Results of Field Tests in Japan

International PV Module Quality Assurance Forum

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Moscone Center, San Francisco, CA, US

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Goal of our research

Specifying degradation factors for lifetime-evaluation corresponding to outdoor exposure during 20 ~ 30 years

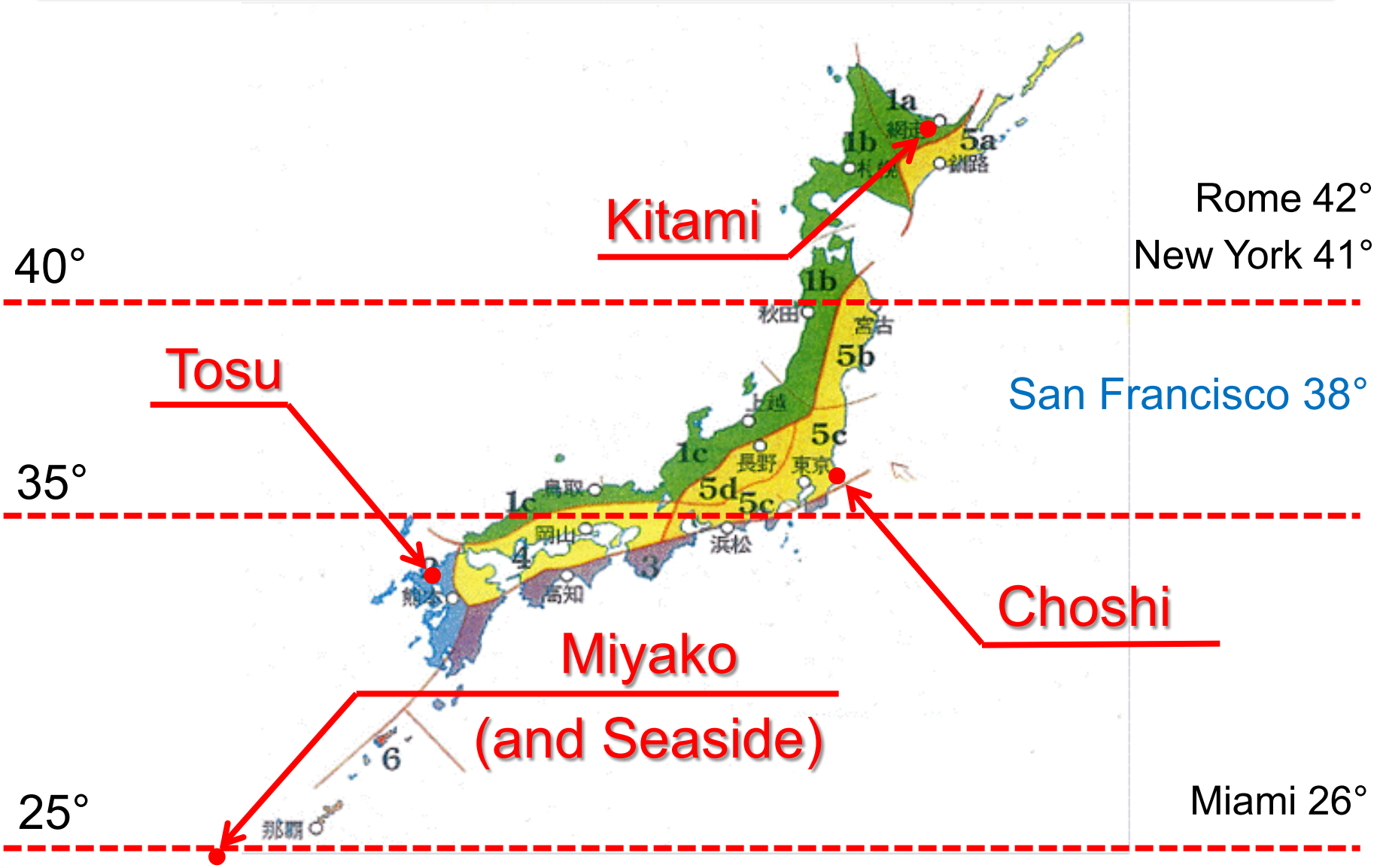
Research by AIST

Data acquisition

- Outdoor exposure test in Japan
  - Kitami
  - Choshi
  - Tosu
  - Miyako
  - Seaside
- Investigation of PV modules at field tests
  - Domestic system — Various operating periods
  - Foreign system — Various meteorological envirionment
- Literature research
  - Various academic literatures

Outdoor exposure test in Japan

Sites of outdoor exposure test



Appearance at each site

Since 1991

Since 1992

Since 1992

Since 1992

Since 2007

(State in 2009)

Stress factors

All stress factors are defined as ratio to Tosu.

Items	Definition	Expressions
UVA, UVB	Ratio of UV irradiation (A and B respectively)	$SK_{\mathrm{UVA}} = \frac{H_{\mathrm{UVA}}}{H_{\mathrm{UVA\ Tosu}}}$ $SK_{\mathrm{UVB}} = \frac{H_{\mathrm{UVB}}}{H_{\mathrm{UVB\ Tosu}}}$
T_{m}	Half-law* using difference in temperature of modules between sites	$SK_{\mathrm{MT}} = 2^{\frac{(T_{\mathrm{m}} - T_{\mathrm{m\ Tosu}})}{10}}$
ΔT_{m}	Ratio of difference in temperature of modules at each site	$SK_{\mathrm{MTG}} = \frac{\Delta T_{\mathrm{m}}}{\Delta T_{\mathrm{m\ Tosu}}}$
Relative humidity	Half-law* using difference in relative humidity between sites	$SK_{\mathrm{RH}} = 2^{\frac{(RH - RH_{\mathrm{Tosu}})}{10}}$

*Half-law is an empirical rule that characteristics decrease by half by the increase in 10 ºC.

