The acceleration of degradation by HAST and Air- HAST in c-Si PV modules

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INTRODUCTION

Background : The damp heat test (DHT) in IEC 61215 is defined as 85 ºC /85% RH condition for 1,000 h, as the high hygrothermal test. However, it has been suggested that DHT under these conditions cannot assure the long-term reliability of c-Si PV modules.

Purpose : In order to propose the novel hygrothermal test-condition, we attempt to clarify the effect of higher hygrothermal stresses (HAST and Air-HAST) on the degradation of mini c-Si PV modules, along with the extended DHT.

Air-HAST is the test procedure which is carried out in the high temperature humanized atmosphere with air, although the air is completely exhausted in ordinary HAST condition.

Table 1. Partial pressure of test conditions.

	Tem-perature (℃)	Humidity (%)	Water vapor (MPa abs.)	Total pressure (MPa abs.)	Air (MPa abs.)
R.T.	25	60	0.0016	0.1013	0.0997
DH	85	85	0.0495	0.1010	0.0518
HAST	105	100	0.1208	0.1208	0
	120	100	0.1985	0.1985	0
Air-HAST*	110	85	0.1216	0.2498	0.1282

*Each value in Air-HAST is obtained by theoretical calculations.

EXPERIMENTS

Table 2. Specification of samples.

Material	Specification	Supplier
Cell	Multicrystalline Si cell (156 mm × 156 mm)	Q Cells
Glass	Semi-tempered glass	AGC
Encapsulant	EVA (Fast Cure)	SANVIC
Interconnector	A-SPS (Leaded, Ag)	Hitachi Cable
Back sheet	TPT	Nondisclosure

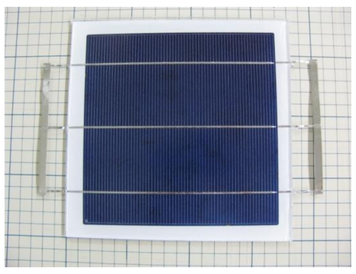


Fig. 1. Photograph of single-cell module.

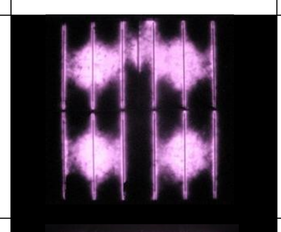
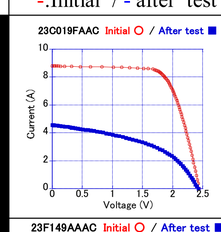
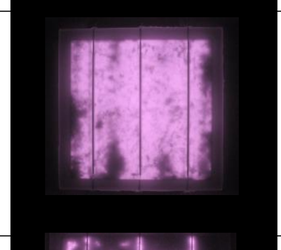
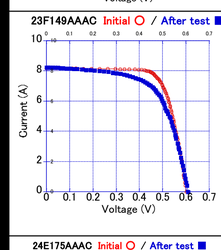
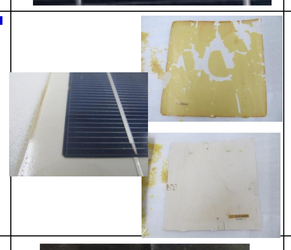
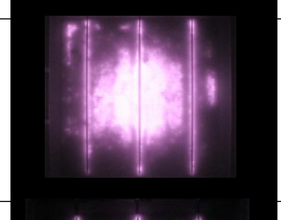
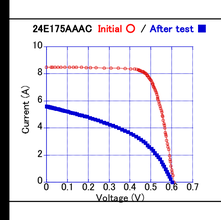
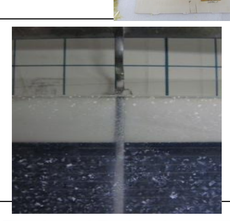
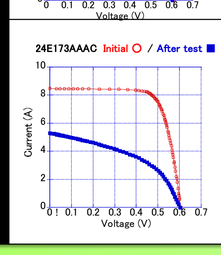
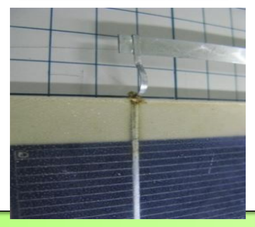
Table 3. Test conditions.

