2nd Atlas/NIST PV Materials Durability Workshop
November 13-14

2013.11.13

Acetic acid production rate in EVA encapsulant and its influence on performance of PV modules

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Outline

1. Background

2. Corrosion due to stress test

3. Acetic acid production and its influence on reliability of PV modules

4. Summary

Mitsui Chemicals Group in PV industry

Reliability evaluation and diagnosis for PV modules and PV systems based on experiences of technical services of encapsulant and owner of PV power plants

Equipments for accelerated test of PV modules and materials

Outdoor test site for diagnosis of PV system and modules

1. Background

✓We have attempted to figure out correlation between power reduction of a PV module and degradation of an EVA encapsulant using long-term field aged PV modules.

✓Further we have attempted to predict chemical changes of EVA encapsulant due to stresses suffered during 25 years period of time.

✓We, Mitsui Chemicals groups, have 30-year-old history for commercialization of EVA encapsulant sheet. Furthermore, we have been manufacturing old grade EVA sheets since 1992, thus we can compare performances of field aged EVA with initial one.

2. Corrosion due to stress test

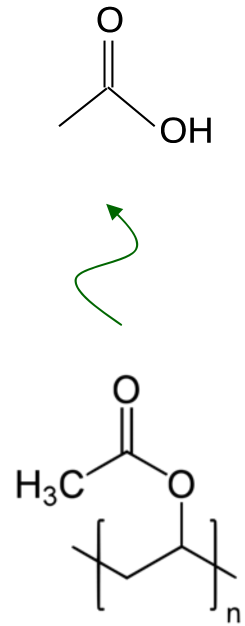
Failure modes related to EVA encapsulant

- Corrosion
- Browning
- delamination

Chemical change of EVA ⇔ acetic acid (main by-production)

Chemical change of additives

Break of adhesive coupling



EVA

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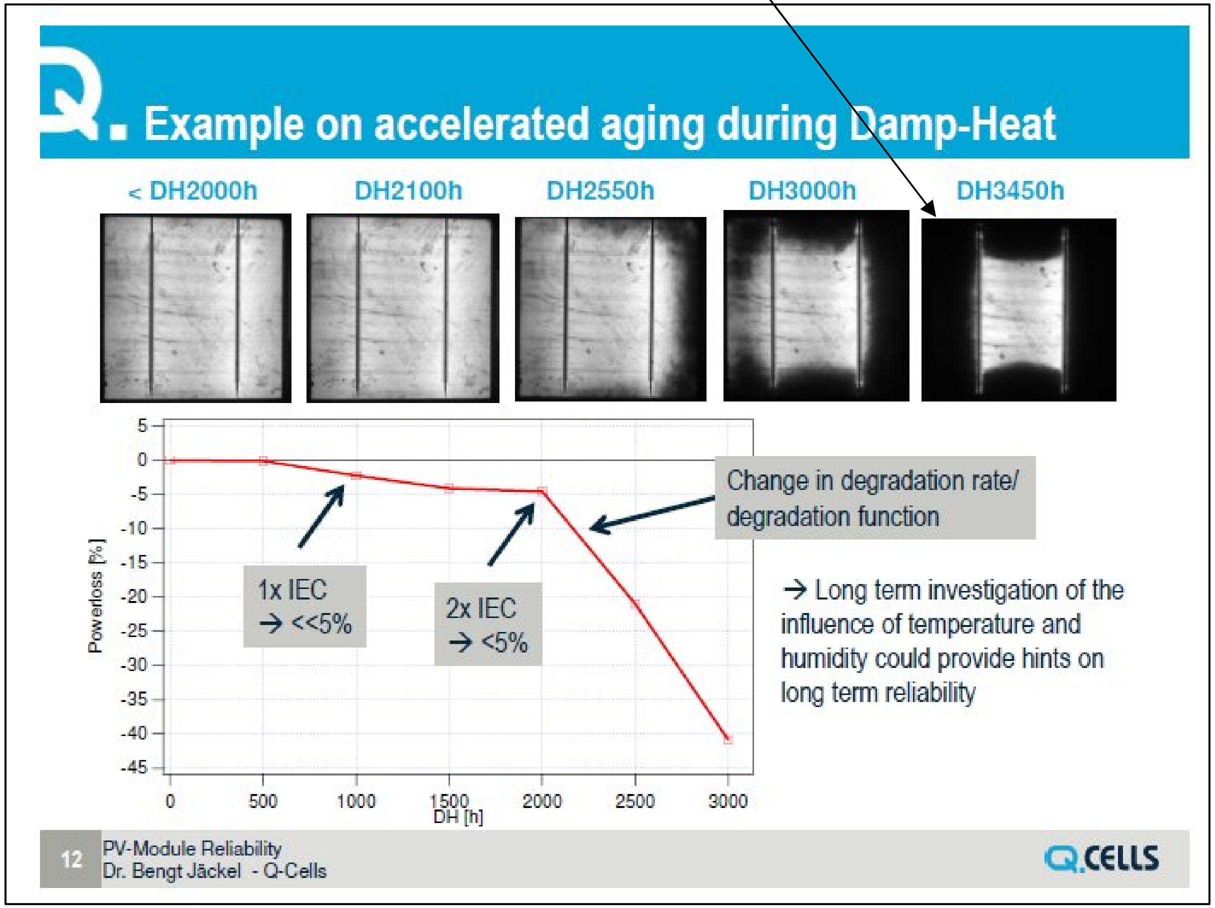
2. Corrosion due to stress test

Failure modes related to EVA encapsulant

Corrosion

Typically damp heat (DH) test

Dark area in EL image is typically expanding from outside of a cell.

