ThreeBond
TECHNICAL NEWS

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Dye-Sensitized Solar Cell Sealant

Introduction

Renewable energy development is currently underway all across the world in an effort to ensure sufficient energy resources. Among such research, there are high expectations for the permanent and clean energy produced by solar cells, so a variety of solar power generation system specifications are being constructed. While silicon solar cells are currently the most widely used, research on alternative materials is aggressively pursued due to the high cost of silicon and supply issues concerning silicon materials. One of these alternatives is the dye-sensitized solar cell (hereafter abbreviated as DSSC).

As we mentioned in Technical News No. 65, ThreeBond has long been engaged in the development of DSSC sealant and we are pleased to announce the release of three dye-sensitized solar cell sealants, ThreeBond 3035B, ThreeBond 3035C and ThreeBond 3118.

In this article, we will explore their properties advantages and usage.

Hereafter, ThreeBond is abbreviated as TB.

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1. What are DSSC?

Solar cells are systems that convert energy from sunlight into electrical energy. They are classified by materials used as indicated in Figure 1. Dye-sensitized solar cells are an organic type of solar cell where dyes absorbed within titanium oxide nanostructures absorb light energy, convert it into electrons via electrochemical properties then extract it as electricity. Though inferior to the more widely used silicon solar cells in terms of power generation efficiency, their materials are inexpensive, they are easy to construct and their design is excellent. They can also generate power with weak indoor light, and such generation is not easily influenced by the angle of incident light. Thus, development continues to progress towards their practical application as a next-generation solar cell.

One of the issues getting in the way of this application is long-term durability. If the organic solvent electrolite solution that fills the cell should leak, performance dramatically.

2. DSSC Electricity Generation Mechanism

DSSC generate electricity through the mechanism shown in Figure 2.

(1) Dye is excited by exposure to light, exciting the ground-state electrons.

(2) Excited electrons pass through the outer circuit, moving toward a counter electrode.

(3) Having reached the counter electrode, the electrons reduce the triiodide ions contained in the electrolytic solution into iodide ions.

(4) These iodide ions are then oxidized into triiodide ions by redox reaction with the dye.

Electric energy is extracted through repetition of the process from (1) to (4).

