SAND2011-3607C

Transforming the sun's energy into electricity in a cost effective manner: Microsystems Enabled Photovoltaics

Jose L. Cruz-Campa, Gregory N. Nielson, Murat Okandan, Paul J. Resnick, Carlos A. Sanchez, Peggy J. Clews, Tammy Pluym, William Sweatt, Tony Lentine, Vipin Gupta

AVS SYMPOSIUM
MAY 23th, 2011
Albuquerque, NM

Agenda

- Microsystems enabled PV (MEPV)
  - Introduction
  - Silicon MEPV
  - GaAs MEPV
  - CdTe MEPV

Energy

Nobel Laureate
Richard Smalley

“Energy is the single most important challenge facing humanity today”

Solar Energy/ Photovoltaics (PV)

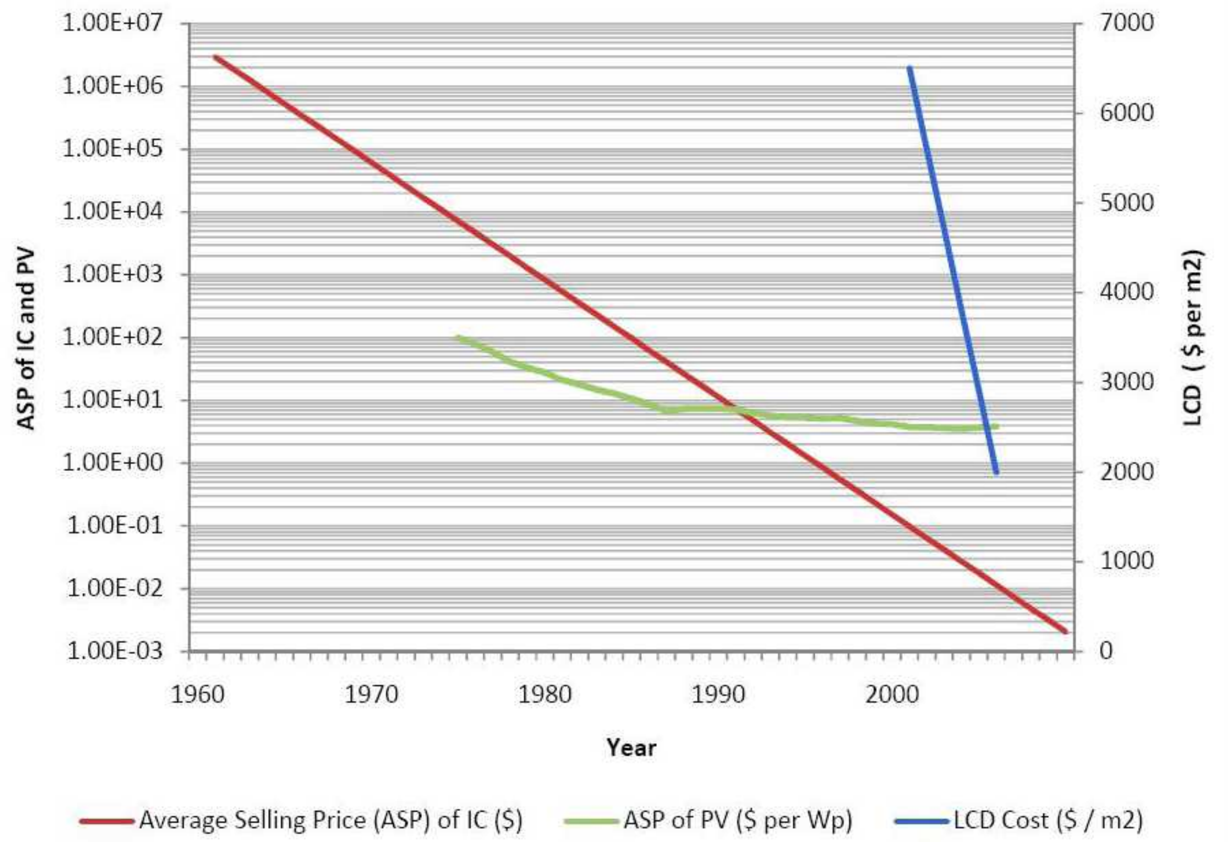
- 1 hour of irradiation on Earth’s surface could power the humanity needs for a year

- PV directly transform the energy from the sun into electrical energy.
- Virtually maintenance free for the life of the module.