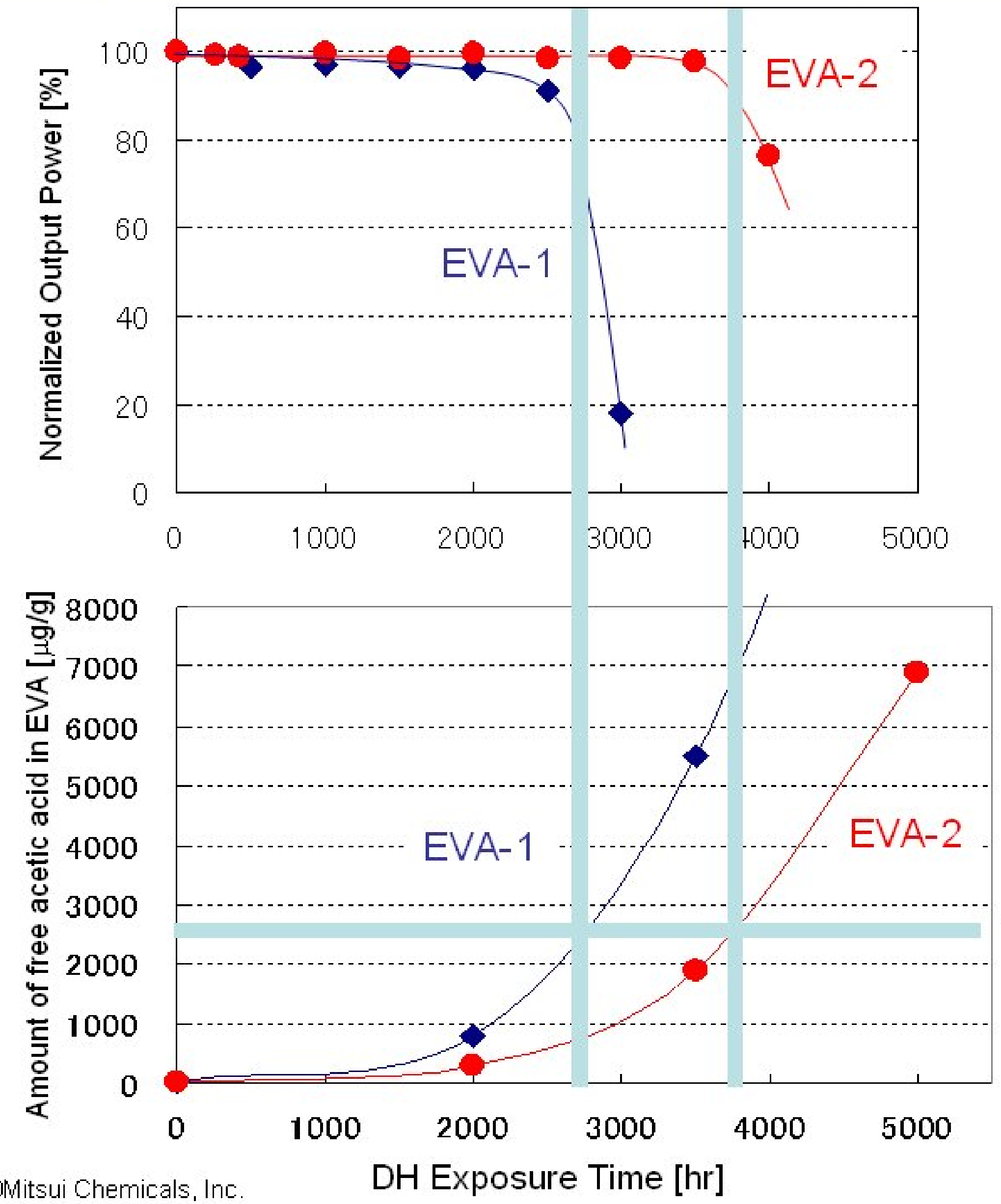


Source : Bengt Jackel; PV Module Reliability Workshop at Berlin Apr. 2011

Questions:

1. Is dark portion due to corrosion of Ag fingers?
2. Is acetic acid from EVA root cause?

Output reduction of module depending on grade of EVA



Mini PV module
18 cells

"2500 µg/g" corresponds to ~1% of all vinyl acetate groups.

✓Higher amount of acetic acid than 2,500 µg/g leads to degradation of module performances.

T. Shioda; presentation at QA forum TG3 held in Golden Feb. 2012.

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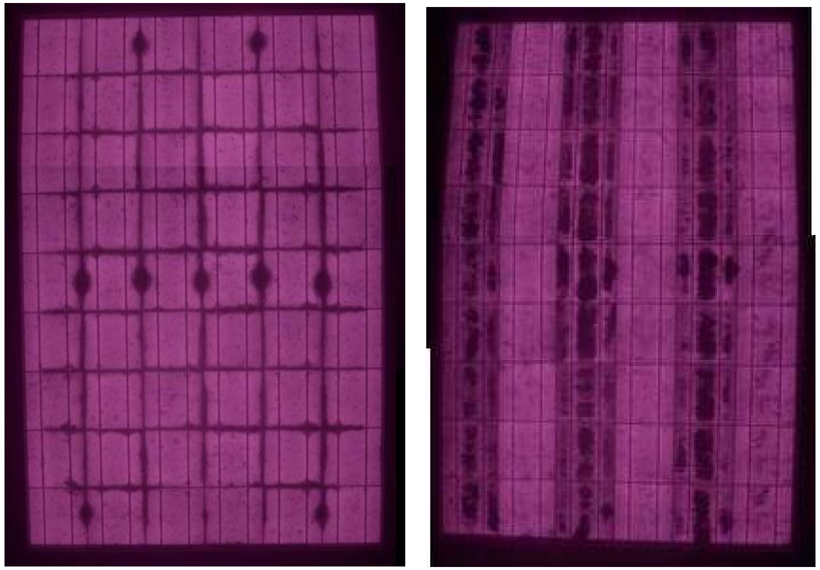
EL image patterns induced by DH test

There are many types of EL pattern for DH-aged c-Si PV modules.

Ag paste and its **sintering condition is also key factor for duration of DH test.**



PV modules aged with DH3000
(w/o) Al layer in backsheet
same EVA,
different production lot of cells

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3. Acetic acid production and its influence on reliability of PV modules

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A) DH induced degradation would depend on durability of cell, water vapor, acetic acid.

B) From view point of encapsulant, water vapor diffusion phenomenon during damp heat test and acetic acid production rate for various stress tests should be understand.
-> review and show some data today

C) Most important point is correlation of these indicators between indoor test and outdoor exposure.
-> show some the correlation today

Water absorption and diffusion coefficient of EVA

	VA content [%]	Water absorption @ 85^{O}C/85%RH	Diffusion coefficient @ 85^{O}C/85%RH
EVA-a	33	1	1
EVA-b	33	~0.8	~1
EVA-c	28	~0.7	~1

