

Processing and Device Oriented Approach to CIGS Module Reliability

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Proposal:

- Process and Performance driven R&D should be integrated with Reliability
- Device level changes are a big part of module reliability. Greater attention to device issues at the process stage is needed and can only help the big picture.

Status/ Gaps:

- Device fabrication and understanding is now more mature than a decade ago.
- Many reported effects such as metastability can be understood and described by models.
- Lab and industry devices are reaching same level performance in spite of vastly different processing approaches.
- Lab – industry cooperation is now stronger (F-PACE).
- Cell level stability has been neglected. This is a good time to pick up the pace.

Impact:

- It is possible the drivers of cell and module performance also drive stability.
- Examples provided here illustrate the ability of scientists in Lab and academia to solve industry issues.
- Continued cooperation can provide clarity to seemingly complex issues.
- Assurance of reliability is necessary to gain consumer acceptance.

Past collaboration with Shell Solar, Thin Film Partnership, 1998-2003:

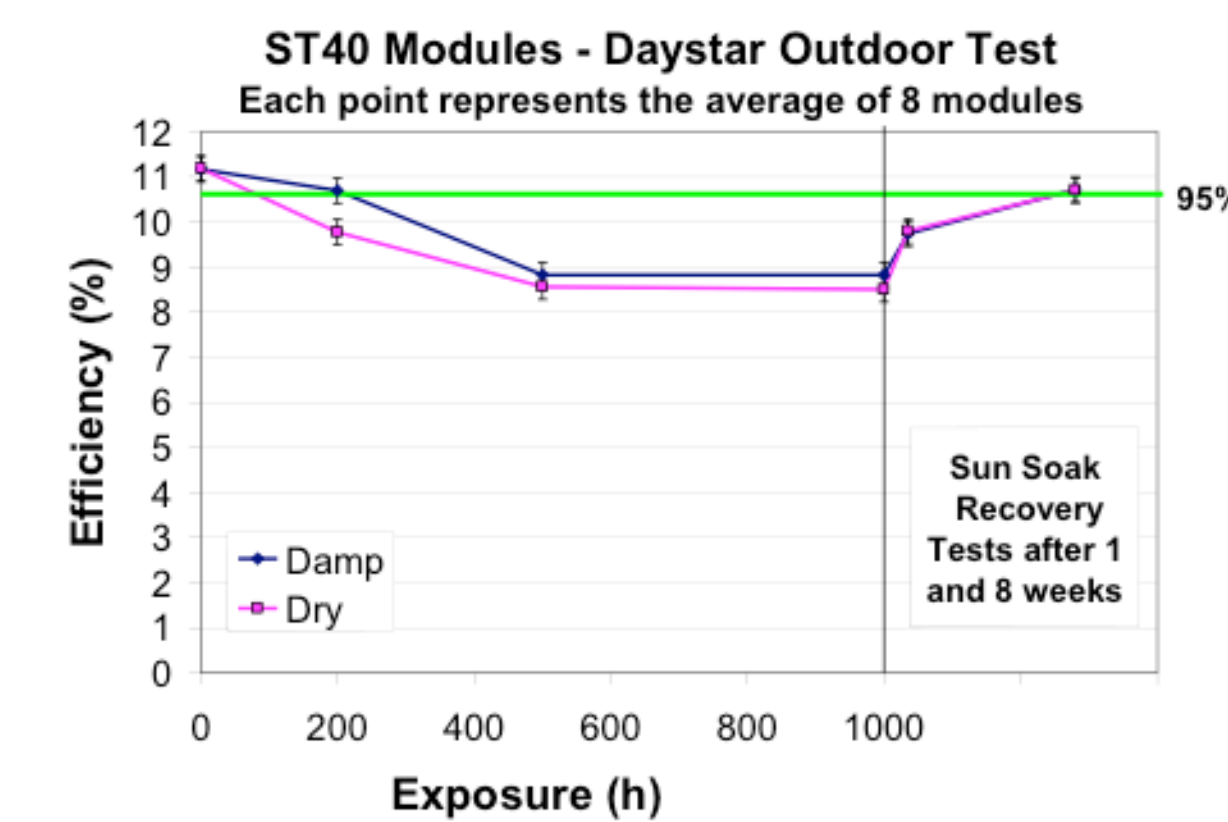
SSI approaches National Team with “transient effect” problem.

