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. Need much greater attention to the effect of processing on cell and module reliability.
- It is possible the drivers of cell and module performance also drive stability.

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 the same level of performance in spite of vastly different processing approaches.
- Lab/academia – industry cooperation is now stronger (F-PACE).
- There has not been much emphasis on small coupon/ device work with a focus on reliability. As a result, the fundamental mechanisms are not clarified.
- This is a great opportunity to accelerate the progress in understanding the fundamental mechanisms that cause device properties to change under various external stress factors.

Impact:

- Examples provided here illustrate the ability of scientists at NREL and academia to solve industry issues.
- Continued cooperation can provide clarity to seemingly complex issues.
- Work will demonstrate reliability of CIGS devices and ensure acceptance of CIGS products.

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

SSI approached National Team with the "transient effect" problem.

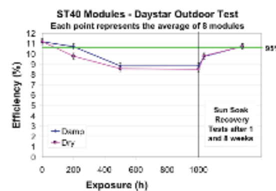
Change under light soaking was a problem for testing and certification, was not a performance issue.

Wanted to understand the root cause.

Accelerated Test Results

Problem statement

- "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.



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Shell Solar

NREL – Shell Solar Interleaving Study, 1998-2001

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

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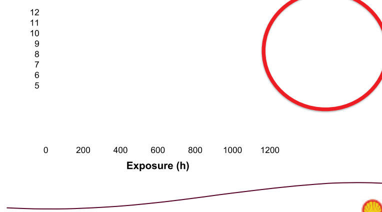
Problem mitigation

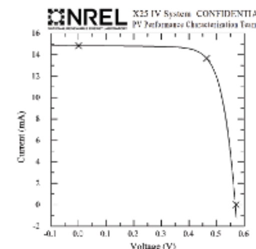
NREL process interleaving work was done on 10x10 cm mini-circuits *and* small area devices. Special substrates were provided by SSI.

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

Suggested process changes improved stability (2003)



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



Industry baseline CdS cell: 15%

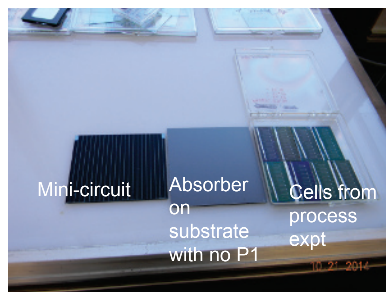
NREL begins study of CdS interface.

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

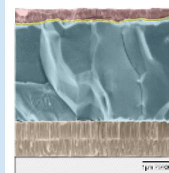
"Device level studies: A necessary complement to module reliability"

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

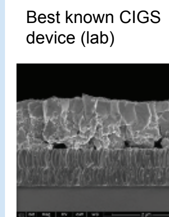
Small area device capability enables testing and validation of process modifications.



"Process => Measurements => Root Cause Identification: Methodology to sort out the 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 appropriate 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?
- Complete the cycle of learning. Intervene at the process stage to resolve issues.

SunShot U.S. Department of Energy

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