TAIYANGNEWS

ALL ABOUT SOLAR POWER

Market Survey
Backsheets & Encapsulation 2021

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CYBRID
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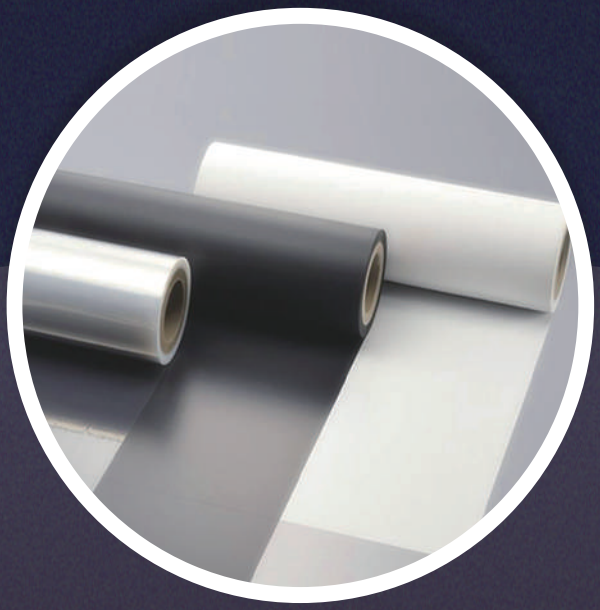

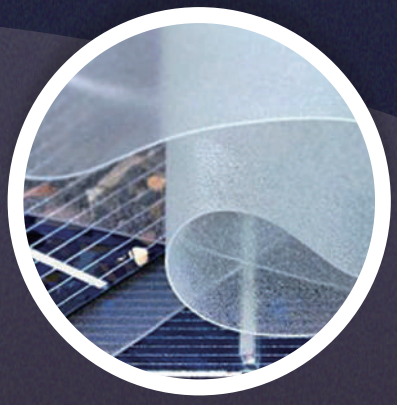

Innovative Polymer Material Solution Provider for PV

Cybrid Technologies Inc.

Executive Summary

The story of 2021 has been one of hardship for the PV industry, a trend that started in 2020. Not just limited to silicon, but also polymer wraps that are part of solar module manufacturing have been in short supply. Given this backdrop, this shortage naturally finds itself at the center of this 3rd combined market survey on backsheets and encapsulation materials. Apart from the obvious consequence – price hikes, this survey delves deep into the other techno-commercial developments in the backsheets and encapsulation materials segment.

In this survey, we cover a total of 12 companies and 90 products, of which 68 are backsheet models and 22 encapsulation films. Our survey also received inputs from leading component suppliers for backsheets and encapsulants. The current market for backsheets has a plethora of choices – structures consisting of a variety of polymers. A typical backsheet is a 3-layered structure, with two protective layers sandwiching a film of PET core. And based on the chemistry of the protective layers, backsheets can be categorized into 2 segments – fluoropolymer based backsheets containing at least one fluoropolymer film and non-fluoropolymer based backsheets that are free from these halogen components. Similarly, the encapsulation segment is divided into EVA (Ethylene Vinyl Acetate) and non-EVA.

The most notable development in the backsheet segment is the increase in PVDF prices, the key component of the most popular PVDF / PET / coating backsheet structure. The main beneficiaries of this situation were solar glass manufacturers, although they themselves are not too happy with where glass prices are currently. Glass, which itself was in short supply in 2020, saw its prices plummet in 2021 to levels where it has become beneficial for module manufacturers to replace backsheets with glass. In short, with increasing PVDF prices, glass manufacturers' efforts in adding capacity over the 2020 level shows up in its adoption at more and more module makers. And with module manufacturers finding an effective alternative in glass, even outside of its area of competence in bifacial, the overall backsheet market is expected to shrink slightly compared to 2020.

There is a different market share battle taking place in the bifacial segment among backsheet makers. Transparent backsheets, another important topic in its segment, are now part of almost every backsheet maker's product portfolio. That there is a transparent variant of all leading configurations points to the fact that the manufacturers are quite upbeat about the potential of these clear rear covers in bifacial applications, especially with modules getting larger. Technically, the backsheets are ready, but a big hurdle of cost optimization stands in their way. At present, the only configuration close to acceptable price levels for transparent backsheets is CPC.

It remains to be seen if it will turn into a big trend or not, but there is definite interest in the coextrusion process from a few key stakeholders of the backsheet segment. All-PP based commercial coextruded backsheet products are expected to hit the market soon. There is an increasing concern about using polyolefin-based films on the inner side of a larger module as such backsheets may not withstand the hotspot testing protocols. Recycling seems to be taking hold in the backsheet segment. DTF and Coveme, in collaboration with each other but at different levels of the supply chain, had announced that they were going the recycling route, and both have been successful. DTF has developed PET films with 33% recycled content, and Coveme has developed a backsheet using this film. Tests have shown that backsheet made with recycled content is no different to a conventional one both in performance attributes and reliability. As for the encapsulation segment, except for the price increase, there is nothing new as such with the traditional transparent EVA. Encapsulant suppliers are developing solutions for advanced cell architectures such as HJT and TOPCon. White EVA is increasingly preferred for the rear side of a standard module. Encapsulation material suppliers are also working on developing a multilayer stack of transparent EVA and white EVA to make it softer to be compatible with thin and larger cell formats.

With regards to the bifacial segment, transparent EVA is still used for the front side, while POE has been the material of choice for the rear. The coextruded structure is increasingly spreading its roots in the segment, mainly to negate the shortcomings of single-layer POE such as bubble formation, longer processing times and processing complexities in the MBB module layout. The EVA/POE/EVA (EPE) structure has become so popular that it may even end up replacing the single-layer POE sometime soon. Given high EVA prices, module makers are evaluating the use of this EPE structure even on the front side to save on material costs. There is some push on the part of thermoplastic polyolefins as an alternative to POE in bifacial applications. Given the low temperature processing, this non-cured class of encapsulants has good scope in temperature-sensitive cell architectures such as HJT and, more importantly, perovskites. Dow has introduced an innovative liquid silicone-based solution that can be cured at room temperature, mainly aimed at BIPV applications. The USP of this solution is to extend the lifetime of solar modules to 50 years to match other building components.

The market survey also includes brief descriptions of the products offered by the 12 companies listed (see Chapter 7) and tables with the key product specs (see Chapter 10).

In an interview with Cybrid, the leading backsheet supplier with strong ambition in encapsulation as well shares its views on the key trends in these two market segments (see Chapter 9).

Enjoy reading our Backsheets & Encapsulation 2021 Market Survey

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1. Introduction

Despite its continued growth in times of Corona, it is no secret that the PV industry has been going through a difficult time, as have many others, over the past year and a half due to material supply shortages. Starting with glass towards the end of 2020 to polysilicon early 2021, supply shortages continue to negatively impact the entire manufacturing and supply chain of PV. Module makers bear the brunt of this to a large extent as the higher prices resulting from short supply get cumulatively passed on to module manufacturers. As modules are unexpectedly expensive these days, many solar project developers have delayed finishing their projects, resulting in less installed solar capacity than planned for the year 2021.

