KOREA UNIVERSITY
SOLAR ENERGY RESEARCH CENTER

Analysis of the degradation of multi-crystalline silicon solar cells after damp heat tests

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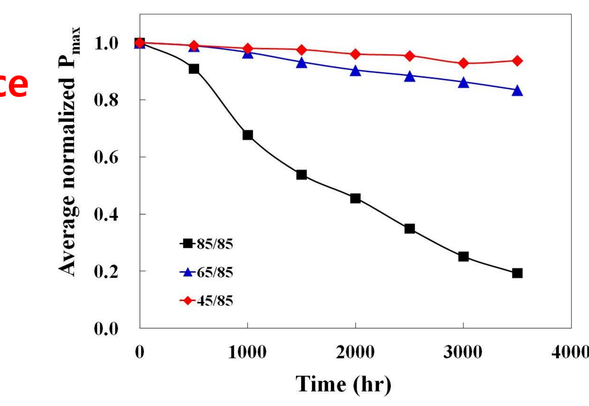
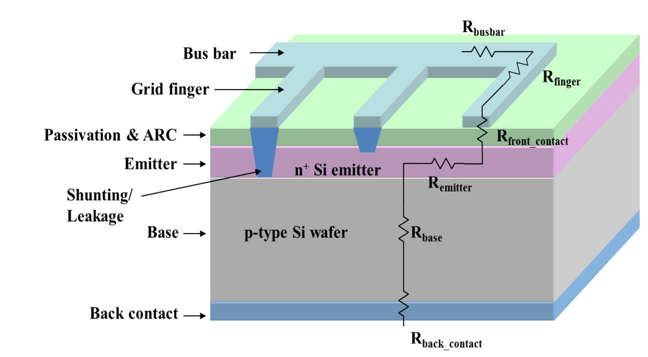
ABSTRACT

Lower performance is usually observed after long-term damp heat test (DH) at 85℃/85% Relative Humidity (RH) condition. It is known that the phenomenon of degradation results from fill factor (FF) loss by high series resistance. However, the cause for the series resistance increase is unclear. We attempted to evaluate the dominant factor on the solar cells. We conducted 3 kinds of damp heat tests using un-packaged multi-crystalline silicon solar cells. Also. We analyzed Light I-V, EL, Suns-Voc, QSSPC, Corescan and SEM after damp heat test. Samples were over-stressed sufficiently under thermal and moisture conditions. Severe degradation by FF loss after damp heat condition (85/85) originated from the contact resistance between Si and Ag finger. Especially, Ag crystallites in the edge of Ag finger were oxidized and could not play a role of current path of photo-generated electrons. We also calculated the contact resistance and transfer length using transfer length method (TLM) after dicing of samples.

MOTIVATION

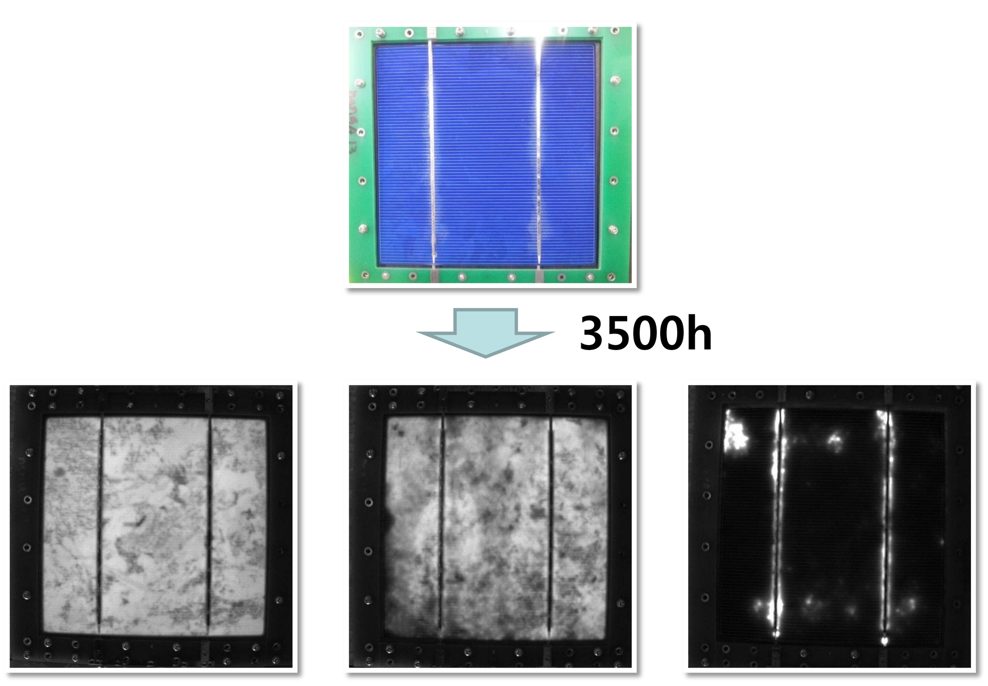
- Low performance after long-term damp heat test at 85℃/85%RH condition is usually observed.
- Many researchers know the phenomenon of degradation resulting from FF loss by high series resistance.
- However, the part which affect series resistance is unclear. Especially, we attempted to evaluate dominant factor in respect of solar cells.
- We focused on contact resistance in Ag/Si interlayer.