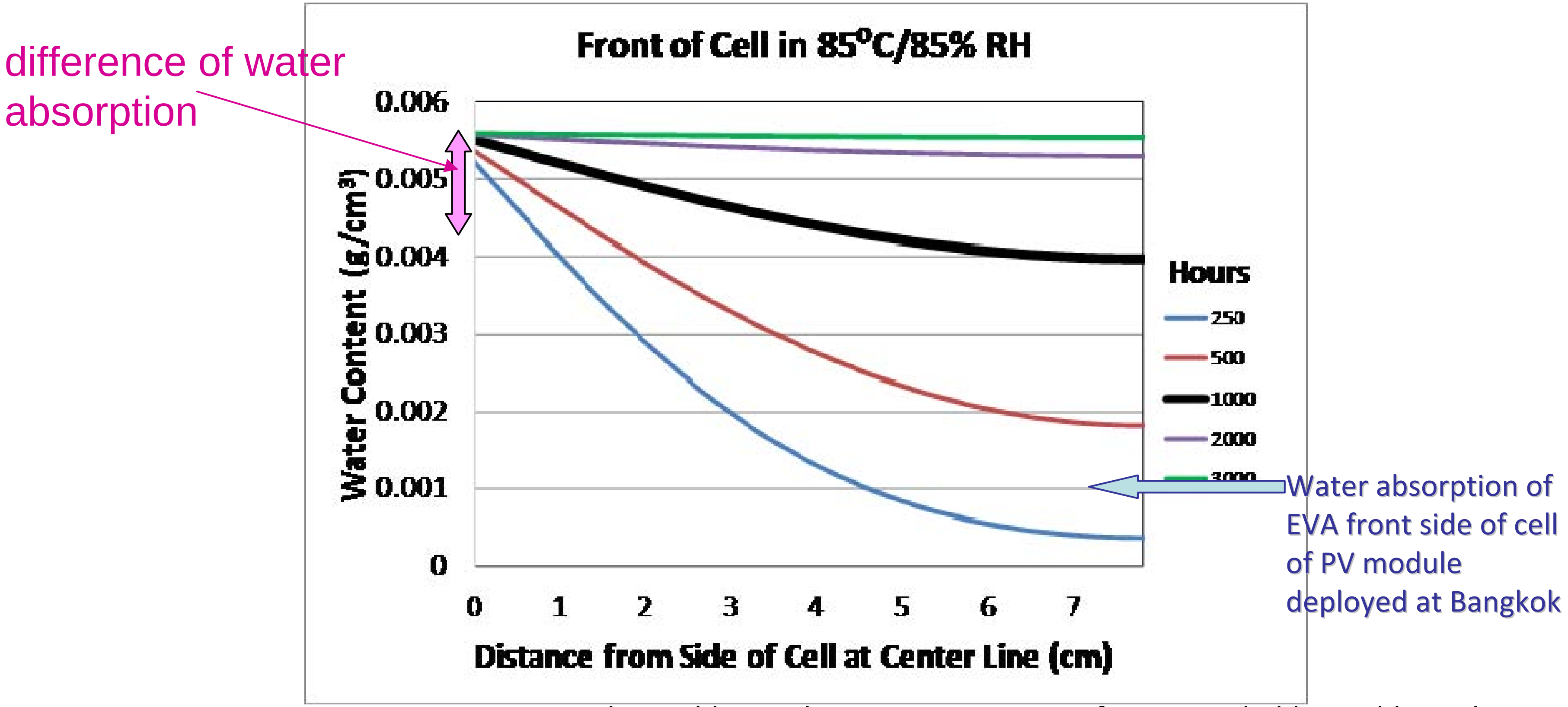
Different formulation

Different VA content

Water absorption and water vapor diffusion coefficient for EVA-b and EVA-c are normalized by those of EVA-a.
EVA-a is the **oldest grade EVA**, which has been commercialized since **1992**.

Water absorption slightly depends on formulation and on VA content according to this table. However moisture diffusion coefficient does not depend on VA content, their formulation of EVA.

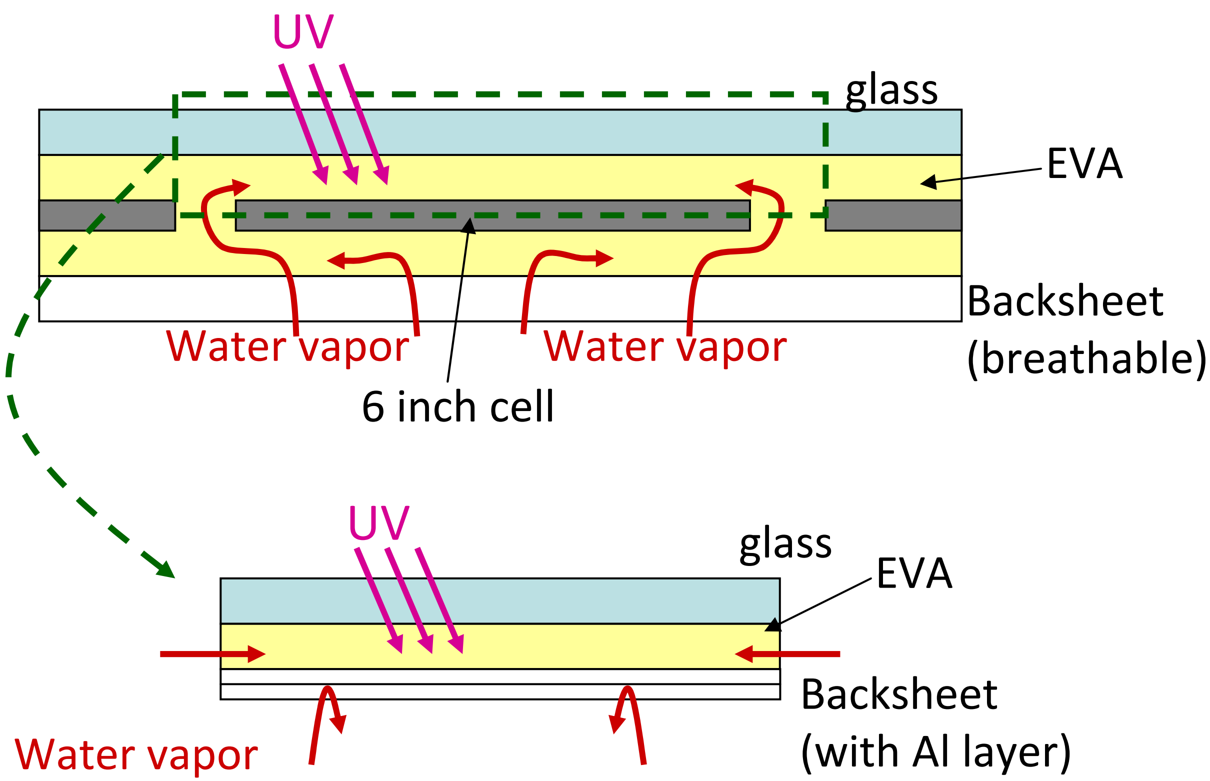
Moisture diffusion phenomena into EVA during DH



John Wohlgemuth; presentation at QA forum TG3 held in Golden Feb. 2012.

- ✓ There is slight difference of water absorption at edge of cell among those EVA encapsulants in this graph.
- ✓ There is no difference of water vapor diffusion rate into EVA.
- ✓ DH 1000 is almost sufficient for filling with water vapor in EVA, may be over-stress, compared to actual water absorption in tropical climate.

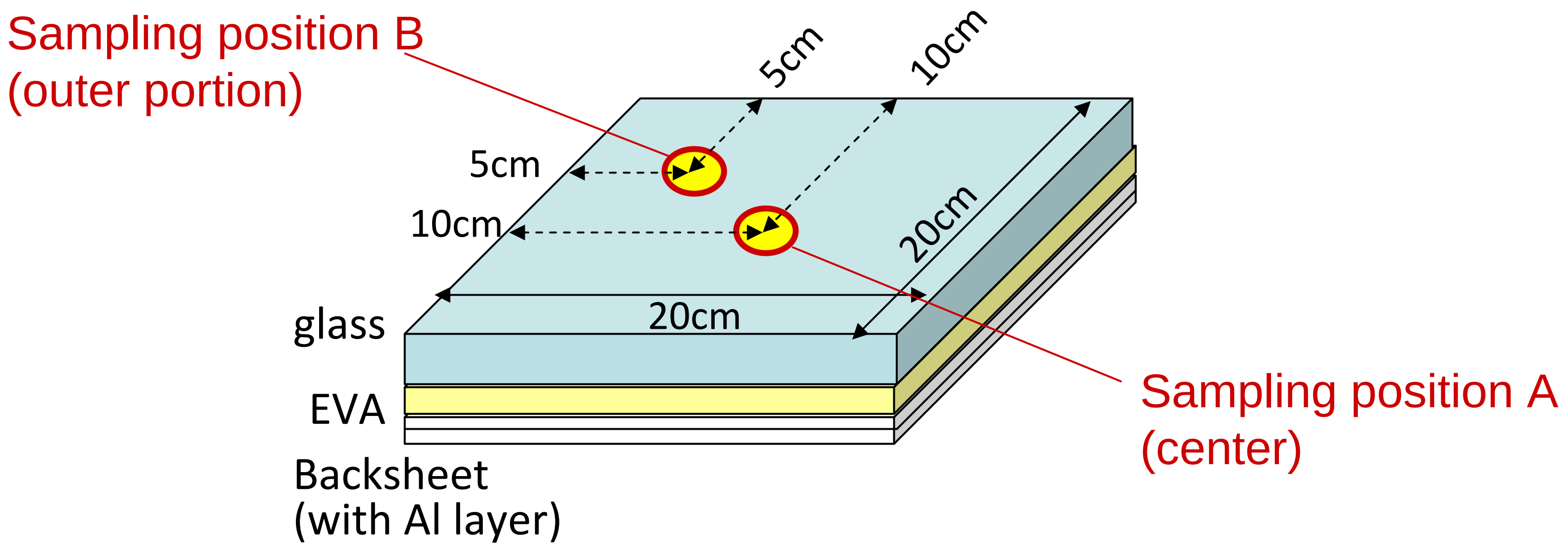
Evaluation of acetic acid production rate



