Area: 7 Performance and Reliability of PV Modules

ELECTRICAL IDENTIFICATION OF "AGING SIGNATURE" IN CRYSTALLINE SILICON PHOTOVOLTAIC MODULES EXPOSED IN FIELD FOR LONG-TERM

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A major degradation-mode in photovoltaic (PV) modules has been elucidated as the corrosion of front electrodes, which induces current-collection failure in the pathway from surface of crystalline silicon (Si) PV cell to front grid-lines. And, this corrosion is facilitated by acetic acid (HAc) which is liberated by hydrolysis of ethylene vinyl acetate (EVA). Indeed, the high content of HAc is monitored in PV modules exposed in fields for long-term, and that is also confirmed in PV modules during damp-heat (DH) stress test.

We have proposed the two-phase degradation mechanism involved in this corrosion process, which comprises of power-losses induced by fill factor (FF)-reduction (Phase I) and by short-circuit current (I_{sc})-reduction (Phase II), by the electrical measurement of bare PV cells exposed to HAc vapor and PV modules conducted under DH stress condition (Figs. 1 and 2)[1]. It has been already reported that the degradation in Phase I is due to the formation of gaps underneath front electrodes, which can be detected as two AC impedance signals (the increase in resistance [R_3] associated with the emergence and following reduction of capacitance [C_3]) derived from these formed gaps (Figs. 1 and 2)[1]. In addition, we suggest that the power-loss in Phase II (with I_{sc}-reduction) is caused by the formation of rectifying contact between silver bulk and Si emitter in front electrodes, which is demonstrated by the increase in DC bias-voltage dependency of the capacitance [C_3] originating from this contact[2].

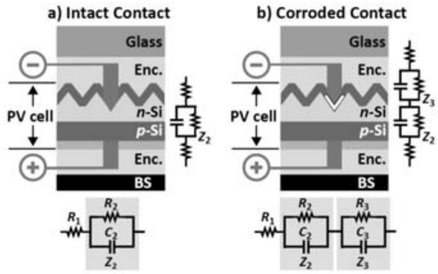

Figure 1: Evolution of AC equivalent circuit by corrosion.

In the present study, we tried to detect these electical "Aging Signatures" in the PV modules exposed in a field for 20 years. In these PV modules, the power-loss with significant decreases in FF and I_{sc} was induced, although densed discoloration was not recognized.

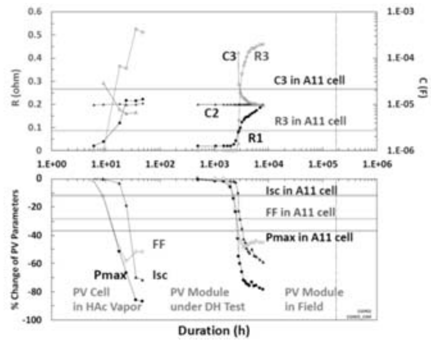

Figure 2: Evolution of AC impedance and *I-V* characteristics during two acceleration tests and those in fielded PV module.

The occurrence of two "Aging Signatures (the increase in R_3 associated with the emergence of C_3)" could be obivously detected in the individual PV cells comprized in these fielded PV modules (Fig. 2). Furthermore, each extent of these signals was coincided with the respective extents of these signals observed during two acceleration tests (HAc exposure of bare PV cells and DH stress test of PV modules), even though several recent technologies were applied to the PV cells tested in these indoor tests. Interestingly, the dependency on DC bias-voltage of C_3, which was indicated as the mean slope of C_3^{-2} in reverse DC bias region (C3_SLOPE), was roughly correlated with the extent of I_{sc}-reduction, as well as the C3_SLOPE was linearly decreased during two acceleration tests (Fig. 3).

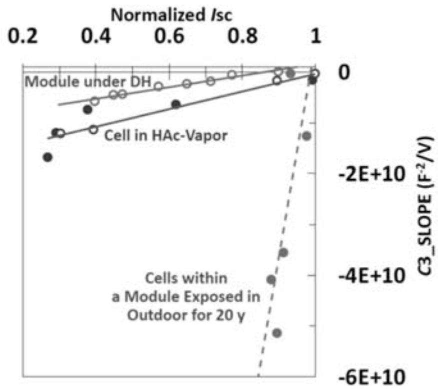

Figure 3: Correlation of I_{sc}-reduction and C3_SLOPE.

These results indicate that all three "Aging Signatures" can be detected in the fielded (aged) PV modules, as in the PV cells/modules which are artificially degradated by hygrothermal stress, and suggest that the durability of PV cells/modules to this stress in fields would be quantitavely predicted by the extents of these signatures during the indoor acceleration tests, although further accumulation of data relevant to these "Aging Signatures" in a wide variety of fielded PV modules should be required. [*The authors wish to thank the supprot by NEDO, Japan*]

[1]: T. Tanahashi et al., *Proc. 43rd IEEE Photovoltaic Spec. Conf.*, 2016, pp. 1075–1079.

[2]: T. Tanahashi et al., *Proc. 44th IEEE Photovoltaic Spec. Conf.*, 2017 (to be published).