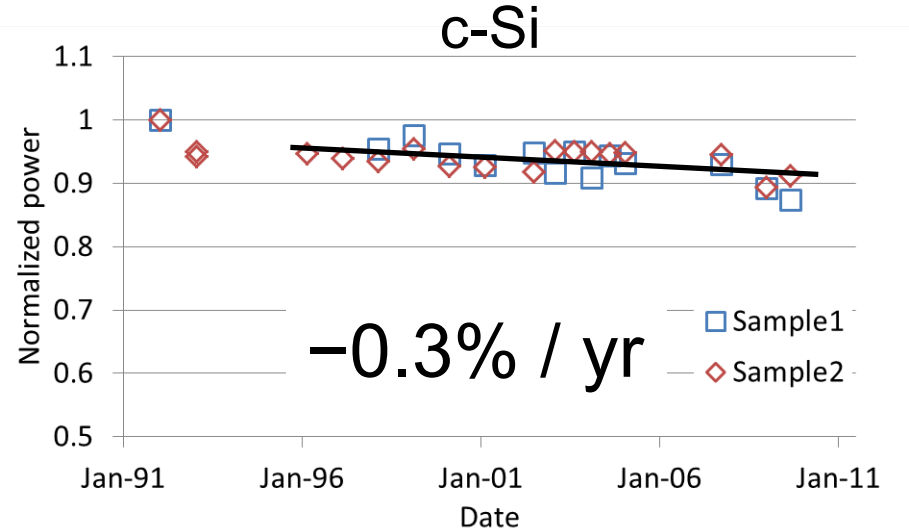
Comparison of stress factors

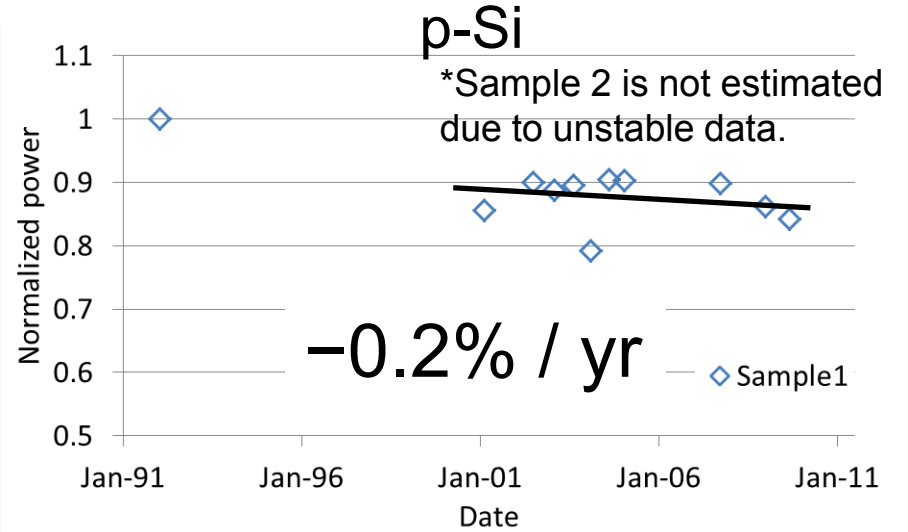
	Tosu	Kitami	Miyako	Choshi
UVA	1.0	0.9	1.5	1.3
UVB	1.0	0.5	1.8	1.5
T_m	1.0	0.5	1.6	0.9
ΔT_m	1.0	1.1	0.7	0.8
Relative humidity	1.0	0.4	0.8	0.8

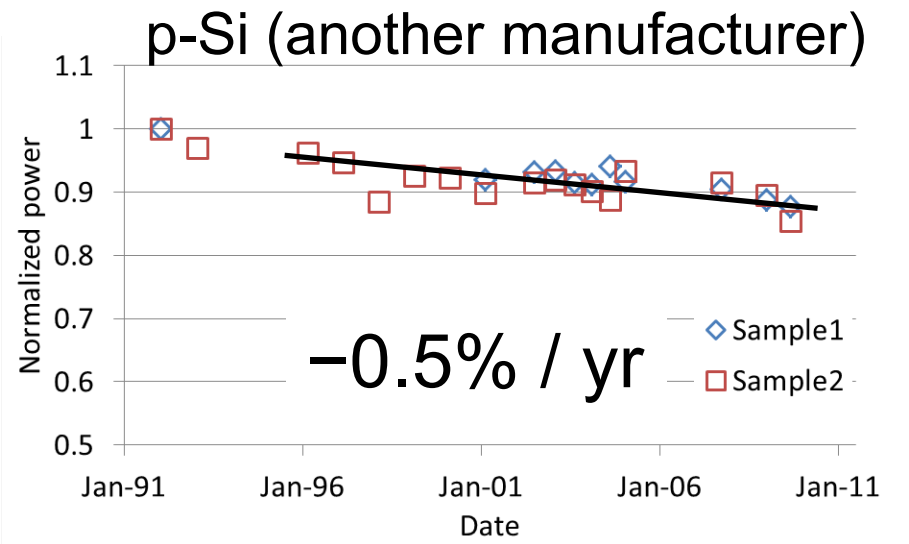
Test samples at each site

	Tosu	Kitami	Miyako	Choushi
c-Si (A)	2 modules	2 modules	3 modules	—
p-Si (B)	2 modules	2 modules	2 modules	—
p-Si (C)	2 modules	2 modules	2 modules	—
c-Si (D)	—	—	3 modules	3 modules
p-Si (E)	—	—	3 modules	3 modules
a-Si (F)	—	—	3 modules	3 modules

