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Author(s)	Yamaguchi, Seira; Yamamoto, Chizuko; Masuda, Atsushi; Ohdaira, Keisuke
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Description	

Influence of backsheet materials on potential-induced degradation in n-type crystalline-silicon photovoltaic cell modules

Seira Yamaguchi[1*†], Chizuko Yamamoto[2], Atsushi Masuda[2], and Keisuke Ohdaira[1]

[1]*Graduate School of Advanced Science and Technology, Japan Advanced Institute of Science and Technology, Nomi, Ishikawa 923-1292, Japan*

[2]*Research Center for Photovoltaics, National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki 305-8568, Japan*

[*]E-mail: s-yamaguchi@toyota-ti.ac.jp

We investigated the influence of backsheet materials on potential-induced degradation (PID) in n-type crystalline-silicon (c-Si) photovoltaic (PV) cell modules. Silicon heterojunction PV cell modules and rear-emitter n-type c-Si PV cell modules were fabricated by using aluminum backsheets composed of poly ethylene terephthalate (PET)/aluminum/PET as well as typical backsheets. PID tests of the modules were performed by applying a negative bias in a dry environment (<2% relative humidity). Regardless of the types of cells, the modules with the aluminum backsheets showed smaller degradation. This indicates that aluminum backsheets reduce PID effects, and to alter backsheets may be a potential measure to reduce PID.

[†] Present address: Graduate School of Technology, Toyota Technological Institute, Tempaku, Nagoya 468-8511, Japan

Potential-induced degradation (PID) has been identified as one of the most important reliability issues of photovoltaic (PV) modules.[1–6] PID behaviors are known to be changed not only by cell materials but also by module encapsulation materials such as cover glass and encapsulant materials.[7] On the basis of this fact, several measures to reduce PID effects have been proposed so far.[7–12] Backsheet materials are also considered to indirectly influence PID behaviors because backsheets are related to the degree of moisture ingress into module encapsulants from the rear sides of PV modules. On the other hand, when relative humidity is very low and its influence is negligible, the backsheet materials have been considered to have a minor or no impact on PID. This assumption has, however, not yet been verified.

On the basis of this background, we have investigated whether backsheet materials influence PID behaviors or not. In this rapid communication, we briefly introduce the preliminary experimental results.

Rear-emitter crystalline-silicon (c-Si) PV cell modules and rear-emitter silicon heterojunction (SHJ) PV cell modules were fabricated in a typical module laminator. We fabricated 45 × 45-mm^2-sized modules including 20 × 20-mm^2-sized cells for the rear-emitter c-Si PV cell modules and 180 × 180-mm^2-sized modules including 156 × 156-mm^2-sized cells for the SHJ PV cell modules. The module lamination procedure was the same as that used in our previous studies (for example, Ref. 13). The modules were composed of conventional tempered cover glass/ethylene-vinyl acetate copolymer (EVA) encapsulant/cell/EVA encapsulant/backsheet. In this study, to investigate the influence of the use of an alternate backsheet on PID, we used two kinds of backsheets: typical backsheets composed of Tedlar® poly vinyl fluoride (PVF)/poly ethylene terephthalate (PET)/Tedlar® PVF and aluminum (Al) backsheets composed of PET/Al/PET. The former and the latter are referred to as TPT and PAP backsheets, respectively.

PID tests were performed by applying a bias of −1000 or −2000 V to shorted interconnector ribbons of a cell with respect to an Al plate placed on the module cover glass. The tests were conducted at 85 °C and in a dry environment (a relative humidity of <2%). This means that the effect of moisture ingress into modules during PID tests is negligible. We performed current density–voltage (*J*–*V*) measurements of PV modules under 1-sun illumination before and after the PID tests.

Figure 1 shows the *J*–*V* curves of the rear-emitter n-type c-Si PV modules with the TPT backsheet and with the PAP backsheet before and after the PID tests in which a bias of −1000 V was applied for 2 h. The both modules exhibited previously reported typical degradation behaviors which are characterized by reductions in the open-circuit voltage (V_{oc}) and in the fill factor (FF)[14]. (The PAP-backsheet module showed a lower short-circuit current density (J_{sc}). This was because of a lower reflectance at the interface between the encapsulant and backsheet. The TPT backsheet was white-colored whereas the front surface of the PAP backsheet was black-colored.) However, there was a difference in the degree of degradation.

