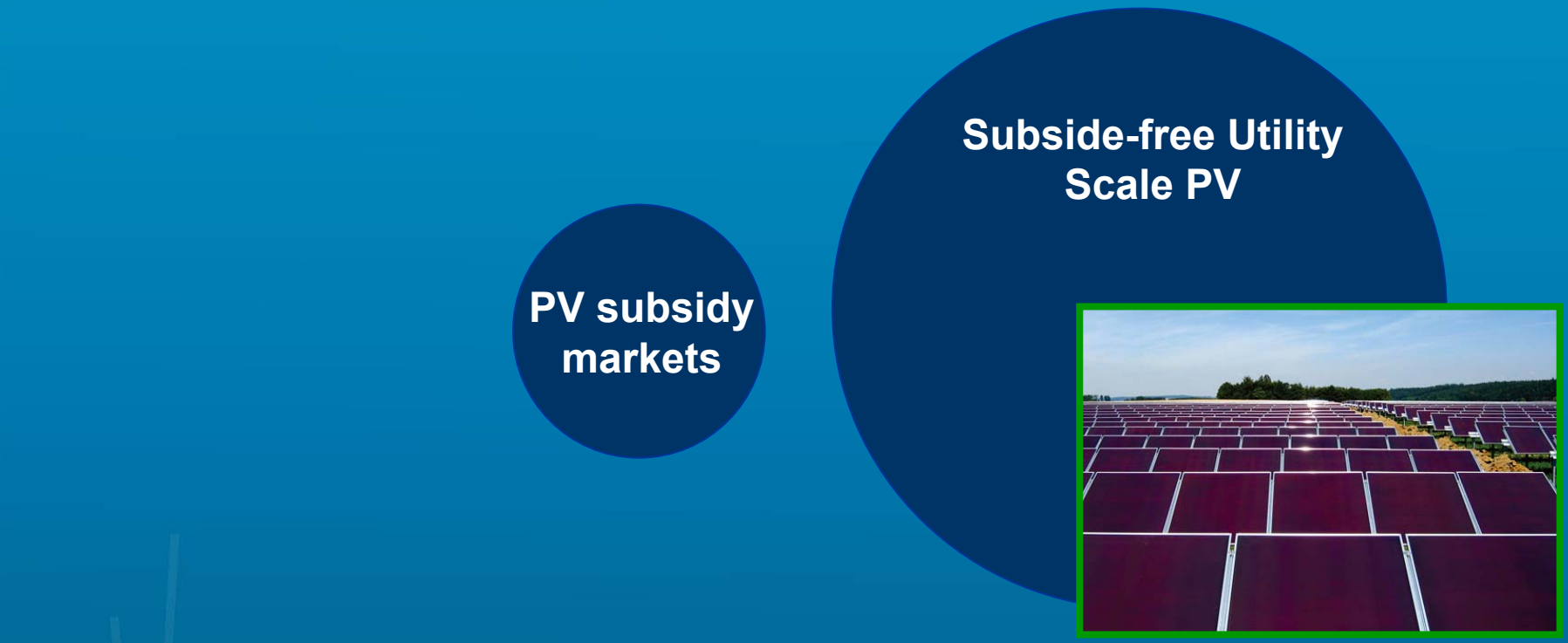
NOW



Cost per watt

External Use

The Utility Scale PV Challenge



BOS price	~$2/Wp	$1.5-$1/Wp	
Module price	$2-$3/Wp	~$1.5/Wp	40-50% reduction
Installation price	*~$4 - $5/Wp*	*$2.5 - $3/Wp*	

External Use

Tackling the utility scale challenge: SunFab™

- Complete production line of world largest 5.7m2 largest PV modules
- Thin film silicon glass-PVB-glass module design
- > 65MW* single line capacity w/ multi-line Cluster designs
- 2010 goals: < $1.00/Wp module production cost @ >10% efficiency
- > 20% reduction in module BOS cost by design

