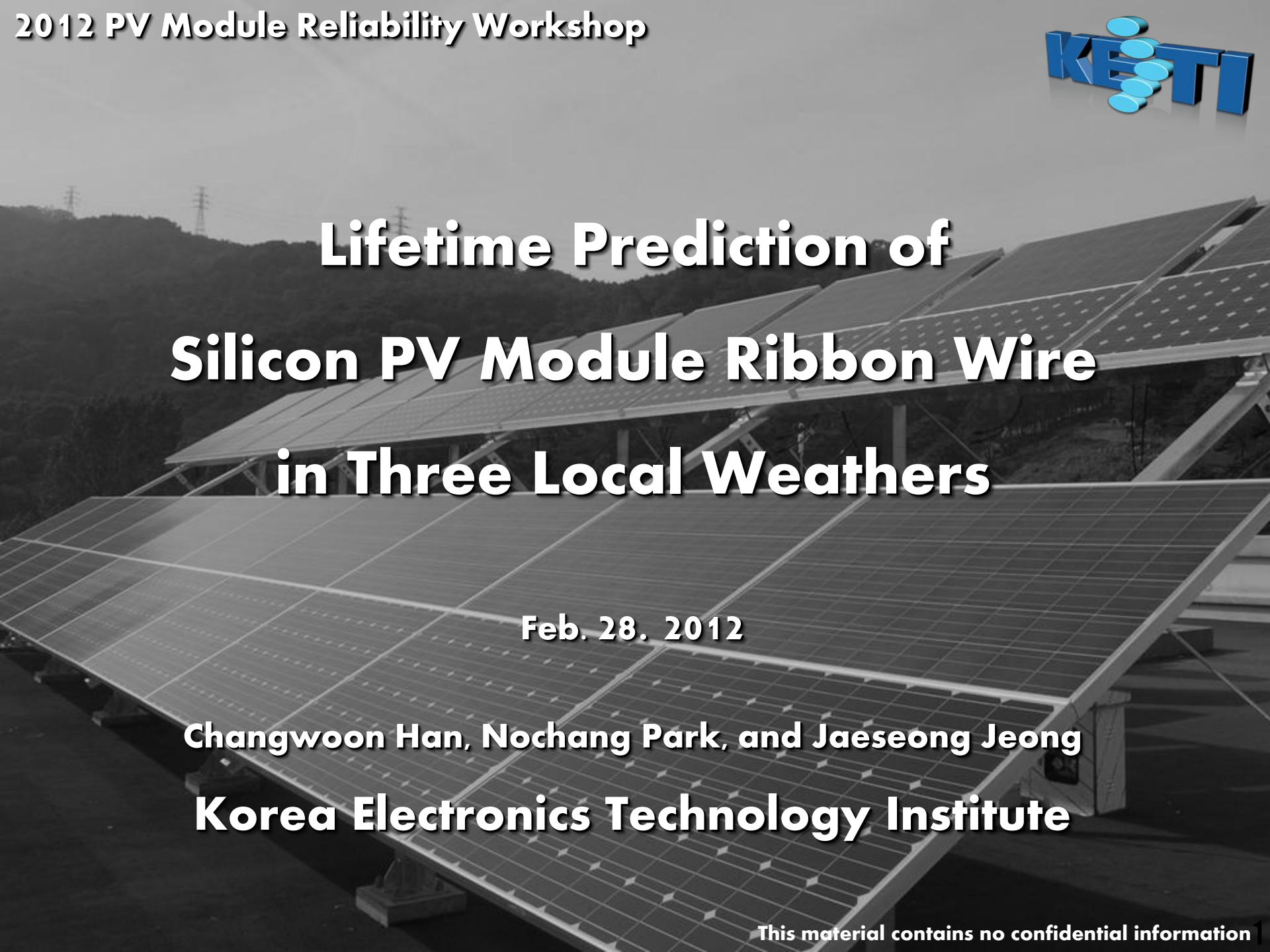


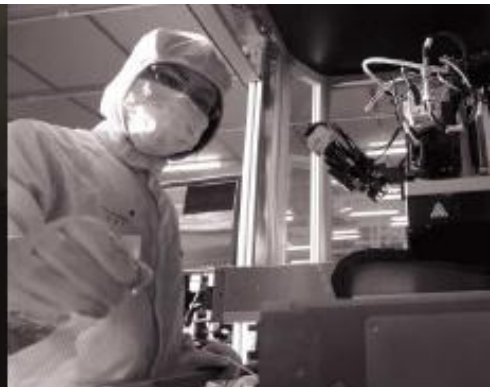
Lifetime Prediction of Silicon PV Module Ribbon Wire in Three Local Weathers

