

2008 Solar Annual Review Meeting

Session: Wafer Silicon

Organization: National Renewable Energy Lab

Funding Opportunity: NREL Core Program



Qi Wang

qi_wang@nrel.gov

Ph: 303-384-6681



Budget and Solar America Initiative Alignment



<i>Wafer Si NREL</i>			
Project Beginning Date	FY07 Budget	FY08 Budget	Total Budget
10/1/07	\$2.42 millions	\$ 1.912 millions	\$ 4.34 millions

- This project supports the Solar America Initiative by working on
 - Wafer Si accounts for 92% world-wide solar cell production
 - Research to fill the industry R&D pipeline for the issues in wafer Si
 - Development of industry collaborative research
 - Improvement of NREL tools and capabilities
 - Strengthen US wafer Si research

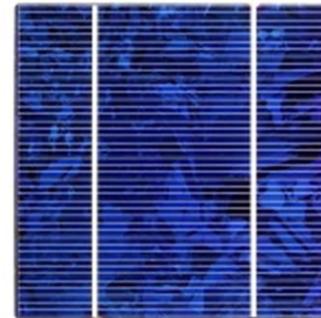
Project Overview: Two Roadmaps



High efficiency
single c-Si



Low cost
mc-Si: casting and ribbon



Common to both roadmaps

Interconnect, packaging, reliability,
process diagnostics and modeling,
and reduced Si consumption

Project Alignment with Technology Roadmap



What needs in the Technology Roadmap are your project responding to?

Need	Significance
------	--------------

single c-Si

2. Surface passivation	Lower surface recombination is needed to yield cell efficiencies > 25%.
3. Light management for thin cells	Thinner cells need very effective light-trapping and reduced metallization shadowing.
4. Low recombination contacts	High efficiencies require metallization schemes for low recombination contacts.

mc-Si

1. Bulk defect engineering & passivation	Identify performance-limiting mechanisms in cells made from current c-Si feedstock materials. It will provide a pathway to using lower-cost feedstock and higher efficiency on lower-cost cells.
3. Solar-quality feedstock	Reduce cost of Si materials in cell without hurting efficiency.

What approaches are you using to address those needs?

Our approach

a-Si/c-Si surface passivation and high efficiency SHJ solar cells
Uniform pyramid, nano feature surface, AR coating and infrared enhancement
Study metal to doped μ c-Si and TCO contacts

a-SiNx and a-Si passivation and Hydrogenation at high temperature
Evaluate solar Si feedstock

Project Update



2007

2008

Planned work since last Program Review	Status
Si Heterojunction solar cells	Meet FY07 milestone of 19%
Measurement and characterization	Successful c-Si WS & support industry
3" CZ Grower	Place order on March, 2008
Si Heterojunction solar cells	Working on increase Jsc and large area cell in Si cluster tool
Surface and bulk passivation	Waiting for Si cluster tool
Black Si and solar cells	Master black surface preparation and work on solar cell
Interdigitated/heterojunction solar cell	Mask and design near complete
Direct-writing to contacts	narrow line and high conductivity on solar cells
Novel TCO for c-Si solar cell	Anticipated 9/2007
18th c-Si workshop	8/3-6/08 Vail, CO

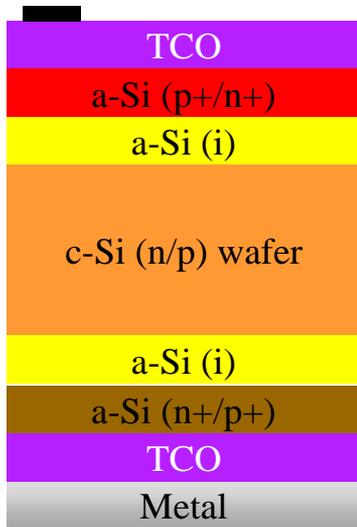


Silicon Heterojunction solar cell

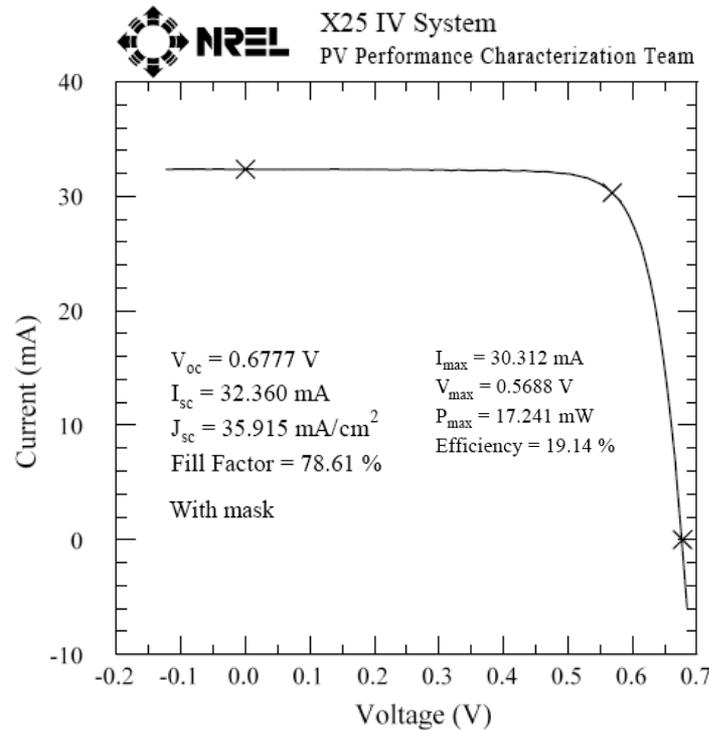
19.1% on *p*-type FZ c-Si
18.7% on *p*-type CZ c-Si