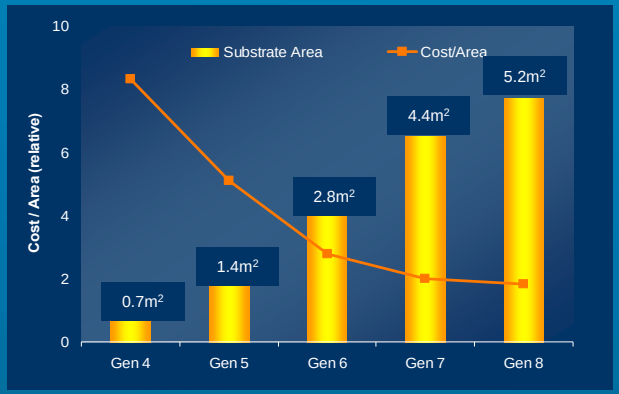
** Tandem Junction*

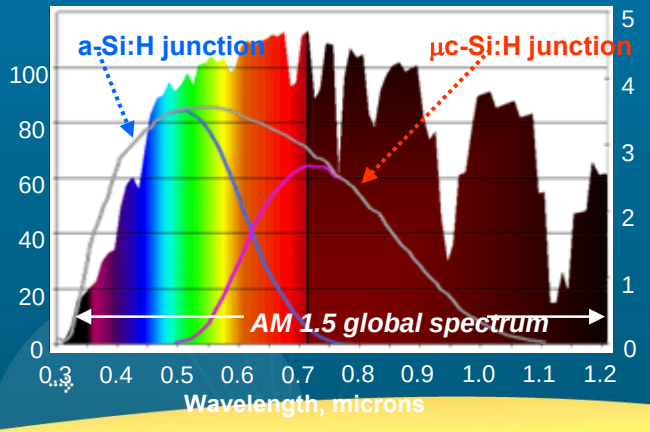
External Use

Cost Reduction Strategy

$$\$ \text{ Production / Watt} = \frac{\text{Cost / m}^2}{\text{Watt / m}^2}$$

- Reduce cost / m^2
  - Manufacturing scale
  - **Materials cost reduction**
- Increase watt / m^2
  - **Si absorbing layers engineering**
  - **BC layers engineering**
  - **Front glass TCO**

