

2008 Solar Annual Review Meeting

Session: Process Development and Integration Lab (PDIL)

Organization: National Renewable Energy Laboratory

Funding Opportunity: PDIL Capital Equipment



Wafer Replacement Cluster Tool

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Wafer Replacement Cluster Tool



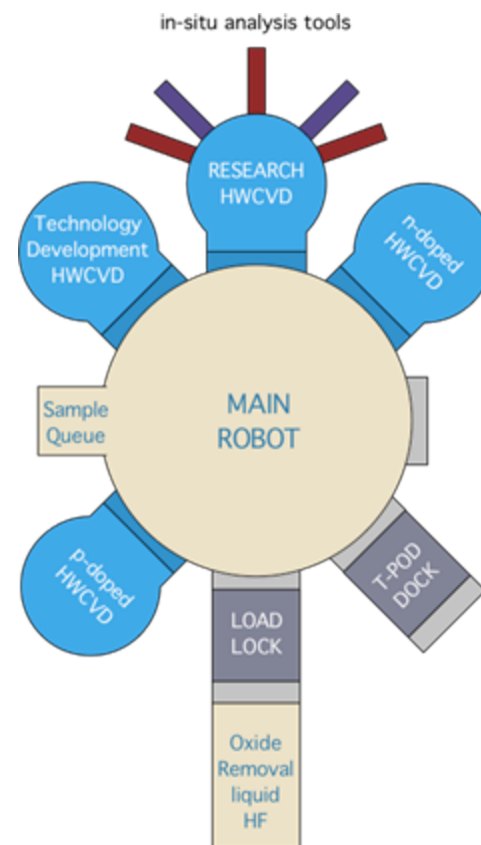
- Platform for advanced R&D toward SAI 2015 Cost Goal
 - Crystal silicon PV at area costs closer to amorphous Si PV
 - 15% efficiency
 - Inexpensive substrate
 - Moderate temperature processing ($<800^{\circ}\text{C}$)

- Why silicon?

- Industrial and knowledge base
- Abundant and environmentally benign
- Market acceptance
- Good efficiency

- Why replace wafers?

- Expensive
- High embedded energy content
- Use 50-100 times more silicon than needed