✓We assume that EVA front-side of cell can be simulated by the sample shown in lower schematic drawing.

✓Water vapor can diffuse into EVA from only end faces of the sample.

Sample geometry



- ✓The sample size is 20 cm x 20 cm.
- ✓There is two sampling points for measurement of acetic acid in EVA after only DH test.
- ✓One is a center of the sample. Another is an outer position of the sample as shown in the figure.
- ✓EVA sample is obtained by peel-off after removing backsheet.
- ✓Free acetic acid is extracted from EVA with hot water.

Stress tests

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1. Damp heat (DH)

85^{O}C, 85%RH

2. High temperature exposure (HT)

120^{O}C

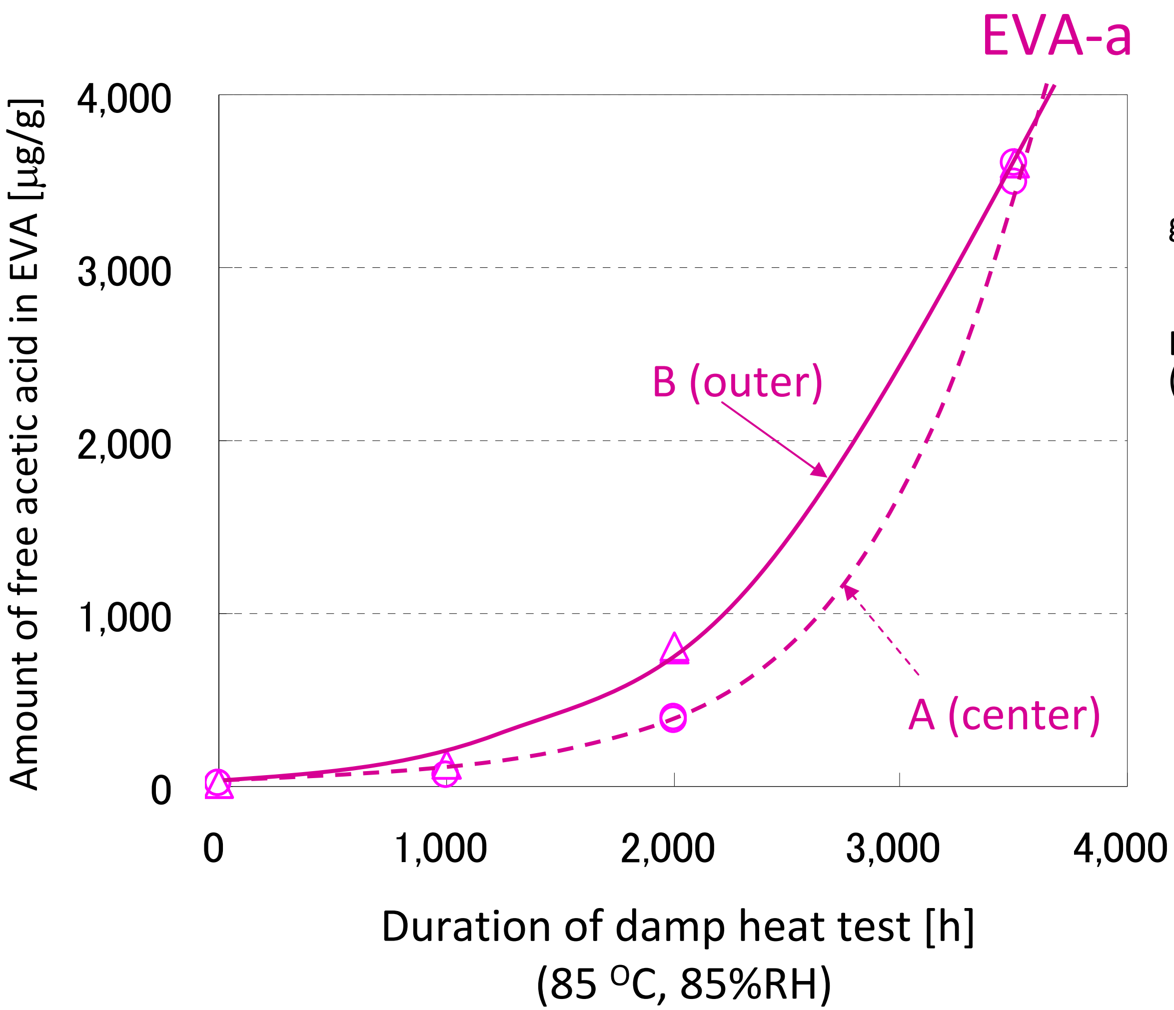
3. UV test using Xe weather-o-meter (XWOM)

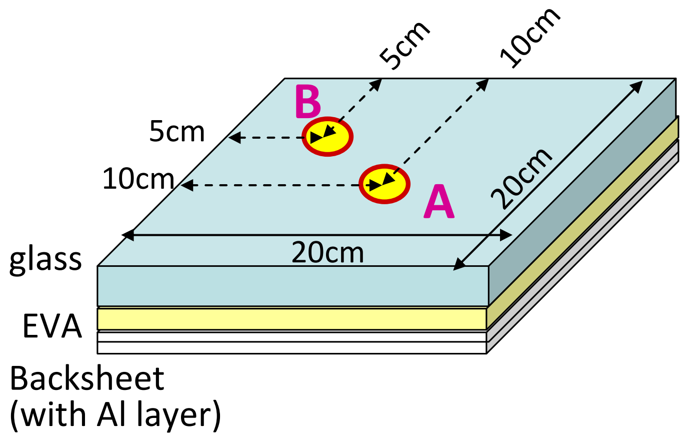
60 W/m^2 (300~400nm), Black panel temperature (BPT): 110^{O}C
(Chamber temperature: 80~85^{O}C, Chamber humidity: 10~20%RH)

✓We have attempted to obtain acetic acid production rate of EVA for three types of stress test.

✓Furthermore, we have challenged prediction of free acetic acid production during outdoor exposure in Japan.