Power degradation in Tosu



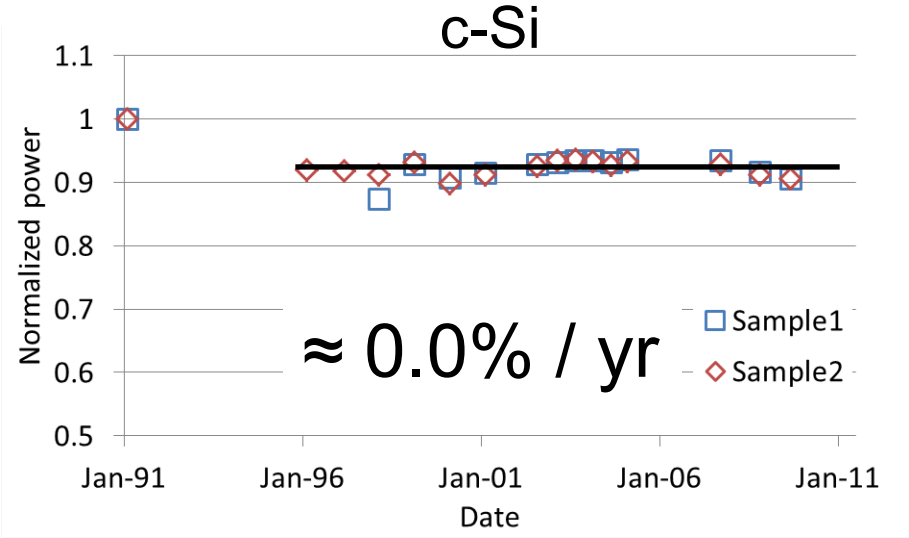


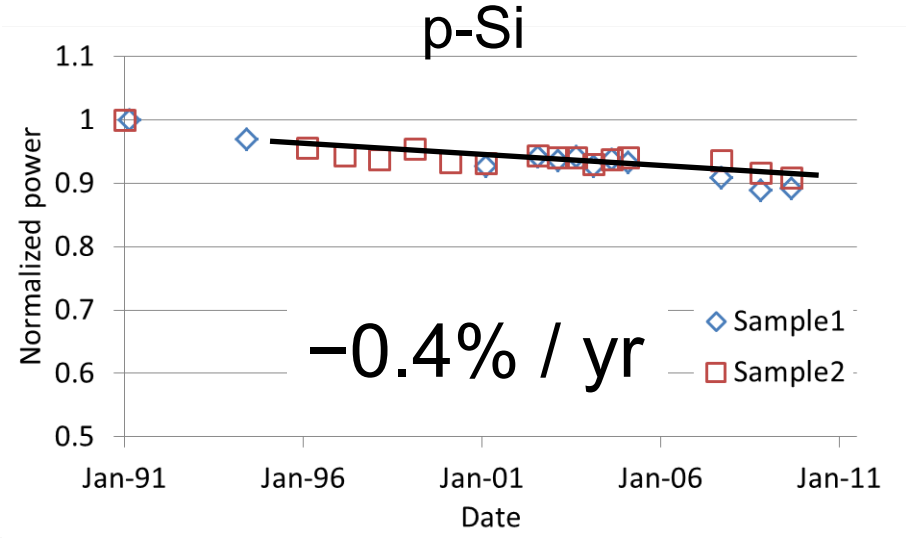


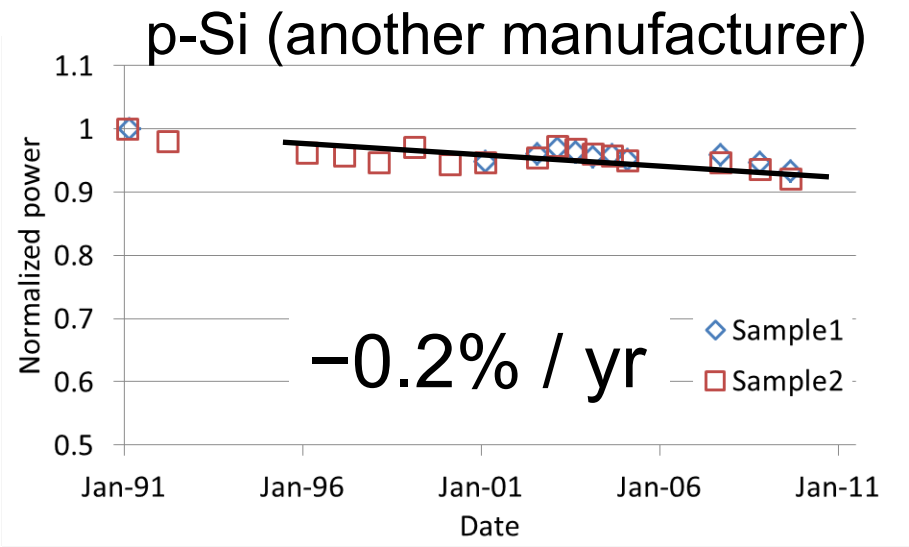
Power degradation rate is good agreement with other reports about long term exposure. [1–3]

1. J. H. Wohlgemuth *et al.*, *LONG TERM RELIABILITY OF PV MODULES*, Photovoltaic Energy Conversion, Conference Record of the 2006 IEEE 4th world conference.
2. D. Chianese *et al.*, *ANALYSIS OF WEATHERED c-Si PV MODULES*, 3rd WCPEC, Osaka, May 2003.
3. M. A. Quintana *et al.*, *DIAGNOSTIC ANALYSIS OF SILICON PHOTOVOLTAIC MODULES AFTER 20-YEAR FIELD EXPOSURE*, 28th IEEE PV Specialists Conference, Anchorage, 2000.