Figure 2 shows $V_{oc}/V_{oc,0}$ and FF/FF_0 of the modules as a function of PID-stress duration, where the subscript 0 indicates the initial values. The reductions in $V_{oc}/V_{oc,0}$ and FF/FF_0 of the PAP-backsheet module were smaller than those of the TPT-backsheet module. This result shows that the PAP backsheet reduces PID in rear-emitter n-type c-Si PV modules, and is different from the assumption that backsheet materials have no impacts on PID behaviors when humidity is very low and moisture ingress is negligible. (Note that in this study, the PV modules were placed in a dry environment with a relative humidity of <2%, and moisture ingress is negligible in this experimental condition.) This implies that the reduced degradation due to the use of the PAP backsheet is caused by any other reason(s).

Figure 3 shows the PID-stress-duration dependence of $J_{sc}/J_{sc,0}$, $V_{oc}/V_{oc,0}$, FF/FF_0, and $P_{max}/P_{max,0}$ of the SHJ PV modules with the TPT backsheet and with the PAP backsheet that underwent the PID testing in which a bias of −2000 V was applied, where the P_{max} is the maximum output power and the subscript 0 indicates the initial values. This kind of PV cell modules are known to exhibit PID which is characterized by reductions mainly in the J_{sc}.[15,16] The both modules showed reductions in the J_{sc}. However, the degradation rates of the PAP modules are slower than those of the TPT modules. From this result, the PAP backsheet reduces PID effects not only in rear-emitter n-type c-Si PV cell modules but also in SHJ PV cell modules.

At present, the mechanism of the reduction effect of using the PAP backsheets is unclear. One possible explanation is that free electrons present in the Al sheet of the backsheet counteract a part of an electric field caused by PID-test bias application and result in reduced PID. When a bias is applied between the cover glass surface and the cell, an electric field is created. The electric field exerts a force to the free electrons in the backsheet and induces the polarization of charges. The induced charges also create an electric field and counteract the original electric field. As a result, PID is reduced. (Note that relative humidity in our test is < 2% and we can neglect the influence of moisture ingress.) On the basis of this hypothesis, the conductivity of backsheet materials is important, and backsheets involving electrically conductive films may reduce PID effects. However, we have to perform additional experiments and discussion to elucidate the actual mechanism that explains the above observed phenomena. Additionally, we have to confirm whether the PID reduction effect occurs in modules fabricated from other types of PV cells such as conventional p-type c-Si PV cells or not.

From a practical point of view, the PID reduction effect by the use of alternate backsheets is very important since it may realize novel low-cost measures to reduce PID effects. So far, various preventive measures on the module level have been proposed based on the use of alternate cover glass[7–9] and the use of alternate encapsulants[7, 10–12]. On the other hand, there were no or few proposed measures to reduce PID effects by the use of alternate backsheet materials. If measures based on backsheet alternatives are established, options for anti-PID structures will broaden. As observed in this study, backsheets involving an Al sheet reduce PID effects. Furthermore, such backsheets are low-cost. Therefore the use of Al backsheets can be readily applied to the current PV technologies, as a low-cost measure to reduce PID effects.

In summary, we investigated the influence of the use of the PAP backsheet on PID. In PIDs both in rear-emitter n-type c-Si PV cell modules and in SHJ PV cell modules are reduced by the use of the PAP backsheet. The actual mechanism is unknown at present, and, however, the PID reduction effect might be explained by a reduced electric field by induced charges in the backsheet. From a practical point of view, the use of alternate backsheets may be a novel, low-cost measure to reduce PID effects.

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Figure Captions

Fig. 1. Representative *J–V* characteristics of the rear-emitter n-type c-Si PV cell modules (a) with the TPT backsheet and (b) with the PAP backsheet before and after the PID tests in which a bias of −1000 V was applied at 85 °C for 2 h. (The PAP-backsheet module showed a lower J_{sc}. This was because the PAP backsheet was black-colored and there was a lower reflectance at the interface between the encapsulant and backsheet.)

Fig. 2. (Color online) Changes in $V_{oc}/V_{oc,0}$ and FF/FF_0 of the rear-emitter n-type c-Si PV cell modules with the TPT backsheet and with the PAP backsheet before and after the PID tests in which a bias of −1000 V at 85 °C for 2 h.