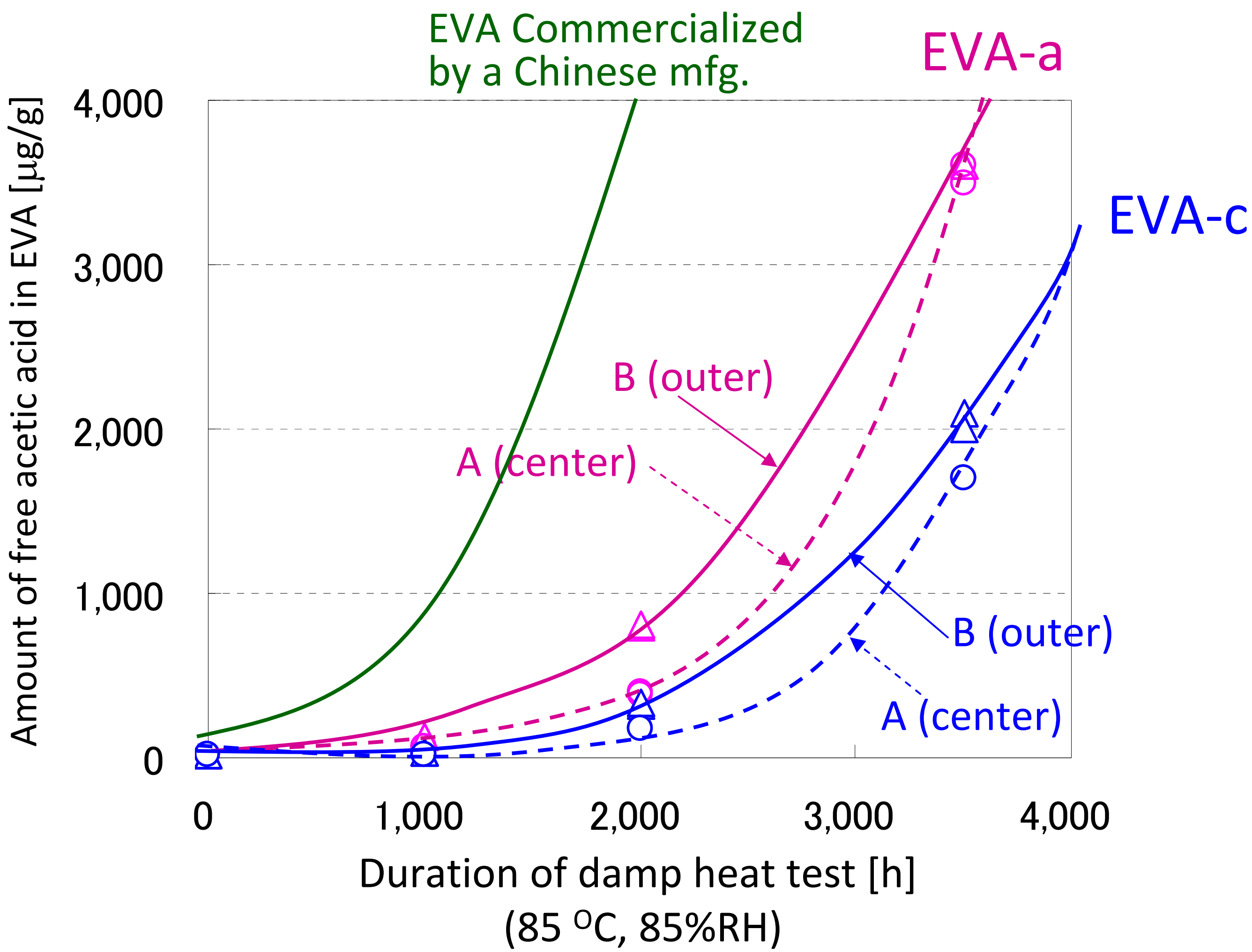
Acetic acid production in EVA during DH test





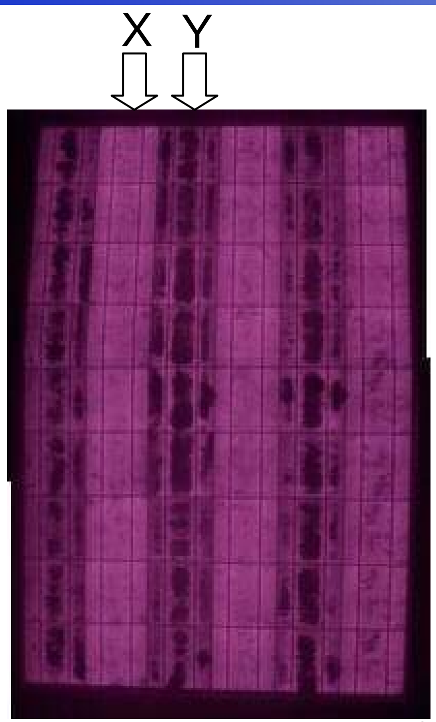
Acetic acid formulation rate is different between outer and center.