- Meet FY07 19% milestone
- FY06: 18.2%,
 - FY07: 19.1%
 - FY08: 18.7% on CZ wafer

Metal



c-Si sandwich
between thin Si
layers



FY07 work area :

- Back contact to increase FF
- Textured c-Si and cleaning

FY 08 work area:

- Large area SHJ solar cells
- Increase red absorption



Surface and bulk passivation

a-Si:H or a-SiNx:H
using PE-, HW-, VHF-CVD

c-Si & mc-Si

Compare
as grow vs. annealing

Evaluation

Lifetime: ~ 1 ms

Surface velocity: ~15 cm/s

H-profile

Project Update – Inkjet Contacts for Si Solar Cells

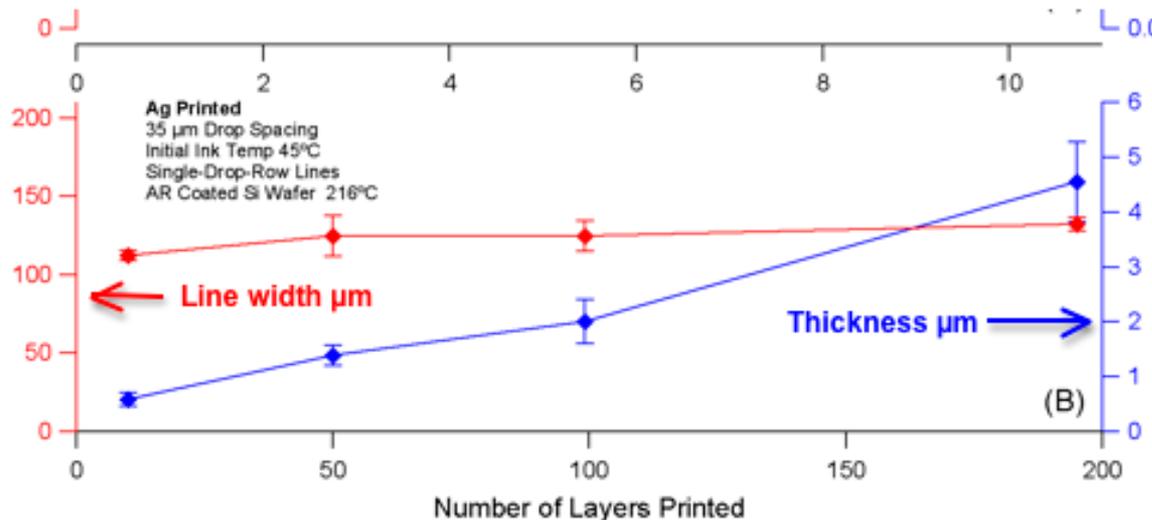


Progress	1 st gen	2 nd gen	Now	Next
Line thickness:	10 μm	15 μm	10 μm	15 μm
Line width:	400 μm	250 μm	80 μm	<100 μm
Dep. temperature :	180°C	180°C	180°C	180°C
Ann. temperature:	850°C	850°C	750°C	<750°C
Cell efficiency	8%	8%	13%+	15%+

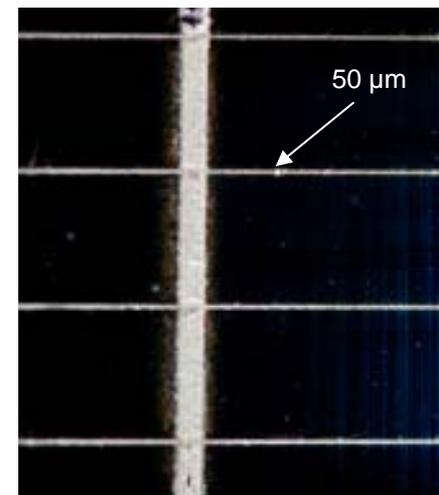
Contact Resistance
7 m Ω

AR-coated Si substrates from Evergreen Solar

Multi-layer printing of Ag showing constant line width with increasing thickness



Inkjet printed burn through and Ag contacts ~50 μm wide and 10 μm thick





Si materials

Si



Ingot

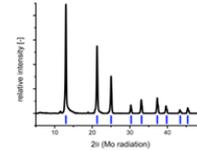


Wafer

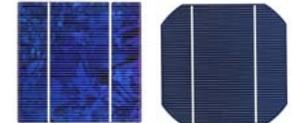


Evaluation

Si analysis



Solar cell



Solar Si
EG-Si
Mixed-Si

3" CZ
Grower

Casting?

ID saw

Wire?

Structure
Defects
Impurities
Electronic

Diffused
SHJ
Back-interdigitated
Passivation
Contacts
Light mgmt



Barriers encountered or anticipated that may inhibit success of programs

- Lack of proper equipments and sufficient staff
 - Current equipment is about 20 years old
- How to transfer laboratory cell to production
 - Scale up