Silicon related costs account for less than half of the cost of a module. Non-silicon costs, which represent a larger chunk of about 60%, are dictated mainly by materials such as glass, backsheet, encapsulant and frames. After all, a solar module is nothing but a multilayered polymer wrap of interconnected cell circuitry, attached to a glass sheet. But except for glass, prices of all these materials have increased quite significantly over the course of 2021.

PVDF, the chief component of the majority of the backsheets which serves as the outer layer, has been affected by the limited availability of resin. As a result, prices of PVDF as well as backsheets have gone up. The same is the case with EVA, the universal encapsulant, with shortages causing prices to shoot up in 2021. Not just the economics, these important bills of materials also shoulder another huge responsibility – reliability. The collective goal of these module processing materials is to protect the inner cell matrix from environmental impacts for the warranted period of power output, which is usually 25 to 30 years. While the glass facing the front acts as the first line of defense, the polymer wrap consisting of the encapsulant and the backsheet is equally important to module reliability. So, given their role in both cost and reliability, backsheets and encapsulants have always been prime candidates for optimization and innovation.

Controlling quality: The backsheet, laminated to the rear of the solar panel stack, has significant impact on the quality and reliability of the solar module, thus its manufacturing process includes several quality checks, as shown here from leading backsheet producer Jolywood.

When taking a look back, there have indeed been a lot of developments since our 2020 survey was published. Typical backsheets follow a three-layer polymer structure, while twin and mono layers have been available for some time now. There is also a wide choice of polymer chemistry to choose from for the components of the backsheet. Traditionally, backsheets are opaque. However, clear variants of this polymer stack have become progressively available to cater to the demands of innovative technologies such as bifacial. The state of the art for making backsheets is lamination, while alternative technologies such as coatings and, more recently, coextrusion are also tweaked to make polymer back covers for the PV panels.

When it comes to encapsulation, while the choice of polymer chemistry is not so wide, there has been significant progress. These polymers have been improved to support shorter cycle times in manufacturing, improve optical performance and combat specific kinds of field degradation.

Acknowledging the importance of these two important polymer wraps used in module manufacturing, TaiyangNews has been publishing a combined annual market survey covering both backsheets and encapsulation since 2019, while summarizing the developments in the backsheets segment alone since 2017. In this 3rd edition of TaiyangNews Market Survey on Backsheet and Encapsulation Materials 2021, we continue to provide an overview on key techno-commercial developments associated with these two important elements of module BOS along with a detailed description of the products from leading suppliers.

2. Overview

Backsheets, as the name implies, are typically stuck to the rear of the solar module designated with basic responsibilities — provide electrical insulation to cell matrix and block moisture ingression. Proper electrical insulation is necessary as several cells are connected in series, which leads to high operational voltages. It is even more important to block moisture ingression, as not only are all the interconnectors metal based, but also much of the cell surface is covered with metal, which when exposed to water vapor leads to risk of corrosion. More than the electrical parameters themselves, the environmental conditions in which the modules operate are quite dynamic, depending on the geographical location, season, and sometimes even unexpected extreme weather conditions. Thus, the degree of protection required from the backsheets also varies.

Ideally, a backsheet should be selected keeping the geographical location and local weather conditions of the installation site in view. With increased awareness about the importance of backsheet selection and the knowhow involved, a few large-scale end-customers such as EPC and power plant owners are also specifying the type of backsheet they desire. However, module production is not "made-to-order." The major chunk of the modules is built with backsheets that comply with universal conditions or at least application-specific products. Still, since the required weathering barrier can be achieved with different configurations and polymer chemistries, the current backsheet segment offers a wide variety of products from various suppliers.

The encapsulation film provides a cushion for the fragile cells from mechanical shock and vibrations, as well as promoting adhesion to the front glass and the rear backsheet/glass. They also act as an air-tight barrier to moisture ingression. Typically, the encapsulation material sandwiching the cell matrix is transparent. Of late, reflective (white) encapsulants that boost the optical absorption are also being used on the rear.

In summary, today's backsheets and encapsulation material suppliers offer a wide variety of products based on different polymer chemistry, construction and manufacturing processes that are aimed at satisfying the different needs and budgets of module makers and, ultimately, the end customers.

2.1 Survey Participants

This 3rd edition of combined market survey on backsheets and encapsulation materials consists of 12companies, including most market leaders. The participants are listed in the table on p. 9.

Three companies of the 12 listed are exclusive encapsulation material suppliers — HIUV, Borealis and Sveck. Hangzhou First and Cybrid supply both backsheets and encapsulation materials, and the remaining are pure backsheet producers. We have data for 90 products in total, of which 68 are backsheet models and 22 encapsulation materials.

2.2 Backsheet suppliers

The backsheets section of the survey has 9 participants, one less than our previous edition. Three companies opted out — Agfa, Bischof + Klein and ZTT — and two joined the list. While ZTT has limited itself to supplying PVDF films to backsheet makers having exited the backsheet business, Europe's Agfa and Bischof + Klein do not seem to be too active in the solar PV supply business these days, both have not replied to our inquiries anymore. Crown from China and Shingi Urja from India make a re-entry into the current survey; while Crown missed the spot in previous overview, Shingi Urja comes back after taking part the last time in our 2018 survey.

The list of backsheet models in this survey is a bit shorter, by 3 models, compared to 71 in the previous edition. As with our previous surveys, we have categorized these backsheet products into two segments — fluoropolymer based and non-fluoropolymer based. Fluoropolymer-based backsheets are those that contain at least one layer of fluoropolymer in the backsheet configuration, while backsheets that are completely free from the halogen component are characterized as non-fluoropolymer products. The total number of fluoropolymer backsheets listed in the current survey is down by 4 to 39, while the non-fluoropolymer number has gone up by 1 to 29.

Manufacturers of Backsheets / Encapsulation Materials in TaiyangNews Survey 2020 *(bold-faced words indicate how the manufacturer is referred to in the survey)*

Manufacturer	Backsheets	Encapsulation
Aluminium **Féron** GmbH & Co. KG, Germany	✖	
Borealis, Austria		✖
China **Lucky** Group Corporation, China	✖	
Coveme Spa, Italy	✖	
Crown advanced material co.ltd	✖	
Cybrid Technologies Inc., China	✖	✖
Endurans Solar (formerly DSM)	✖	
Hangzhou First PV Material Co., Ltd., China	✖	✖
Jiangsu **Sveck** New Material Co., Ltd		✖
Jolywood (Suzhou) Sunwatt Co., Ltd., China	✖	
Shanghai **HIUV** New Materials Co., Ltd., China		✖
Shingi Urja Pvt. Ltd	✖	

Source: © TaiyangNews 2021

The leaders are in: The number of companies that took part in the survey – 12 – doesn't seem high, but it includes the leading suppliers of backsheets and encapsulation sheets covering the bulk of the market.

A few companies among these — **Endurans** (formerly DSM) and **Féron** — exclusively sell non-fluoropolymer backsheets, while **Cybrid, Coveme, Hangzhou First, Lucky Film, Crown and Shingi Urja** supply both variants. **Jolywood**, on the other hand, is not listing any non-fluoropolymer products as far as this survey is concerned.

In addition to the typical backsheet suppliers, important component suppliers such as **DuPont Photovoltaic Solutions, Hangzhou Foremost Material Technology Co., Ltd. (Fumotech)** from China, **DuPont Teijin Films (DTF) and ZTT** have also provided inputs. However, since their products are not backsheets in and of themselves, their products are not included in the survey tables.