Acetic acid production in EVA during DH test

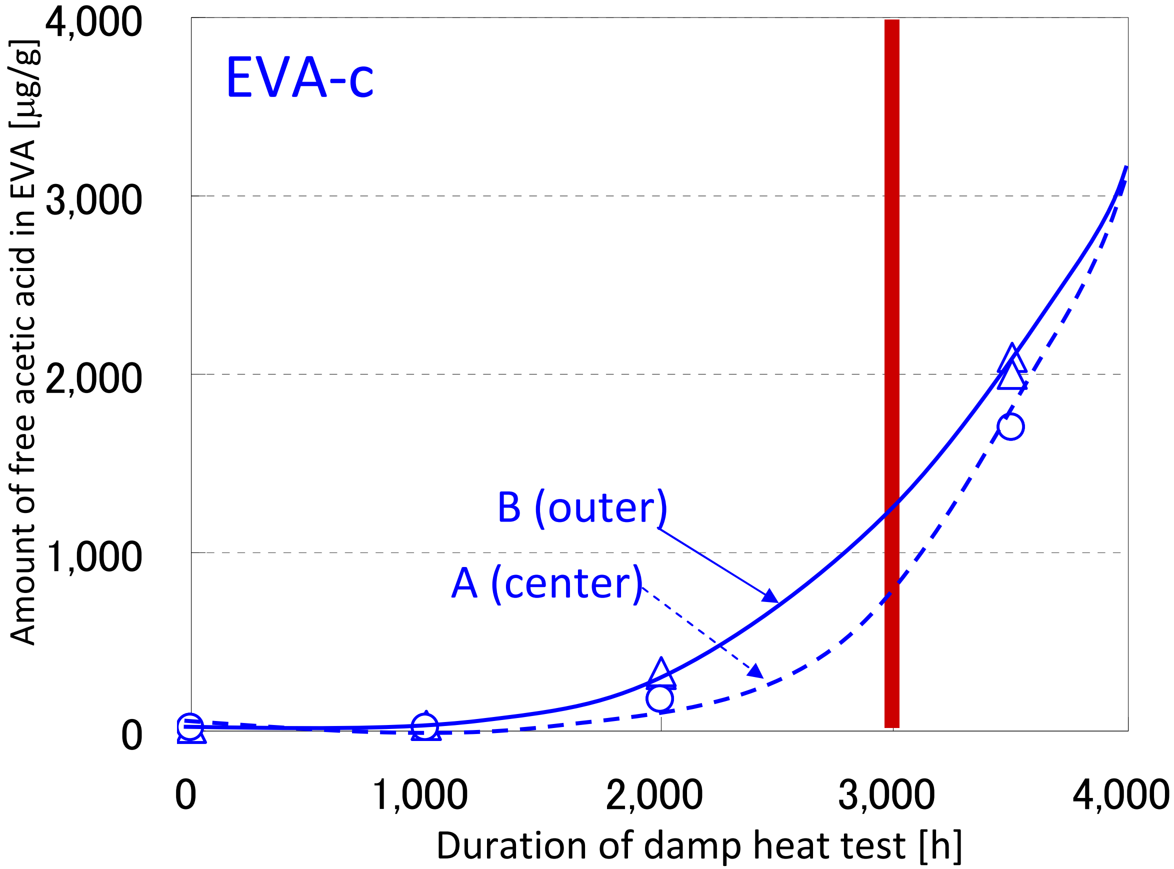


Acetic acid formulation rate depends on formulation of EVA

Its influence on performance of a PV module



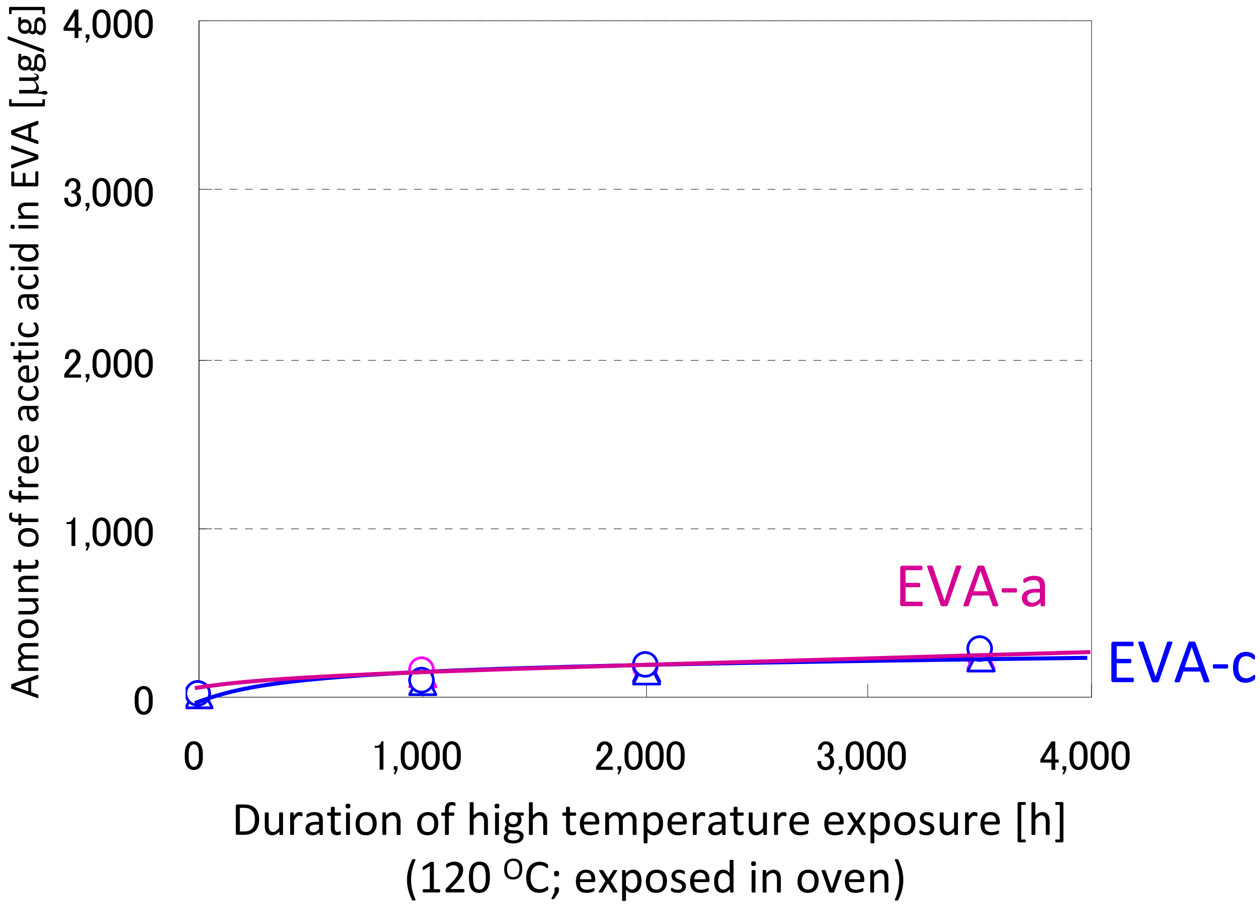
EL image of PV module (with NOT durable cells for DH test) with EVA-c after DH3000



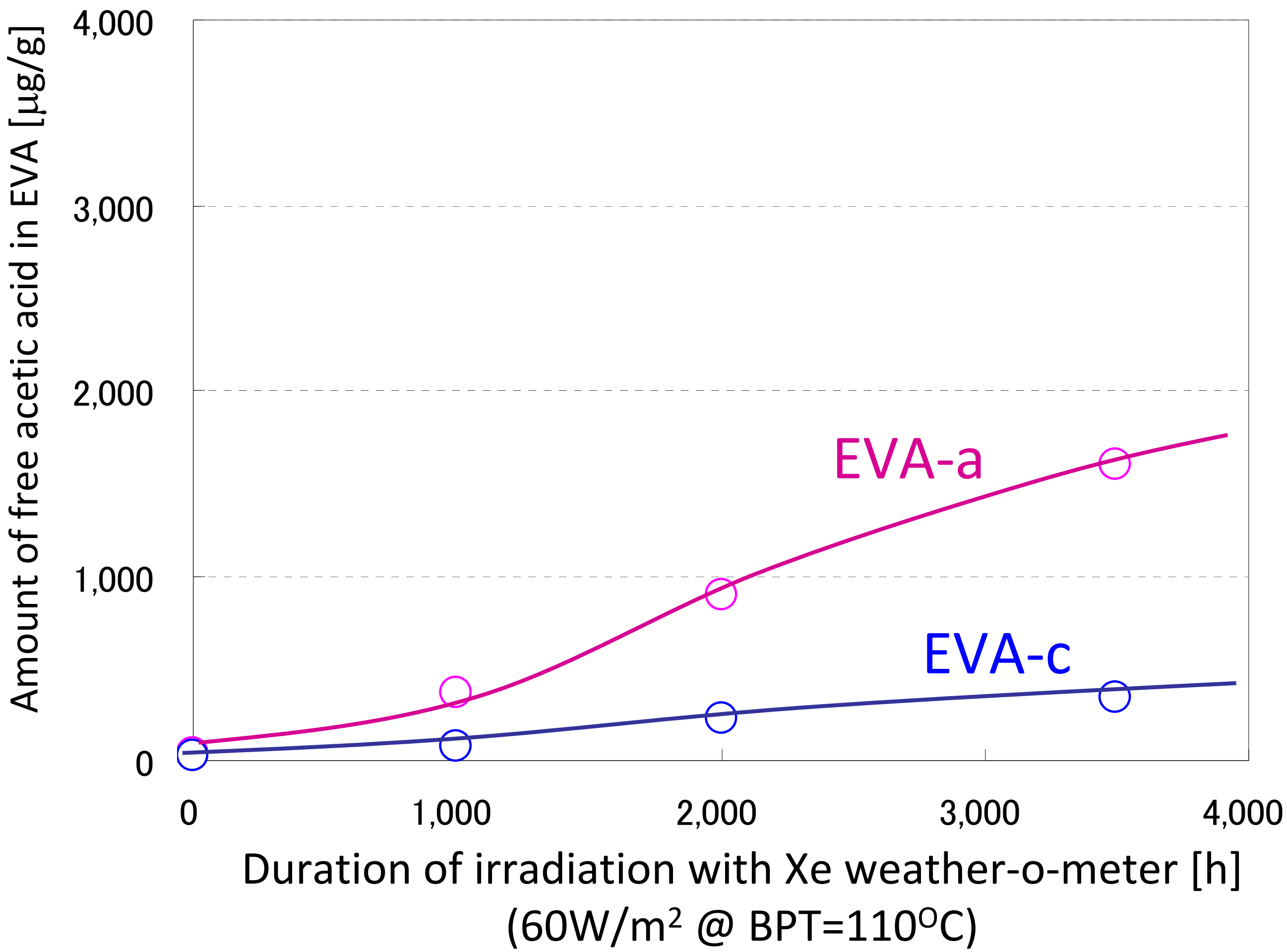
✓Cells in row "X" are durable for DH test, however cells in row "Y" are not durable even less amount of acetic acid than 1,000 μg/g.