Dr. R. E. Smalley, “Top Ten Problems of Humanity for Next 50 Years", Energy & Nanotechnology Conference, Rice University, May 3, 2003

Use microsystems to solar

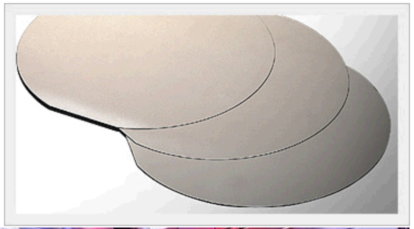
- Take advantage of mature technology of microsystems to create inexpensive photovoltaics



Rajendra Singh, "Why silicon is and will remain the dominant photovoltaic material" Journal of Nanophotonics, Vol. 3, 032503 (16 July 2009)

Silicon MEPV

Current process



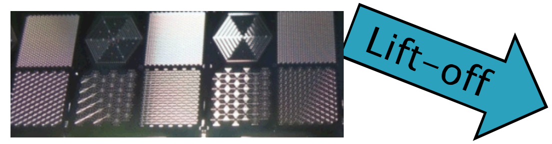
Full wafer
300μm
thick cells

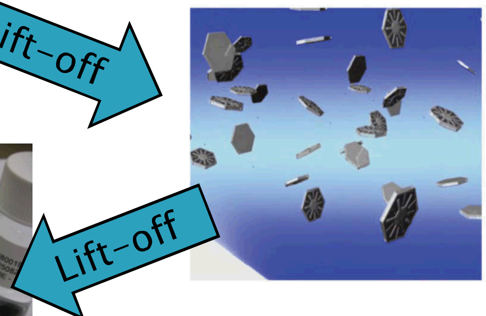
6 inches
wide cells

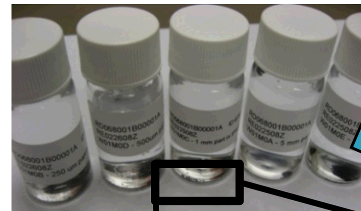
Expensive
modules

V. Gupta, J. L. Cruz-Campa, M. Okandan, G. N. Nielson, *Microsystems-Enabled Photovoltaics: A Path to the Widespread Harnessing of Solar Energy*, Future Photovoltaics 1, (2010) 28-36