Change under light soaking was a problem for testing and certification, not a performance issue.

Wanted to understand root cause.

Accelerated Test Results

- “Degradation” is due to dark heat, not humidity ingress.
- Thermal effects are reversible transients.
- Losses due to dark heat exposure may not reflect real world effects.



Problem statement

NREL – Shell Solar Interleaving Study, 1998-2001

SSI absorbers	# of samples	Unpatterned	Patterned	SSi	SSi	SSi	NREL	NREL	NREL	NREL	SSi	SSi	SSi	SSi	NREL
				CdS	ZnO	ships to P3 & Meas.	CdS	Std. ZnO	Thin ZnO	ships to SSI	CdS	ZnO	P3 & Meas.	ships to Meas.	grids & Meas.
Description															
SSI Baseline	9			X	X	X									X
SSI Baseline, Held at SSI	9			X	X	X					X	X	X		
Traveling SSI Baseline	9						X	***	***		X	X	X	X	
NREL Baseline CdS & ZnO	5						X	X	X					X	
Exp. 1, NREL CdS / SSI ZnO	5			X	X	X	X	X	X		X	X	X	X	X
Exp. 2 NREL CdS & thin ZnO / SSI ZnO	5			X	X	X	X	X	X		X	X	X	X	X
	2			X	X	X	X	X	X		X	X	X	X	X

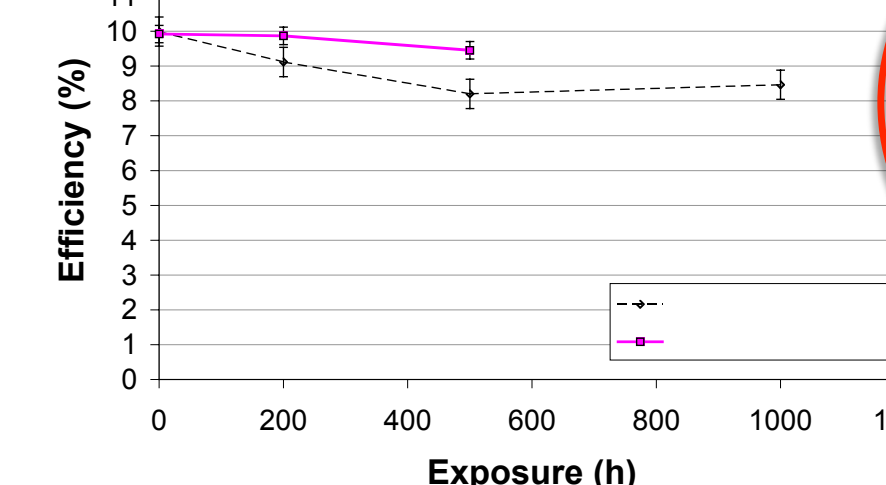
Problem mitigation

Modified Processing for Thermal Stability

Dry Heat Test Only

10W Laminates - LAPSS Test

Each data point represents the average of 21 laminates



What was changed?

- Increased CdS thickness
- Low CIG ratio

NREL process interleaving work was done on 10x10 cm mini-circuits and small area devices. Special substrates were provided by SSI.