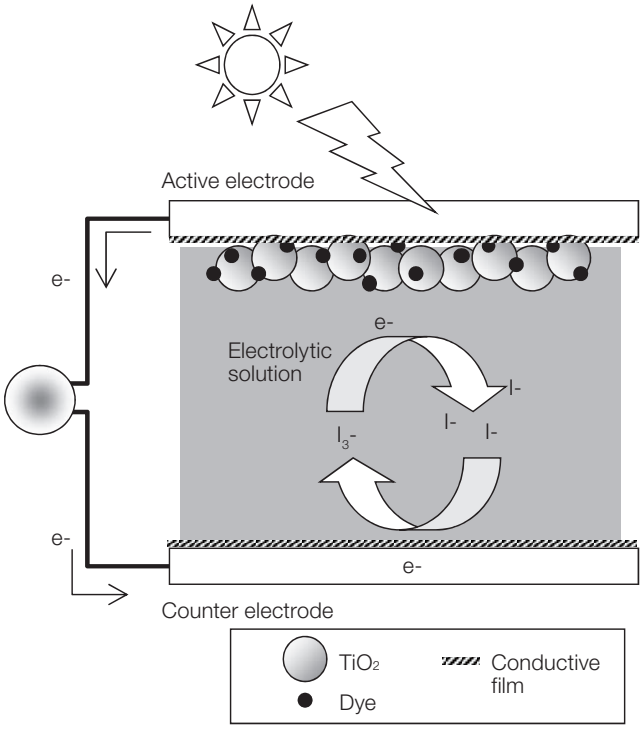


Fig. 2 DSSC Electricity Generation Mechanism

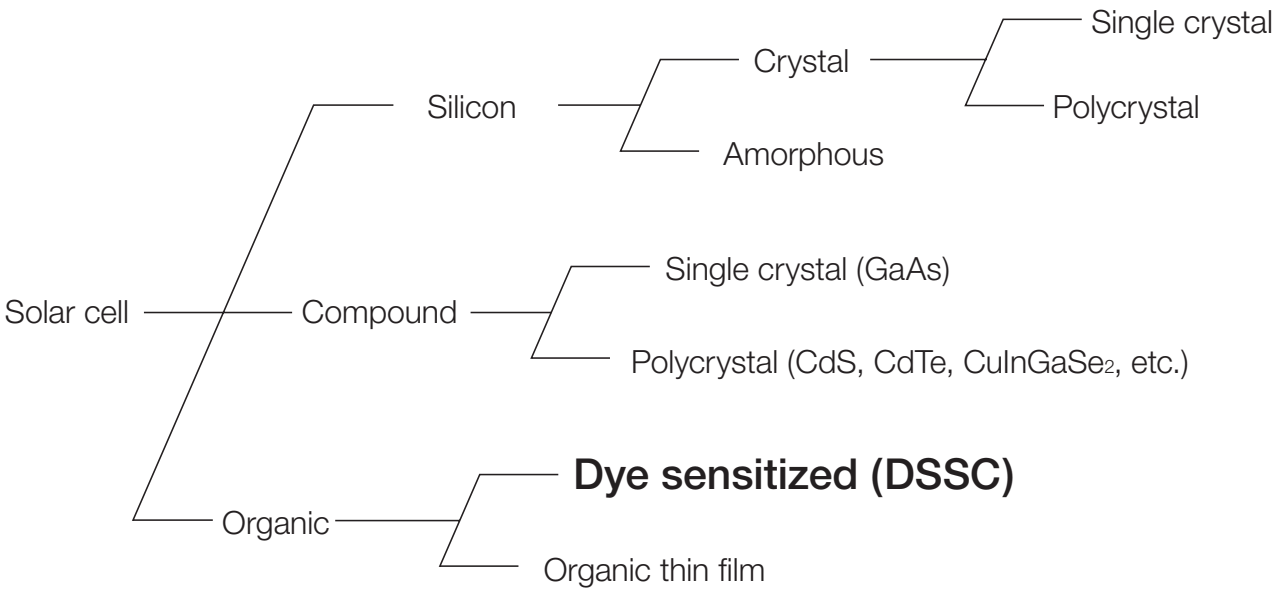


Fig. 1 Solar Cell Classification

3. DSSC Composition

DSSC are structured as indicated in Figure 3 and mainly made of the following materials.

- Substrate (glass or film with a transparent conductive film)
- Electrolytic solution
- Main sealant that encapsulates the electrolytic solution
- End sealant that fills the electrolytic solution injection hole

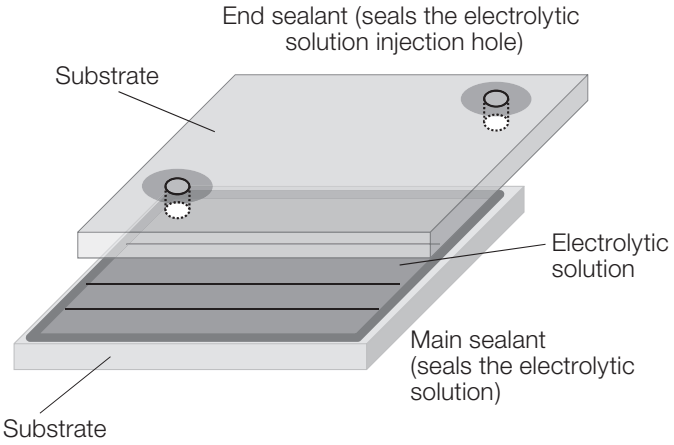


Fig. 3 DSSC Composition

4. Properties Required for DSSC Sealant

DSSC generate electricity through the chemical reaction between the dye and the electrolytic solution. Protection against leakage of electrolyte solution is vital to the efficient electricity generation and prolonged DSSC performance.

Main and end sealant interface and permeation leakage are considered factors in electrolytic solution leakage from DSSC as indicated in Figure 4. Strong adhesion is required between the sealant and the substrate to prevent interface leakage, and protection is needed to prevent permeation leakage of the electrolyte solution.