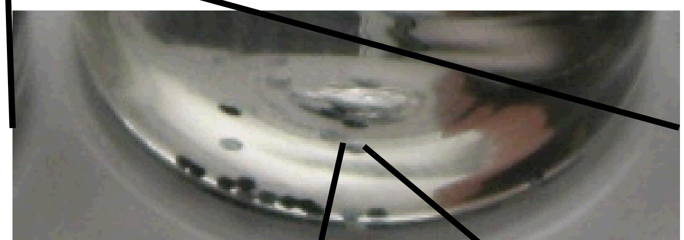
Sandia process



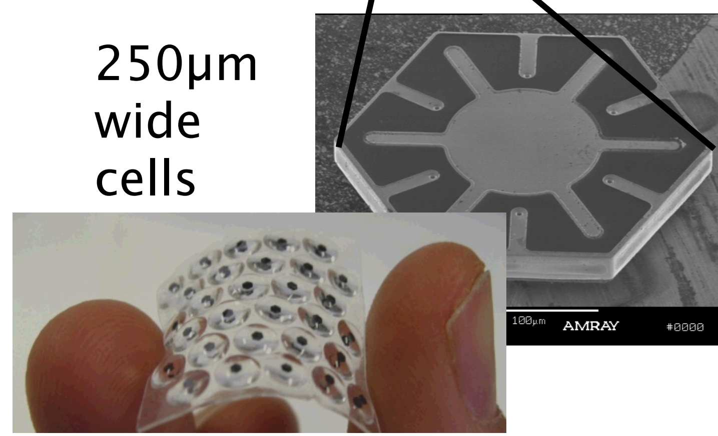




Sub
millimete
r 20 μm
thick
cells

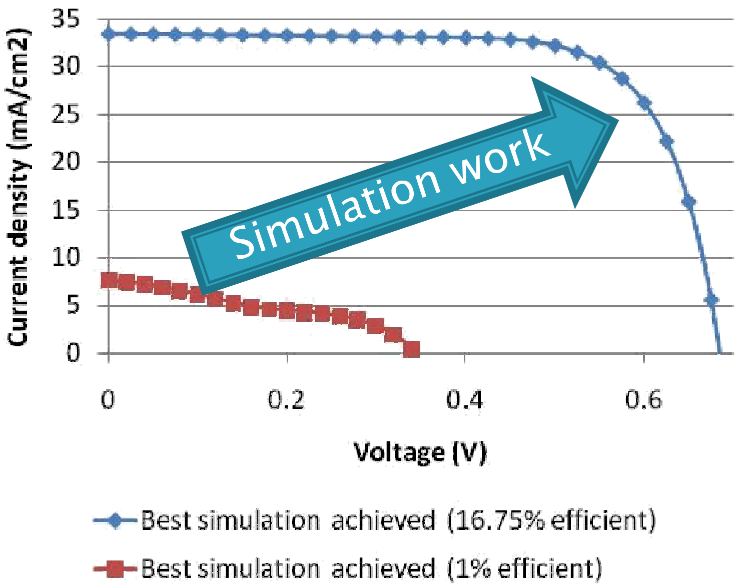


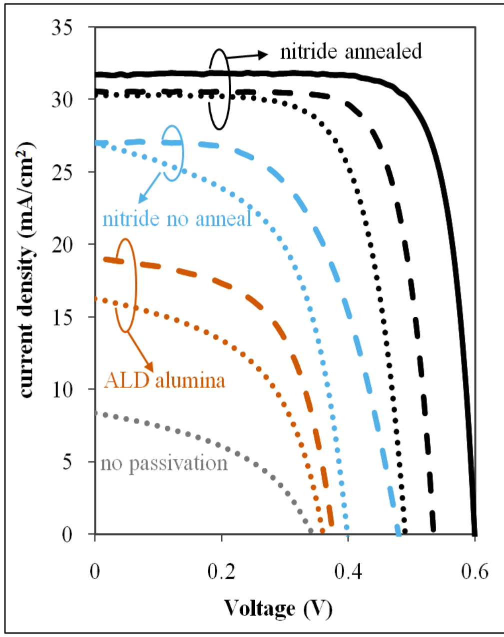
250μm
wide
cells



Inexpensive and flexible
modules

Simulations and experimental work





Key	Efficiency	Coating	Annealing type	Anneal time and temperature
	1.24%	N/A	N/A	N/A
	2.95%	ALD alumina	Hot plate	30min at 430°C
	4.14%	ALD alumina	Oven forming gas	30min at 430°C
	5.94%	Nitride: Low ammonia, low RF, high Temp	N/A	N/A
	7.40%	Nitride: high ammonia, high RF, high Temp	N/A	N/A
	10.30%	Optimized nitride	Oven forming gas	1 hr at 450°C
	12.20%	Optimized nitride	Oven forming gas	2 hr at 450°C
	14.86%	Optimized nitride	Oven forming gas	3 hr at 450°C

From left to right, Sandia researchers Murat OKandan, Greg Nielson, and Jose Luis Cruz-Campa, hold samples containing arrays of microsolar cells. (Photo by Randy Montoya) Click on the image to download a high-resolution image.

