UV-Thermal Combined Stress Acceleration Test

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Background and Purpose

Over 30 years long life PV module is expected

ΔPm as the index of degradation is very small.
⇒To evaluate 30 years life time, it needs few months even if combined stress acceleration test is adopted.

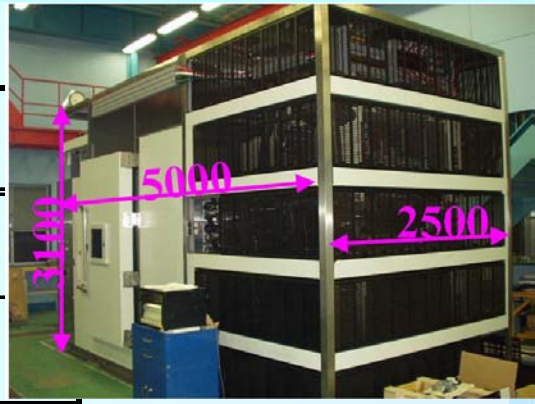
In the STD's test, long term thermal stress tests are performed without light irradiated stress.

Purpose is to figure out the acceleration rate of the UV-thermal combined stress test and to find out what type of failure appears.

Experimental apparatus

Specifications

item	spec
temperature control (w/ o irradiation)	- 40 ~ +90 ℃
temperature control (w/ irradiation under 3UV)	+50 ~ +90 ℃
humidity control (w/ o irradiation over room temp.)	(max) RH 85± 5%
maximum irradiance	3 UV
temporal instability of irradiance	under 10%
non- uniformity of irradiance in the test plane	under 15%
maximum sample size	1218H x 445W
sample capacity	3 panels



Acceleration Test: UV-Thermal Combined Stress

Testing recipe

(1) continuous irradiation and high temperature [HT.Irr]

Test : HT.Irr

continuous irradiation: 3UV or 1UV
module temperature: 90℃ or 65℃
output terminal: open

Degradation of window materials

(2) TC w/ irradiation @ high temperature [TC.Irr]

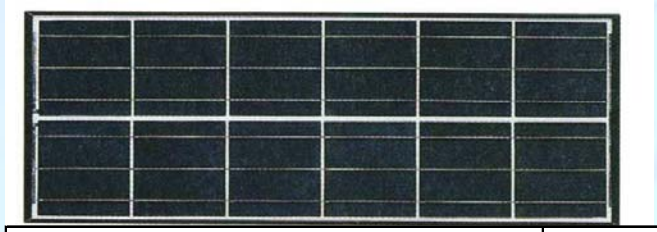
Test : TC.Irr

irradiation @ high temperature: 3UV
module temperature: 75℃ 1hr, -20 ℃ 1hr
(2hr / 1cycle), repeat cycles
output terminal: open

Test modules

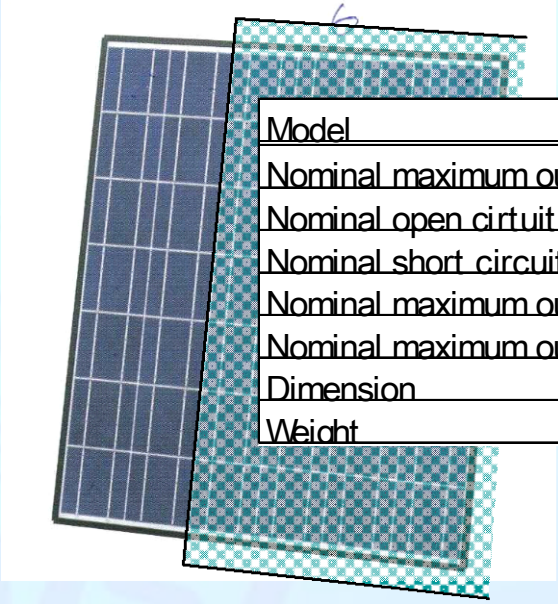
2 models (companies) were selected as test modules.
Outdoor exposure test has started since 2007 in Miyakojima, Okinawa by JET.