Power degradation in Kitami

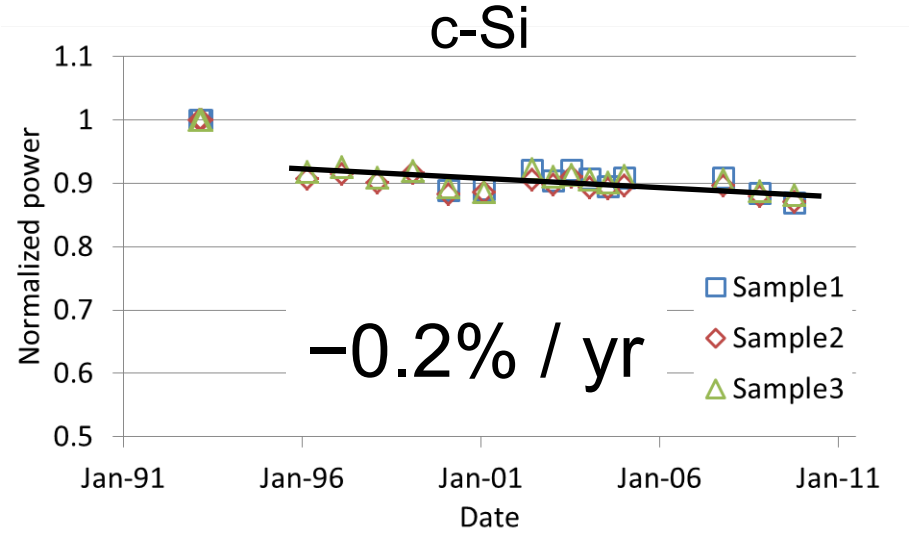


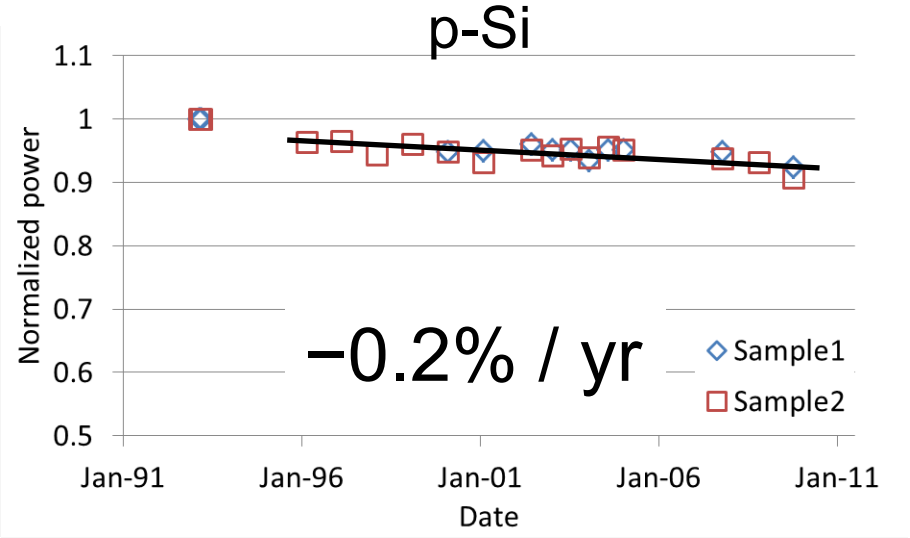


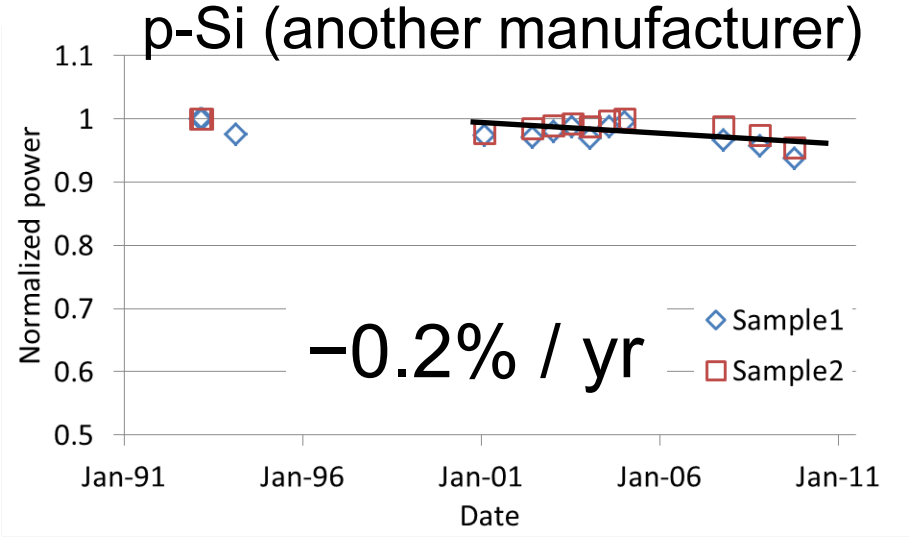


Power degradation rate tend to be lower than Tosu.

Power degradation in Miyako (1)