2.3 Encapsulation Material Suppliers

The survey includes top suppliers in the encapsulation segment, featuring a total of 22 models from 5 suppliers. **Hangzhou First, HIUV** and **Sveck** have traditionally been the top 3 companies in encapsulation, especially EVA, while **Cybrid** is close on the heels having now made a name for itself in the encapsulation segment as well. The current survey consists of 14 EVA products compared to 12 in the previous edition. These four companies also supply non-EVA based encapsulation solutions. The only company that is exclusively promoting polyolefin (POE) based encapsulation materials is **Borealis**. A total of 8 POE models are listed from these five companies, two more than last survey.

2.4 Different Backsheet Structures

The current crop of backsheet products are based on different structures using a variety of polymers. These compositions have evolved over time, in tune with the changing needs of module makers.

As mentioned above, the backsheet has two key roles, which polyester (PET) alone can fulfill and that too in a very cost-effective way. However, PET's rather poor UV stability means that it is limited in its ability to become a self-sufficient backsheet material.

Thus, this core layer of the backsheet is sandwiched between two UV resistant films leading to the typical three-layer construction of a backsheet; and UV protection is where fluoropolymers come in.

To provide some historical context, the early PV modules used backsheets based on an **FPF** structure with the core PET layer sandwiched between two layers of fluoropolymer. The fluoropolymer here is nothing but the proprietary polyvinyl fluoride (PVF), commercially known as Tedlar from US-based chemical giant DuPont. Such a backsheet structure was often referred to as **TPT**, which was also the first backsheet composition used for PV module applications. TPT dominated the backsheet market for many years.

PVDF, also belonging to the fluoropolymer stream and used in other outdoor UV-proof applications, has found a footing for itself in the backsheets segment as well. Chemical company Arkema, headquartered in France, developed a special three-layer PVDF film with the Kynar brand name. The backsheets based on Kynar also follow a similar structure as TPT, abbreviated as **KPK**, which is also a registered trademark of the company. Even today, every fluoropolymer film based backsheet supplier has at least one product representing this symmetrical structured backsheet.

As module prices continued to decrease, the cost pressure on the backsheet producers was growing. At some point, they realized that making symmetrical structured backsheets with fluoropolymers on both sides was a bit of over-engineering, especially when the cumulative UV exposure of the inner film is only about 1/10th of the outer layer of the backsheet. During this time, backsheet manufacturers replaced the rather expensive fluoropolymer films with a more economical polyethylene, which is usually referred

Source: Jolywood

Old habits die hard: While there are several developments regarding manufacturing in the backsheets segment, lamination is the still the predominantly followed method, despite new techniques such as coextrusion, which comes with cost savings potential.

to as "**E**" or "Primer" layer. This initiated the first configuration change in backsheets. All fluoropolymer backsheets then shifted to a polyethylene-based inner layer, leading to new backsheet abbreviations such as **TPE** and **KPE**. All of the suppliers involved with fluoropolymer film based backsheets then started offering the symmetrical variants as well as products with an inner "E" layer.

What also led to this shift to the "E" layer was the fact that Tedlar was in short supply during this period of time, pointing the research in the direction of fluorine-free backsheets. Benefiting from the successful implementation of the polyethylene inner layer and the PET core, which are both fluorine-free anyway, the only effort needed here was to develop a fluorine-free outer layer. Coveme, the development leader in this field then, as they still are now, came out with a UV-stable PET in close cooperation with DTF, which has provided the base material. This backsheet configuration is denoted as **PPE**, which is still Coveme's main product. The fluorine-free aspect of these backsheets has not only been used to market this product as "environmentally friendly", but has also made them less costly than their fluoropolymer-based counterparts.

Some companies followed this template to redefine the backsheet structure by replacing the films with coatings. Such backsheets are commonly abbreviated as CTC, where "C" stands for coatings of both types – with and without fluorine. Hangzhou First and Jolywood are both offering fluorine-containing coatings, while Aluminium Féron from Germany is supplying backsheets coated with non-fluoropolymers.

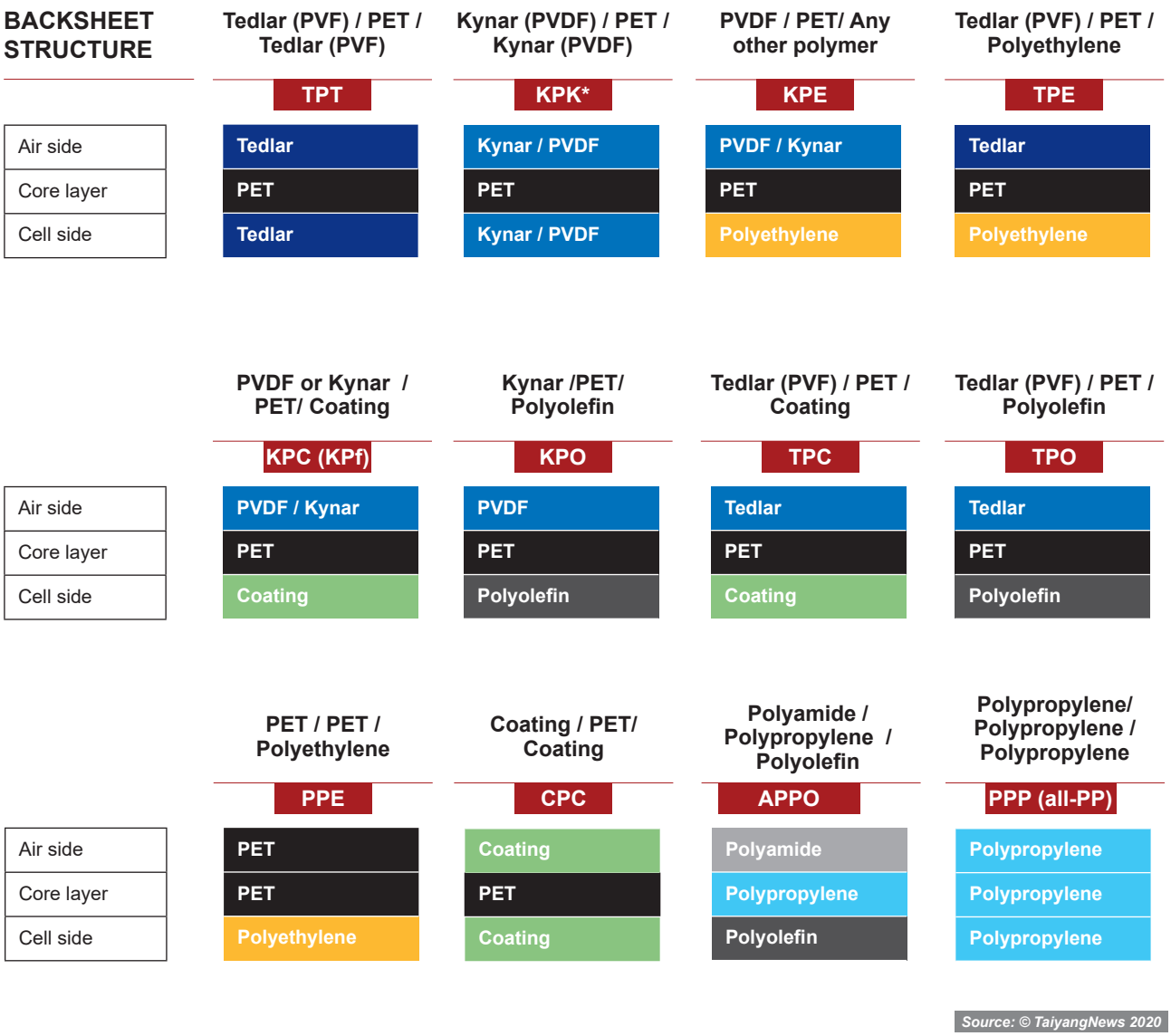
While the inner layer of the backsheet is not exposed to UV as much as the outer layer, the radiation cannot be neglected altogether. Cybrid worked on this idea and developed a so-called fluorine skin, which is essentially a fluorine coating denoted as **KPf**. Cybrid's inner coating solution fully addresses the UV protection concerns on the cell side. At the same time, the coating is far less expensive than a fluorine film. The idea sold so well that the then young Chinese company soon became the market leader of the segment.