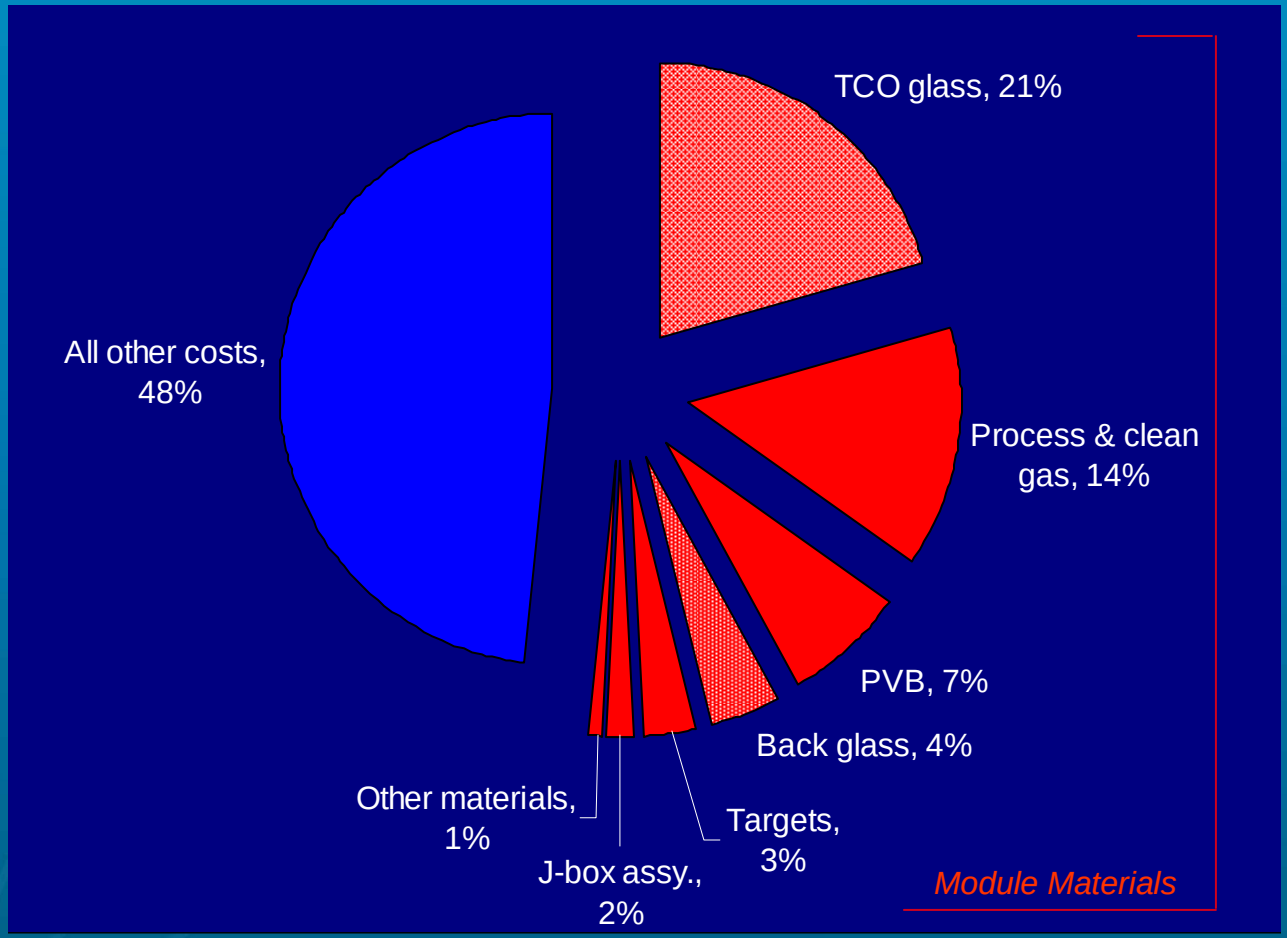




External Use

APPLIED MATERIALS

Glass impact to module production cost today



Glass is highest cost element of thin film Si PV (> 25%)