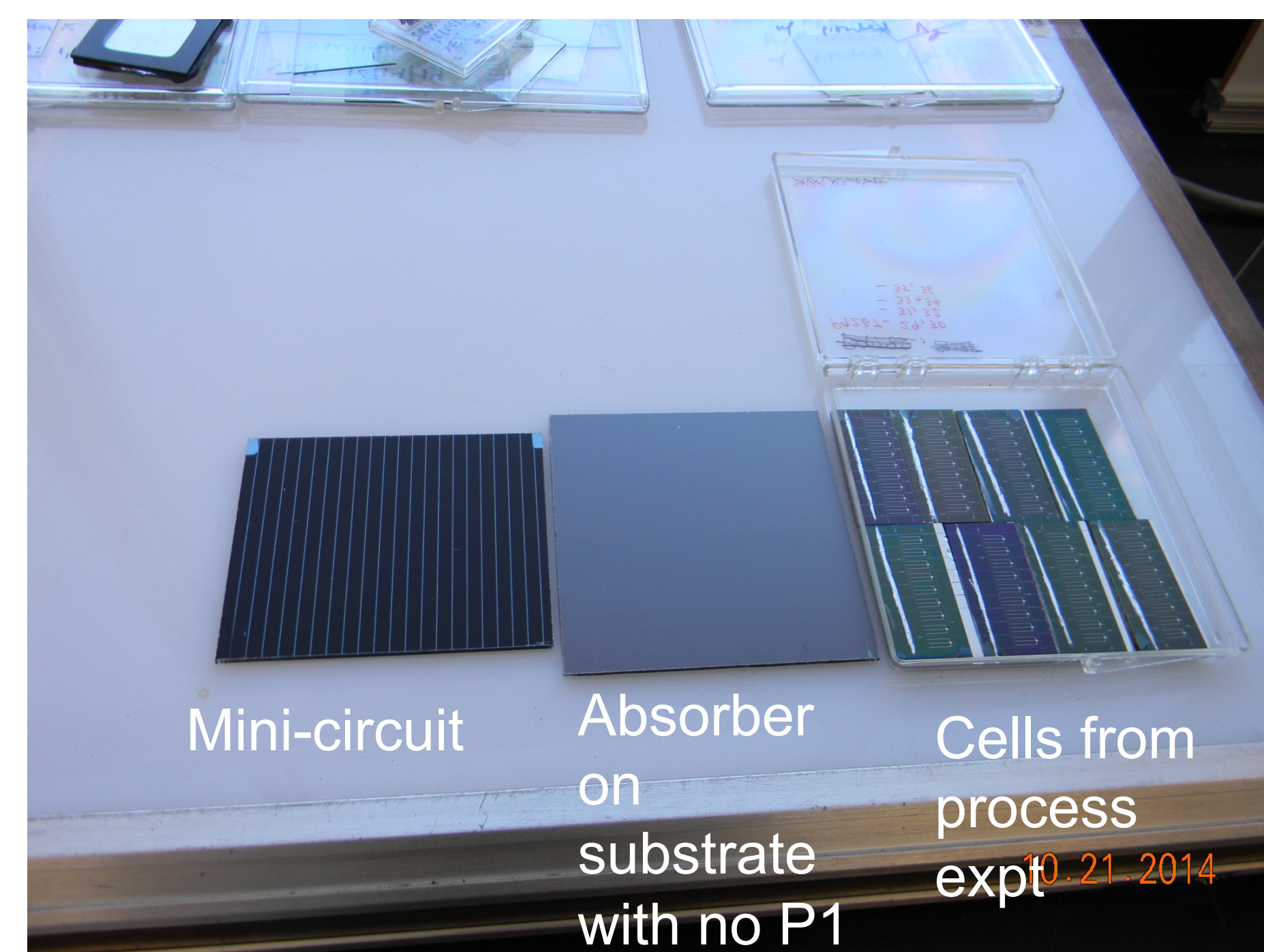
NREL process: thicker CdS, different recipe. Led to higher V_{oc}

Led to process change and improved stability (2003)

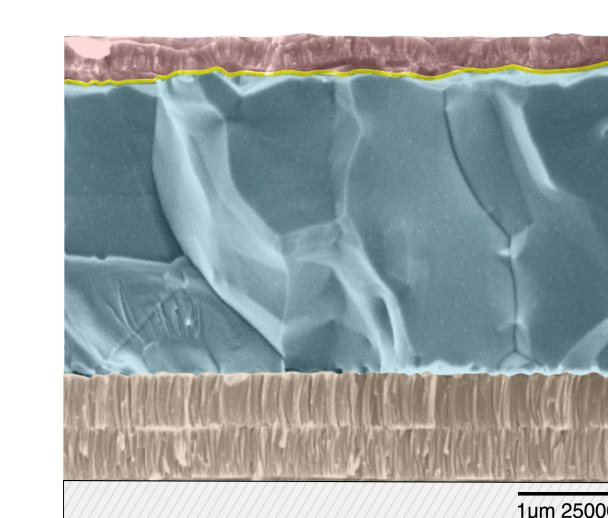
Device level studies: necessary complement to module reliability:

Small area devices enable a host of device characterizations not possible in modules.