Cybrid is supplying its backsheets predominantly based on PVDF as outer layers, while Kynar-based backsheets are also a part of its portfolio. Cybrid's success with this approach was enough to lure other companies to inner coatings. This move was actually very easy for companies that had already been working on coating-based solutions, such as Hangzhou First, to use their expertise for cell-side coatings.

Hangzhou First is also offering backsheets in the PVDF/PET/coating format. Jolywood, another coating expert and an important laminator for

Tedlar-based products, introduced yet another structure called **TPC**, adapting Cybrid's template into its proprietary coating technology. For module manufacturers that are not comfortable with coatings, backsheet suppliers such as ZTT and Lucky Film started offering backsheets with polyolefin as inner layer, denoted as **KPO**. While ZTT has exited the backsheet business, now focusing on process material, and Lucky Film not promoting this configuration actively, Cybrid and Hangzhou First are still promoting this structure. On the other hand, Lucky Film has started offering a Tedlar variant, characterized as **TPO.**

What's common about all the backsheet structures mentioned above is that they are all based on PET as the core layer. Endurans, taking a different route, developed backsheets that use polyolefins as core layers – coextruded instead of the typically followed lamination method. The structure is made



Source: © TaiyangNews 2020

*Note: *While KPK is a trademark of Arkema, today the abbreviation KPK is not only used for Kynar/PET/Kynar structures but often used for any PVDF/PET/PVDF solar backsheet structures as well.*

Wide variety: The composition of different polymers in multi-layer backsheets enables many configurations, as shown in the above graphic.

of a polyamide top layer, with a polyolefin inner layer and core with slightly modified chemistries between them. This backsheet can be denoted as **APPO**. However, being a resin supplier, Borealis is strongly promoting an **all-PP** coextrusion solution, and its customers expect first products to hit the market sometime this year.

To summarize, the major backsheet configurations in today's market are TPT, TPE, TPC, TPO, KPK, KPE, KPf, KPO, PPE, CPC, APPO and all-PP. The infographic on p. 12 lists the most popular backsheet structures and their abbreviations.

2.5 Materials and Structures for Encapsulation

The story of encapsulation is rather straightforward. The material typically used for this application is Ethylene-Vinyl Acetate (EVA). It had made such a name for itself in the market that it was synonymous with encapsulation, enjoying a monopoly for over three decades. Polyolefin (POE), however, is evolving strongly as an alternative, especially with the growing popularity of bifacial technology. Though bifacial is growing at a faster pace, monofacial market is still larger, meaning EVA still dominates this sector. Therefore, we categorize encapsulation materials into two segments – EVA and non-EVA.

While encapsulation materials were limited to a single layer construction in the past, a recent development in the field of polyolefins saw a few companies develop a coextruded multilayer encapsulation material, which is meeting quite some interest in the market. The typical composition of such a structure is a POE film sandwiched between two EVA films (EPE).

Source: HIUV

While EVA is still dominating the market, its white variant and derivatives of POE are increasingly preferred as the rear encapsulant.

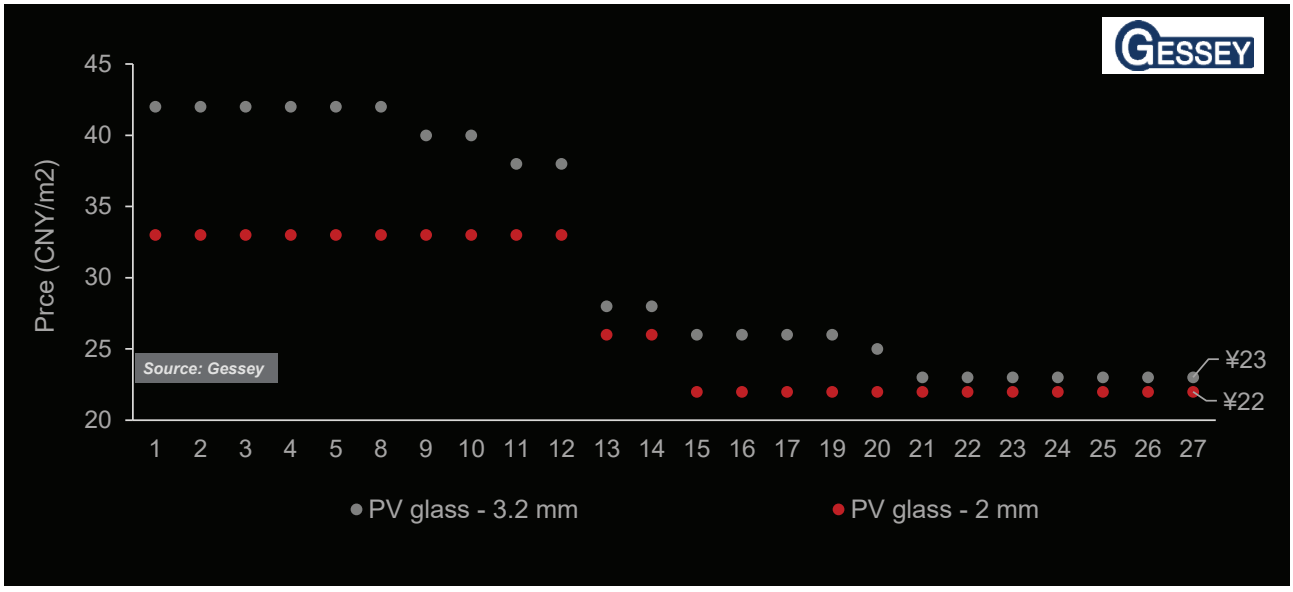
3. Backsheet Market Update

Backsheets have lost their monopoly status as the de facto choice in a solar module – courtesy of the ever increasing popularity of bifacial technology. With glass being the back cover of choice for bifacial, the market share of polymer backsheets has started to decline. And even as transparent polymer backsheets promise to provide the same level of reliability and lower weight, glass remains the main choice for bifacial modules.