Tandem Junction Module

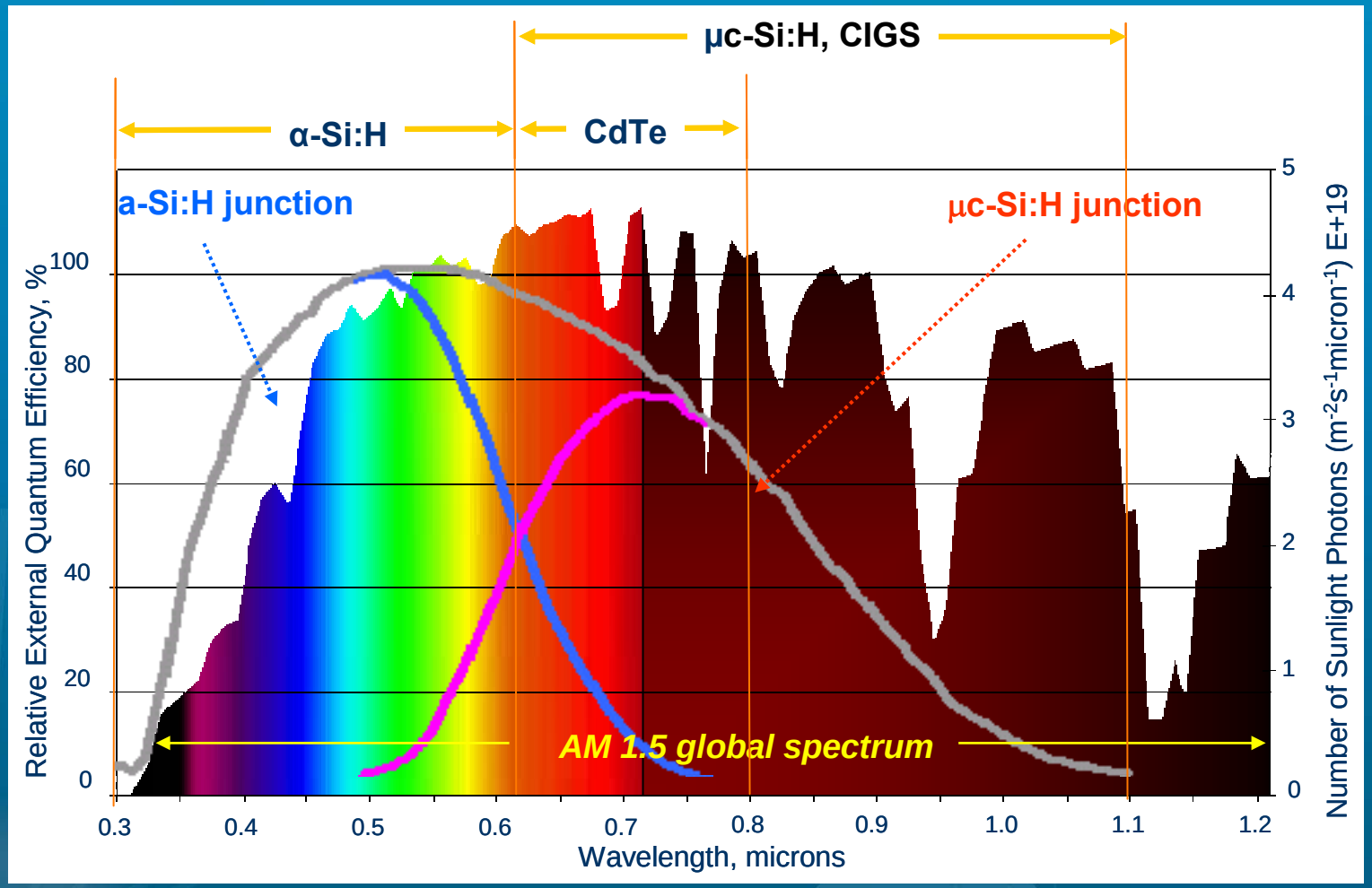
External Use

Challenges for glass makers: enabling utility scale PV with thin film Si

Efficiency improvement	▪ High transmission ▪ Light scattering and trapping ▪ High conductivity TCO layer
Reliability	▪ Barrier layer quality (sodium migration, de-lamination)
Enable < $1/Wp	▪ Drive $/sqm cost down while driving efficiency up
Production Capacity	▪ Keep up with rapid demand growth