The electrolytic solution used for DSSC consists of organic solvent, iodine and additives. Organic solvents generally used here are characterized by their high polarity and the ease with which they dissolve organic compounds. Ordinary polymer compounds cannot achieve sufficient chemical resistance, which may cause the sealant to be affected by the electrolytic solution. A resin with a chemical structure that resists erosion due to polar solvents and iodine is required in order prevent both the organic solvent and the iodine from escaping the cell.

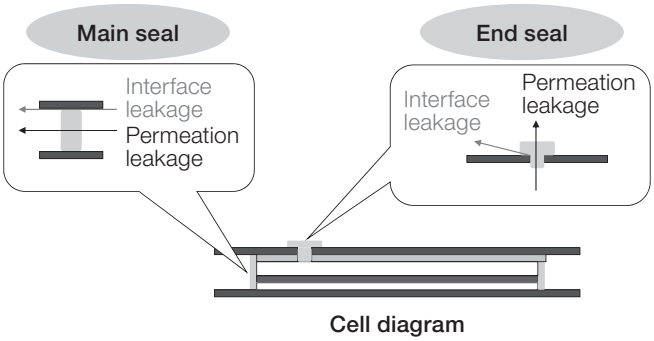


Fig. 4 DSSC Electrolytic Solution Leakage

Mixture with outside moisture causes the dye to detach as well as interior cell damage, so moisture protection is also necessary.

5. DSSC Sealant and Application

At ThreeBond, we have developed TB3035B, TB3035C and TB3118, UV-curing DSSC sealants. These sealants take productivity into account and enable application of sealant as called for by design width and height.

As indicated by usage shown in Fig. 5, the main sealant is either screen printed or dispense coated, and once the substrates are stacked, the main sealant is cured under the recommended curing conditions. After this, electrolytic solution is injected through the hold, end sealant is applied and then exposed to UV rays to completly seal the cell.

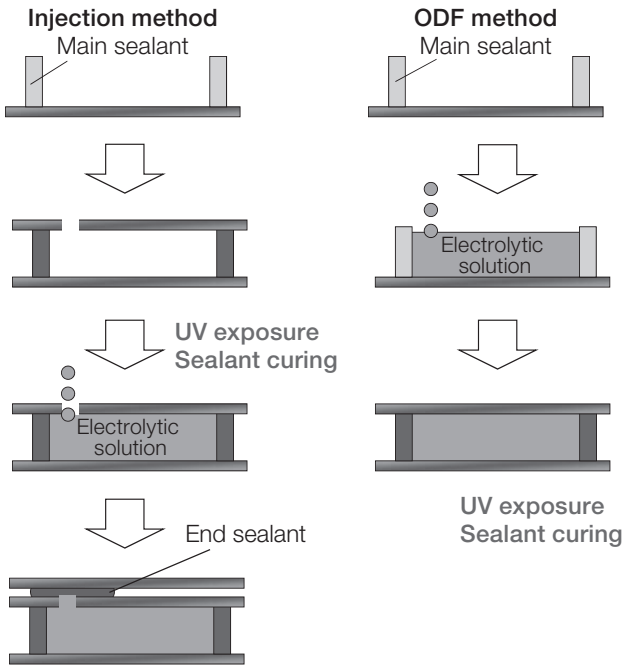


Fig. 5 Sealant Application

In the ODF (One Drop Fill) method, the main sealant is either screen printed or dispense coated followed by injection of electrolytic solution. Once the substrates are stacked, they are exposed to UV rays to cure the main sealant.

5-1 DSSC Sealant TB3035B

TB3035B is an acrylic DSSC sealant that cures when exposed to UV or visible light with a wavelength of 200 to 420 nm. (Fig. 6).