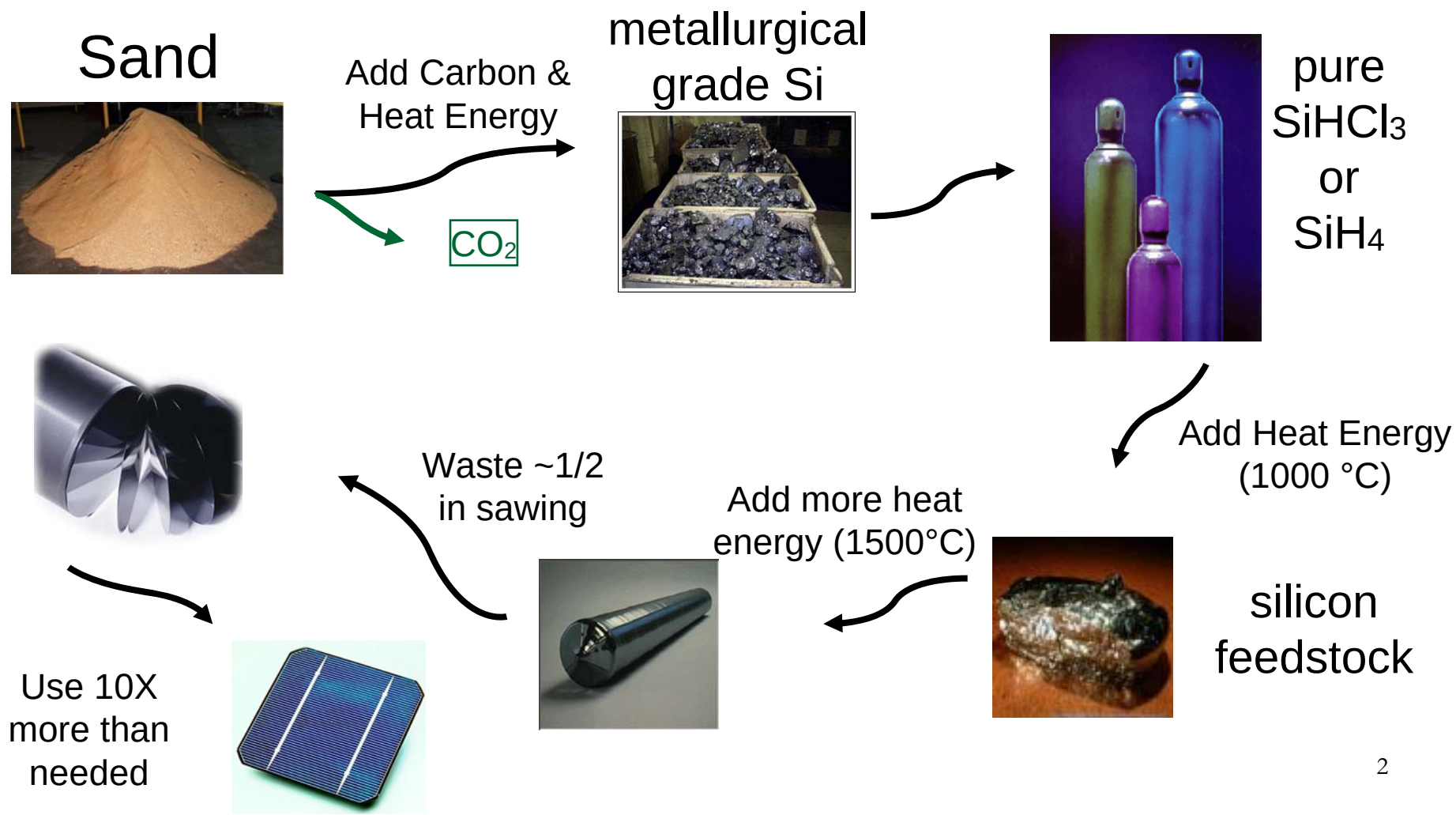


Energy and Si-intensive wafers



Current process:

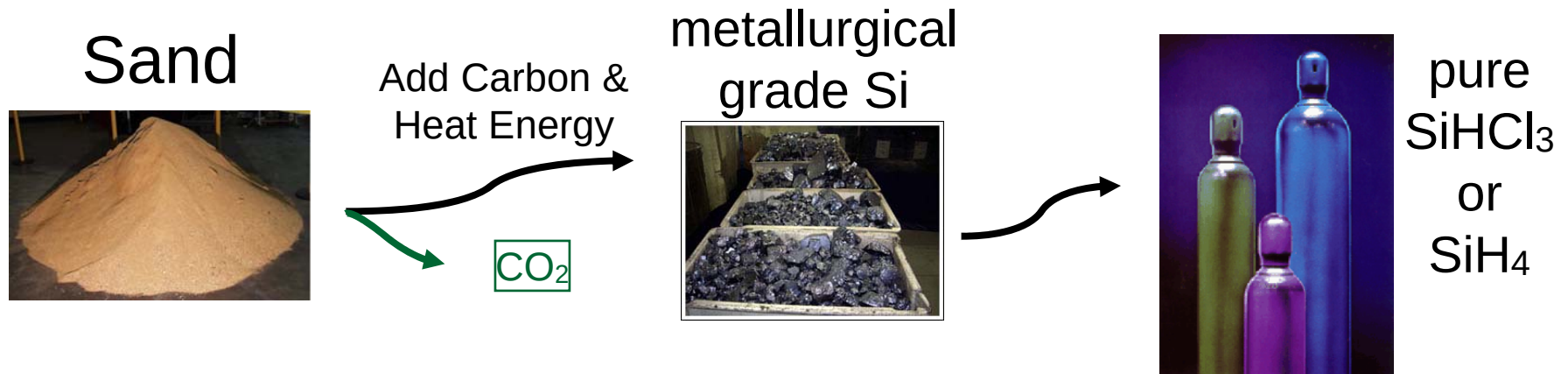
- 2 yr energy payback
- \$0.60/W - \$1.00/W for feedstock alone



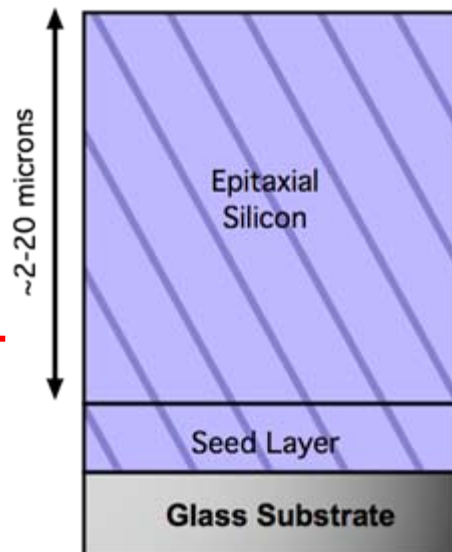
Vision for wafer replacement Si



Film Si growth:



HWCVD is best
low-T scalable
technique

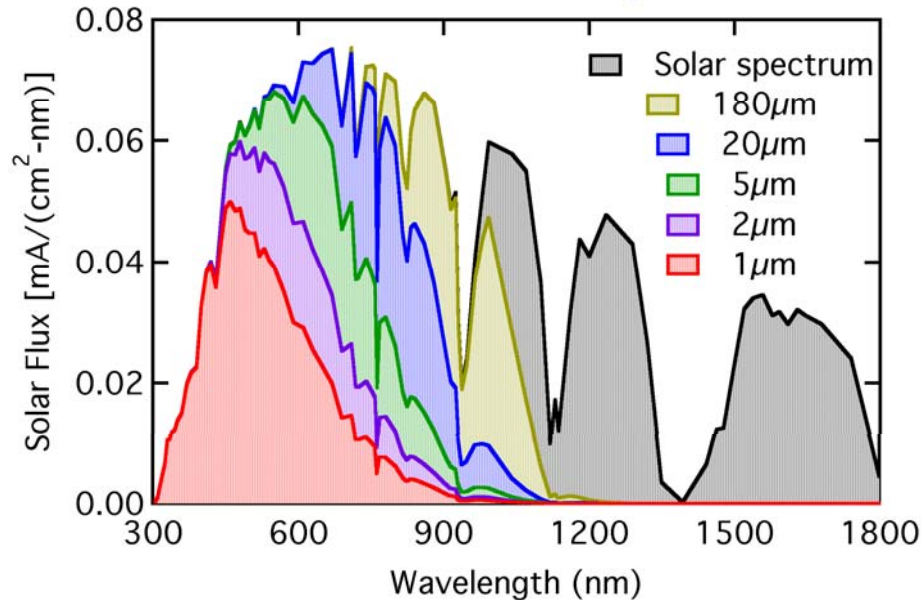


Directly deposit
enough pure silicon
for light absorption

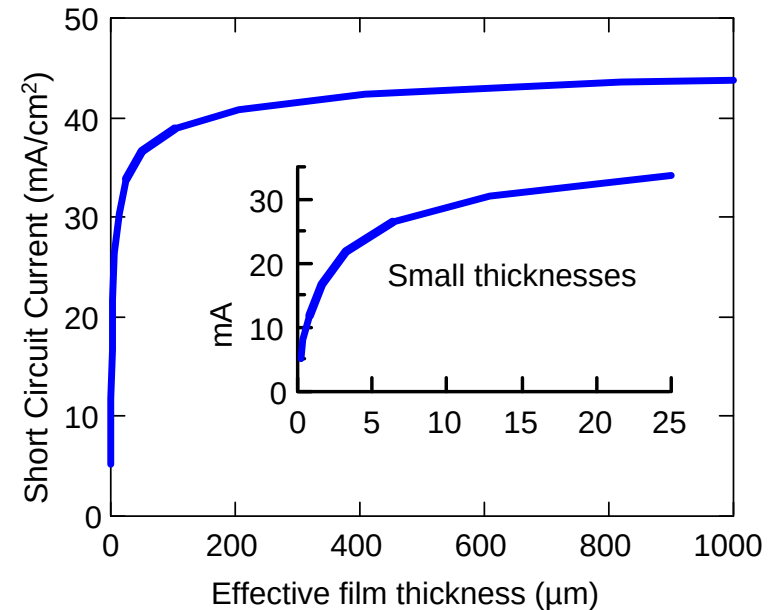
Thick wafers not needed for c-Si PV



Si film solar absorption



Potential Current vs effective thickness

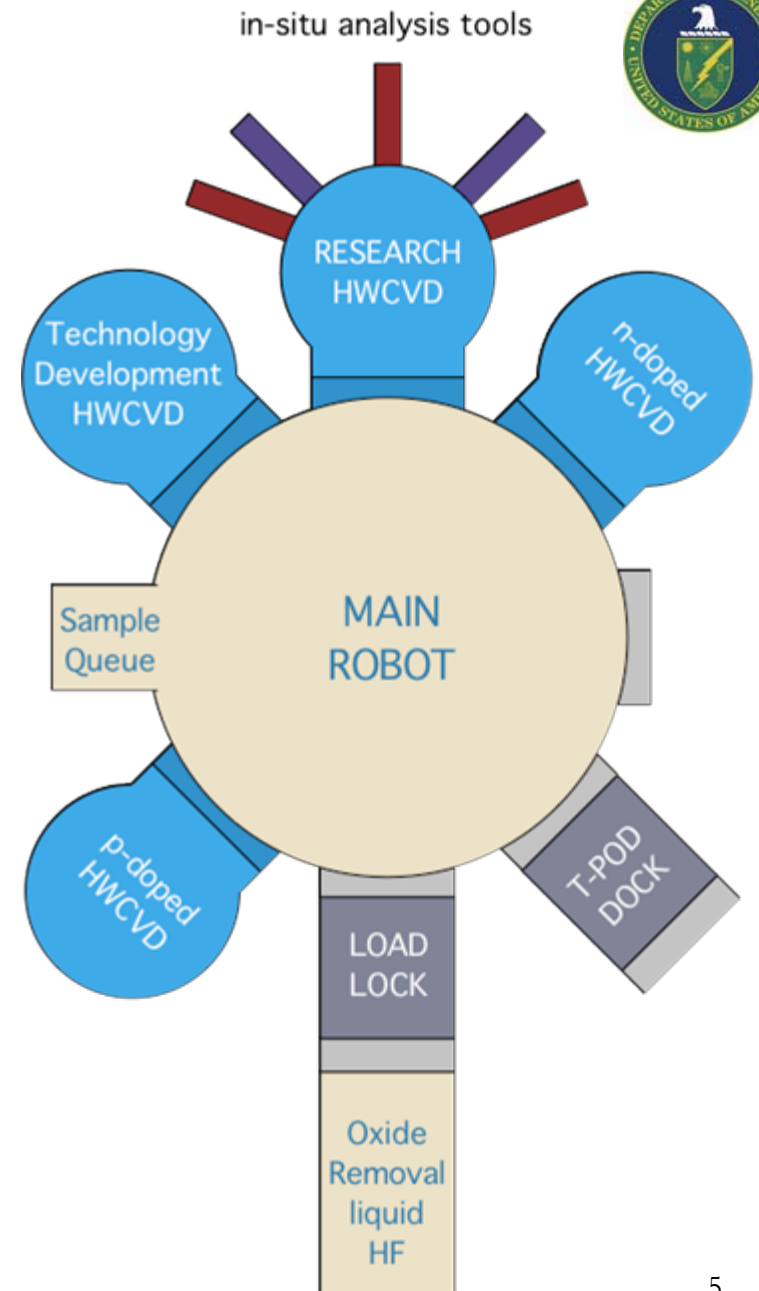


- Most current available at 20 μm effective thickness
- Over 30 mA attainable for 5- μm silicon with 5X light trapping
 - absorbs like 25 μm silicon layer

Tool and its capabilities



- Substrate to 800°C
- 156-mm samples queue in vacuum
- Automated liquid-based oxide removal
 - key last-minute step
- Doping control in separate chambers
 - n-type
 - p-type
- Research HWCVD
 - 10^{-8} Torr vacuum, low impurity
 - RTSE, RHEED, pyrometer, RGA
- Technology development HWCVD
 - Develop new filament and heater designs
- Load Lock
- Vacuum Transfer Pod to other PDIL Tools
- Spare port for alternatives and collaborations



Tool Alignment with Film c-Si Technology Roadmap



Roadmap

Wafer Replacement Tool

Need	Significance	
Develop inexpensive large-grain or single-crystal, high-quality c-Si film growth processes and materials for use with low-cost substrates	Higher efficiency than amorphous, but lower cost than wafer-based silicon	Scalable hot-wire (HWCVD) epitaxy – 300 nm/min, 10 μ m, with low dislocations – Epitaxy on all orientations
Develop seeding techniques for high-quality epitaxial c-Si film formation on low-cost substrates	Increased efficiency	Will enable us to evaluate seed layers