RESULT AND DISCUSSION

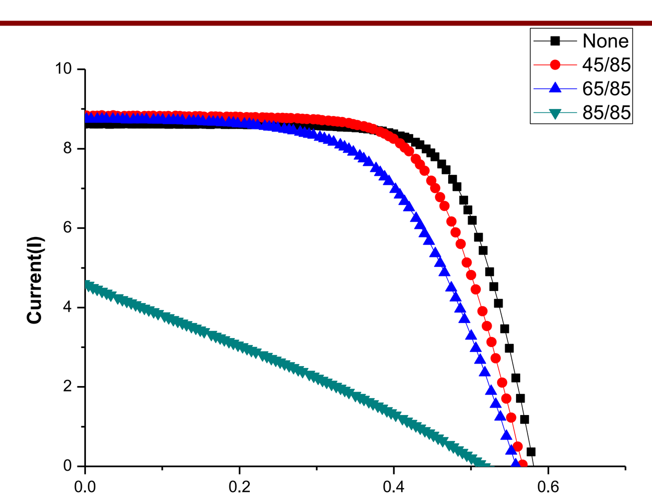
1. Sample & Electroluminescence image



45℃/85% 65℃/85% 85℃/85%

- Sample : Multi-crystalline Si solar cell + PV ribbon soldering

2. Light I-V



Samples	Jsc(mA/cm2)	Voc(V)	FF	Rs(Ω)	Rsh(Ω)	P_{max} ratio(%)
None	36.43	0.581	0.706	0.01	28.52	100
45℃/85%	36.30	0.567	0.665	0.013	9.658	94.2
65℃/85%	35.94	0.558	0.579	0.016	4.361	80.0
85℃/85%	18.87	0.517	0.287	0.076	0.124	19.1

- Sample at 85/85 condition is degraded severely.