Module A



Model	xxxx
Nominal maximum output	45W
Nominal open cirtuit voltage	6.0V
Nominal short circuit current	7.50A
Nominal maximum output voltage	7.4V
Nominal maximum output current	8.28A
Dimension	W972 x L345 x H8
Weight	3.7 kg

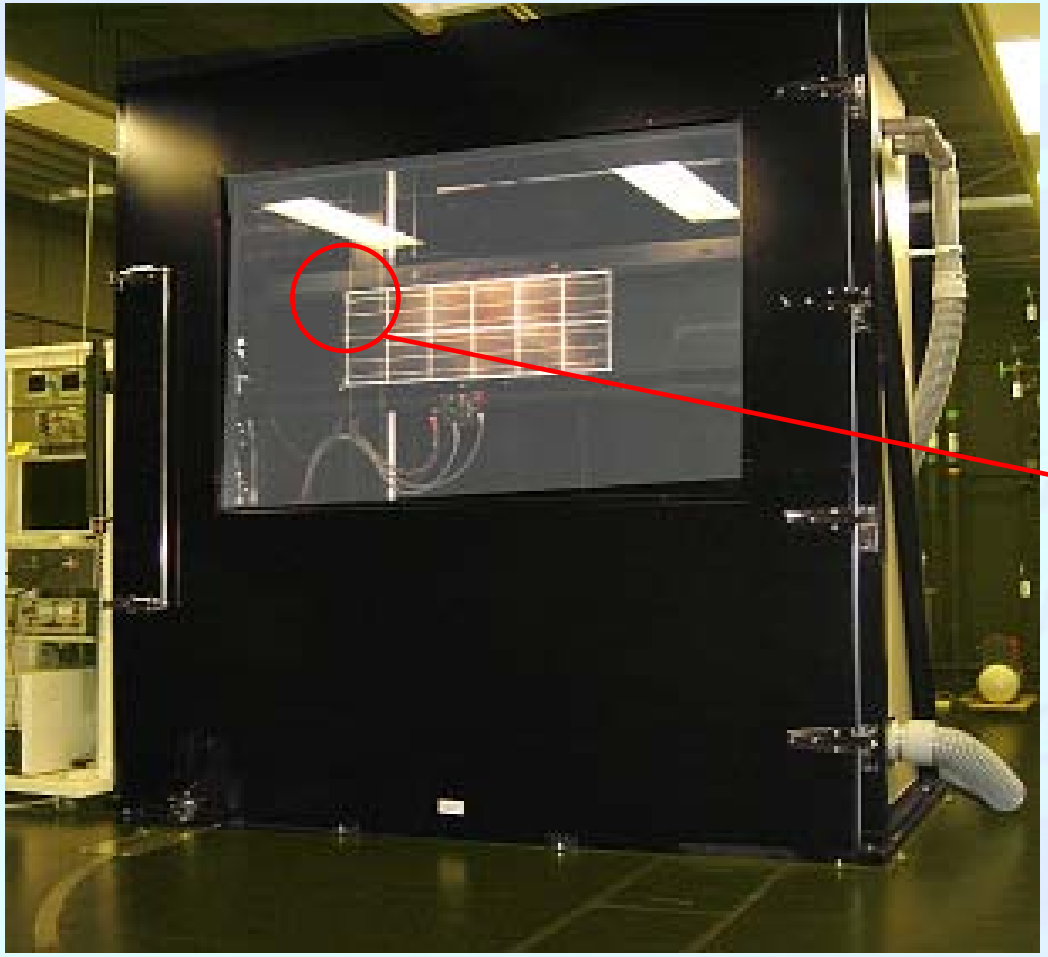
Module-B



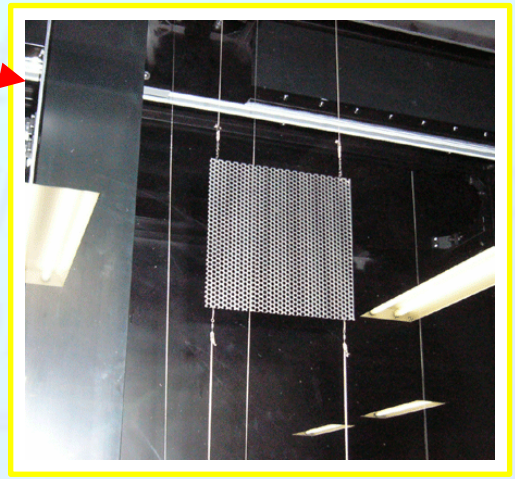
Model	xxxx
Nominal maximum output	153W
Nominal open cirtuit voltage	25.61V
Nominal short circuit current	8.21A
Nominal maximum output voltage	20.30V
Nominal maximum output current	7.54A
Dimension	1165 x 990 x 46mm
Weight	14.5kg

Module A（multi-crystalline 156mm x 156mm 12 cells, 972H×345W）
Module B（multi-crystalline 156mm x 156mm 14 cells, 1180H×355W）

Isolation of IV curve



Dimmer board with xy moving mechanical was equipped in the thermostatic chamber to obtain single cell's IV curve from the module IV curve.