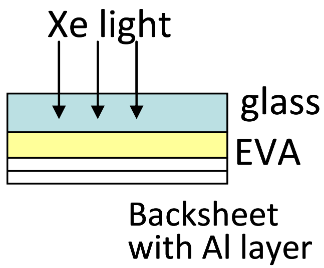
✓**Lower limit for amount of acetic acid, which leads to degradation, strongly depends on durability of cells in a PV module.**

Acetic acid production in EVA during HT test



Acetic acid production in EVA during UV test





We found that there was big difference of production rate between EVA-a and EVA-c.

Acetic acid production in EVA during outdoor exposure

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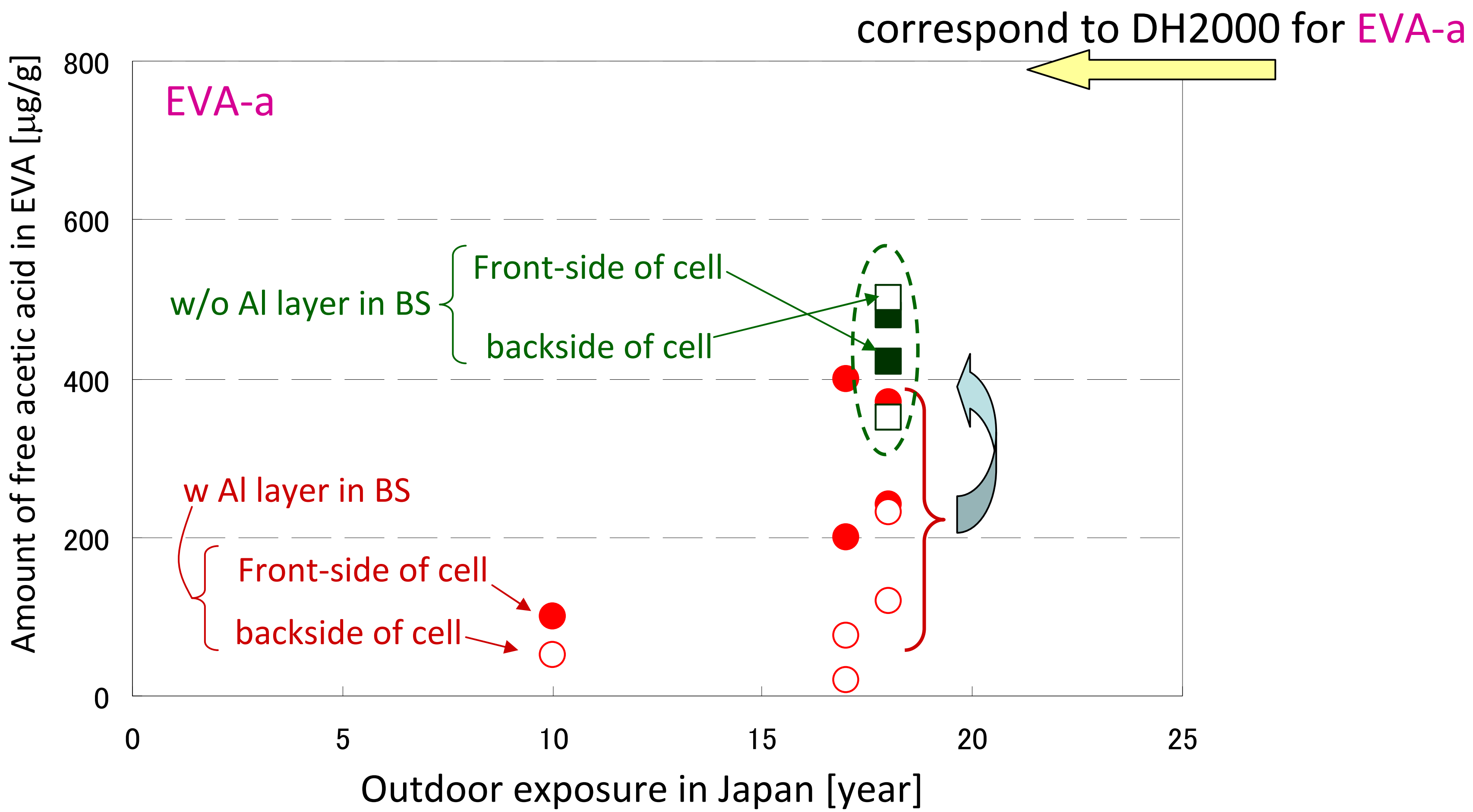
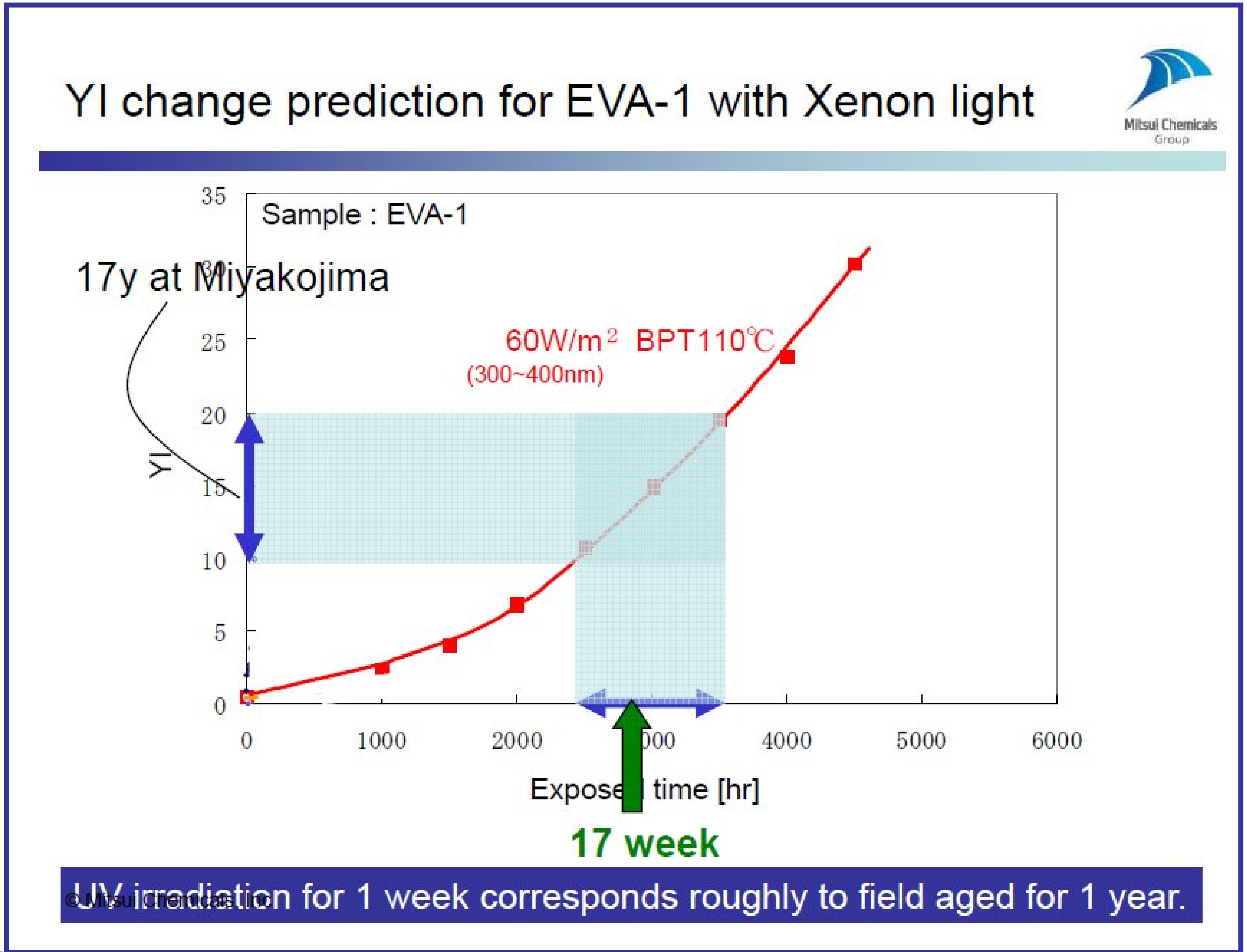