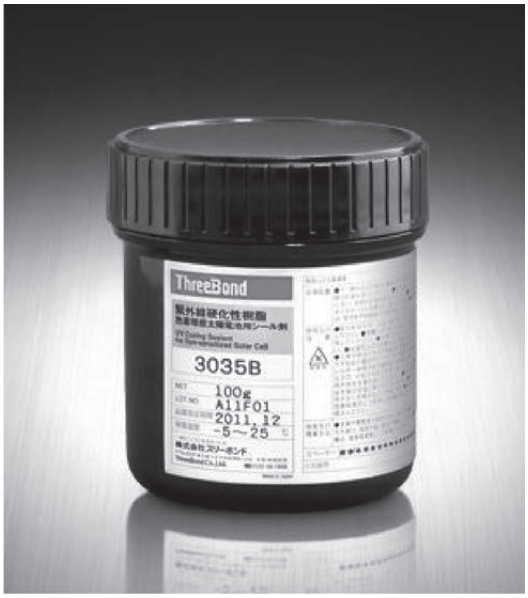


Fig. 6 TB3035B Product Specifications

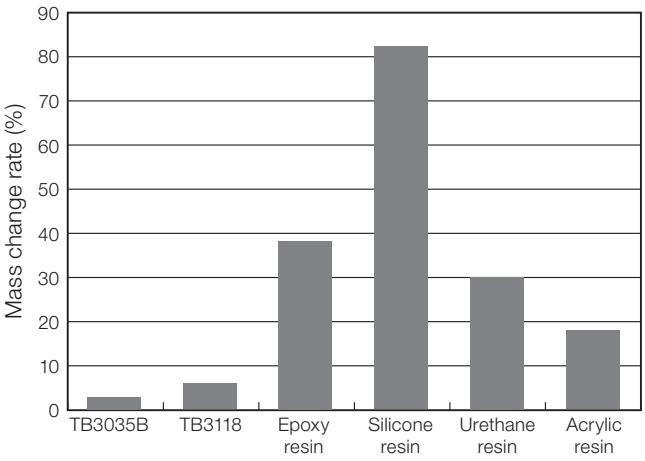


Fig. 7 Post-Curing Electrolyte Resistance per Resin

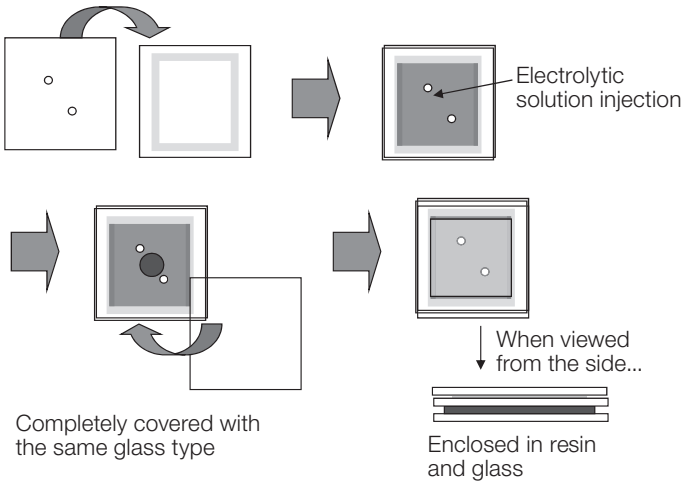


Fig. 8 Creating a Dummy Cell

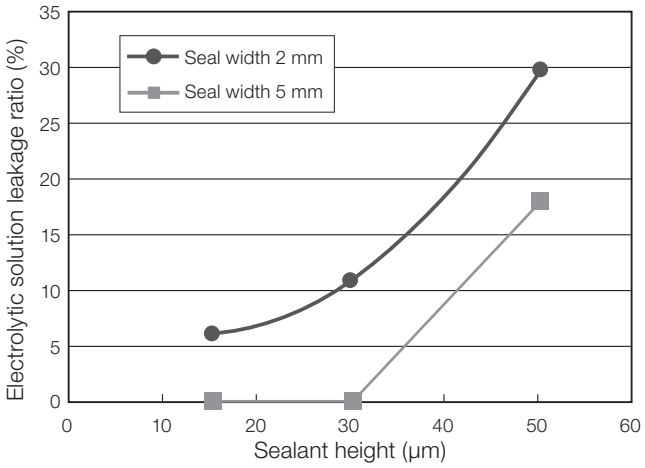
Table 1 Sealant Properties

Features	Unit	TB3035B	TB3035C	TB3118	Testing method	Remark(s)
Appearance	-	Milky white	Milky white	White	3TS-2100-002	
Recommended curing conditions	-	30 kJ/m^2	30 kJ/m^2	30 kJ/m^2 + 80°C × 1 h	-	
Absorption wavelength	-	200 to 420 nm	200 to 420 nm	200 to 350 nm	-	
Viscosity	Pa·s	51	47	86	3TS-2F00-007	2.5 rpm
Hardness	-	D48	D42	D83	3TS-2B00-004	
Cross-peeling strength	MPa	4.8	4.1	6.0	-	Glass/Glass
Glass transition temperature	°C	26	24	101	3TS-4730-001	
Water-vapor permeability	g/m^2·24h	97	90	32	JIS K 7129	85°C, 85%RH
Solvent permeability	g/m^2·24h	258	275	13	JIS Z 0208	85°C, 3-methoxypropionitrile

TB3035B characteristics are indicated in Table 1. Using acrylic resin that erodes very little in electrolytic solution further increases electrolytic solution resistance. Figure 7 compares the electrolytic solution resistance of conventional reactive resin and TB3035B.

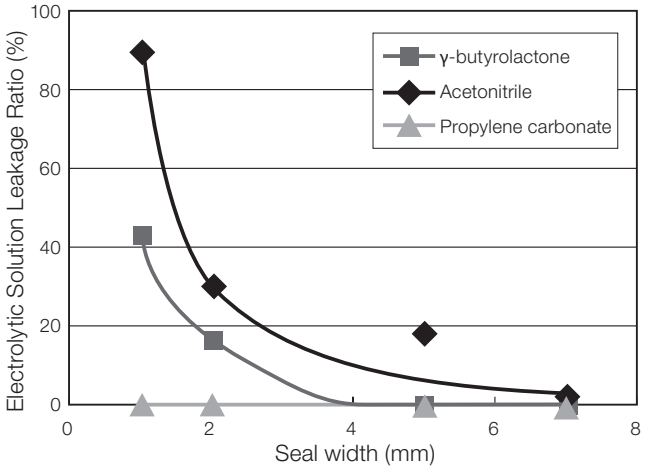
This figure indicates that TB3035B has a lower affinity to electrolytic solutions than silicone, epoxy, acrylic and urethane resins.

Figure 8 shows how we used a dummy cell to test TB3035B sealing performance, the results of which are indicated in Figure 9 and 10.



Test conditions: 102 min. sun, 18 min. rainfall;
Light source: Xenon lamp, 100 cycles