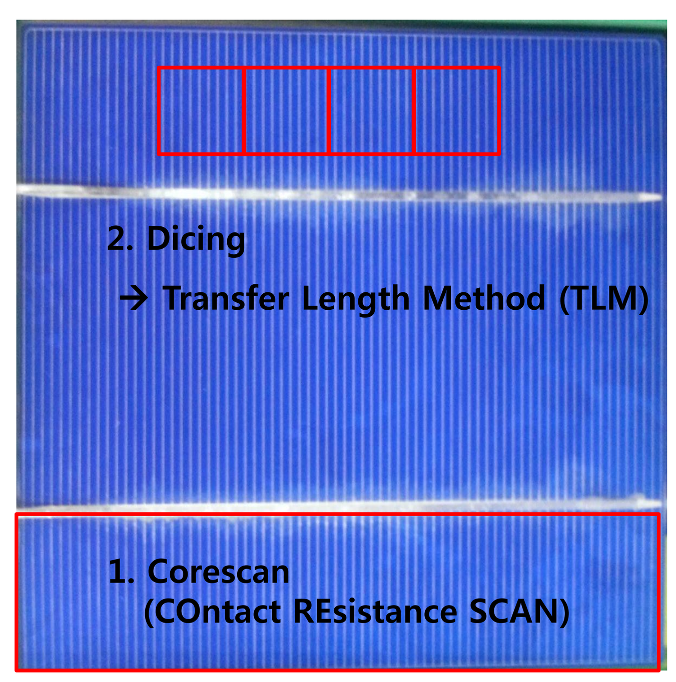
3. Suns-Voc

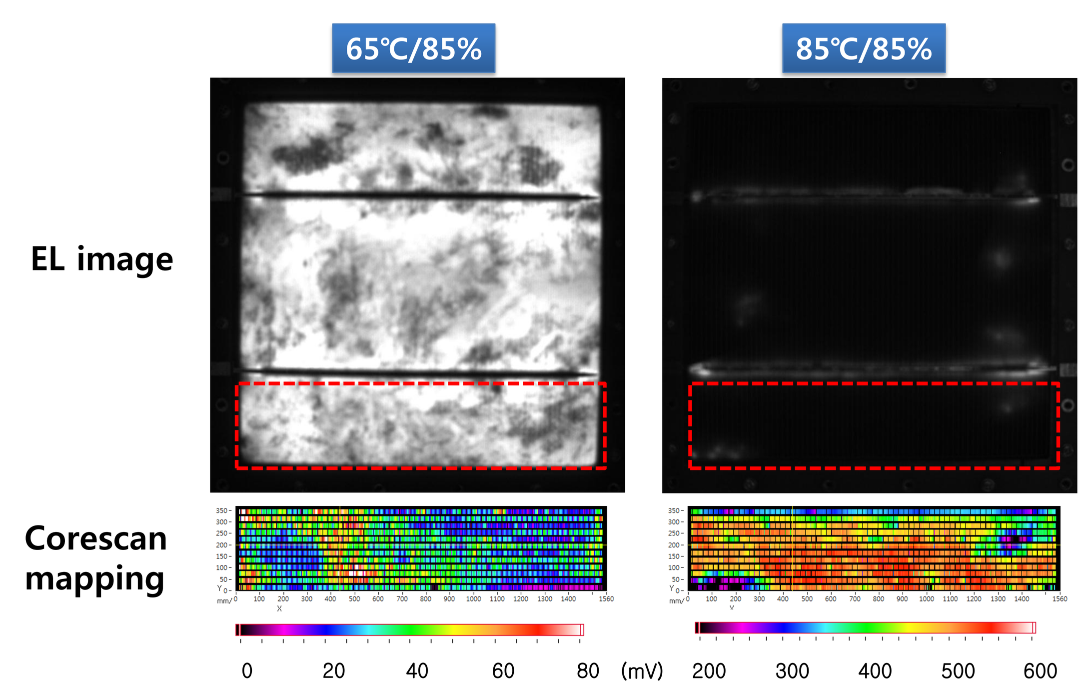
- Suns-Voc can measure pseudo Fill Factor (pFF).

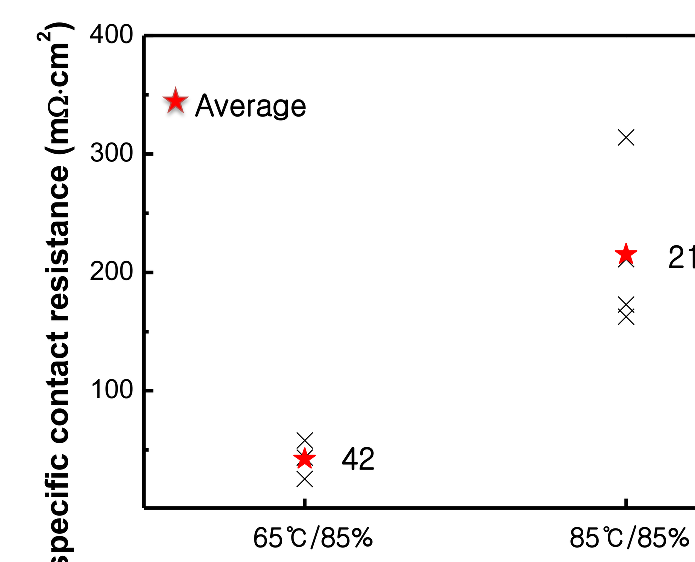
Samples	Jsc (mA/cm2)	pFF	FF	pFF-FF	FF_0	FF_0-pFF	Rs(Ω)	Rsh(Ω)
None	35.43	0.813	0.706	0.107	0.817	0.004	0.01	28.52
45℃/85%	36.30	0.805	0.665	0.140	0.810	0.005	0.013	9.658
65℃/85%	35.94	0.802	0.579	0.223	0.809	0.007	0.016	4.361
85℃/85%	18.87	0.814	0.287	0.527	0.823	0.009	0.076	0.124

- pFF - FF = FF loss by series resistance (Rs)
- FF0-pFF = FF loss by shunt resistance (Rsh)
- Low performance is due to series resistance, not shunt.