In late 2020, solar glass was in short supply, turning the industry's focus towards transparent backsheets for bifacial applications. However, this inflated demand was short lived. Leading glass makers were quick to react by adding capacity considerably, not only making sure that this tight supply situation had normalized by the end of Q1/2021, but exceeding demand by end of H1/2021. As a result, glass prices went down dramatically, from about CNY 33 /m2 during the start of the 2021 to about CNY 22 /m2 by late H1/2021. The price drop was even more pronounced – about 45% – with 3.2 mm glass; not only were the prices down from CNY 42 /m2 to CNY 23 /m2, the price difference between 3.2 mm and 2 mm glass dramatically narrowed down to CNY 1 /m2 from CNY 9 /m2 during this period.

This meant for module makers: 1.) little motivation to shift to transparent backsheets, and 2.) they found it more beneficial moving from monofacial to bifacial using double glass as there are no additional costs involved in making a bifacial PERC at the cell level. Moreover, there is an industry-wide acceptance for extending the module's power warranty to 30 years when using glass as rear cover. Thus, a double-glass structure is becoming more and more appealing to EPCs, even though it means handling much heavier modules. In short, glass is increasingly becoming competitive, not just against the transparent backsheets, but backsheets as a whole. "The share of double glass will reach 60% in ground-mount installations in China by end of 2021," anticipates Jiajing Wei from the marketing department of leading PVDF supplier Fumotech. Globally as well, the bifacial share is increasing drastically. Out of total module shipments of about 140 GW in 2020, bifacial accounted for roughly 35-40 GW, with glass claiming the lion's share and transparent backsheets totaling

Modules Prices 2021 – Week 27



From short supply to oversupply: While glass prices went up from the later part of 2020 towards the beginning of 2021, which led to a strong increase of glass prices, massive investments in new production capacities resulted in an oversupply situation that pushed glass prices to rock bottom after the 2021 spring festival in China, as analyzed by Chinese market research firm Gessy.

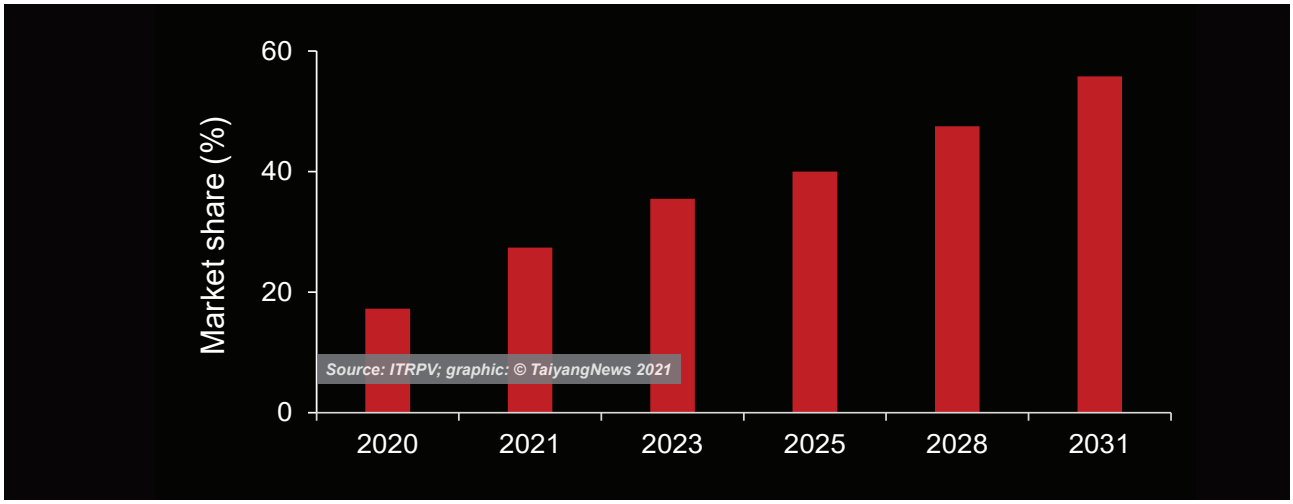
8-10 GW. All in all, the backsheet market size in 2020 was about 110 GW. According to the 12th edition of the International Technology Roadmap for Photovoltaic (ITRPV), the market share of bifacial modules was close to 20% in 2020 and is expected to increase progressively to close to 25% in 2023, 40% in 2025 and finally about 55% by 2031.

While it does sound ominous, bifacial's increasing presence is not considered a big of a threat by backsheet suppliers. Almost every backsheet manufacturer we talked to is very optimistic about the prospects of the transparent backsheet. Acknowledging the fact that glass is still the first choice for bifacial applications, especially in China, Coveme's COO Monica Manara says that the transparent backsheet is gaining ground in other major markets such as the USA, Turkey and India. "This demand is further fueled by the high duties imposed on glass in various countries," she added.

Fumotech's Wei, for example, believes that the transparent backsheet market size will grow to 15 GW in 2021. And according to Chad Yuan, marketing director of leading backsheet supplier Jolywood, the global market share of transparent backsheets will increase from 8% in 2020 to 10% in 2021. The basis for this estimation is that more and more module manufacturers are producing very high power modules with power ratings exceeding 600 W; as a result, the size of the module is also increasing. Since such high power modules are mainly for utility applications, for which bifacial is an important characteristic, using glass-glass configuration for such modules requires additional care providing enhanced mechanical stability, while the transparent backsheets alleviate that extra effort.

The backsheet market in general fared fairly well in 2020. Despite the COVID-19 outbreak, which caused setbacks in manufacturing as well as logistics in different parts of the world during H1/2020, the second half more than compensated for the total year. Jolywood's Yuan estimates that a total of 630 million m2 of backsheet were shipped in 2020, an increase of 14.5% from the total shipments of 550 million m2 in 2019. In 2021, on the other hand, the spike in the prices of several raw materials, more importantly polysilicon, negatively impacted the demand for solar modules, leading to inventory pile-up at the manufacturers. Nevertheless, the backsheets segment as a whole did well in H1. According to Yuan, about 340 million m2 of backsheets were shipped during the first half of 2021, which is a year-on-year growth of 15%, while the shipments for the whole year are expected to shrink slightly by about 5% to 600 million m2.

Bifacial Market Share Development - ITRPV



Towards domination: ITRPV expects the share of bifacial technology (bifacial cells & modules) to increase progressively from about 20% in 2020 to a PV market dominating share of 55% by 2031.

As explained earlier, a backsheet is a multilayer polymer structure, and there is a wide variety of polymer chemistry to choose from. There are also a few variances in the structure of these rear protection films. Most importantly, the backsheets are segregated and abbreviated based on the polymer chemistry of their components.

Among the two streams of backsheets, fluoropolymers are currently ruling the market with a share of about 90% within the backsheets segment. Most leading Chinese module makers have been predominantly using fluoropolymers and have been expanding continuously, all the while increasing their share in global module production. As a result, the prominence of fluoropolymers in the backsheet is also increasing. Within the fluoropolymer segment, there are two popular designs and the most predominant one is a fluorine film on the air side attached to the PET core and a fluorine coating applied on the cell side. The other, with fluorine-based coatings on both sides, has also been gaining in popularity recently. Backsheets with non-fluorine based coatings on both sides of the PET film are also available. But the non-fluoropolymer configuration with UV-resistant PET on the outer side and a polyethylene layer towards the cell side and a PET core is the most popular.