Jose L. Cruz-Campa, Murat Okandan, Paul J. Resnick, Robert K. Grubbs, Peggy Clews, Tammy Pluym, Vipin P. Gupta, David Zubia, Gregory N. Nielson; Microsystem Enabled Photovoltaics: 14.9% efficient 14µm thick crystalline silicon solar cell, Solar Energy Materials and Solar Cells 95-2 (2011) 551-558

https://share.sandia.gov/news/resources/news_releases/glitter-sized-solar-photovoltaics-produce-competitive-results/

MEPV: GaAs micro-solar cells

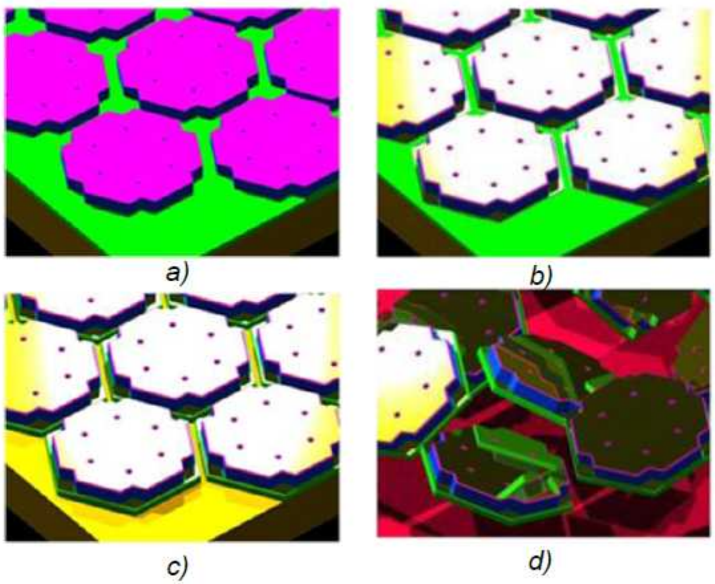


Figure 3. Sequence for solar cell release (1 mm design shown). a) the device area of the cells is defined; b) metallization; c) a directional etch to access the release layer; d) submersion of the cells in the etch solution to release the cells.

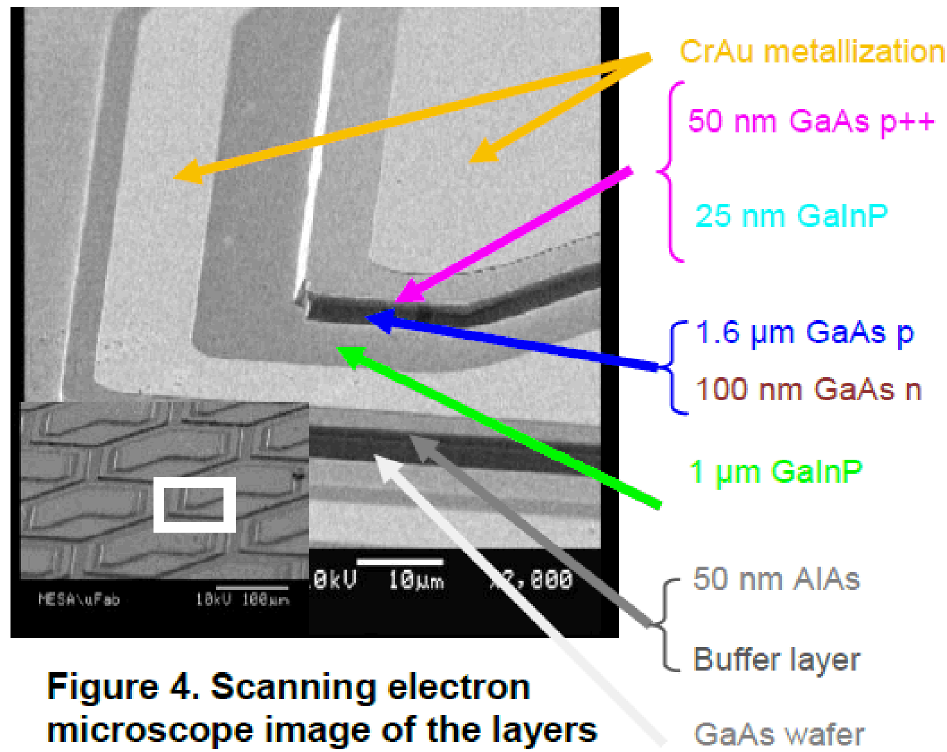


Figure 4. Scanning electron microscope image of the layers formed in the processing steps

