Reliability and durability impact of high UV transmission EVA for PV modules

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ABSTRACT

Newly developed high UV light transmission ethylene vinyl acetate (EVA) has recently been extensively introduced for use in PV modules. It has been proved that this type of EVA can result in potential power gain because of the better blue light response of the solar cell, which in turn can further reduce the cost per watt of the PV module. However, if only high UV transmission EVA is used as an encapsulant, too much UV light irradiates the backsheet, which can cause the backsheet to yellow. In order to improve the reliability and durability of the modules, SUNTECH, as a module manufacturer, therefore uses combined EVA, i.e. high UV transmission EVA as the front encapsulant and conventional UV cut-off EVA as the rear encapsulant, to protect the UV-sensitive backsheet. This paper presents the results of an investigation of the reliability and durability of high UV transmission EVA in PV modules, through an enhanced UV test which exceeds IEC standards.

Introduction

A number of solar cell manufacturers have recently introduced high-efficiency products with improved quantum efficiency at short wavelengths. Conventional ethylene vinyl acetate (EVA) encapsulant, however, has a short wavelength cut-off at ~380nm and therefore cancels out the benefit of the potential power gain from cells with better blue light response. This cut-off is due to UV absorbers and stabilizers present in the EVA, which block the UV light and thus protect the backsheet. Newly developed high UV light transmission EVA, which can capture the UV light through reducing or removing UV absorbers and stabilizers, has therefore been extensively implemented in PV modules with better blue-light response cells; a power gain of at least 1% has in fact been demonstrated compared with conventional EVA [1].

> "If only high UV transmission EVA is used as the encapsulant, too much UV light irradiates the backsheet, which can cause the backsheet to yellow."

In actual applications, if only high UV transmission EVA is used as the encapsulant, too much UV light irradiates the backsheet, which can cause the backsheet to yellow. The majority of module manufacturers therefore use combined EVA – i.e. high UV transmission EVA as the front encapsulant and conventional UV cut-off EVA as the rear encapsulant, to protect the UV-sensitive backsheet. As is well known, however, the UV absorber and stabilizer additives can prevent backsheet degradation in sunlight but can also decay over time. Whether the combined EVA can really provide the desired long-term durability for modules therefore needs to be proved.

This paper present the results of a study carried out by SUNTECH of the reliability and durability of high UV light transmission EVA as the front encapsulant in PV modules, by the use of enhanced UV tests which exceed IEC standards. At the material level, high UV light transmission EVA as the front encapsulant has been found to be more stable than conventional EVA during long-term UV exposure. The light transmission of high UV light transmission EVA does not show any change, and also no yellowing phenomenon can be observed. Conventional EVA, on the other hand, exhibits an obvious degradation of light transmission and slight yellowing.

The use of high UV light transmission EVA as both front and rear encapsulant, however, will fail to protect the UV-sensitive backsheet as a result of too much UV light irradiating the backsheet; this can cause the backsheet to yellow, with the yellowing index (YI) potentially rising to a value of 50.

The issues above can be addressed by the use of combined EVA. Although the UV light transmission can increase from 20% to 45% (which is quite close to the value for high UV transmission EVA) after 300kWh/m^2 UV exposure, no yellowing of the UV-sensitive backsheet can be observed, and the YI

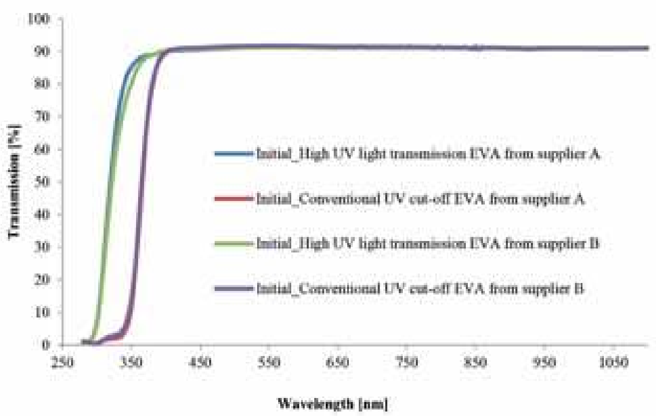

Figure 1. Light transmission curves of conventional UV cut-off EVA and high UV light transmission EVA from two different suppliers.