Test condition	Temperature/ humidity	Test time
Damp heat test	85 ℃ / 85%	4000 h
HAST	105 ℃ / 100%	1000 h
	110 ℃/85%	800 h
	120 ℃ / 100%	400 h
Air-HAST	110 ℃ / 85%	800 h

HAST (Highly-Accelerated Temperature and Humidity Stress Test)

RESULTS & DISCUSSION

Table 4. Comparison of characteristics after each environmental test.

Test conditions	EL	I-V -:Initial / - after test	Appearance	Remarks
Damp heat test 85 ℃/85% 4000 h				Dark region in EL image appears from the cell edge. Degradation occurs after DH 3000 h. P_{max} was reduced by 60%. Change to brown in interconnector, BS and EVA.
HAST 120 ℃/100% 400 h				Dark region in EL image appears from the cell edge. P_{max} was reduced by 16%. Peeling of the outside sheet of BS. Stress is possibly too strong. It may be different degradation mode from DH.
HAST 110 ℃/85% 800h				Dark region in EL image appears from the cell edge. P_{max} was reduced by 56% in I-V . Change to brown in BS. No change to brown in interconnector and EVA.
Air-HAST 110 ℃/85% 800 h				Dark region in EL image appears from the cell edge. P_{max} was reduced by 70% in I-V . Change to brown in interconnector, BS and EVA. It is possible to correlate with DH. It is possible to accelerate DH by 5 times.

1. Pmax was decreased by less than 5% and 40% in DHT condition for 1,000 and 4000 h, respectively.
2. The HAST condition (120 ºC/100% RH) is extremely high-stress condition with the particular failure-modes, unlike in the cases of other conditions.
3. For 800 h at these conditions, the reduction levels of Pmax were 50~60% and 60~80% at HAST condition (110 ºC/85%) and Air-HAST condition, respectively. In addition, the expansion levels of dark area in EL imaging were similar. It is suggested that the air in surrounding atmosphere of PV module (probably oxygen) induced the additional degradation .
4. By comparing the appearance of modules after Air-HAST for 800 h, HAST (110 ℃/85%) for 800 h and DHT for 4000 h it was found that the color is changed to brown for interconnector and EVA in the same manner for DHT and Air-HAST. The color was also changed to brown for BS at HAST (110 ℃/85%) but no change in color occurred for interconnector and EVA.
5. From the results of dark I-V measurement, it is also revealed that the change of I-V parameter induced by these hygrothermal stresses are not so much the decreasing of shunt resistance (Rsh) as the increasing of series resistance (Rs).

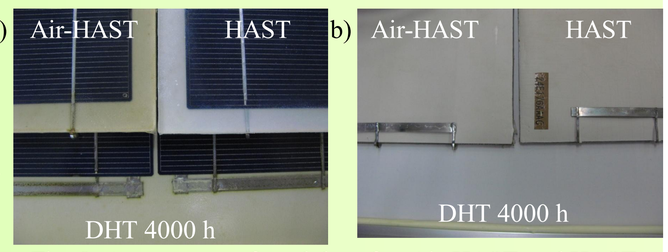


Fig. 2. Appearance of modules after Air-HAST and HAST.
a) Front side. b) Back side.

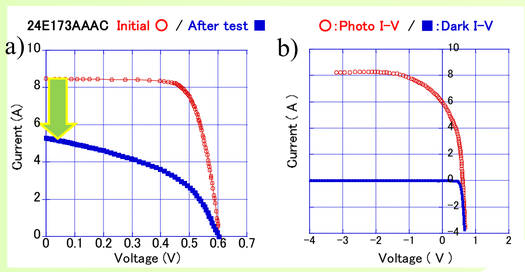


Fig. 3. I-V a) First quadrant. b) Photo I-V and dark I-V.

SUMMARY

In this study, we show that the highest hygrothermal condition which is able to accelerate the degradation without different failure-modes from those of DHT is 110 ºC /85% RH (Air-HAST). We have to elucidate the effect of air on the degradation of PV modules in the further investigation.

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This work was supported by the Consortium Study on Fabrication and Characterization of Solar Cell Modules with Long Life and High Reliability (National Institute of Advanced Industrial Science and Technology, Japan).
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