GaAs micro-solar cells

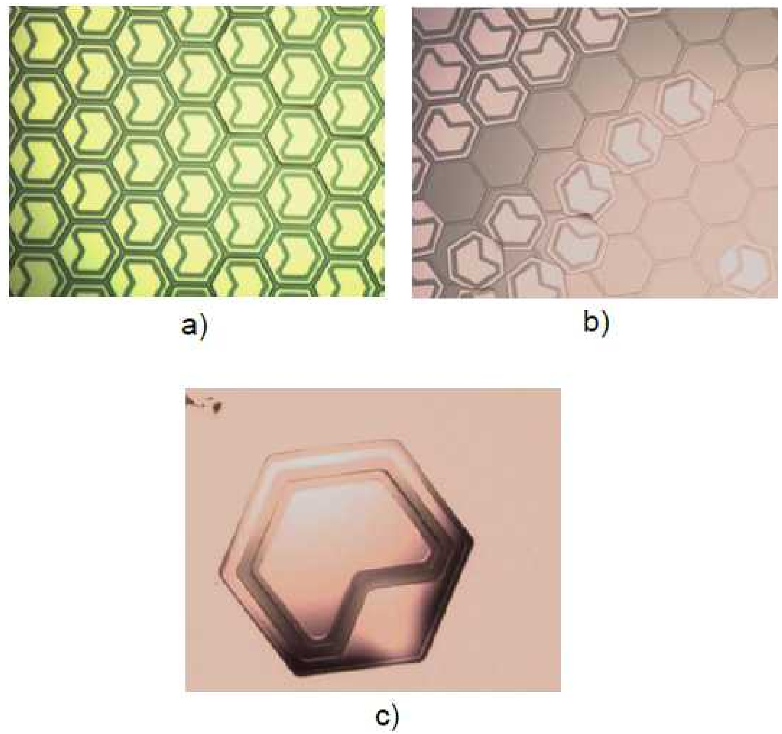


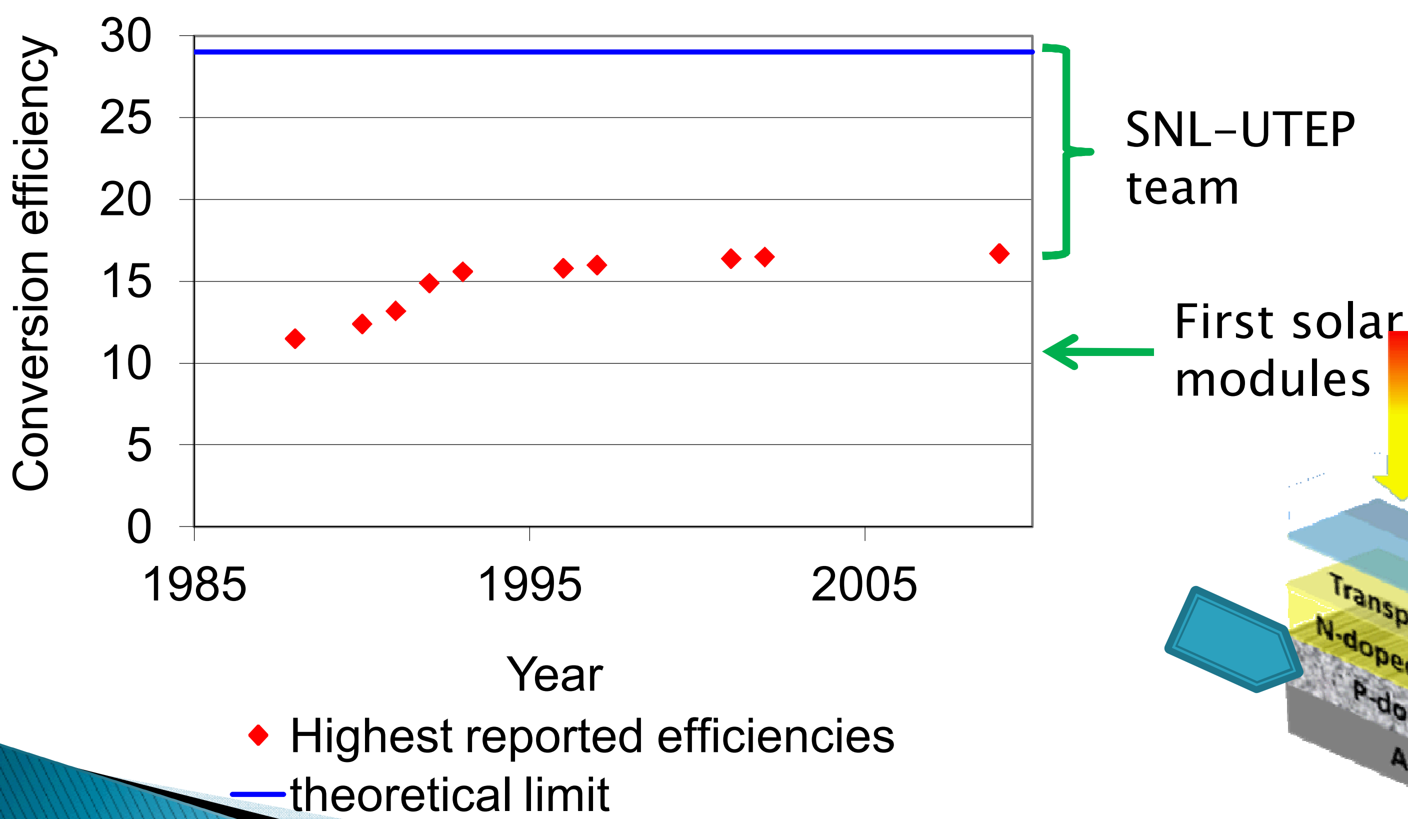
Figure 5. a) unreleased array of cells. b) cells in the process of being released. c) released cell. The shadows on the released cells indicate curvature of the cells, resulting from residual stress in the layer stack.