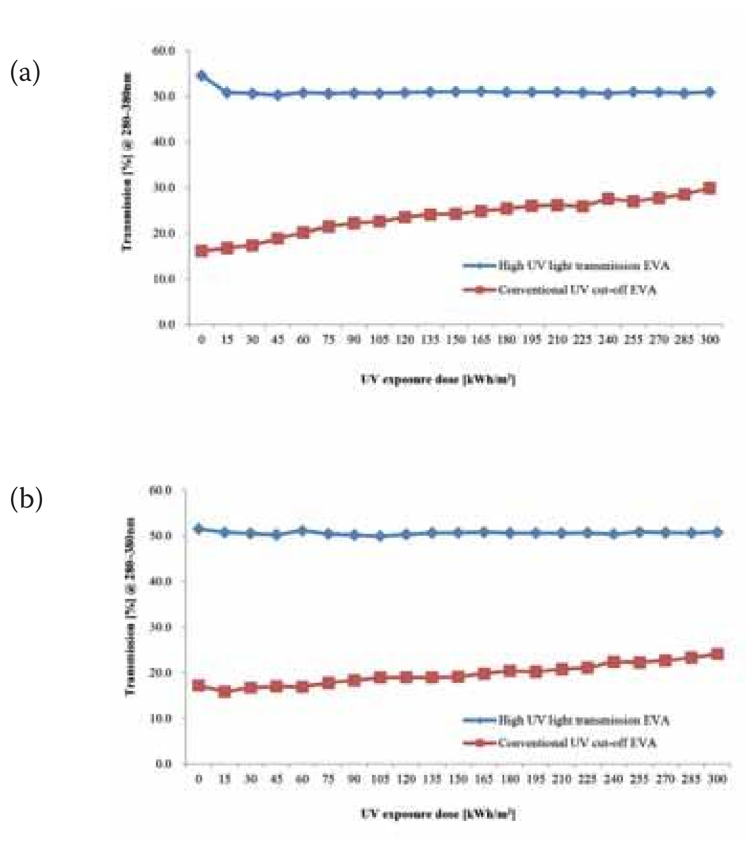

Figure 2. Transmission change at short wavelengths with UV exposure: EVA from supplier A; (b) EVA from supplier B.