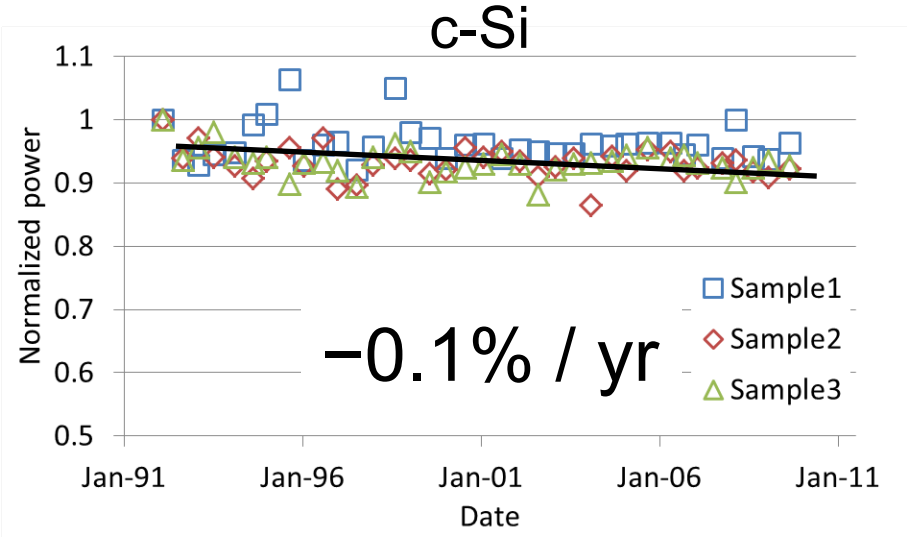


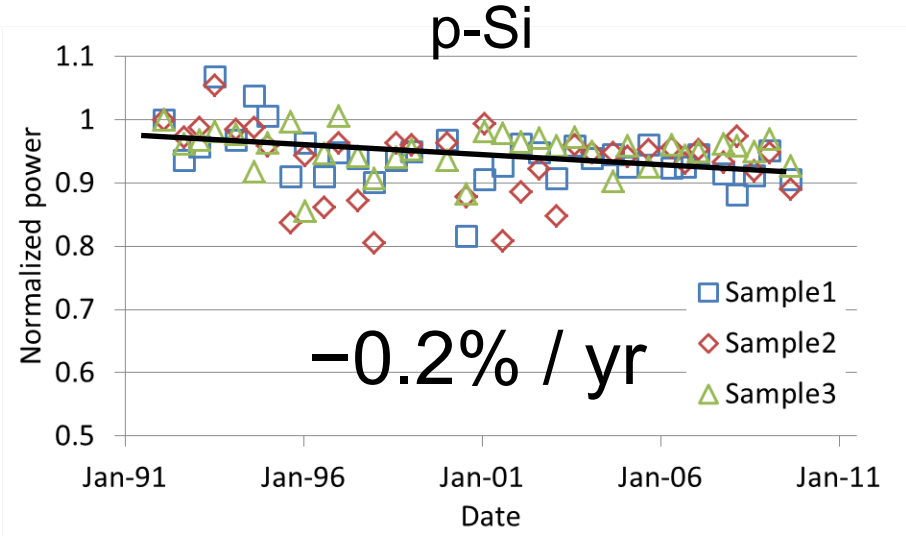


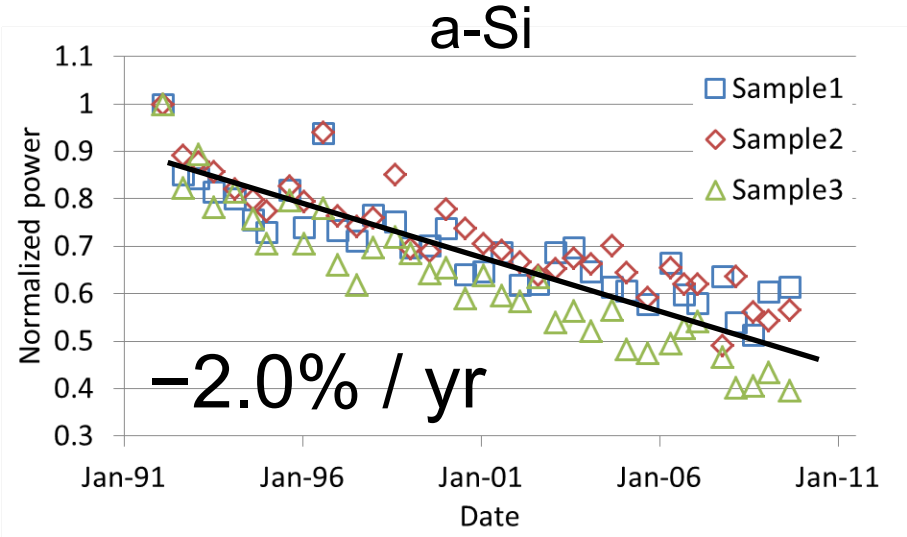


Each power degradation rate is almost the same as the rate in Tosu.

Power degradation in Miyako (2)



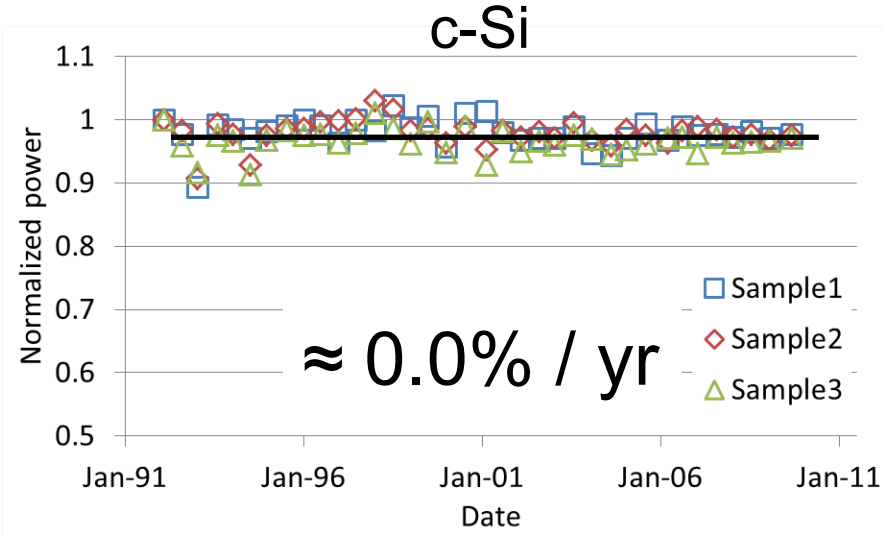


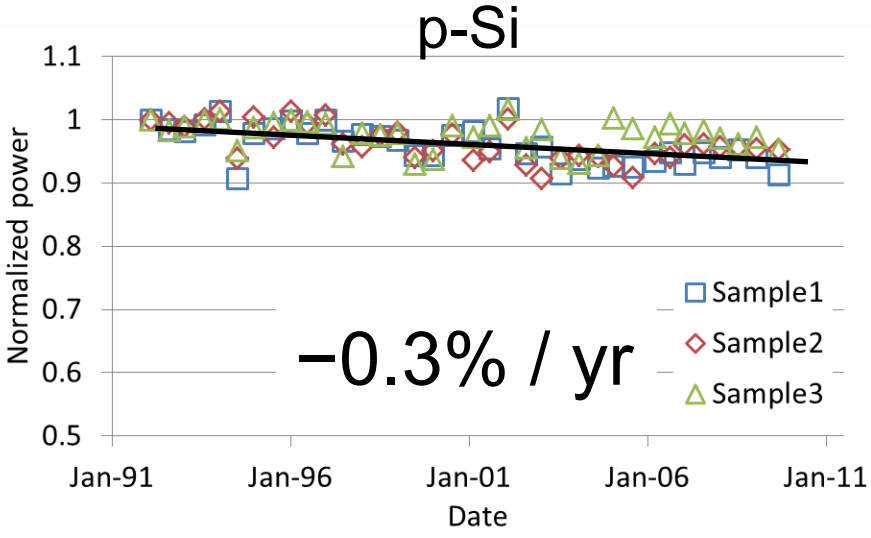


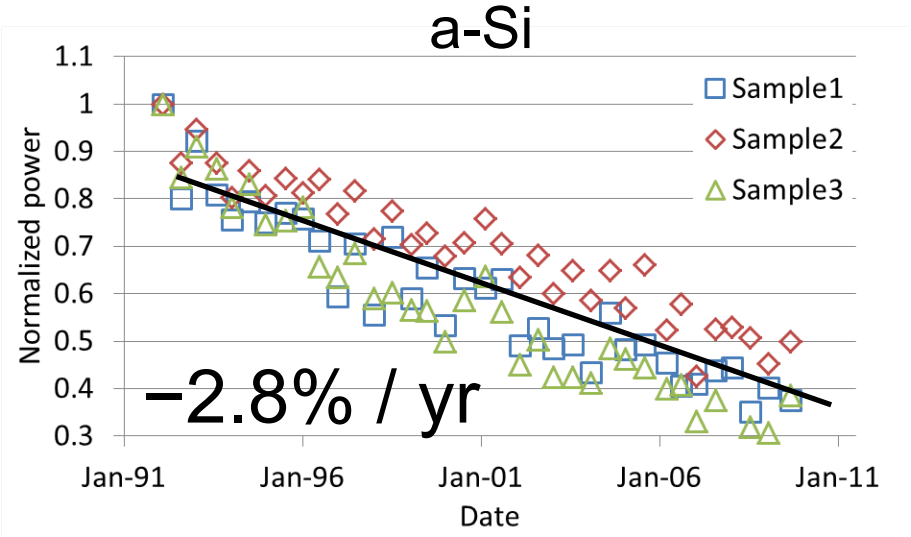
Each power degradation rate of crystalline Si is identical with the rate of another test.
The rate of a-Si is agreement with other reports [4].