Resin used: TB3035B
Electrolytic solution: Acetonitrile base (iodine 0.05 M, potassium iodide 0.01 M)

Fig. 9 Connection Between TB3035B Seal Width and Sealant Height



Test conditions: 102 min. sun, 18 min. rainfall;
Light source: Xenon lamp, 100 cycles
Resin used: TB3035B
Sealant Height: 50 μm

Fig. 10 TB3035B Sealing Performance by Electrolytic Solution

Figure 9 shows the results of the UV exposure test regarding electrolytic solution leakage performance depending on sealant width and sealant height. This figure indicates that a wide seal width and a low seal height improve electrolytic solution leakage performance strength.

Next, we performed the same test with different types of electrolytic solution. These results are indicated in Figure 10. The results make clear that there are large variations in electrolytic solution barrier performance depending on the type of electrolytic solution.

From the results above, we were then able to adjust electrolytic solution leakage performance strength via seal width, sealant height and electrolytic solution type.

In addition to use as a main and end sealant for glass substrates, TB3035B also boasts use as a main and end sealant for UV ray-cutting film DSSC due to flexibility which enables it to cure in visible light as mentioned above.

TB3035B has been praised as an all-around main and end sealant that deftly handles any configuration of firm or flexible substrate.

5-2 DSSC Sealant TB3035C

TB3035C is the same kind of acrylic DSSC sealant as TB3035B but with a 30 μm spacer added (Fig. 11).