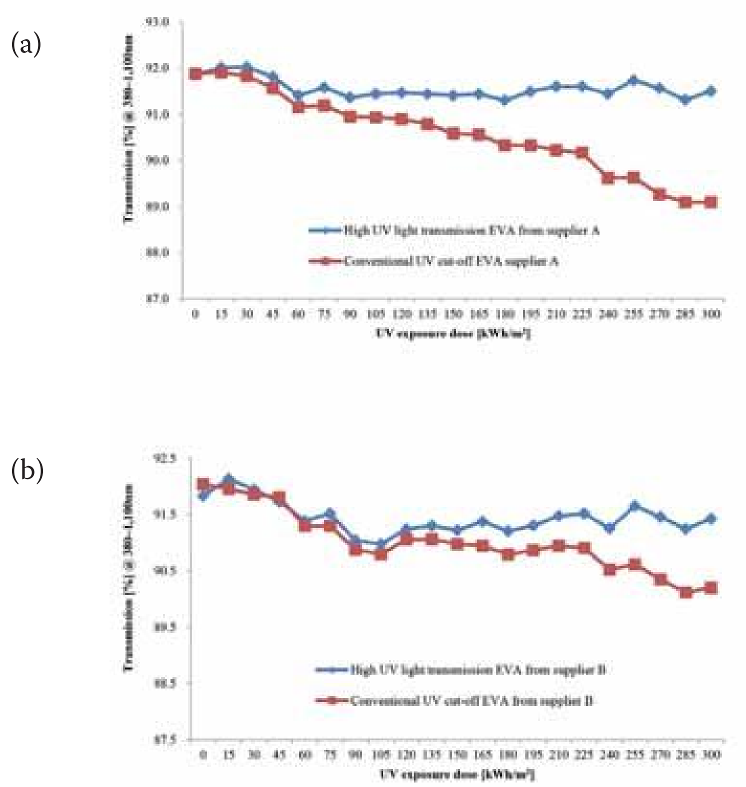

Figure 3. Transmission change at visible light wavelengths with UV exposure: EVA from supplier A; (b) EVA from supplier B.

of the UV-sensitive backsheet increases only slightly, implying that combined EVA serves as protection for the sensitive backsheet.

At the module level, the long-term impact on power was also investigated in the study. Suntech PV modules encapsulated with combined EVA were subjected to UV extended testing with UV doses of up to 330kWh/m^2. Test results reveal that the output power loss is less than 2.1% and that there are no visual defects.

Materials and procedure

High UV light transmission EVA and conventional UV cut-off EVA from two EVA suppliers are used for this study; the light transmission is shown in Fig. 1. Two backsheets with a fluoroplastic/polyester/tie layer structure are used, with one UV sensitive and the other UV non-sensitive. The UV exposure tests of the materials and modules are carried out in accordance with IEC 61215:2005 (Ed. 2.0) [2].

Results

Light transmission change

The change in light transmission via the front EVA to the cells not only affects module power output but also reveals the ageing of the materials. In order to evaluate the long-term performance of the high UV light transmission EVA and conventional UV cut-off EVA as front encapsulants, two such EVAs were laminated in a glass/EVA/glass arrangement and received long-term UV exposure up to 300kWh/m^2. Light transmission was measured at each 15kWh/m^2 UV exposure.

The results indicate that there was no change in light transmission at short wavelengths for the high UV light transmission EVA, while there was an obvious increase (of up to 10%) for the conventional UV cut-off EVA, as shown in Fig. 2. This indicates that the UV absorber and stabilizer additives in the conventional UV cut-off EVA decay with UV exposure.

Fig. 3 shows the light transmission change at visible light wavelengths. It can be observed that the light transmission clearly decreases by ~2–3% with UV exposure for the conventional UV cut-off EVA; however, there is a decrease of only ~0.5–1% in light transmission for the high UV light transmission EVA. The light transmission decrease in both cases is mainly caused by ageing of the materials.

The changes in the transmission curves from 280nm to 1,100nm before and after UV exposure are shown

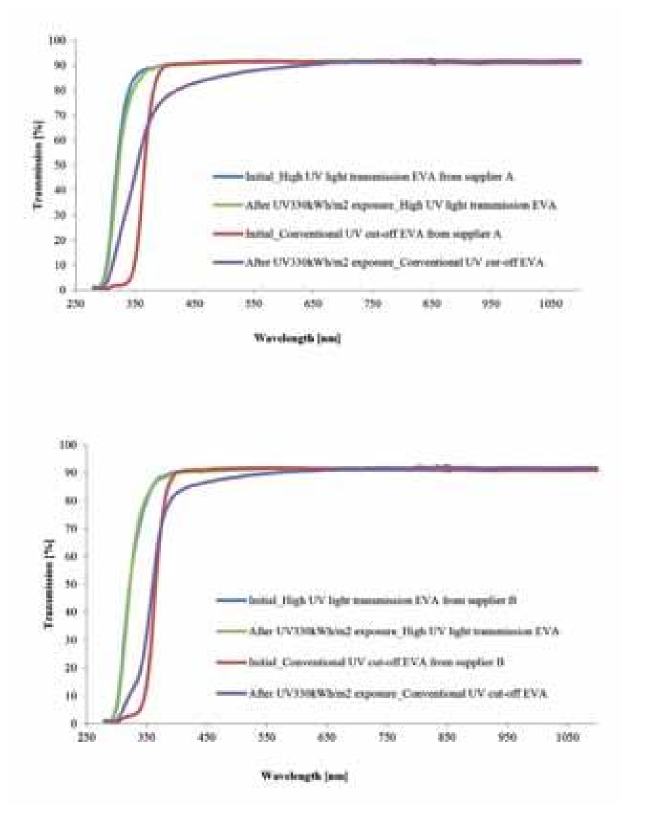

Figure 4. Transmission curve before and after 300kWh/m² UV exposure: (a) EVA from supplier A; (b) EVA from supplier B.