Fig. 3. (Color online) PID-stress duration dependence of $J_{sc}/J_{sc,0}$, $V_{oc}/V_{oc,0}$, FF/FF_0, and $P_{max}/P_{max,0}$ of the SHJ PV cell modules with the TPT backsheets and with the PAP backsheets. In the PID tests, the bias was set to −2000 V. The data points represent the mean values of two identical modules.

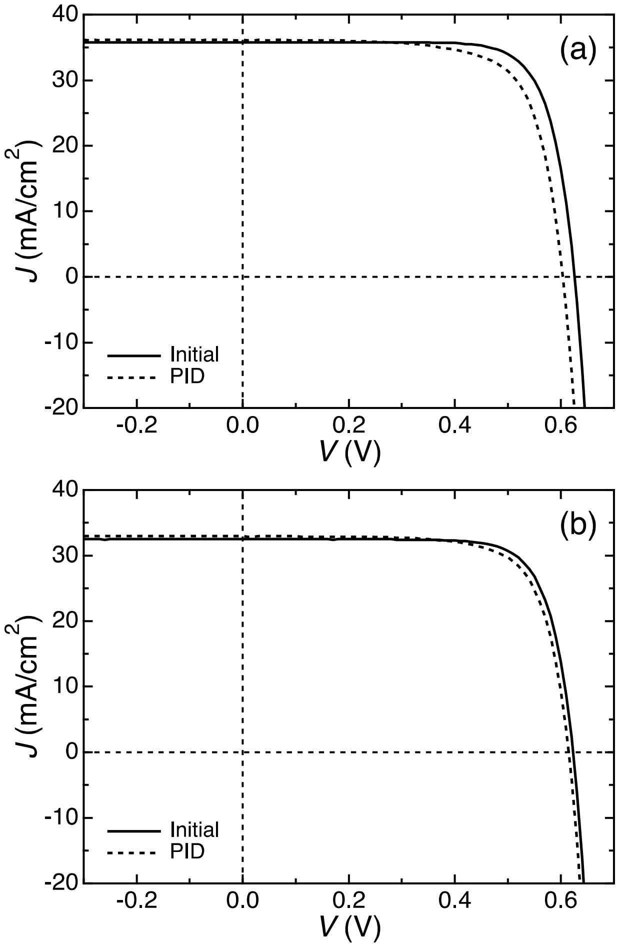


Fig. 1

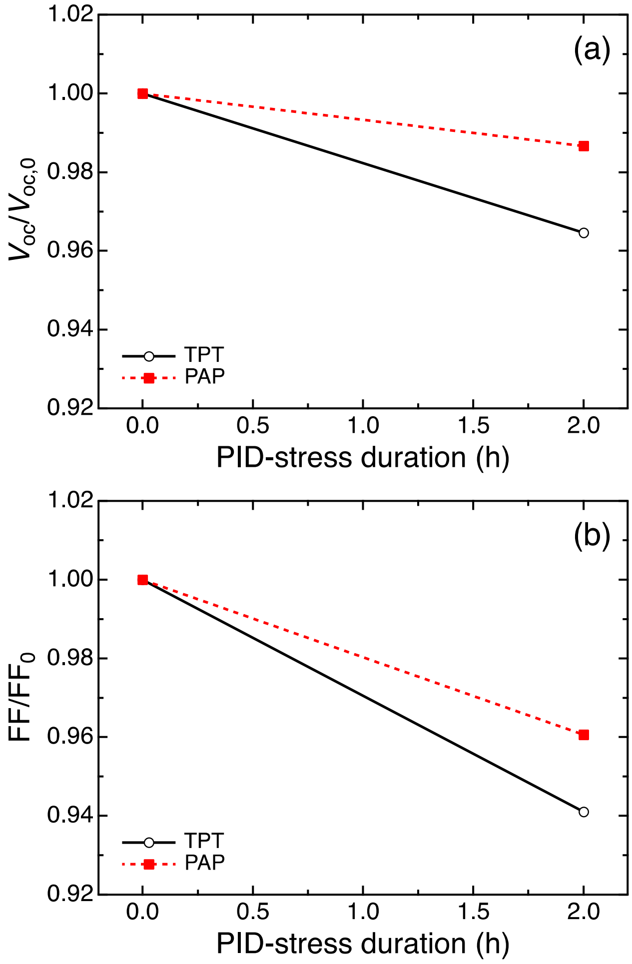