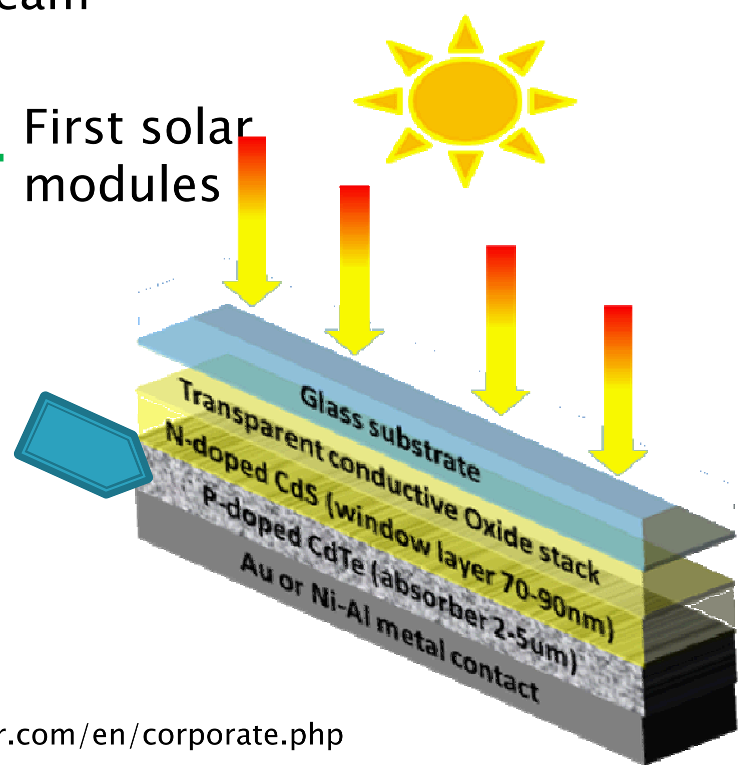
Cruz-Campa, J. L.; Nielson, G. N.; Okandan, M.; Wanlass, M. W.; Sanchez, C. A.;Resnick. P. J.; Clews, P. J.; Pluym, T.; Gupta, V. P. Back-contacted and small form factor GaAs solar cell 35th IEEE Photovoltaic Specialists Conference Proceedings. Hawaii, (2010) 1248-1252