4. Measurement of contact resistance (Corescan, TLM after dicing)



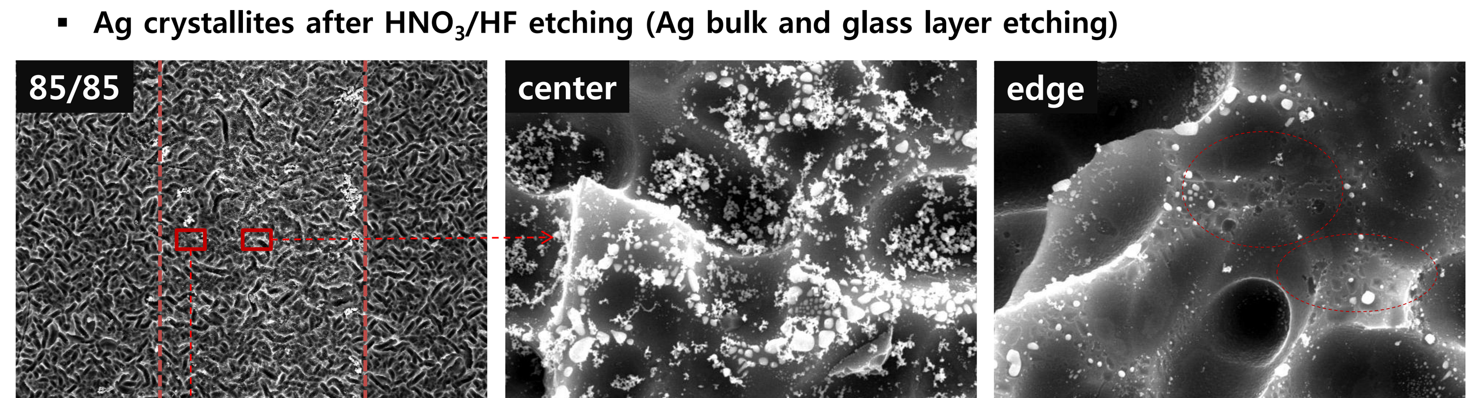




- Low performance in EL mainly depends on contact resistance between Si and Ag finger.
- Specific contact resistance(ρ_c) at 85/85 is 5 times bigger than that at 65/85
- Specific contact resistance measured by TLM is more correct than mapping by Corescan.