3.1 Backsheet Components Market

While every layer of a typical 3-layered backsheet is important, the outer UV protection layer is the most critical. It not only takes most of the responsibility of protecting the module from weathering – the primary job of a backsheet – the versatility and variety is also high. When it comes to the core layer, PET has been serving as the universal core layer. As for coatings, be it the inner side or the outer, these formulations are proprietary for their developers and thus the generic differences are hard to identify. Within the fluoropolymers branch, especially in the film based segment, the choice for the outer layer is between PVDF and Tedlar.

PVDF is the leading composite for the outer layer of the backsheet. More than 50% of the modules made in 2020 have used backsheets based on this fluoropolymer. According to Wei from Fumotech, the leading supplier of PVDF, about 300 million m2 of PVDF was used by the PV industry in 2020, half of which has been supplied by the company. “We shipped 150 million m2, equivalent to backsheets worth 30 GW and a market share of 25% in the backsheet business,” said Wei. The company has an installed production capacity of 250 million m2.

ZTT is another leading PVDF supplier. The company was also an important backsheet supplier with 50% captive consumption, but chose to exit the backsheet business due to lean margins. With an installed capacity of 300 million m2 that is also serving other industries, ZTT shipped about 80 million m2 of PVDF to backsheet suppliers.

Looking back at backsheets: Compared to 2020, in the meantime several changes have taken place in the backsheet segment – primarily price increases.

Since PVDF is such an important component, some backsheet suppliers are also producing PVDF in-house. Leading backsheet maker Cybrid operates a PVDF production facility with a capacity of 20 GW.

While 2020 was a good year for PVDF manufacturers. PVDF is a key challenge now as the price of the resin has increased significantly, which is also making related backsheets expensive. On the other hand, module producers are under high pressure to reduce cost. Consequently, backsheet manufacturers are pushing other configurations such as coatings and non-fluoropolymers. Even glass is gaining demand on account of high PVDF prices.

PVF, or Tedlar, which is exclusively supplied by DuPont, is also benefiting from the high PVDF prices. Tedlar, even with its high price tag but a proven track record in terms of reliability, is mainly used by two world leading module manufacturers – JinkoSolar and LONGi Solar. Since these PV giants have been expanding considerably, so is the demand for Tedlar. Not only that, DuPont has started offering a clear variant of its Tedlar for use in transparent backsheets for bifacial applications instead of glass. Backed by extensive testing, DuPont has convinced module JinkoSolar to offer the same 30-year power warranty as glass. The high price of glass at the end of 2020 also motivated a few module makers to adopt Tedlar-based transparent backsheets, according to DuPont's Mark Ma, who declined to reveal exact shipping data, "as a policy of the company." However, our research indicates that Tedlar-based backsheets were used in roughly 22 - 25 GW of modules in 2020.

PET is another important backsheet component. In addition to being the unanimous choice for the core layer, the chemistry of the polyester film is also optimized with UV protection attributes to be used as the outer layer. DTF, the inventor of polyester films, is active in supplying PET for core layers as well as the outer layer. Like any other component supplier, DTF also supplies backsheet components, but not the final product. However, the company, in close cooperation with Coveme, played an instrumental role in the development and commercialization of PET-based backsheets. DTF offers its PET solutions to the PV industry under the Mylar brand name. The UVHPET range is specially designed for enhanced UV barrier and hydrolysis resistance properties to serve as the outer layer of the backsheet. "We have a proven track record of using Mylar UVHPET in 200 million modules, which is 50 GW," emphasized DTF's PV marketing manager Steven Davies. However, he did not disclose any shipment data. The company also supplies a Mylar core PET film, which according to DTF has been used since the birth of the solar industry and can complement any outer layer.

Source: Fumotech

In short supply: PVDF, an important component of the most famous backsheet configuration FPF, is in short supply and its price has increased quite a bit.


Source: DTF


Source: Coveme

The PET proponents: Coveme (right) in close cooperation with DTF, has played a significant role in commercializing UV-protective PET for the outer layer of the backsheet as an alternative to fluoropolymers.

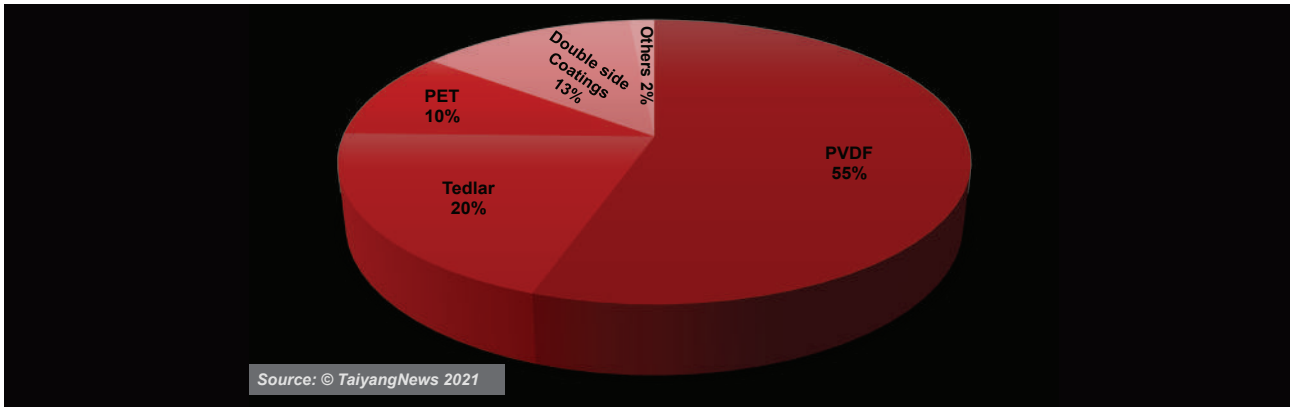
According to our research, in 2020, PVDF had a market share of 55%, while Tedlar had owned above 20%. Backsheets with coatings on both sides – with fluorine-based coatings dominating the segment –, had a 13% share and PET contributed 10%. Other structures represented the remaining 2%. However, due to the increase in the price of PVDF, the share of backsheets that are not using PVDF will considerably increase by the end of 2021.

3.2 Backsheet Market

In 2020, **Cybrid** led the pack in finished backsheet product shipments, as it has since 2015. The company shipped 132 million m2, according to Cybrid. Supporting such a high level of shipments is its installed production capacity of 18 million m2 per month. Its best-selling product, KPf configuration, is the main driver behind Cybrid's rule at the top for 6 consecutive years. This backsheet configuration is based on PVDF as the outer film, while the Chinese company also does honor special requests to supply the same configuration with Arkema's Kynar.

Jolywood, the second largest global backsheet supplier in 2020 missed the top spot marginally. The company shipped 129 million m2, and its production capacity of about 200 million m2 per year also places it second in the race. However, as per data for H1/2021, the company has already surpassed Cybrid in terms of shipments. Jolywood had shipped 70 million m2 by the end of H1/2021, 10 million m2 more than the former leader, according to Yuan. He estimates his company to reach total annual backsheet shipments of 180 million m2 of a market size of 600 million m2 by the end of 2021. To support this, Jolywood has a plant under construction as part

Market Shares of Backsheet Technologies in 2020



PVDF still on top: As in 2019, the PVDF based backsheet structure was clearly leading the sector in 2020, but this dominance very likely lessened during 2021 due to its short supply and increased prices.

of its expansion plans, but Yuan would not provide any details. The reason for Jolywood gaining market share in H1/2021 is the backsheet structure — to be precise, PVDF resin prices more than tripled during this period (see chapter 5 for more details). This humongous increase in the price of PVDF meant a strong cost increase rise for Cybrid's key product based on the KPf structure. Jolywood, on the other hand, has been mainly promoting its double-sided coatings based backsheet, which gained demand. Yuan believes the share of PVDF containing films is expected to drop from over 50% in 2020 to 35-40% in 2021.