CdTe MEPV Opportunity

First Solar, a CdTe based solar cell company, reached the $1/watt barrier, making them the cheapest solar module available.

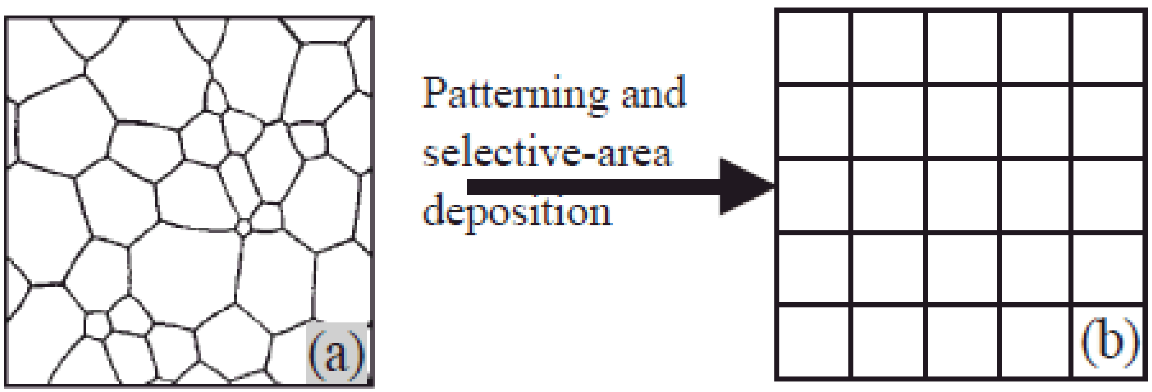
CdTe/CdS solar cell efficiencies

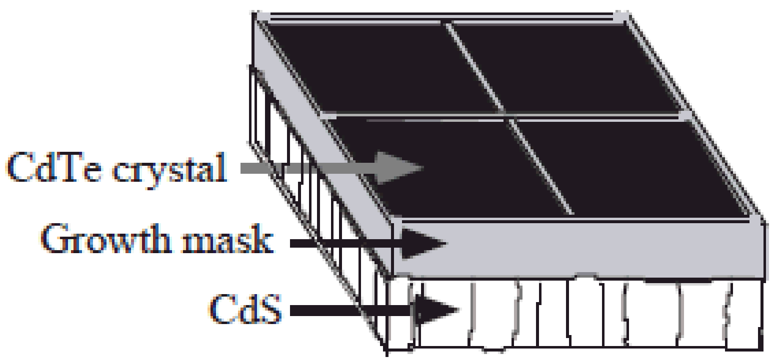




http://www.firstsolar.com/en/corporate.php

Microarrays





Enablers:
•Transport mechanisms
•Nucleation
•Growth conditions

Javier Terrazas, Aaron Rodriguez, Cesar Lopez, Arev Escobedo, Franz J. Kuhlmann, John McClure, David Zubia, Ordered polycrystalline thin films for high performance CdTe/CdS solar cells, Thin Solid Films, Volume 490, Issue 2, IMRC 2004, 1 November 2005, Pages 146-153

Questions?