Feb. 28. 2012

Changwoon Han, Nochang Park, and Jaeseong Jeong

Korea Electronics Technology Institute

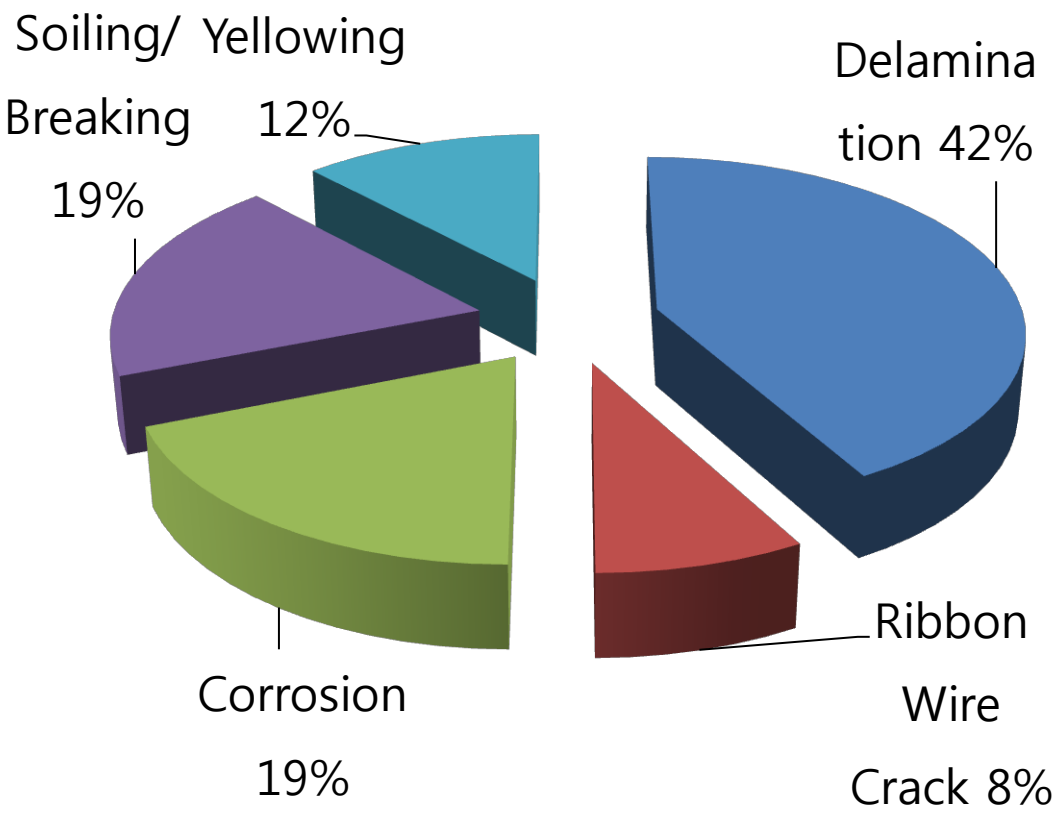
Who are we?



Located at South Korea, More than 600 Research Engineers

Research Areas : Component & Material, Energy & Display, System IC

Silicon PV Module : Failure Modes



References

1. K.Morita et al., Degradation factor analysis of crystalline-si PV modules through long-term field exposure test, 3rd World conference on photovoltaic energy conversion, 2003.
2. A.R. Gxasheka et al., Evaluation of performance parameters of PV modules deployed outdoors Renewable Energy 30, 2005.
3. E. D. Dunlop et al., 20 Years of Life and More : Where it the end of life of a PV Module Photovoltaic Specialists Conference, 2005.
4. Y. Hishikawa et al., Field Test results on the stability of 2400 PV modules manufactured in 1900's, 3rd World conference on photovoltaic energy conversion, 2002.
5. M.A. Quintana et al., Diagnostic analysis of Silicon PV Module 20 Years field exposure, Photovoltaic Specialists Conference, 2000.
6. K. Otani et al., Performance and reliability of MW PV Power facilities in AIST," Photovoltaic Energy Conversion Conference, 2006
7. E. D. Dunlop, Lifetime performance of crystalline silicon PV Module, 3rd World conference on photovoltaic energy conversion, 2003.
8. E.E. van Dyk et al., Investigation of Delamination in an edge-defined film-fed growth PV module, Solar Energy Materials & Solarcell 88, 2005.
9. A.Realini et al, Mean time before failure of PV, Active solar energy PV Program in Swiss, 2002.
10. J. H. Wohlgemuth, Long term Reliability of PV module, NCPV and Solar Program review meeting, 2003.