4. D. L. King *et al.*, *Performance Degradation Rates in Commercial Photovoltaic Modules*, DOE Solar Program Review Meeting, Oct. 2004.

Power degradation in Choshi







Power degradation rate of amorphous Si is larger than Miyako.

→ Why?

Summary of outdoor exposure test

- All power degradation rates are good agreement with other reports about long term exposure in spite of difference in climatic condition.
- The power degradation rates of c-Si and p-Si are up to −0.5% / yr around Japan.
- Another stress factor is necessary to account for the degradation of a-Si modules.

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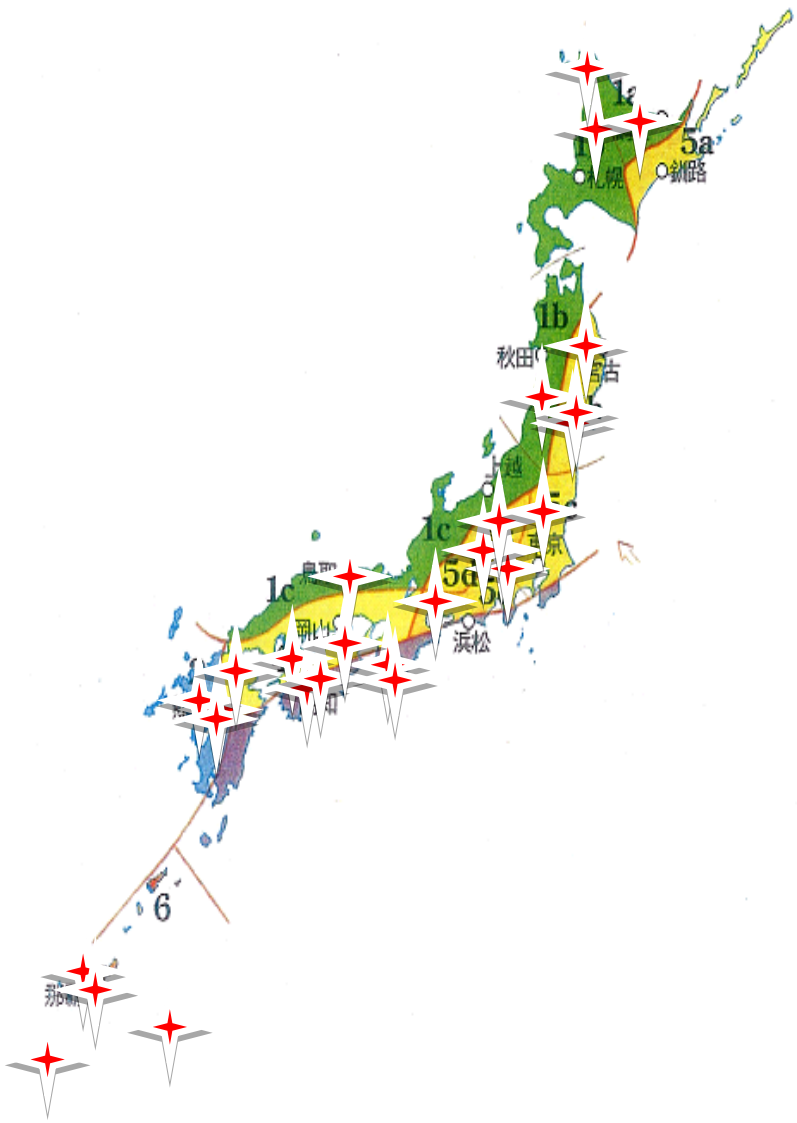
Investigation of PV modules at field tests

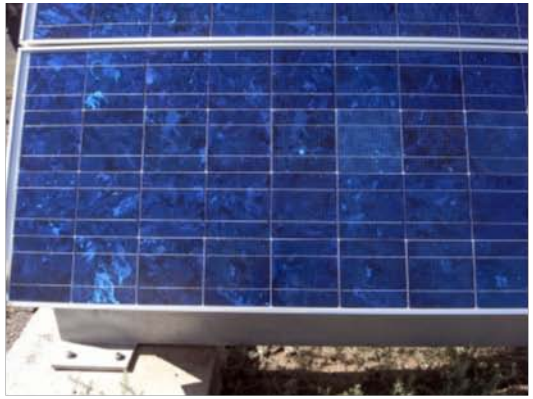
Investigation of modules at field tests



- 32 sites, 67000 modules (the number of p-Si type is 40000 modules)
- Rating modules from L0 to L5 depending on visual defects
- Classifying the rate according to each component

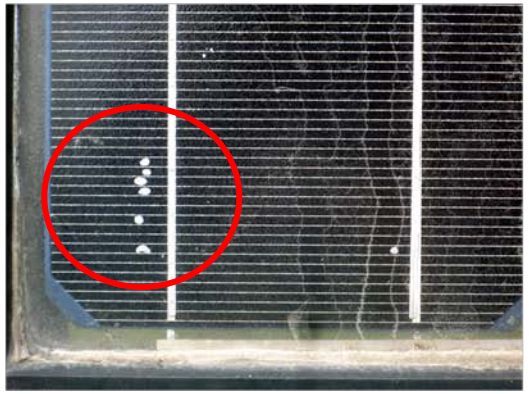
Degradation situations (1)