Evaluate ΔIsc of each cell as degradation index

Degradation factors, estimation of acceleration ratios

Test : HT.Irr

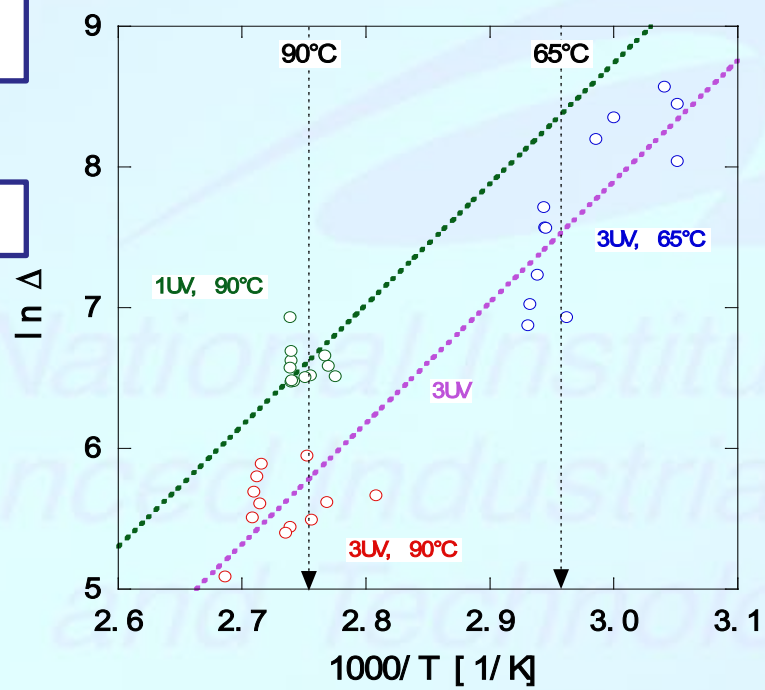
Temp. : Arrhenius's law

Irrad. : n-th power law

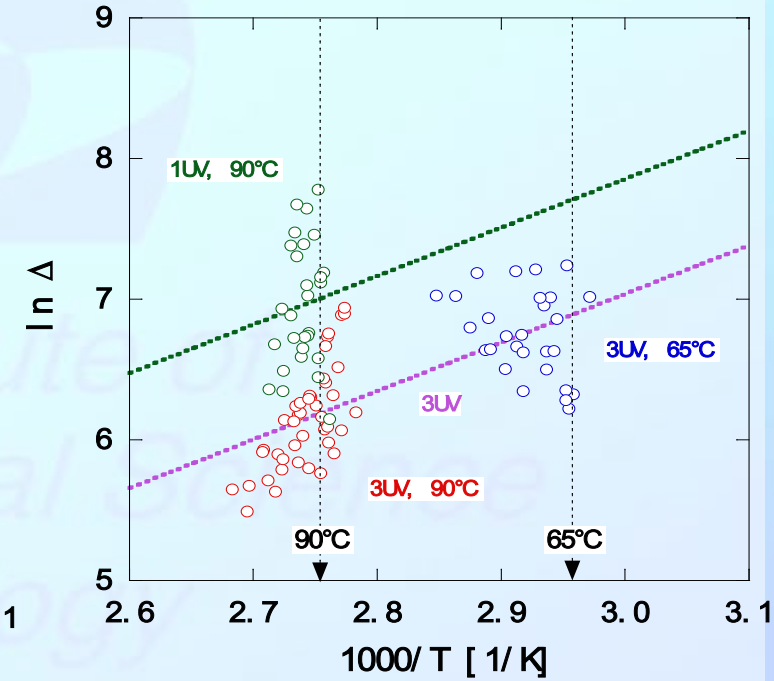
Calculate each factor

Each factor was affected by module model.

Module A



Module B



	Module A	Module B
activation energy	Ea = 0.75±0.05 eV	Ea = 0.30±0.05 eV
factor for irrad.	n = 0.75±0.15	n = 0.75±0.15
acceleration ratio	45～150	10～40

Calculation of acceleration ratio

Basis (Tokyo) : T_0 = 60℃ , A_0 = 3.6kWh・ m^{-2}/day
Test condition : T_t = 90℃ , A_t = 3UV・ 24hr irradiation
→calculate the acceleration ratio "α"

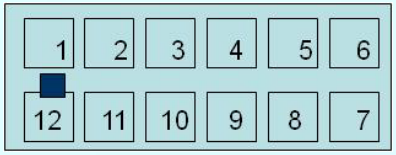
$$\alpha = \left(\frac{A_t}{A_0}\right) \exp\left\{\frac{E_a}{k}\left(\frac{1}{T_0} - \frac{1}{T_t}\right)\right\}$$