R/W Failure Reported in Literatures

Failure Location	Failure Mode	Failure Stress	Failure Mechanism	Figures
Solder–Ag Ink Interface	Crack, Voids	Thermal Cycling 1000cycle (-40℃ ~ 80℃)	Thermo-mechanical Fatigue	Ref.1
Solder–Ag Ink Interface	Crack	Field Failure	Thermo-mechanical Fatigue	Ref.2

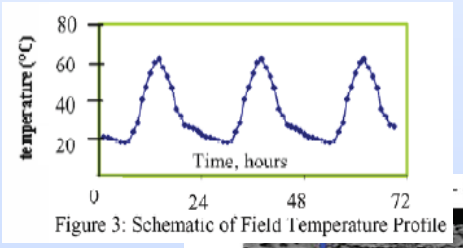


Figure 3: Schematic of Field Temperature Profile

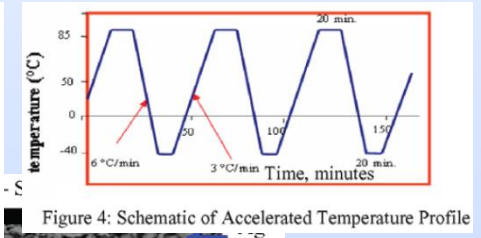


Figure 4: Schematic of Accelerated Temperature Profile

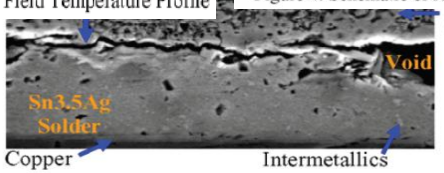


Figure 6: ESEM Image of Sn3.5Ag Solder PV Laminates subject to 1000 Thermal Cycles, Showing the Cracks and Voids in Close to the Solder – Ink Interface

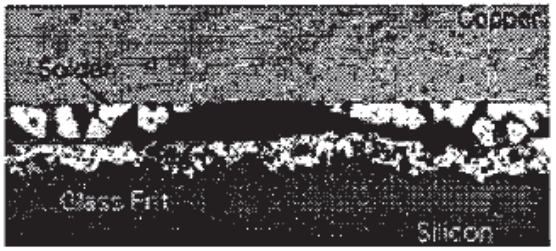
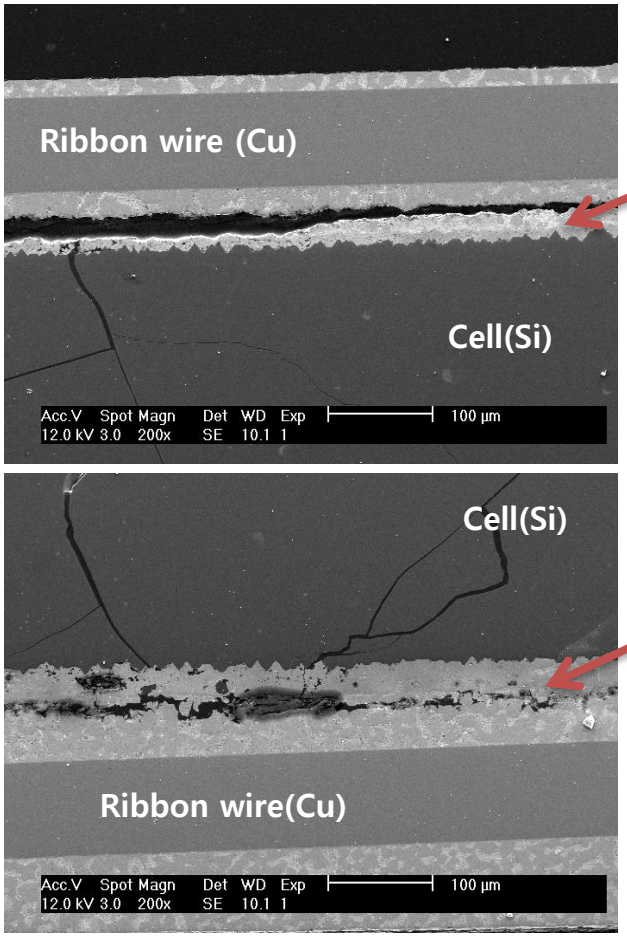


Fig. 3. Solder-joints from two field-aged modules show some coarsening. The 20-year-old joint (top) was more robust while the bottom joint showed voids and dewetting.