- No defects – **L0** modules –



- Trivial or tiny defects – **L1** modules –

Subtle yellowing of encapsulant

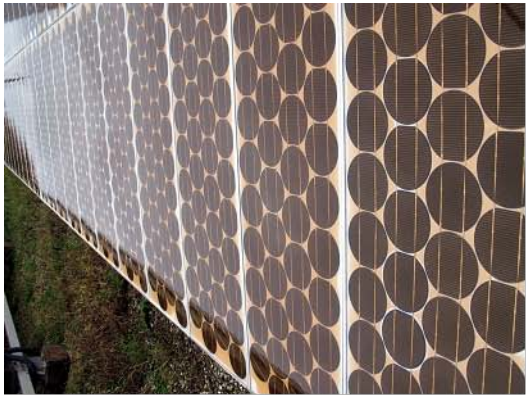


White spots of encapsulant

Discoloration of backsheet

Degradation situations (2)

- Striking defects – **L2** modules –

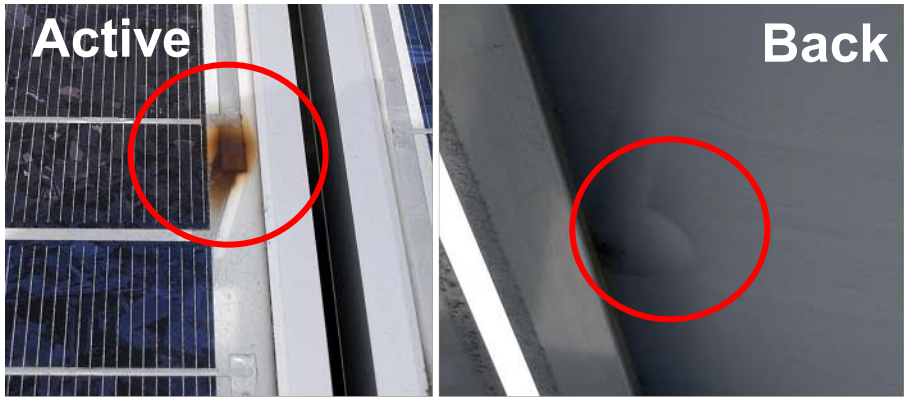


Yellowing of encapsulant

Delamination of encapsulant

Whitening of active surface

- Defects potentially impacting on power or safety of modules – **L3** modules –



Overheat of connection area of bus ribbons

Delamination of encapsulant

Degradation situations (3)

- Defects impacting on power or safety of modules – **L4** modules –

Crack of backsheet

Short between cells

- Defects potentially causing smoking, fire, or electrical shock – **L5** modules –

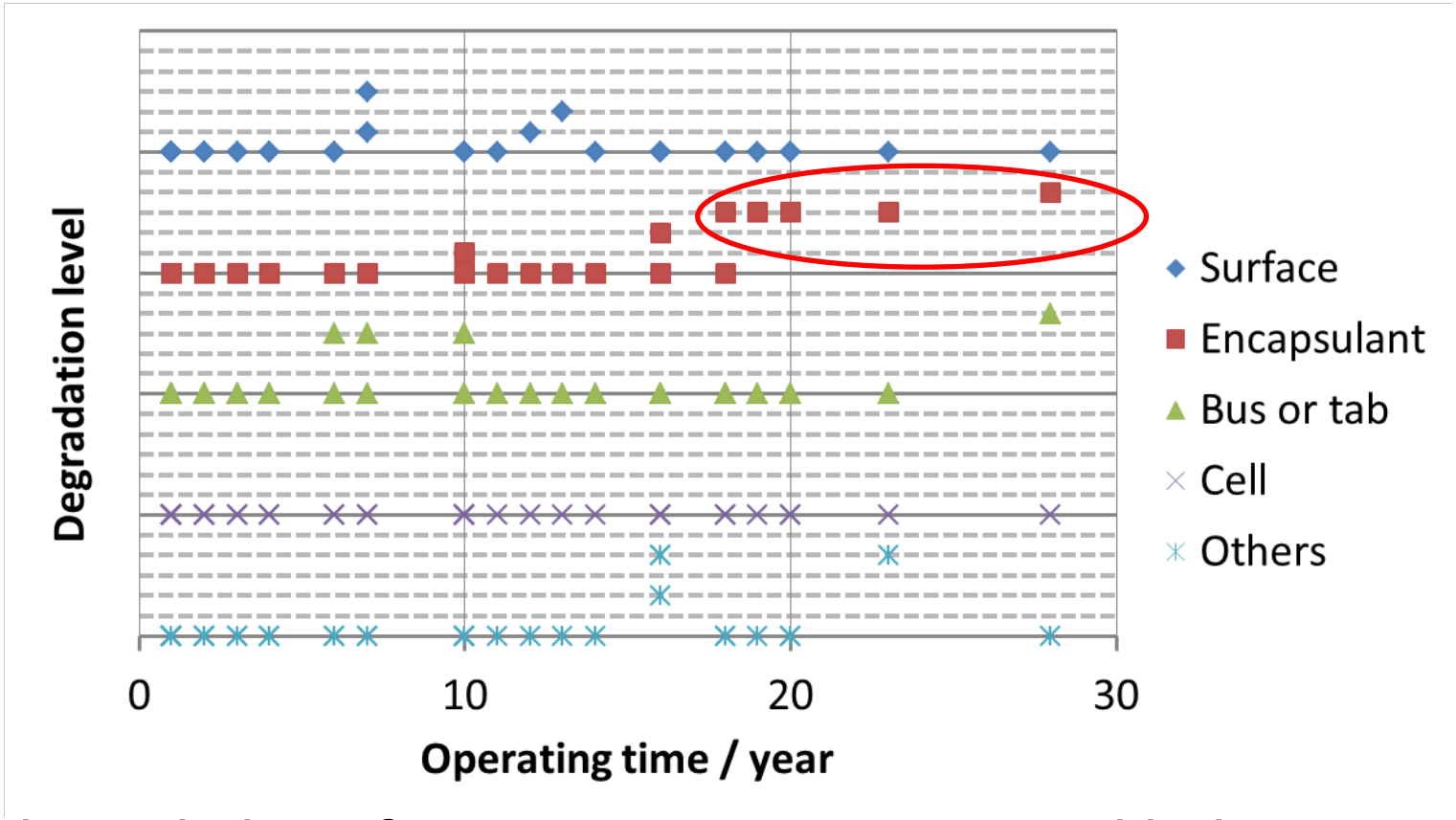
Detachment of junction box

Overheat of connection of output cable

Overheat of connection of busbar

Degradation of components (1)