	Module A	Module B
acceleration ratio	**45～150**	**10～40**

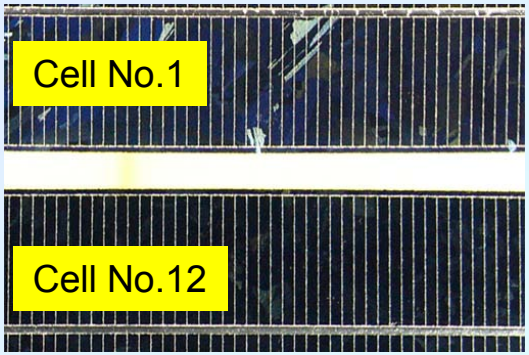
Delamination from TC w/ Irrad

Module A-35 , Cell No. : 1 and 12 (output terminal : Open)

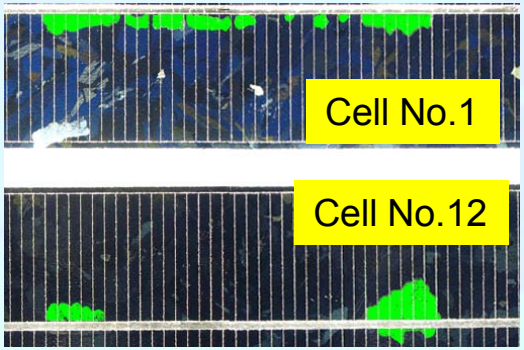
Test : TC.Irr



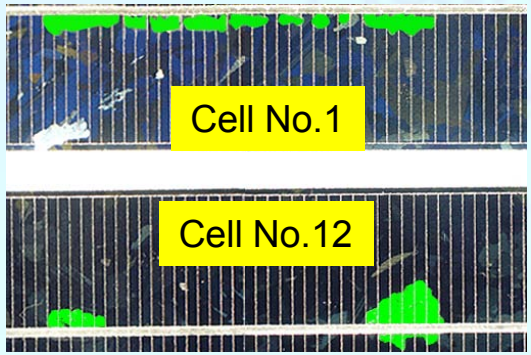
Relative position - cell No. and J-Box:
■ indicates J-BOX viewed from the back sheet side of module.



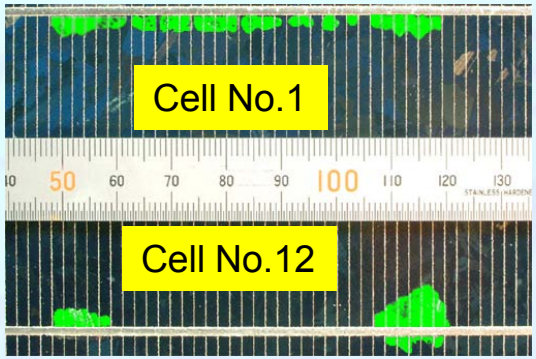
0hr



50hr



150hr



250hr

Condition : 3UV, module temp. 75℃ ~ 0UV, module temp. - 40℃, TC

Control test: TC w/o Irrad, delamination occurred
⇒ Delamination originates from thermal cycle