✓**Amount of acetic acid in EVA-a deployed in Japan for ~20y is relative low, compared to that for DH2000, even though the amount for module without Al layer in backsheet is higher than that with Al layer.**

Correlation between production rate of acetic acid and YI change rate



T. Shioda; 1st Atlas/NIST PV Materials Durability Workshop, October 27 – 28, 2011

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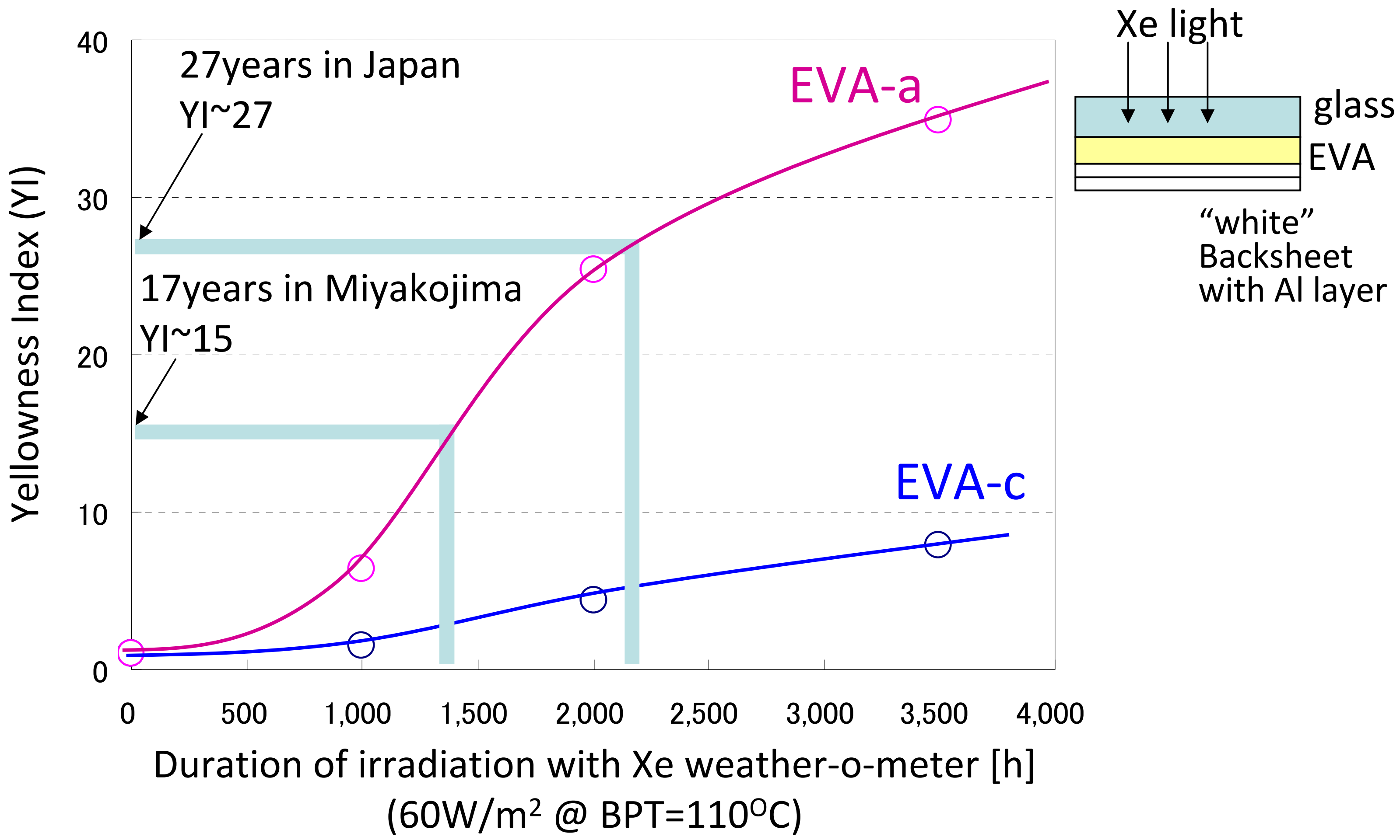
YI change of EVA during UV test



YI change rate depends on sample geometry.

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✓Damp heat (DH) induced degradation rate depends on durability of cell, especially silver metallization process and selection of silver paste, water vapor immersion, acetic acid production from EVA.

✓Acetic acid production rate was shown and it depends on stress type and grade of EVA. We found that EVA with high production rate for DH test also tended to have high rate for UV test.

✓UV stress was not negligible factor in terms of acetic acid production.
Further studies related to UV stress vs acetic acid production and correlation with field aged one are on going, in order to predict acetic acid production rate in a field.

✓PV module manufacturers should know the production rate for EVA encapsulant they use for design of a reliable PV module.