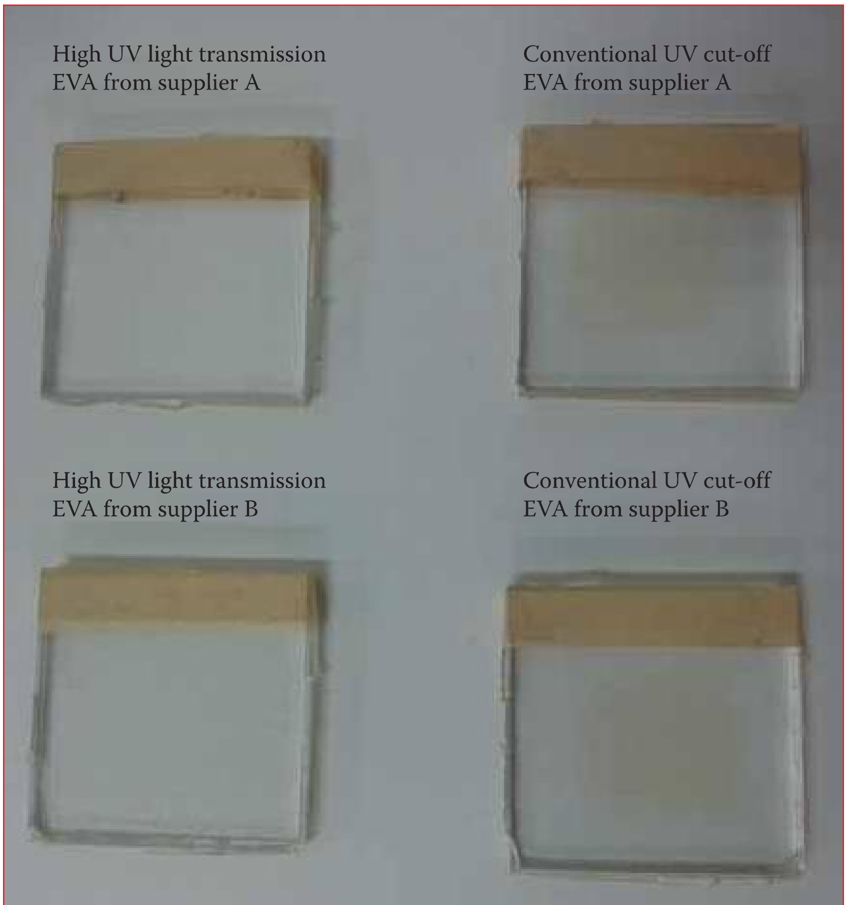

Figure 5. Visual changes in the conventional UV cut-off EVA and the high UV light transmission EVA after 300kWh/m² UV exposure.

in Fig. 4 for the two types of EVA. Again, the curve change clearly shows practically no change in the case of the high UV light transmission EVA. The conventional UV cut-off EVA, however, has degraded after 300kWh/m² UV exposure, which will affect module power output. This implies that high UV light transmission EVA is more stable than conventional UV cut-off EVA during long-term UV exposure.

In addition, the conventional UV cut-off EVA was observed to begin to yellow after 300kWh/m² UV exposure; however, the high UV light transmission EVA exhibited no visual defects, as shown in Fig. 5. It is speculated that the UV absorber and stabilizer additives can block UV light transmission but can also accelerate the material ageing, which will cause the light transmission to degrade and the EVA to yellow.