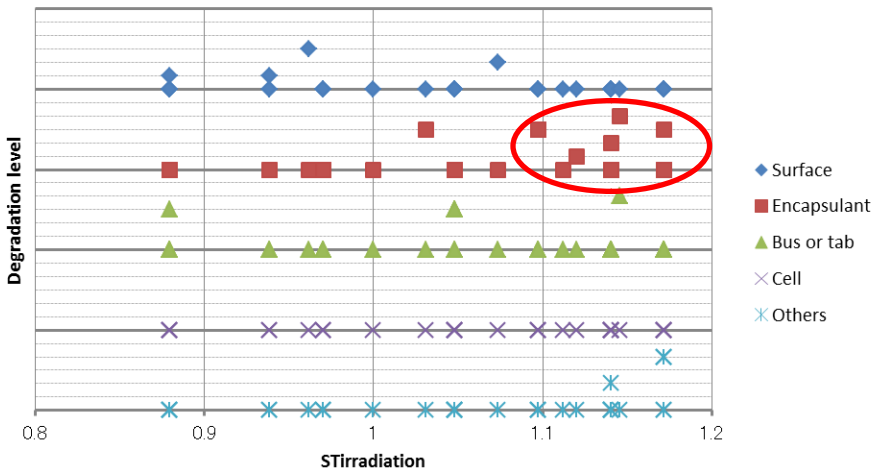
– Operating time

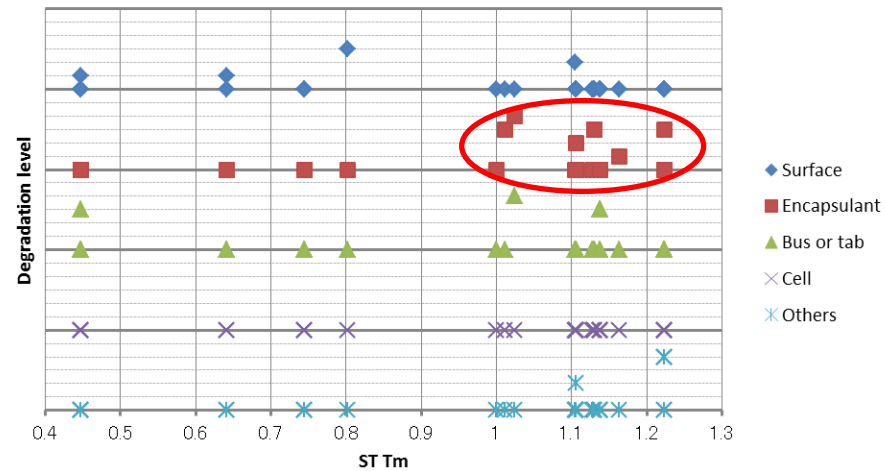


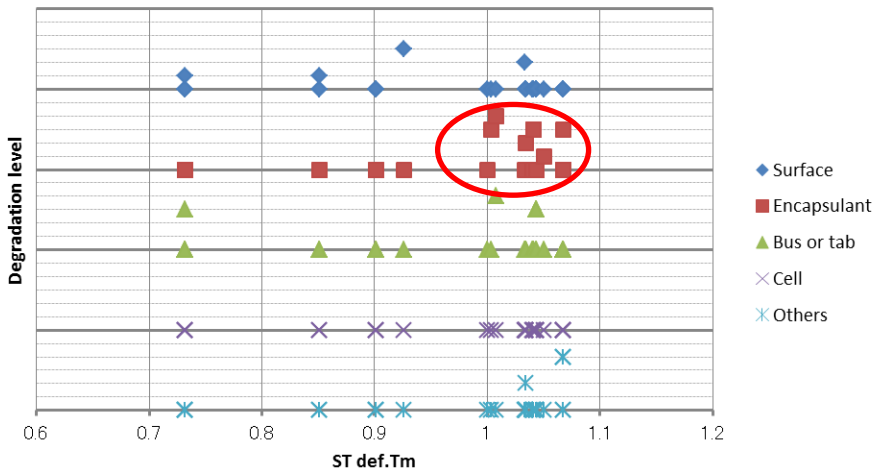
The degradation of encapsulant gets worse with the increasing in operation time.

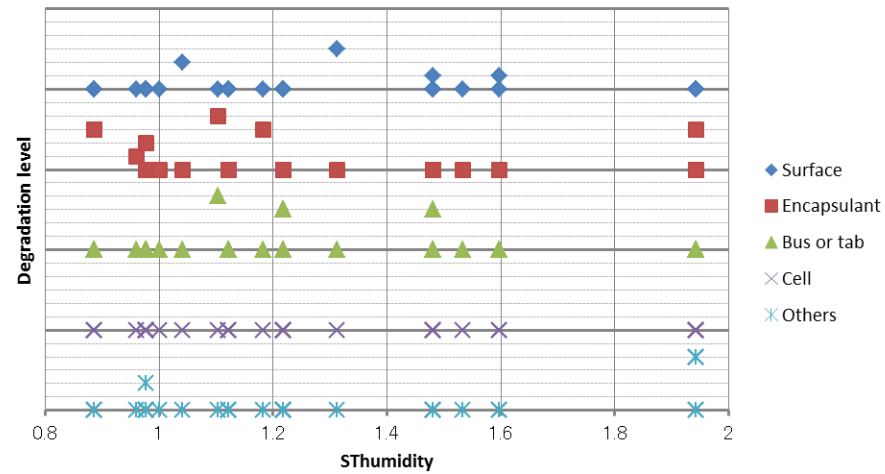
Degradation of components (2)

– Each stress factor









Encapsulant is susceptible to environmental stress.

Summary of the field test

- 67000 modules have investigated, including modules have operated for about 30 years.
- Some stress factors impact encapsulant in terms of visual defects.
- PV modules at field test in much severer condition than Japan should be investigated.

Acknowledgment

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Thank you for your attention.

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References

1. J. H. Wohlgemuth *et al*., *LONG TERM RELIABILITY OF PV MODULES*, Photovoltaic Energy Conversion, Conference Record of the 2006 IEEE 4th world conference.
2. D. Chianese *et al*., *ANALYSIS OF WEATHERED c-Si PV MODULES*, 3rd WCPEC, Osaka, May 2003.
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