Additional test modules

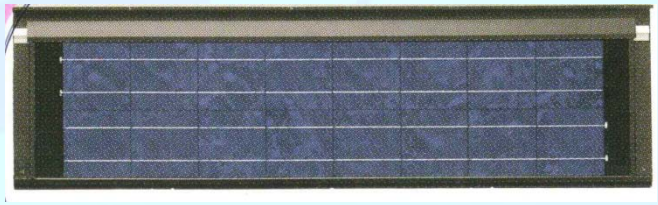
Test ： TC.Irr

Module C

'07 purchased

1209×330×34.9

Pm=38W, Vpm=7.74V, Ipm=4.91A,
Voc=9.70V, Isc=5.40A



Failure: swells in back sheet appeared

Module D

'09 purchased

1228×280×29.7

Pm=38W, Vpm=7.74V, Ipm=4.91A,
Voc=9.70V, Isc=5.40A

No Failure

Swells in back sheet

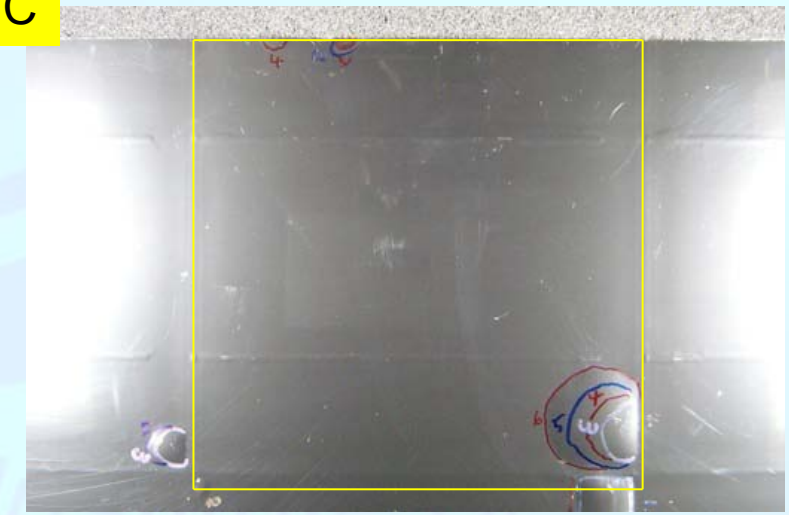
test recipe	cumulative test hours	line No.
3UV, 90degC	230	1
3UV, TC 75degC ~ - 20degC	280	2
	330	3
3UV, TC 75degC ~ - 40degC	380	4
	480	5
	580	6

8	7	6	5	4	3	2	■ 1
9	10	11	12	13	14	15	16

Relative position - cell No. and J-Box:
■ indicates J-BOX viewed from the back sheet side of module.

Pictures represent swells: Similar swells appeared in other cells in No. 5, 6, 7, 9, 10, 11, 12, 13, 14, 16.

Module C

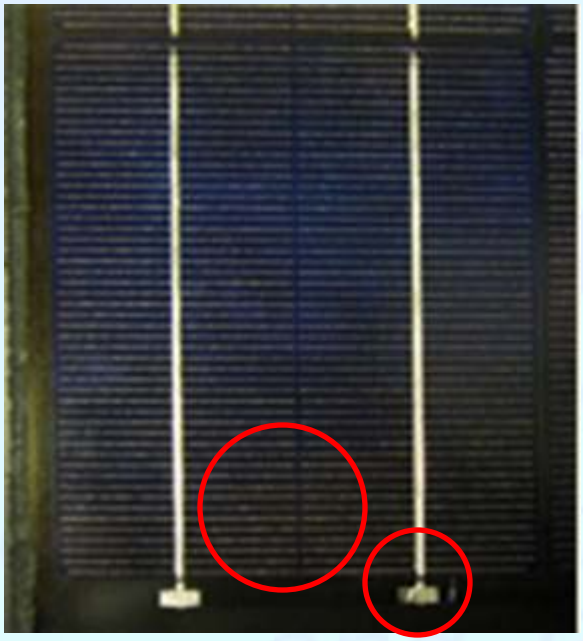


Cell No. 4

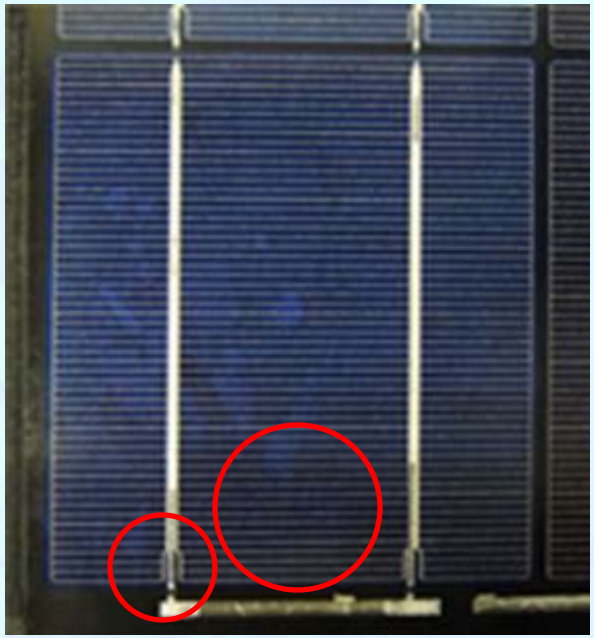
Cell No.8

Improvement?

Module C | ‘07 purchased



Module D | ‘09 purchased



Finger electrodes: separated in center → continuous lines

J-BOX : small → large

Conclusion

(1) As for the factor for irradiation, the difference between module A and B was small, but that for temperature, it was large.

(2) The acceleration ratio obtained from UV-thermal combined stress test was about 100. Degradation of window materials is not so large.

(3)From TC.Irr test, it was shown that cell design such as finger electrode or J-Box affects on failures.

Thank you for kind attention!

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