UV light transmission impact on the backsheet

UV light irradiation of the backsheet can cause yellowing. In order to reduce UV light damage to the backsheet, in actual applications, combined EVA – high UV transmission EVA as the front encapsulant and conventional UV cut-off EVA as the rear encapsulant – is used. However, the amount of UV light that can be blocked by combined EVA, and whether or not its use offers protection to the backsheet, need to be evaluated.

> "Compared with high UV transmission EVA, combined EVA can block more UV light."

Fig. 6 shows the change in light transmission at short wavelengths of such combined EVA with UV exposure; compared with high UV transmission EVA, combined EVA can block more UV light. However, UV absorber and stabilizer additives in combined EVA decay faster than in conventional UV cut-off EVA: after 300kWh/m² UV exposure, the light transmission at short wavelengths increases from 20% to 45%, which is quite close to the value for high UV transmission EVA. The implication is that more UV light irradiation reaches the backsheet with combined EVA than with conventional UV cut-off EVA.

The UV light transmission impact on a UV-sensitive backsheet is shown in Fig. 7. It can be observed that the use of high UV light transmission EVA as both

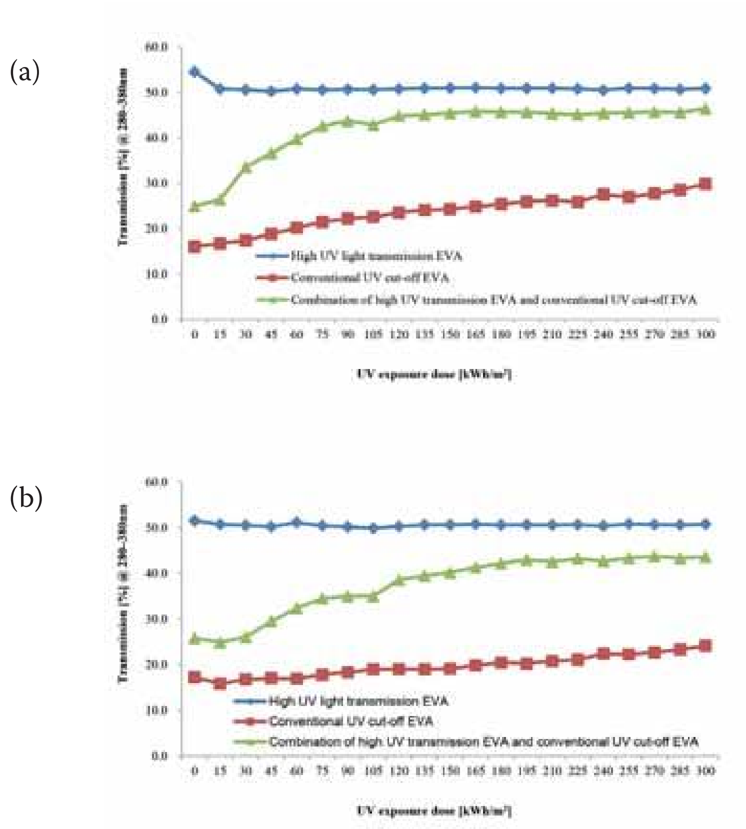

Figure 6. Differences in light transmission at short wavelengths between high UV light transmission EVA, conventional UV cut-off EVA and combined EVA: (a) EVA from supplier A; (b) EVA from supplier B.

front and rear encapsulant can result, after only 15kWh/m^2 UV exposure, in slight yellowing of the UV-sensitive backsheet, which becomes more and more severe with increasing UV exposure. The YI also confirms that the yellowing of the backsheet intensifies with greater UV exposure, reaching over 50 after 300kWh/m^2 UV exposure, as shown in Fig. 8.

The combined EVA, however, offers protection to the UV-sensitive backsheet, as in the case of conventional EVA: only slight yellowing along the edge of a dummy sample could be detected after 300kWh/m^2 UV exposure and the YI showed just a slight increase. The use of the combined EVA can therefore provide long-term durability of the module, even if the backsheet of the module is UV sensitive.