Fig. 11 TB3035C Product Specifications

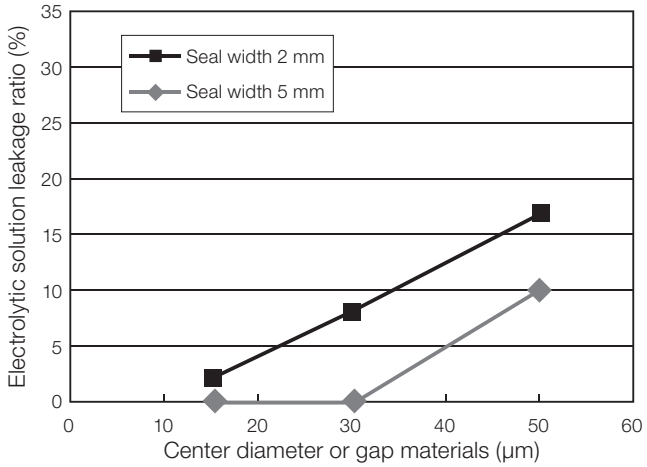
TB3035C characteristics are indicated in Table 1.

A 30 μm spacer is added in advance, making it possible to maintain a constant clearance of 30 between the upper and lower substrates when using the main sealant. This prevents short circuit-causing contact between the substrates.

5-3 DSSC Sealant TB3118

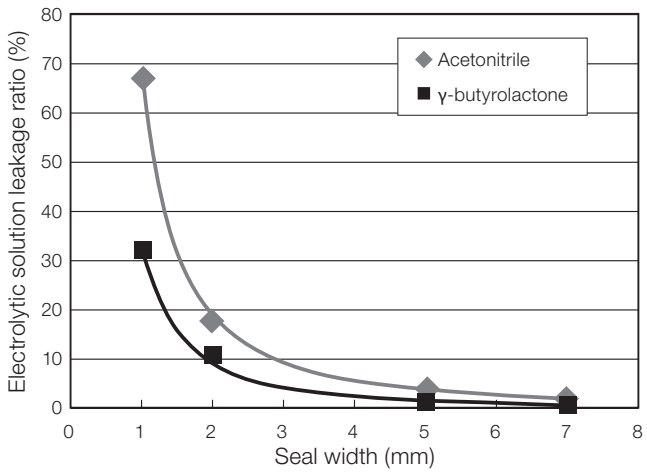
TB3118 is an epoxy DSSC sealant that cures under exposure of UV light with a wavelength of 200 to 350 nm (Fig. 12).

Fig. 12 TB3118B Product Specifications



Test conditions: 102 min. sun, 18 min. rainfall;
Light source: Xenon lamp, 100 cycles
Resin used: TB3118
Electrolytic solution: Acetonitrile base (iodine 0.05 M, potassium iodide 0.01 M)

Fig. 13 Connection Between TB3118 Seal Width and the Seal Gap



Test conditions: 102 min. sun, 18 min. rainfall;
Light source: Xenon lamp, 100 cycles
Resin used: TB3118
Sealant Height: 50 μm

Fig. 14 TB3118 Seal Performance by Electrolytic Solution

TB3118 characteristics are indicated in Table 1. TB3118 contains an epoxy resin that does not mix well with electrolytic solution and has a high crosslink density, making it excellent for water and electrolyte protection.

As shown in Figure 7, this results in electrolyte solution resistance that is higher than that of conventional resins.

TB3118 sealing performance was tested using dummy cells, the results of which are indicated in Figure 13 and 14.

The wider sealant width and lower sealant height of TB3118 also improve electrolyte solution leakage control.