1. G. Cuddalorepatta et al., "Durability of Pb-Free Solder Connection between Copper Interconnect Wire and Crystalline Silicon Solar Cells - Experimental Approach," 2006
2. M.A. Quintana et al., "Commonly Observed Degradation in Field-aged Photovoltaic Modules," 2002

Failure Analysis : 25 year-old PV

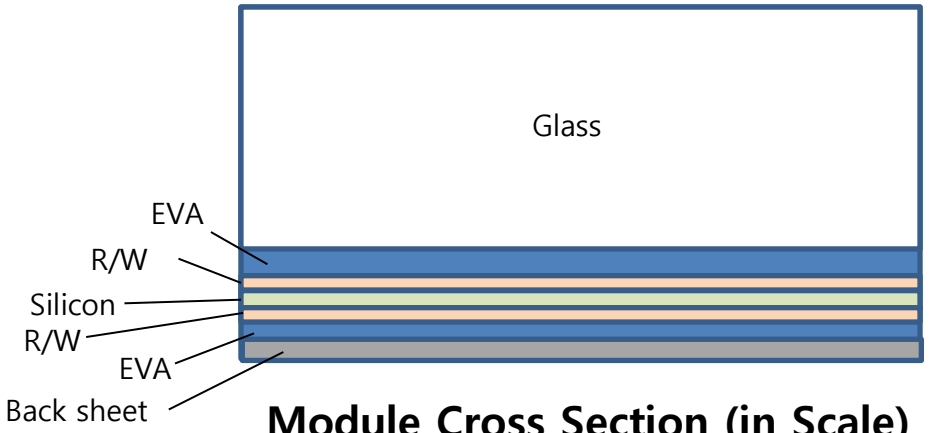
25 year-old PV Module



Failure Analysis Conducted.

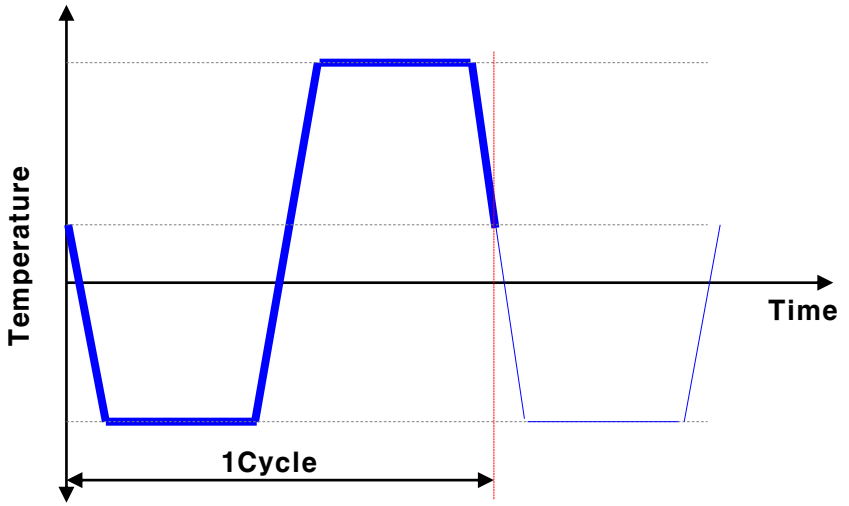
Failure Mechanism Validation

Silicon PV Module



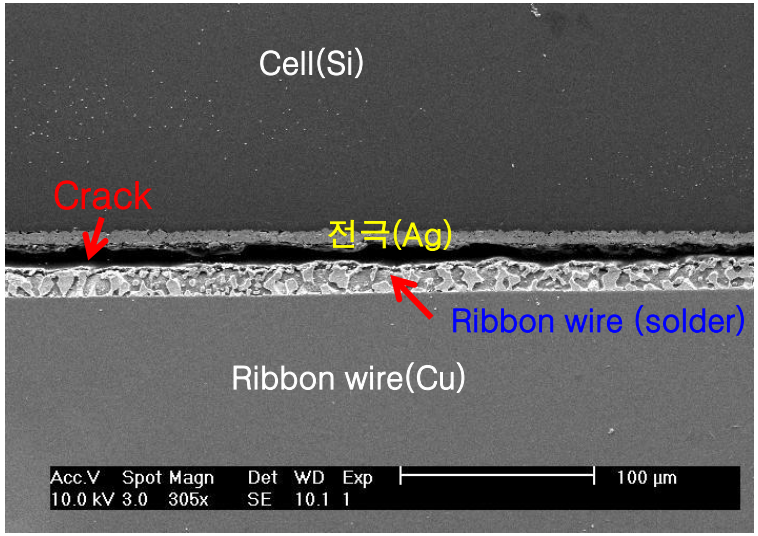
Module Cross Section (in Scale)