In the case of a UV-non-sensitive backsheet, UV light will not damage it; hence, the use of high UV light transmission EVA as both front and rear encapsulant also can provide long-term durability. Fig. 9 shows the visual changes in the UV-non-sensitive backsheet, and Fig. 10 shows the corresponding changes in the YI: backsheet yellowing cannot be observed, and there is almost no change in YI. This means that when the anti-UV performance of the backsheet is sufficiently effective, any of the EVAs can be used as encapsulant.

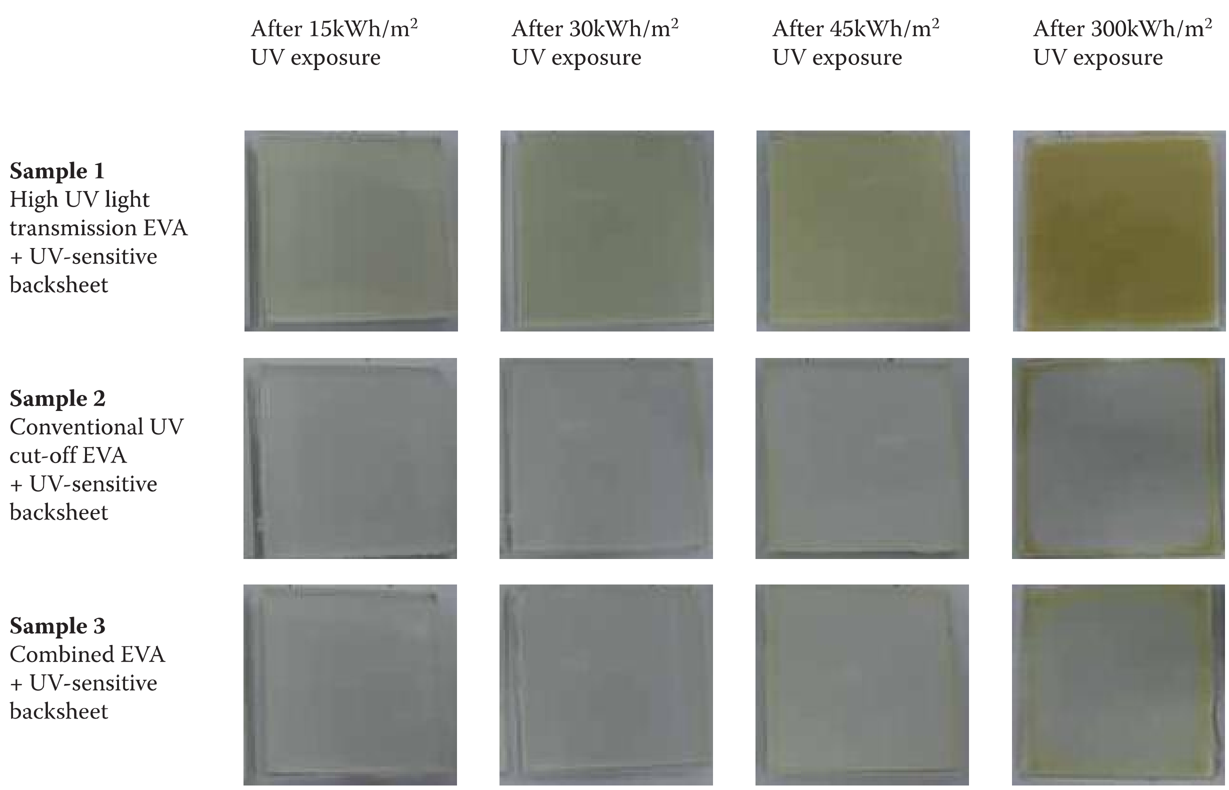

Figure 7. UV light transmission impact on the UV-sensitive backsheet.

Long-term power impact at the module level

The long-term impact on power at the module level was evaluated. Three Suntech PV modules encapsulated with combined EVA were subjected to UV extended testing: one module received up to 330kWh/m² UV exposure and other two received 165kWh/m² UV exposure. The results show an output power loss of less than 2.1% for Suntech modules after long-term exposure, as depicted in Fig. 11. The results at the module level also revealed that the use of combined EVA as encapsulant can provide long-term durability of the module.