Another leading manufacturer, Lucky Group, sold 72 million m2, or close to 15 GW, of backsheets in 2020. The company is an important laminator for DuPont's Tedlar-based backsheet and focuses equally on PVDF, each contributing about half of its total shipments. Lucky Film aims to increase its shipments to 90 million m^2 in 2021, or about 20 GW, and has a total backsheet production capacity of 11 million m2 or 2.5 GW per month. **Hangzhou First,** the global market leader in the module encapsulation business, shipped 60 million m2 or about 12 GW of backsheets, about 95% of its 13 GW production capacity. "We are mainly limited by our capacity," the company said. Hangzhou First has a market share of 8 to 10%, and supplies backsheets with double-side coatings as well as laminated films using PVDF. By the end of 2021, Hangzhou First has expansion plans to add an additional 3 to 5 GW.

For **Coveme**, the pioneer in PET-based backsheets, the market is currently very good. The shipping quantities from both the production houses of the company, in Italy and China, have increased, according to its COO Monica Manara, who underscored that the cost increase in raw materials and logistics has led to a general increase in costs and sales prices. The Italian company shipped about 50 million m2 in 2020 and expects to increase the sales volume by 10 to 15% in 2021. Of these, PET-based backsheets account for the lion's share at 80 to 85%. Coveme has a total production capacity of 8 million m2 per month. While PPE is still its main product, the company is also supplying backsheets using Tedlar and PVDF as the outer layer, especially to those manufacturers who insist on fluoropolymer products. The company has developed technologies not only for inner coatings, but special coatings that make the polymer surface scratch and abrasion resistant, aimed at replacing the front glass with a polymer based front cover.

Already active in the encapsulant and backsheet space through Tomark Worthen, US based Worthen Industries has now acquired Dutch chemical company Royal DSM's backsheets business and renamed it Endurans Solar, which reminds of DSM's erstwhile backsheet product series named Endurance. The former backsheet arm of DSM has welcomed the leadership of the new management. Except for a few senior management positions, which will remain within DSM, all production, commercial, and R&D staff have been transferred to Worthen, meaning no layoffs, according to Annet Hoek, global communication and branding lead. Endurans is expected to benefit from the combined experience from both ends — 120 years from DSM and 150

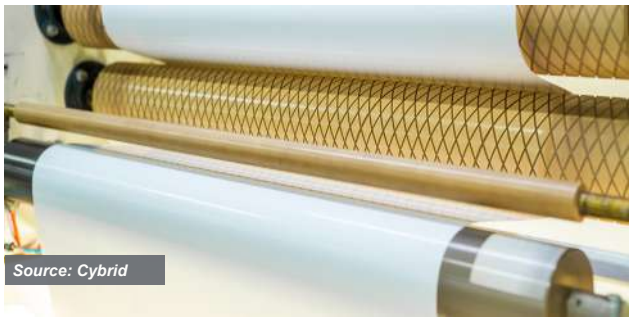

Source: Cybrid


Source: Jolywood

Change in top positions: Cybrid has been leading the backsheet market in terms of shipments for over 6 years with its leading KPF configuration (left). But due to a recent strong price increase in PVDF, Cybrid's close competitor Jolywood (right), who doesn't rely on this material, has now a competitive edge.

from Worthen. Having access to production capacity in the US on top of the existing facilities in Belgium, The Netherlands and China, “This makes us a truly global player,” said Hoek. The company offers two product streams. The Endurans HP launched in 2020 is a coextruded all-purpose backsheet suitable for various module types and applications. The product is making good inroads into the Chinese and Indian markets; becoming active in Europe and the USA would be part of the next phase of action, according to Hoek. The company also has a conductive backsheet specially designed for back-contact solar cells called Endurans CB. Hoek is also optimistic about the prospects of this specialty product, especially after proving the business case through the partnership with Silfab Solar. Endurans sees high scope for this product for use in modules not only for the residential segment, but also other high-end applications such as vehicle-integrated and building-integrated PV. While not disclosing annual shipments, Hoek underscored that more than 15 million modules will feature Endurans backsheet by early 2021. The company doubled its capacity in 2020 and has plans do it again in 2022, but did not provide exact capacity details.

Shingi Urja is relatively a newbie in the backsheets segment, but not completely new to the survey. The Indian company was part of our 2018 survey, when it was promoting an all-polyolefin based backsheet structure. The company, in cooperation with Borealis, is progressing path of developing all-Polyolefin based backsheet, but waiting for the market acceptance for this new backsheet **Shingi Urja** is relatively a newbie in the backsheets

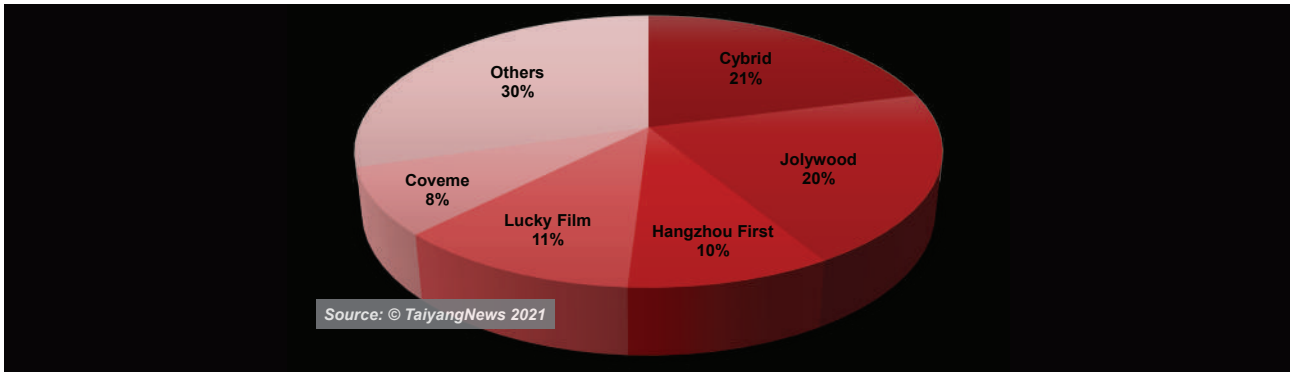

Source: Cybrid

Long leadership: The KPf configuration, which is still the main product of Cybrid, has helped the Chinese company to keep the top position in the backsheet segment for 6 years in a row.

segment, but not completely new to the survey. The Indian company was part of our 2018 survey, when it was promoting an all-polyolefin based backsheet structure. The company, in cooperation with Borealis, is progressing path of developing all-Polyolefin based backsheet, but waiting for the market acceptance for this new backsheet structure to kickstart the commercial activities. As of now Shingi Urja is mainly promoting the PET based backsheets, the mainstream configuration in the Indian market, while has also finished the certification procedures with its PVDF based 1500V configuration. The company is currently ramping up its production facility to 5 GW capacity. It also has in-house know-how expertise and manufacturing technology to produce coatings based backsheets.

