Evaluation and Analysis of 15 years exposure PV module

We conducted various analyses on 15 years exposure modules and investigated the relationship between the exposure year and Damp heat test from material evaluation by molecular weight analysis of the backsheet.

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Visual Inspection

Crystalline silicon type modules in the order of mass, are composed of glass, aluminum frame, EVA resin, solar cell, terminal box, back film, tapping screws, etc. Among these, those which are continuously exposed to external atmosphere are glass, aluminum frame, tapping screws, terminal box, and back film. The below table shows the results of visual observation of modules made by three companies with a focus on these items. The modules made by the three companies had in common that EVA had turned yellow somewhat. It seems that the companies used the same EVA at that time and therefore the same slightly yellowing resulted. In respect to other parts, materials involving the designing concept of the respective companies were used and the conditions are as shown in the below table.

Model No.	A	B	C
Cell type	Mono-crystalline	Multi-crystalline	Mono-crystalline
Front Appearance	Good	Good	Not Good
Back Appearance	Good	Good	Not Good
Al Appearance	Good	Good	Good
Screw Appearance	Good	Good	Good

Material evaluation by molecular weight analysis of the backsheet

- In conducting analysis of the back film, measuring of back film material and molecular weight were made by Gel Permeation Chromatography (GPC). In regard to the product of A type module, the correlation of material deterioration was examined by comparing with the test piece on which JIS reliability test had been conducted.
- The analyzed back film of modules may be roughly divided into two types, one structured with PET type materials as the base material and the other with PVF type materials as the base material. module type A used PET type while module type B and C used PVF type. All three types of modules used a three layer structure of film/ aluminum foil/film. In regard to PET of module type A, the data are all shown in known PET reference standard values of absolute molecular weight and therefore the figures approximate absolute figures. On the other hand, PVF is shown in relative values of polyethylene glycol reference standard and therefore the disparity with absolute values is seen. By comparison with initial stage samples, it was found that the “high temperature, high humidity sample” had shifted more to the low molecular weight side than the “long-term exposure sample.” Therefore it may be judged that JIS high temperature, high humidity conditions are more severe to PET for back film material than long-term exposure conditions.

	Material	Number Average Molecular Weight [Mn]	Weight Average Molecular Weight [Mw]
Module Type B (15 years)	PVF	5860	232,000
Module Type C (15 years)	PVF	6130	214,000
Module Type A (15 years)	PET	6910	25,300
Initial	PET	7350	28,500
After Thermal cycling test	PET	7510	28,800
After Humidity Freeze test	PET	7670	28,900
After Dam Heat test	PET	4500	16,100
After Dry heat test	PET	6910	25,300

Material evaluation of Ethylene Vinyl Acetate

Composition analysis, analysis of additives and measuring of gel fraction of EVA resin sealing the solar cell were conducted and the condition of the EVA after 15 years of exposure was examined. As shown in the below table, the VA value for EVA sheets of the respective companies was 31～32%. From the results of analysis of additives, it was found that although fair amount of light stabilizer and ultra violet ray absorbent were consumed, such still remained in the EVA. Since the amount decreased from initial values, it is thought that the above mentioned two types of light stabilizers functioned as prevention sufficiently. Also, the gel fraction which was around 80 - 85% prior to use of the solar battery had increased. It is believed that this increase was caused by progressing of EVA cross-linking reaction by factors such as temperature increase by long-term exposure

	VA [%]	Crosslinking Agent	Light Stabikizer	UV Ray Absorbent	Gel Fraction [%]
Before Crosslinking	-	100	100	100	-
After Crosslinking	-	40	Over 90	Over 90	80-85
15 years Type A	32	0	37	27	91
15 years Type B	31	0	21	6	93
15 years Type C	32	0	29	37	93

Evaluation of electrical characteristics

The below table shows the electrical performance evaluation of the modules made by the three companies and introduced on the market for 15 years. Comparing the maximum output shown in the Table with the values given on the nameplate, it was found that 90% or more output was maintained. Also, withstand voltage test and measuring of insulation resistance values as specified by JIS were conducted, and no problem was seen on the modules made by the respective companies.

Model No.	A	B	C
Voc [V]	27.8	25.58	17.85
Isc [A]	2.6	2.89	3.19
Pmax [W]	54.64	54.22	40.31
F.F.	0.756	0.732	0.708
Power ratio compared with Type label	0.923	0.972	0.96
Dielectric Voltage Withstand test (2200V, 1min)	OK	OK	OK
Insulation-Resistance test (Applied voltage:1000V)	1200MΩ	1000MΩ	850MΩ

Comparison between exposure year and Damp heat test

From the result of comparison the change ratio of molecular weight of PET backsheet, the condition of outdoor exposure at Rokko is almost same as 300 hours of Damp heat test. Therefore, we assume that the test condition of Damp heat 1000 hour is equivalent for 45 years at Rokko.

		Change ratio (%)				
		Number average molecular weight(Mn)	Weight-average molecular weight(Mw)	Average weight(Mz)	Dispersity (Mw/Mn)	Dispersity (Mz/Mw)
Damp heat test	Initial	0	0	0	0	0
	After 1000h	-38.78	-43.51	-40.43	-7.73	5.00
	After 3000h	-67.96	-79.64	-78.75	-36.29	4.26
15 years exposure	Initial	0.00	0.00	0.00	0.00	0.00
	After 15 years	-5.99	-11.23	-9.57	-5.67	1.67

Figure 1 Change ratio of Molecular weight of PET backsheet after Damp heat test