> "Combined EVA provides long-term durability and an output power loss of less than 2.1% for Suntech modules after 330kWh/m² UV exposure."

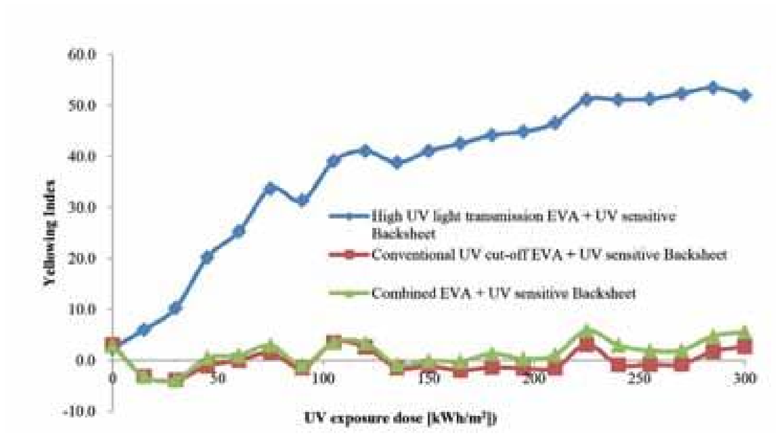

Figure 8. Changes in YI for the UV-sensitive backsheet.

Conclusions

High UV light transmission EVA has the benefit of better blue light response for solar cells; it is also more stable than conventional UV cut-off EVA under long-term UV exposure. At short and visible light wavelengths there is virtually no change in light transmission after 300kWh/m² UV exposure. Conventional EVA, however, exhibits a noticeable decrease and yellowing as a result of the decay of the UV absorber and UV stabilizer.

In actual applications, if high UV light transmission EVA is used as both front and rear encapsulant, the long-term effect on the UV-sensitive backsheet could negate the benefits because of too much UV light irradiating the backsheet, causing it to yellow. However, the use of a combination of high UV light transmission EVA and conventional UV cut-off EVA can not only benefit module power output, but also provide the same protection to the UV-sensitive backsheet as conventional EVA. Enhanced UV tests show that only a slight yellowing occurs along the edges of the dummy samples after 300kWh/m² UV exposure, and that there is a marginal increase in YI.

The results at the module level also reveal that the combined EVA provides long-term durability and an output power loss of less than 2.1% for Suntech modules after 330kWh/m² UV exposure.

After 15kWh/m² UV exposure | After 30kWh/m² UV exposure | After 45kWh/m² UV exposure | After 300kWh/m² UV exposure