Develop light-management strategies for weakly absorbing c-Si films	Increased efficiency	Will enable us to develop light-trapping at 6-inch scale
Develop inexpensive, high-temperature (>600°C) substrates for c-Si films	Reduced cost	Will enable us to evaluate new substrates
Develop inexpensive, reduced-temperature processing for c-Si films	Reduced cost	Glass-compatible temperatures 600 - 700°C
Develop low-temperature passivation techniques for film-Si surfaces, interfaces, and grain boundaries	Increased efficiency	Hot-wire hydrogenation possible, if needed
Develop, automate, and scale up deposition equipment for c-Si film fabrication	Reduced cost and increased yield	Technology development chamber and in-situ diagnostics

Status and schedule



- Conceptual design (chambers) complete
 - based on new test epitaxy chamber (1")
- Detailed design work continuing
- Statement of work for RFQ in preparation
- Bids and vendor selection in FY08
- Delivery of robot and key chambers in FY09

Partnerships anticipated



- Seed layer candidates
 - semiconductor equipment companies
 - display companies
 - glass companies
 - start-ups
 - NREL R&D
 - university and national labs
- PV ventures testing low-T epitaxy step
- Equipment vendors
 - chamber to test HWCVD innovations

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CIGS Platform

Miguel Contreras



Platform	PV Technology Road Maps						
	Wafer Si	Film Si	CPV	CdTe	CIGS	OPV	DSPV
Thin Si							
Wafer Rep.							
CIGS							
CdTe							
Atm. Proc.							
M&C Ind.							
M&C Cluster							