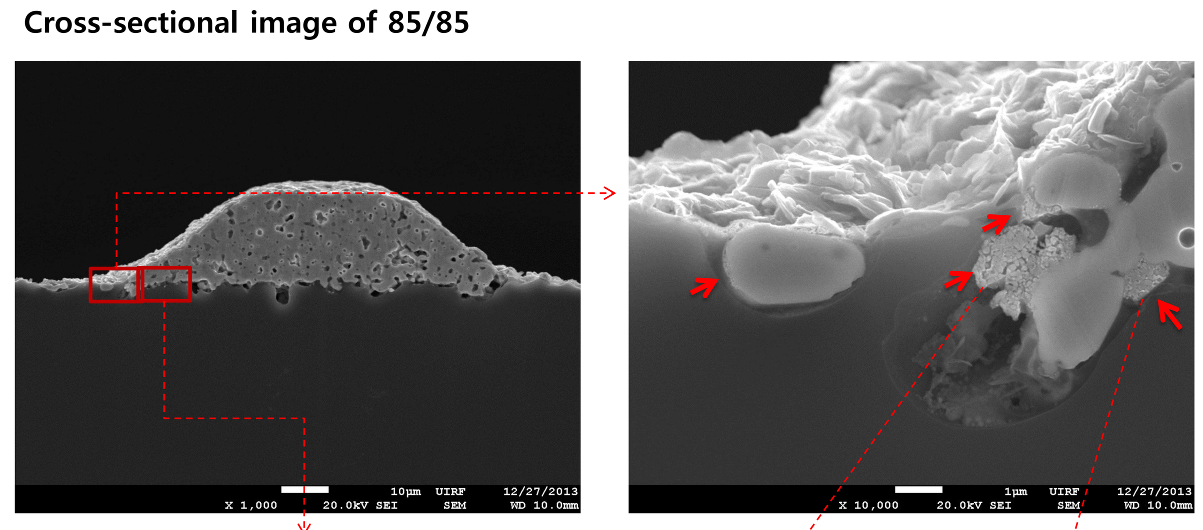
5. SEM image

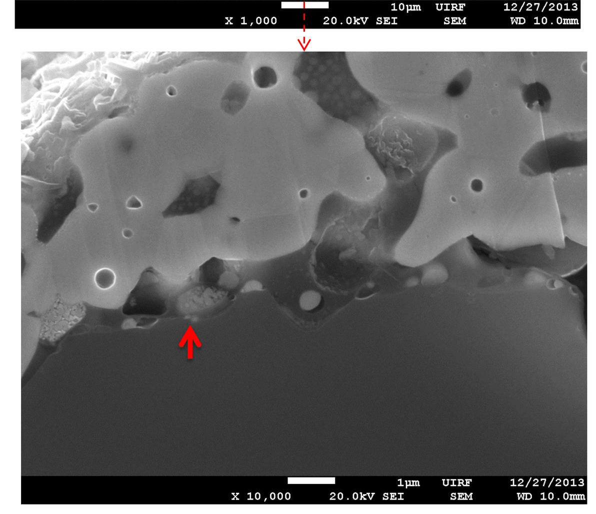
- Ag crystallites after HNO_3/HF etching (Ag bulk and glass layer etching)



- Density of Ag crystallites after etching : center >> edge

- Cross-sectional image of 85/85



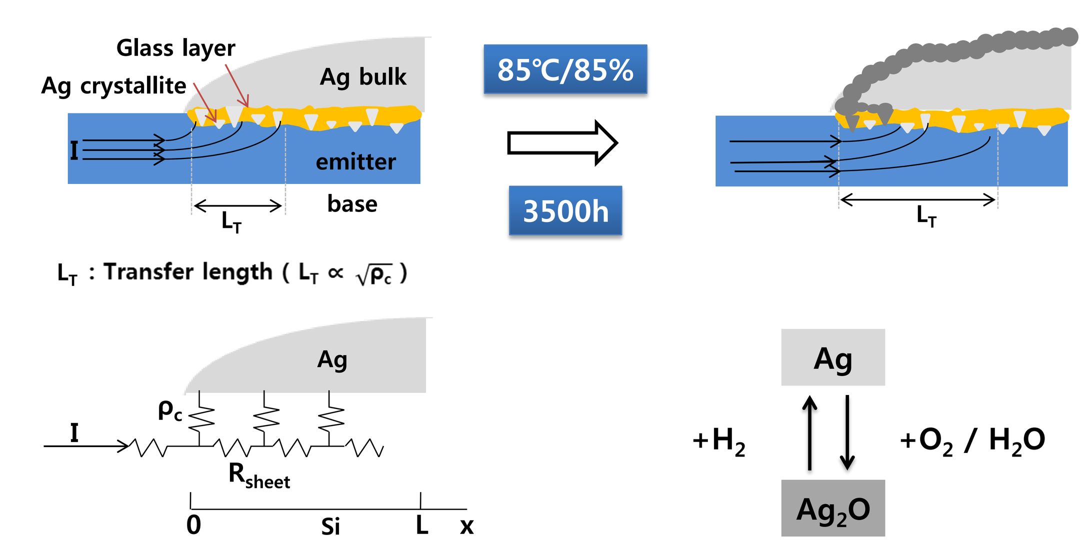


Element	Weight%	Atomic%
C K	18.03	46.39
O K	8.90	17.20
Si K	17.87	19.66
Cl K	2.94	2.56
Ag L	46.54	13.33
Pb M	5.73	0.85

Element	Weight%	Atomic%
C K	5.42	23.33
O K	3.91	12.62
Si K	13.17	24.22
Cl K	2.78	4.04
Ag L	74.72	35.79

- Detection of compound of Ag-Si-Pb-O in the edge of Ag finger

6. Mechanism of low contact resistance



Dieter K. Schroder, Semiconductor Material and Device Characterization, Third Edition 2008

- Degradation factors after DH test are :
  reduction of contact ribbon/Ag
  series resistance of Ag finger
  Ag/Si contact resistance

Summary

- We analyzed the degradation of solar cells after damp heat test. Samples were tested as unpackaged solar cells and over-stressed sufficiently under thermal and moisture conditions.
- Severe degradation by FF loss after damp heat condition (85/85) is due to contact resistance between Si and Ag finger. Especially, Ag bulk and crystallites in the edge of Ag finger were oxidized.

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