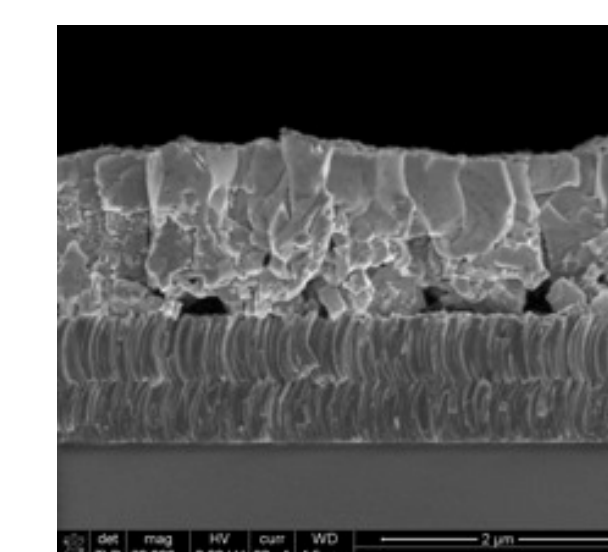
Small area device capability enables testing and validation of process modifications.



Process to Measurements to Root Cause Identification: Methodology to sort out observed effects



Best known CIGS device (lab)

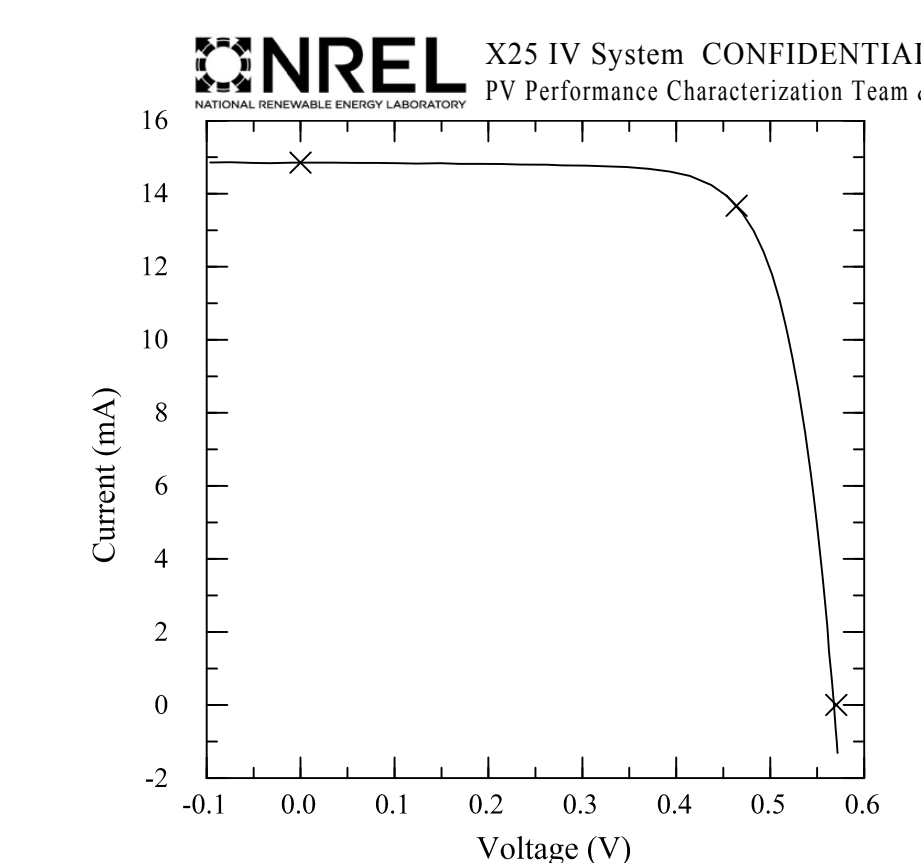


CIGS device by different process, different cell design

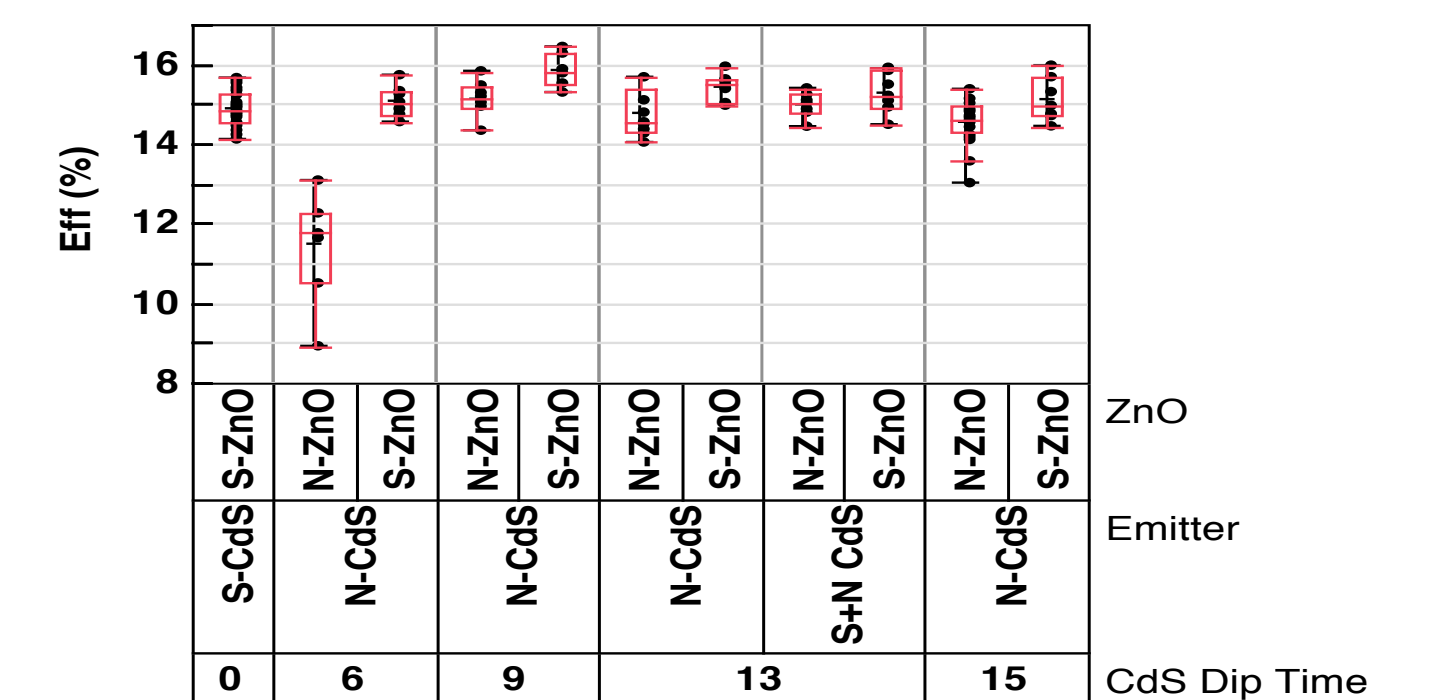
- Initial device characterization
- Decide test/ stress to answer specific question
- Decide relevant packaging
- Conduct tests

- What effects are inherent to CIGS?
- What effects are due to specific process/ device design?
- What process change is needed and why?

Similar work for Stion (F-PACE) shows performance gain



Industry baseline CdS cell: 15%
NREL begins study of CdS interface.



Experiments showed 1% (abs) efficiency improvement. Led to pilot and full scale experiments. Factory process modified. Current product has higher voltage, more power.