Sample 4 High UV light tranmission EVA + UV-non-sensitive backsheet

Sample 5 Conventional UV cut-off EVA + UV-non-sensitive backsheet

Sample 6 Combined EVA + UV-non-sensitive backsheet

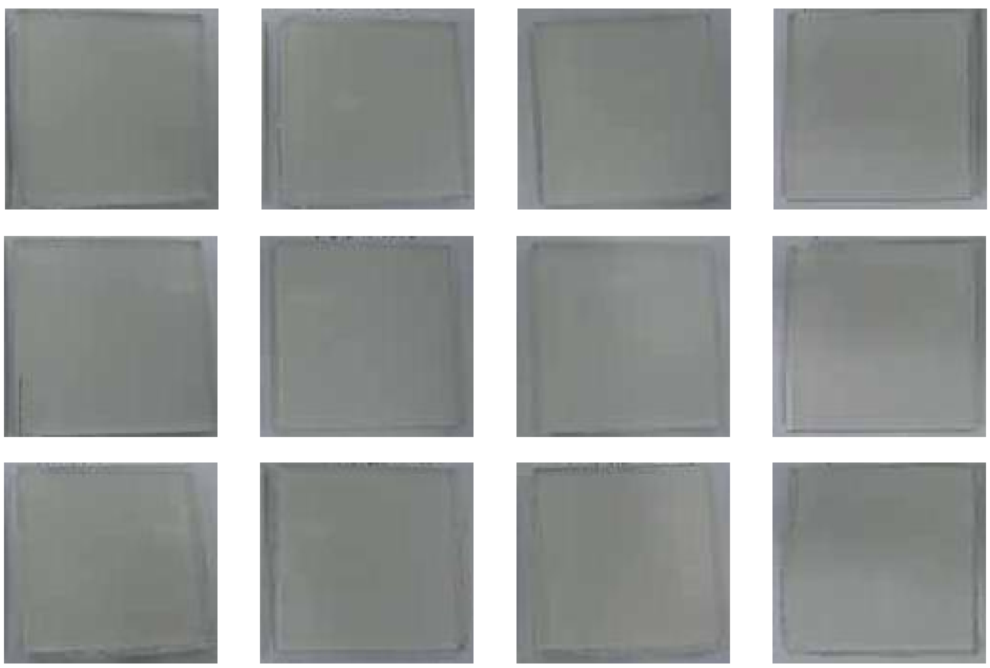

Figure 9. UV light transmission impact on the UV-non-sensitive backsheet.

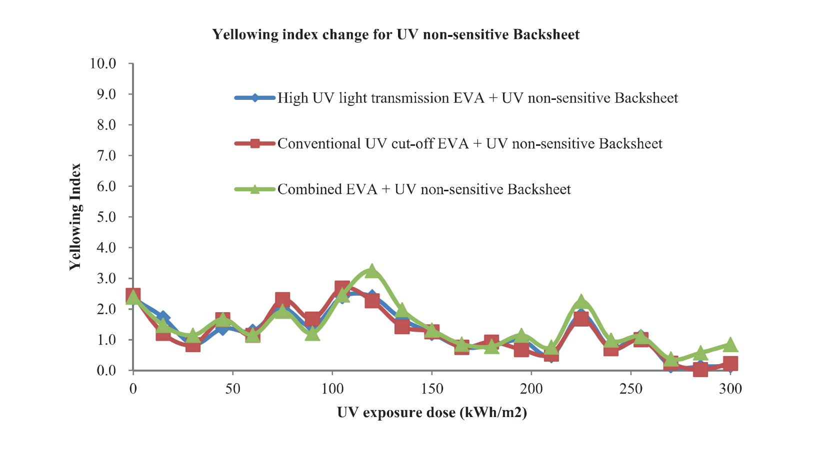

Figure 10. Changes in YI for the UV-non-sensitive backsheet.

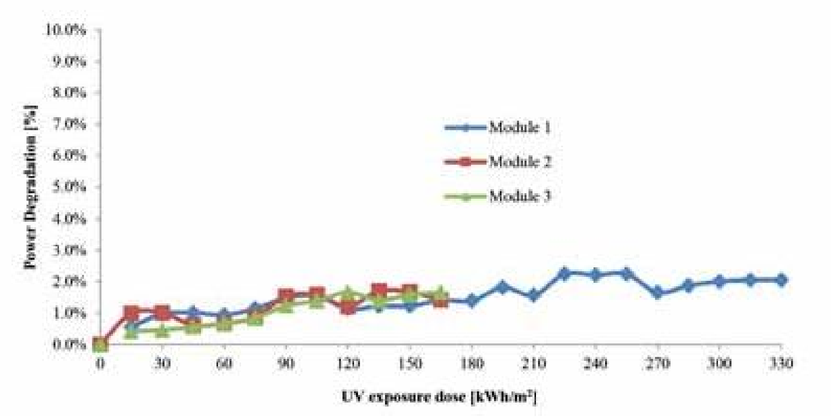

Figure 11. Long-term impact of UV exposure on module power.

References

[1] Schmid, C. et al. 2012, "Impact of high transmission EVA based encapsulation on the performance of PV modules", *Proc. 27th EU PVSEC*, Frankfurt, Germany.

[2] IEC 61215-2005, "Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval".

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