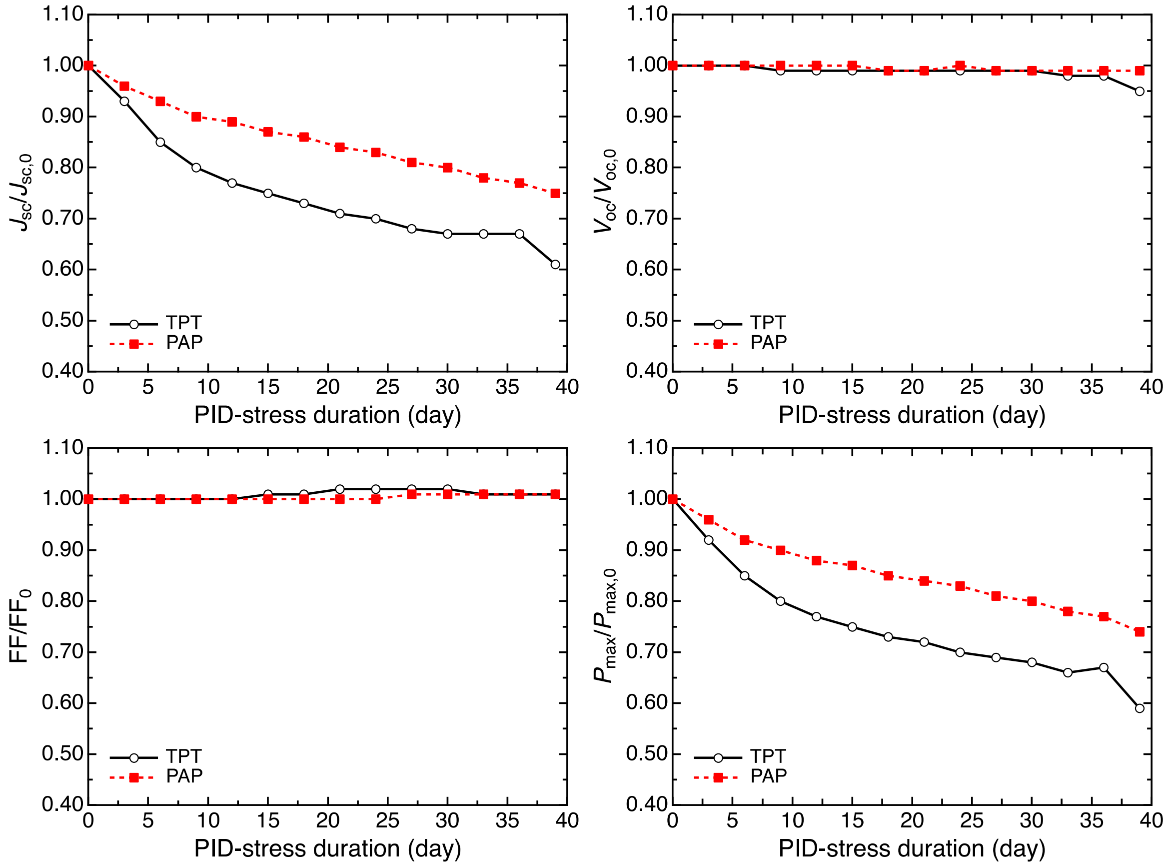

1.02
1.00
0.98
0.96
0.94
0.92
$V_{oc}/V_{oc,0}$
(a)
TPT
PAP
0.0
0.5
1.0
1.5
2.0
PID-stress duration (h)
1.02
1.00
0.98
0.96
0.94
0.92
FF/FF_0
(b)
TPT
PAP
0.0
0.5
1.0
1.5
2.0
PID-stress duration (h)

Fig. 2



1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
$J_{sc}/J_{sc,0}$
$V_{oc}/V_{oc,0}$
FF/FF_0
$P_{max}/P_{max,0}$
TPT
PAP
0
5
10
15
20
25
30
35
40
PID-stress duration (day)

Fig. 3