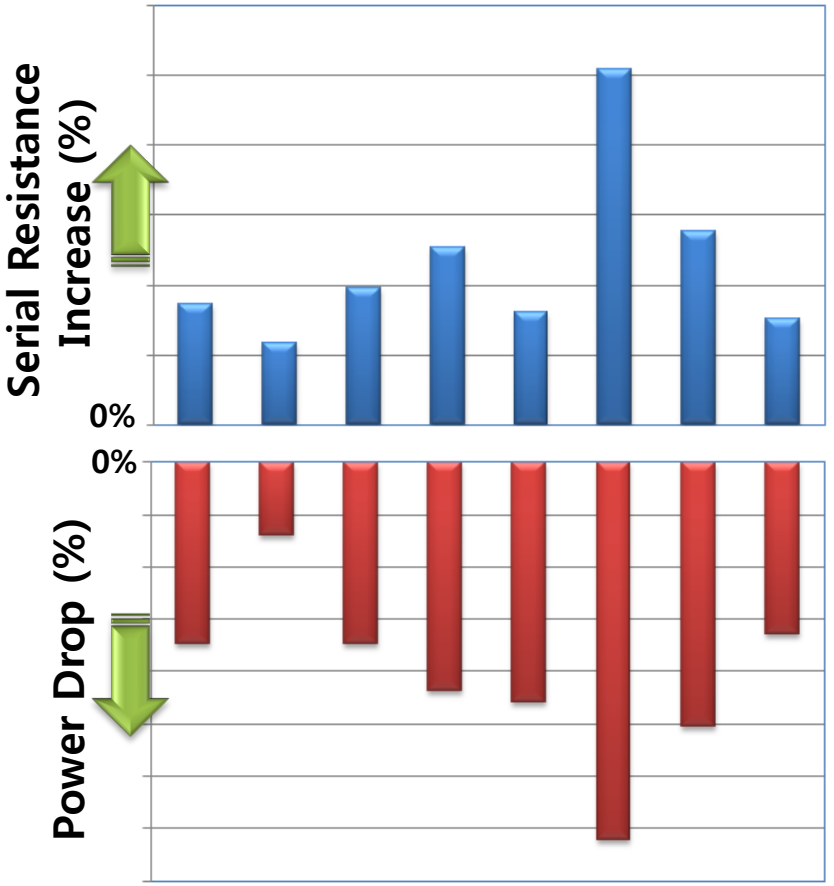
Thermal Cycling Chamber



Thermal Cycling Profile (1,000 Cycling)

