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Combination Accelerating Test for Crystalline Si Photovoltaic Modules

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Abstract

Combination test for photovoltaic modules is effective for accelerating degradation phenomena observed for those modules exposed outside. Damp-heat test, thermal-cycle test, humidity-freeze test or dynamic mechanical load test is combined for some test modules. Chemical corrosion degradation or physical mechanical degradation was reproduced after the test and the degradation is much accelerated by the combination of the loads.

1. Introduction

Reliability of photovoltaic (PV) modules has recently attracted much attention due to the feed-in-tariff policy. Unfortunately, it is difficult to clarify the reliability or lifetime of PV modules before outside exposure since there is no acceleration test for exactly reproducing degradation phenomena observed for those modules after outside exposure. Of course, there is certification test based on International Electrotechnical Commission (IEC) regulation, however, those tests are carried out for only screening PV modules including initial troubles and there is no acceleration test for guaranteeing long-time reliability. Therefore, it is also difficult to expect service lifetime of PV modules based on the acceleration test results although authors' group revealed that damp-heat (DH) test at 85℃, 85%RH for 4000 h may correspond to outside exposure for 30 years in Japan using acetic acid concentration in PV modules as an index [1]. The reason for the difficulty in reproducing degradation phenomena by acceleration test is that there are too many degradation factors for degradation during outside exposure, such as temperature, temperature cycle, humidity, UV light irradiation, mechanical load by wind or snow, sand storm, salt mist, acid rain, of course, current and voltage, etc. and it is almost impossible to give those degradation factors to PV modules during acceleration test simultaneously. It should be also considered that the degradation factors depend on a climate zone or the situation of the exposure site, for example on the coast.

It has been already claimed that combination test of DH and UV irradiation is very effective for acceleration and for reproducing degradation phenomena [2]. In this study, DH test, thermal cycle (TC) test, humidity freeze (HF) test or dynamic mechanical load (DML) test is sequentially combined for crystalline Si PV modules and degradation phenomena observed after test were analyzed. PV modules using cells with microcracks were subjected to DML/TC sequential test.

2. Experimental

Crystalline Si PV modules including 4 or 42 multicrystalline Si cells connected in series were fabricated using tempered cover glass, ethylene vinyl acetate (EVA) encapsulant, polyethylene terephthalate (PET)/polyvinyl fluoride (PVF)/PET back sheet, junction box, silicone pottant, Al frame, etc.

DH test was carried out at 85℃, 85%RH. TC test was carried out between 85℃ and -40℃. HF test was carried out between 85℃, 85%RH and -40℃. All these tests were done in the climate chamber. DML test was carried out between +1000 Pa and -1000 Pa. The repletion rate of positive and negative loads was 3 cycles/min. In this study DH/TC, TC/HF and DML/TC combined test were attempted. Test modules using multicrystalline Si cells including microcracks intentionally made were also employed for DML/TC test. There is no light irradiation or no current flow during the test in this study.

3. Results and Discussion

DH/TC sequential combination test was done by the repetition of DH 1000 h and TC 200 cycles. Change in maximum power with test sequence is shown in Fig. 1 together with those both by only DH test and by TC test with HF 10 cycles just after TC 50 cycles. Initial maximum power is normalized to 1. Rapid degradation after DH 3000 h shown by dotted red line originates from chemical degradation of finger electrodes due to rapid increase in acetic acid concentration in PV modules [3]. On the other hand, gradual and small degradation is observed by TC test including HF 10 cycles, as shown by dotted dark blue line. Change in maximum power by the DH/TC sequential test is shown by green, orange and blue solid lines for 3 samples. After DH 2000 h and TC 400 cycles remarkable degradation is observed. However, the amount of degradation after DH 3000 h and TC 600 cycles is obviously larger than the sum of the degradation by only DH 3000 h and TC 650 cycles including HF 10 cycles. This finding means that DH/TC sequential test accelerates the degradation in comparison with independent DH and TC tests.