External Use

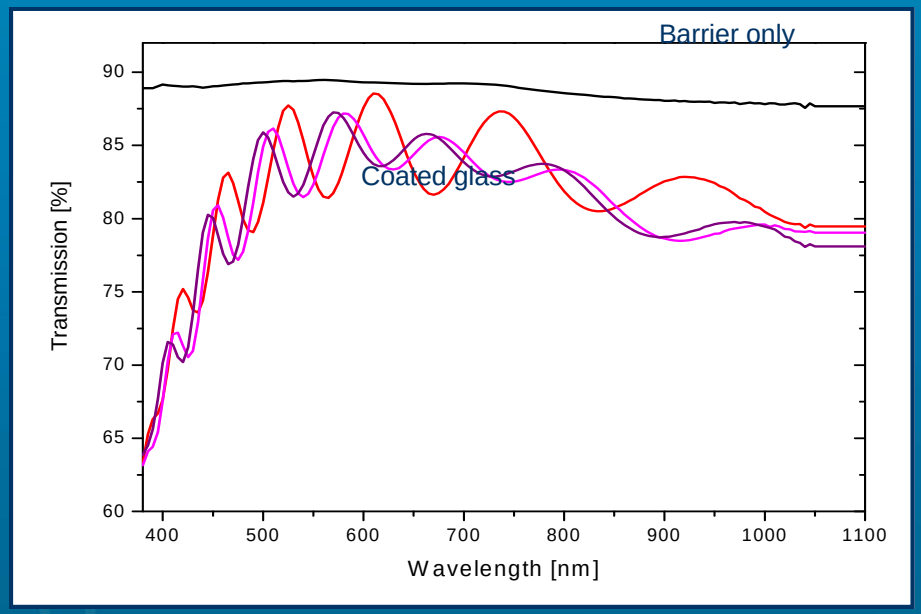
Transmission in Blue & Red



External Use

TCO glass desired transmission profile

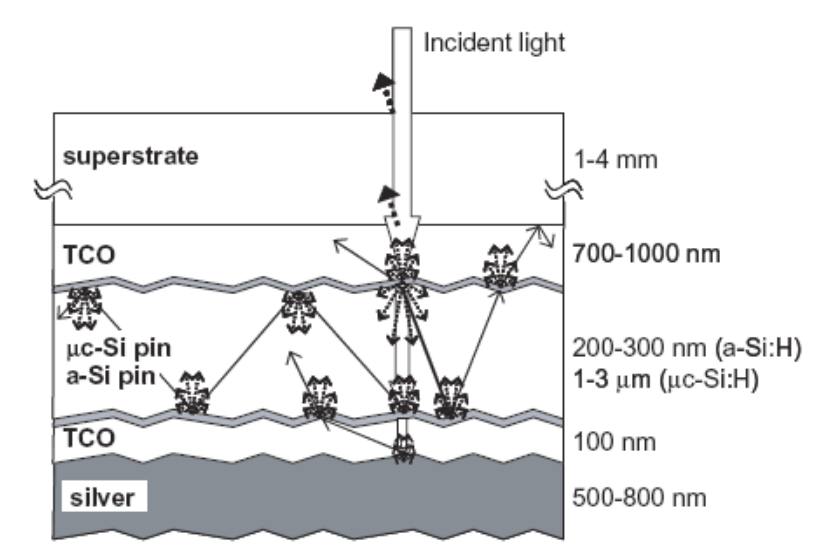
> 80% transmission over desired wavelength range

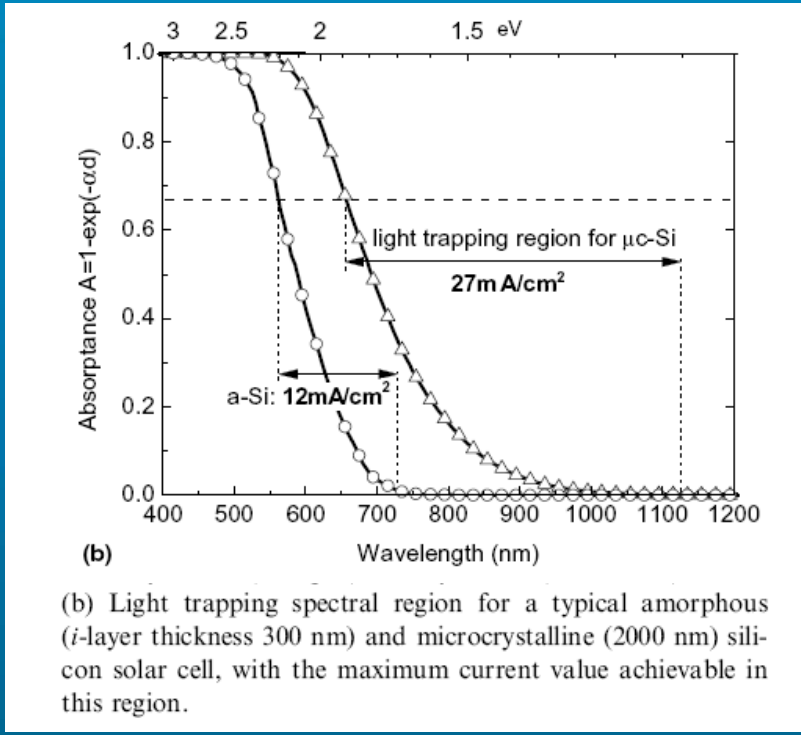


- Thinner glass
  - Trade-off: mechanical strength
- Low carrier concentration
  - Trade-off: keep resitivity low at < 10 ohm/sqm
- Low iron glass
  - Trade-off: cost
- Low reflectance with ARC
  - Trade-off: cost