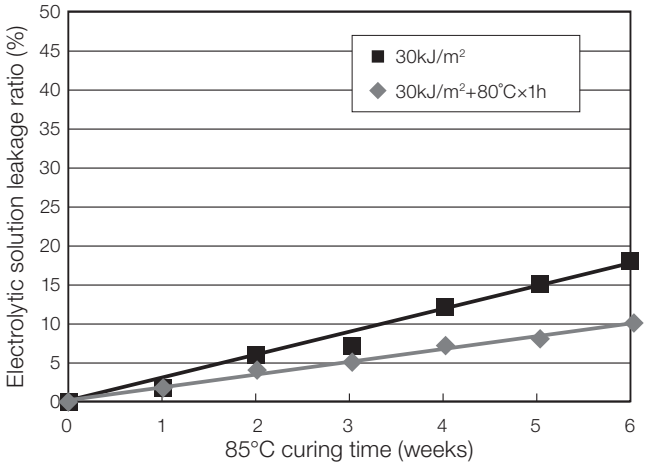
Figure 15 shows electrolytic solution leakage in an 85°C environment when TB3118 is cured as prescribed.

TB3118 was applied to dummy cells, then cured at 30 kJ/m^2 and 30 kJ/m^2 + 80°C × 1 hr. These cells were then left in an 85°C environment for 6 weeks. Results of this test indicate that 30 kJ/m^2 + 30°C × 1 hr curing produces a lower rate of electrolytic solution leakage.

While TB3118 cures to a practical level when exposed to UV rays at 200 to 350 nm, 30 kJ/m^2, adding heat is believed to further accelerate the crosslinking reaction and improve protection against electrolytic solution.

Based on the above results, a combination of UV ray exposure followed by heat application is recommended for optimal curing of TB3118.

When TB3118 is exposed to UV rays, the acid generated acts as a catalyst to cause the curing reaction. This reaction is neutralized if brought into contact with an electrolytic solution containing a basic substance, preventing curing through the acid/base reaction, which makes it unusable as an ODF method end sealant.



Resin used: TB3118
Seal width: 2 mm
Sealant height: 30 μm
Electrolytic solution: Acetonitrile base (iodine 0.05 M, potassium iodide 0.01 M)

Fig. 15 TB3118 Electrolytic Solution Seal Performance by Curing Conditions

Additionally, the film contains a UV ray absorber to prevent deterioration, but this cuts UV ray wavelengths needed for TB3118 to cure, making it impossible to use as a DSSC main sealant. However, as indicated in Table 1, low moisture and solvent permeability provide excellent protection, and cross-peeling bonding strength is high, giving it the durability needed for use as a main sealant.

6. Sealant Selection

There are certain main and end sealant combinations that cannot be used depending on material composition.

This necessitates the selection of sealant that can handle a variety of substrate materials, manufacturing methods and other conditions. Figure 16 shows the process for main sealant selection. Refer to Figure 16 to select the most appropriate sealant.

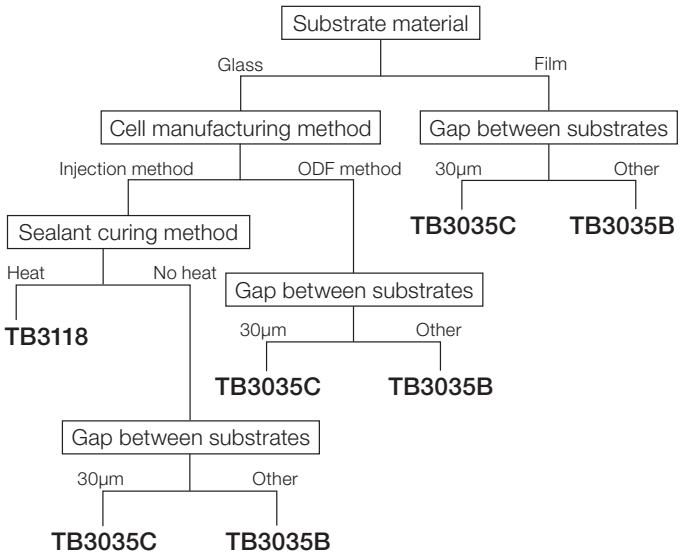


Fig. 16 Main Sealant Selection

Closing

We are pleased to present our DSSC sealant.

Now that DSSC is commercially available, we expect that its utilization will only continue to expand. With this expansion, we are certain that what is required of sealants will also continue to grow.

At ThreeBond, we are dedicated to product and technology development centered on market trends that ensures our product development's continued contribution to the manufacturing industry.

<References>

Technical News No. 65, Dye-Sensitized Solar Cell Sealant

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