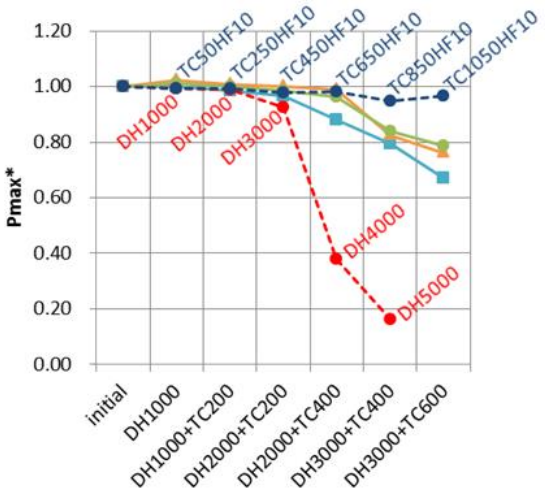

Fig. 1 Normalized maximum power P_{max}* with the test sequence of DH/TC sequential test shown by solid lines, only DH test shown by dotted red line and TC test including HF 10 cycles shown by dotted dark blue line.

TC test including HF 10 cycles just after TC 50 cycles shows only small degradation even after TC 1050 cycles. However, delamination between cover glass and encapsulant was observed. Such delamination is often observed for the PV modules exposed outside for long time although the delamination directly induces no power loss. TC test or TC test including HF test may be effective for reproducing degradation such as delamination although degradation slowly progresses by those tests.

DML/TC sequential test was carried out for 42-cells modules; sample 1 using cells without microcracks, samples 2 and 3 with microcracks. Test sequence and retention of maximum power with the test sequence is shown in Table I and Fig. 2, respectively. Although only small degradation is observed for samples 1 and 3, large degradation is observed for sample 2 as shown in Fig. 2. These results imply that DML/TC sequential test accelerates extension of microcracks, on the other hand, such extension

Table I Test sequence for DML/TC sequential test.

Sequence	Sample 1 w/o microcracks	Sample 2 w/ microcracks	Sample 3 w/ microcracks
1	DML 50 cyc.	DML 50 cyc.	
2	TC 50 cyc.	TC 50 cyc.	TC 50 cyc.
3	DML 50 cyc.	DML 50 cyc.	
4	TC 50 cyc.	TC 50 cyc.	TC 50 cyc.
5	DML 50 cyc.	DML 50 cyc.	
6	TC 50 cyc.	TC 50 cyc.	TC 50 cyc.
7	DML 50 cyc.	DML 50 cyc.	
8	TC 50 cyc.	TC 50 cyc.	TC 50 cyc.

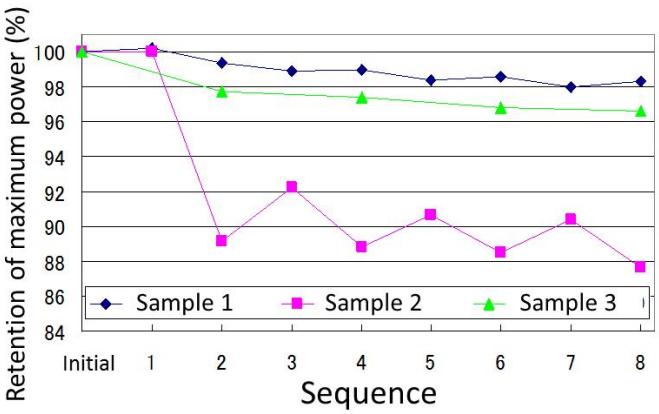

Fig. 2 Retention of maximum power with the test sequence of DML/TC sequential test for samples 1 and 2 and that of only TC test for sample 3. Cells without microcracks were used for sample 1 and those with microcracks were used for samples 2 and 3.

hardly occurs only by TC test. Oscillation of maximum power may originate from subtle attachment of the extended microcracks. Electroluminescence images (not shown) supported such speculation.

3. Conclusions

DH, TC, HF or DML test was combined to develop acceleration test for PV modules. Degradation is accelerated by DH/TC sequential test. Although only small degradation was observed by TC test including HF test, delamination phenomena often observed for PV modules exposed outside for long time were well reproduced. It was also found that extension of microcracks occurs in the cells by DML/TC sequential test, suggesting that the cells with microcracks should be excluded although such cells often influence little initial performance.

Acknowledgements

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References

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