External Use

Un-leashing thin film Si potential: Light scattering and trapping





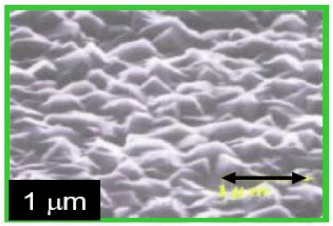
(b) Light trapping spectral region for a typical amorphous (*i*-layer thickness 300 nm) and microcrystalline (2000 nm) silicon solar cell, with the maximum current value achievable in this region.

Light trapping is critical to un-leash bottom cell current

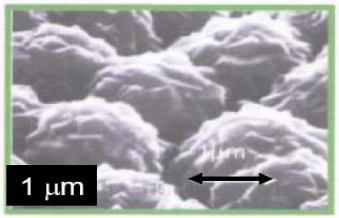
Source: Julich, April 2004

External Use

Finding the optimal TCO texture

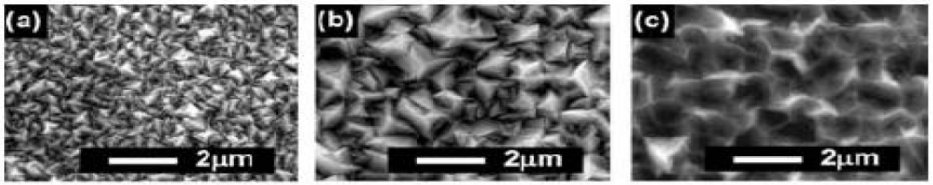


Type U or VU (off-line)
F:SnO2 via APCVD



Type HU
F:SnO_2 via offline APCVD

B:ZnO via LPCVD

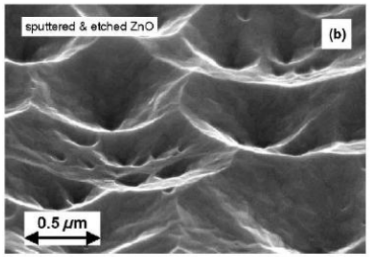


t =1.9 μm

t =4.8 μm

t = 4.8 μm
80 minute plasma etch

Al:ZnO via rf-magnetron sputtering and acid texturing

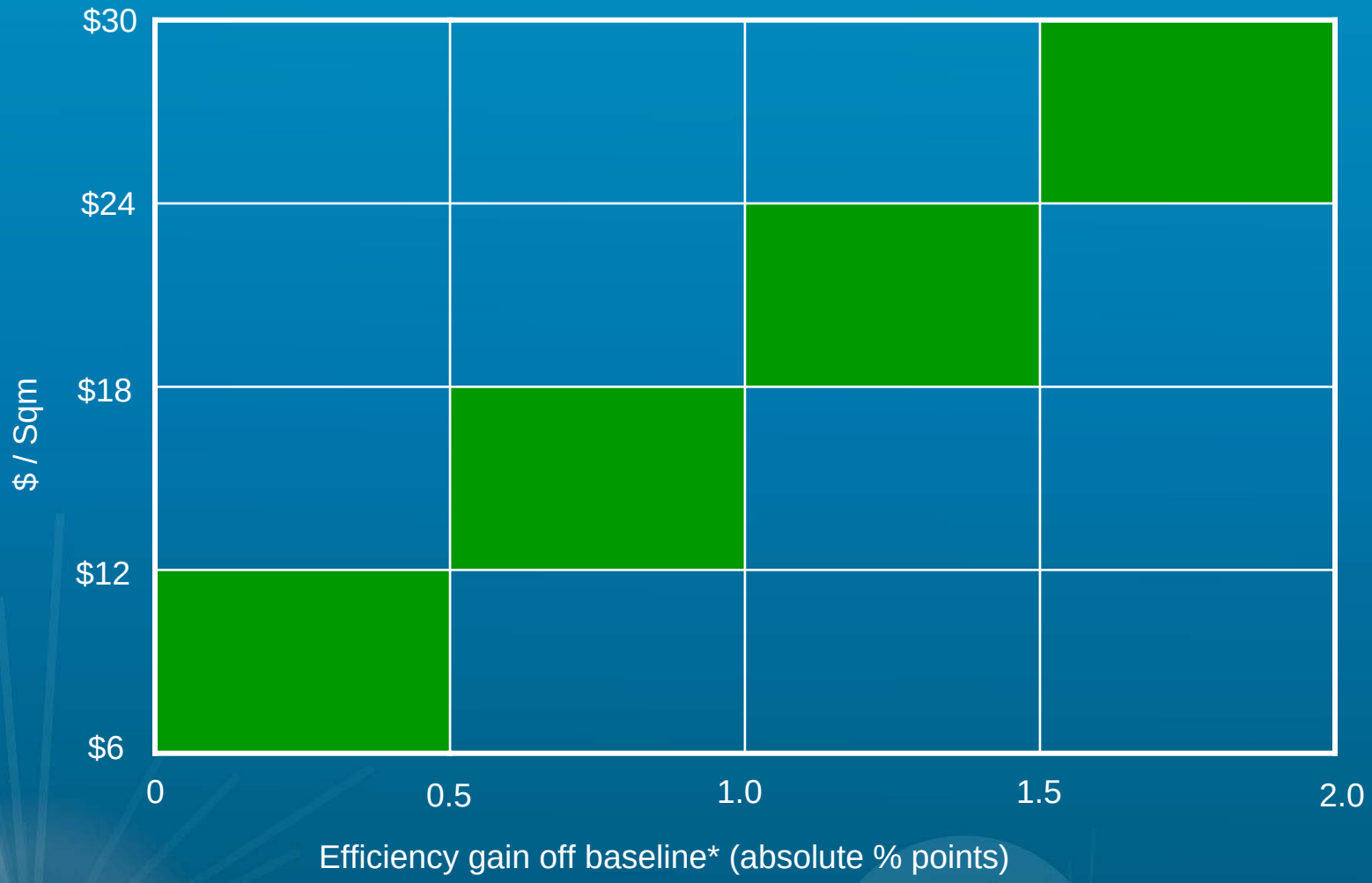


t ~1 μm

The race is on – no conclusions yet

External Use

TCO glass cost – efficiency matrix
Driving to < $1/Wp



*Current commercial Gen8.5 TCO glass

External Use

Anticipating rapidly growing demand

2010	40-50M sqm
2011	50-80M sqm
2012	80-130 Msqm

External Use

Summary

- Sunfab™ thin film Si lines and its world largest modules promise to enable utility scale PV by driving module and BOS cost down while setting the standard for fast production scale-up

- TCO glass, as highest cost element today and with highest potential for providing efficiency improvement, is key to enabling utility scale PV and Sunfab success

- Glass makers face great challenges ahead in developing advanced TCO glass meeting the known optical, electrical, reliability and cost requirements while ensuring enough volume to support rapid growth

- If successful, glass makers will help develop subside-free utility scale PV and a very large fast-growth market for themselves

External Use

think it. apply it.™

APPLIED MATERIALS®

Applied Materials Reporting Segments

Manufacture and sale of equipment to fabricate semiconductor chips

Broad range of products[1] to maintain, service and optimize customers' semiconductor fabs

Design, manufacture, sale, and services of equipment used to make flat panel displays

Design, manufacture, sale and service of equipment used to fabricate solar cells, flexible electronics and energy-efficient glass

External Use

Solar Manufacturing Solutions Strategy

Crystalline Silicon

Preferred for residential applications

- Area limited applications, higher cost, higher efficiency
- Competes mostly with electricity retail price
- Select process step participation: cost enablers
- Thin wafers, automation, productivity and yield

Thin Film

Preferred for large scale applications

- Lower cost, lower efficiency
- Competes mostly with electricity wholesale price
- Complete production line solution w/ 5.7m^2 standard
- Lowest cost of production and installation

Thin Film is the preferred path to utility scale PV

External Use