Failure Mechanism Validation

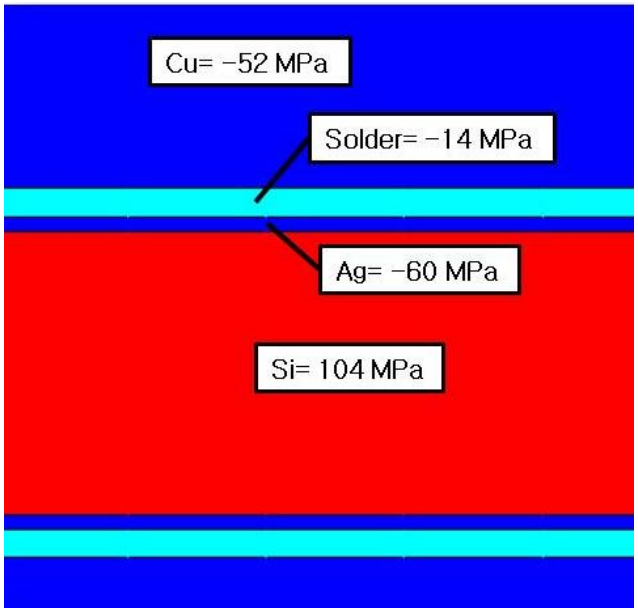


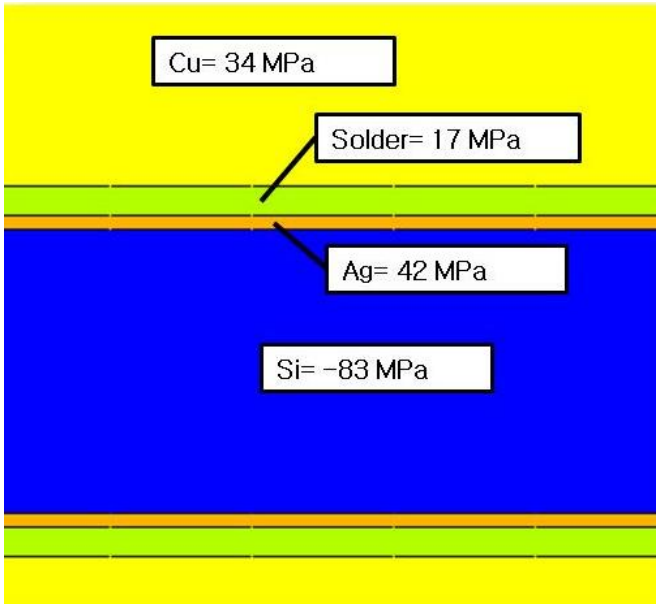


Failure Mechanism Validation

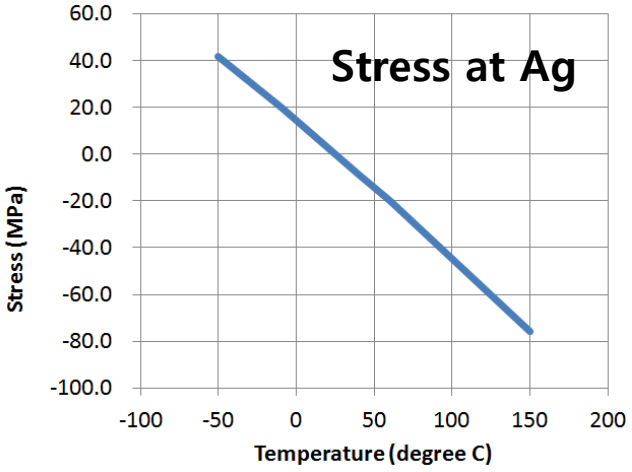
Finite Element Analysis

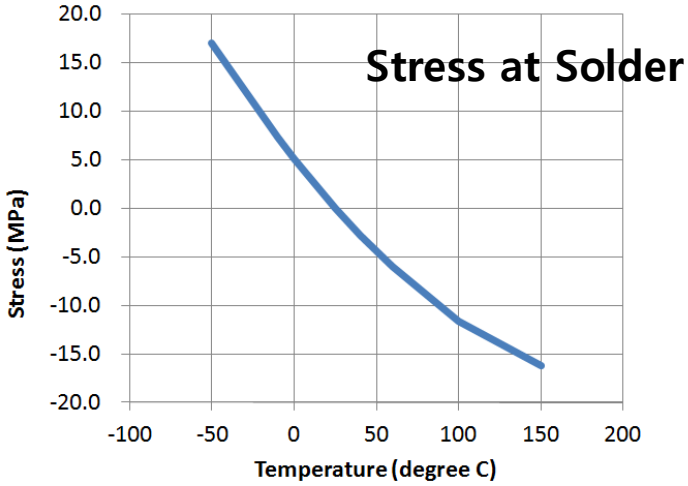
At High Temperature





At Low Temperature





Accelerated Life Test Design

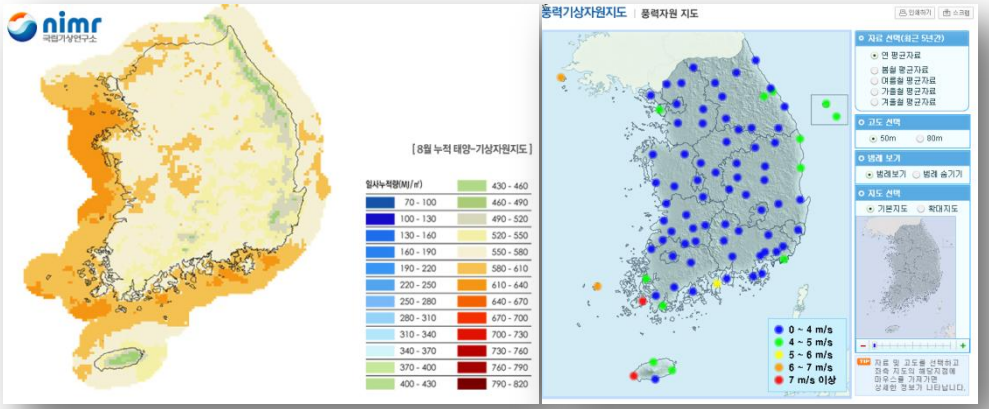
1

Weather data : Temp,

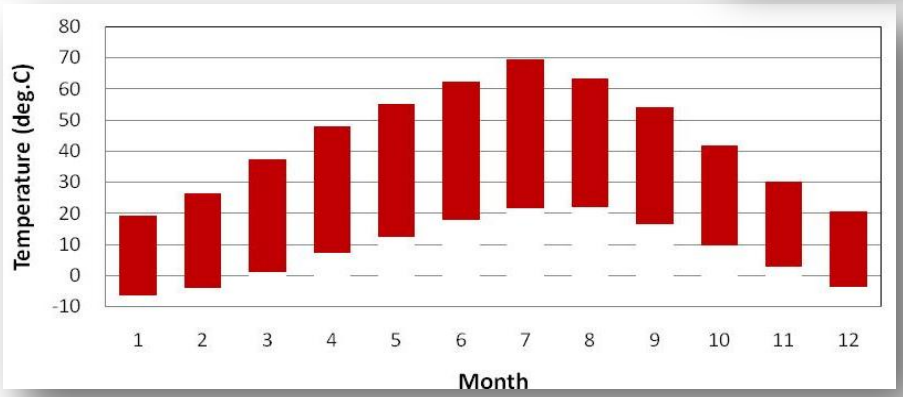
Irradiance,

Wind Speed

$T_m - T_{amb} = Irradiance * exp(-2.98 - 0.0471 * WS)$



2



Module Temperature Variation (Seoul)

T_mean = 7 ~ 46 ℃

Delta _T = 24 ~ 48 ℃

3

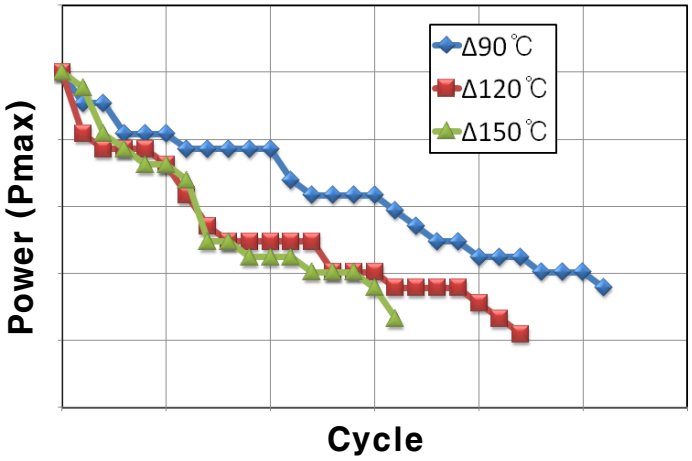
Three accelerated test conditions design

No.	T_low (℃)	T_high (℃)	△T (℃)
1	-20	70	90
2	-35	85	120
3	-50	100	150

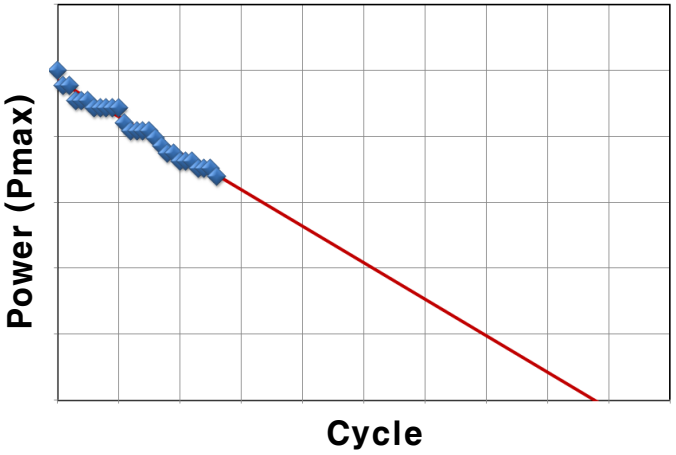
Life Prediction Model Development

1

Test Data

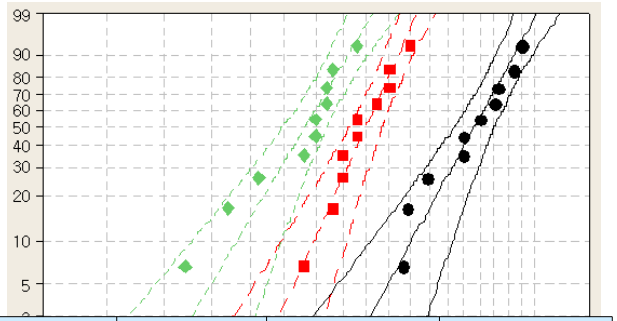


Linear Extrapolation



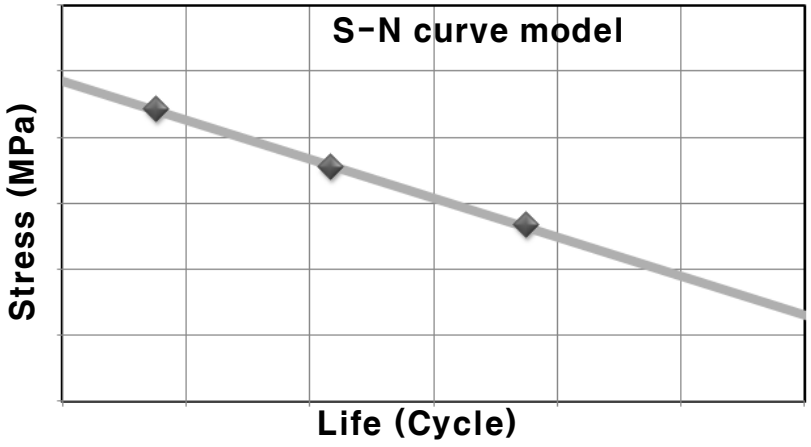
2

Lifetime Calculation

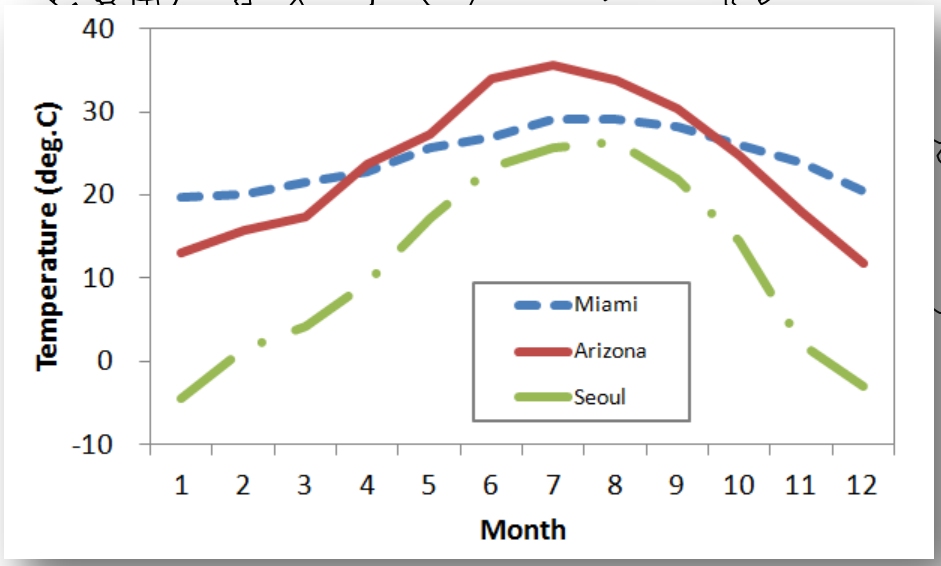


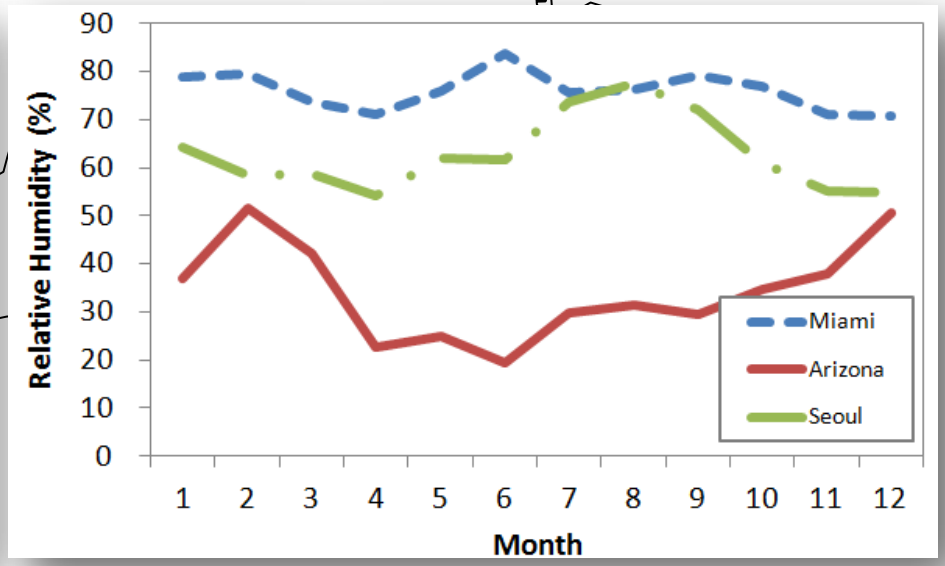
Test condition	△T : 90	△T : 120	△T : 150
Lifetime (cycles)			

Life Prediction Model Development



Weather Data : Three Cities





Lifetime Prediction at Local Cities

1

$$D = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_2}{N_2}$$

Miner's linear damage rule

Month	Day	Minimum Module Temp.(℃)	Maximum Module Temp.(℃)	Module Temp . Change △T	Stress at Min. Temp. (MPa)	Stress at Max. Temp. (MPa)	Stress Change (MPa)	Expected Life (N)	Damage on Life
1	1	-13	7	20	21.6	9.9	11.7	13223	7.56258E-05
1	2	-7	7	14	18.5	10.2	8.3	14128	7.07818E-05
1	3	-11	9	20	20.3	8.5	11.8	13209	7.57038E-05
1	4	-8	2	10	18.8	13.0	5.8	14837	6.7398E-05
1	5	-12	5	17	21.4	11.1	10.2	13611	7.34675E-05
1	6	-13	4	17	21.9	11.7	10.2	13630	7.33697E-05
1	7	-14	6	20	22.1	10.4	11.7	13226	7.56083E-05
...	...	Module Temperature			..	Module Stress		Expected Life	Damage = 1/Life
12	30								

2 **Lifetime Prediction**

City	Miami	Arizona	Seoul
Lifetime	34 years	31 years	36 years

Thank you!

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Feb. 28. 2012

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