While we have received product data from Féron and Crown for their products, our query seeking additional information is yet unanswered.

Market Shares of Backsheet Suppliers in 2020



Top 5 take the major share: While Cybrid shipped more backsheets than any other company in 2020, the Top 5 (excluding Crown) command a market share of about 70%.

4. Encapsulation Market Update

Polymer chemistry choices in the encapsulation segment are primarily between EVA and POE. While traditionally EVA has been enjoying a monopoly, POE gained limelight due to the widespread adoption of bifacial technology.

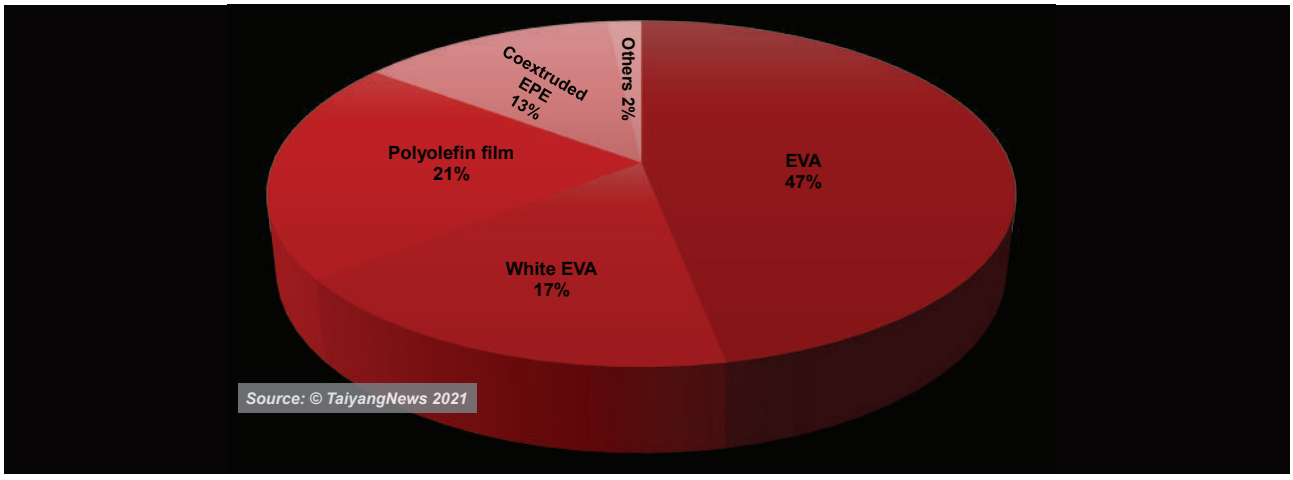
For the first time, and similar to the backsheets segment, our market survey on encapsulation material has received input from one component supplier. Resin supplier Dow provided information but for polyolefin and not for the mainstream encapsulant EVA. Dow has been supplying resins for different polyolefin films used in the PV industry. Dow now offers polyolefin resins for solar applications.

The inventor of POE, Dow has been supplying different polyolefins to a wide variety of industries, including automotive, infrastructure and consumer segments. For PV, the company initially supplied POE films directly to module makers under the ENLIGHT brand. However, in 2013, the US company decided to move up the value chain to supply only resin. While Bifacial PV has grown over the last 3 years, so has the demand for POE. In terms of market share, Yuyan Li from the POE business unit of Dow claims that the company caters to majority of thebifacial market, given that it is the largest producer of POE and its very well established status in PV. The most important trend in the POE segment is faster curing rates that can reduce lamination time. Looking ahead, the topics of making POE compatible with MBB – not being slippery with round interconnection and reducing costs – are also on Dow's radar. The polymer expert is also working towards speeding up the POE film production lines at their customers. On the other hand, Li says that film makers can adjust the formulations to prevent slippage of round ribbon and even module makers have workarounds to avoid it. However, it seems some module producers are still holding on to pure POE films in a bargain for higher reliability.

As far as thermoplastic polyolefins are concerned, Li explains that it is a film technology rather than a resin technology, and even Dow's resin can be used for producing thermoplastic polyolefins. The ENLIGHT, which was sold to Hangzhou First, was also a thermoplastic variant of polyolefin film technology.

At the product level, encapsulation materials fall under different branches following the same chemistry. While EVA has fundamentally been transparent, it has been tweaked to be white in order to improve the optical gains of the module with increased reflections from cell gaps. Polyolefin,

Market Share of Encapsulation Materials in 2020



Leader loosing shares: Transparent EVA, which was enjoying the lion's share of 70% in 2019, had slipped to 54% in 2020, while all the other encapsulation solutions benefited from its fall and gained shares.

typically used on the rear side of p-type PERC bifacial modules, is increasingly being replaced with a coextruded multi-layer structure consisting of a POE film sandwiched between two layers of EVA.

As in the past, transparent EVA is still dominating the encapsulation segment with a market share of 55% in 2020, while white EVA is gaining ground ending 2020 at 20%. The remaining 25% belongs to polyolefins, split between single layer POE at 15% and coextruded EPE at 10%, respectively.

Let alone the choice in polymer chemistry and configurations, even the suppliers for encapsulation materials are not too many. Traditionally, the segment has been ruled by three companies – Hangzhou First, HIUV and Sveck. Similar to encapsulant producers finding their way into the backsheet business, such as Hangzhou First, there's a prominent example for the opposite direction: Cybrid is now also a leading encapsulation material supplier. However, no other supplier comes even close to Hangzhou First, which commands more than half of the market share. The company once again ended up as top supplier in 2020 with its shipments of EVA and POE totaling 865 million m2, a YoY growth of 15.6%. According to Hangzhou First, the shipments represent somewhere between 55 and 60% of the market, with a production base of 1.05 billion m2. By the end of H1/2021 , the company added new capacity of 110 million m2 and sold 416 million m2 of encapsulation material.

The year 2020 was a good year for encapsulation suppliers in general. The shortage of encapsulant materials and the increase in demand played their parts, with the top encapsulation suppliers recording higher revenues and profits, according to Collin Quean from HIUV. However, given that the company is public, Quan declined to reveal annual shipment numbers; instead he pointed to the 2020 financial report, but which only provides financial information. HIUV's net profits increased by 230% year-on-year, its total operating income increased 39.5% in the same period to CNY 483 billion, and the profit in absolute terms reached CNY 221 million. HIUV's improved financial numbers are attributed to its efforts towards expanding its production capacity, increase in sales volume and average unit sales price of EVA film. HIUV estimates its market share at about 15%. It had a production capacity of 30 GW at the end of 2020, increasing to somewhere between 40 and 45 GW by the end of H1/2021. The company plans to quickly and strongly expand its manufacturing base to 100 GW by the end of 2022 . The new facilities coming online will not only cater to increasing solar demand but also address any demand spikes.

Cybrid is also very determined to carve a niche for itself in the encapsulation segment. It sold 66 million m2 of encapsulation material in total, with the bulk of 65 million m2 representing POE and 1 million m2 for EVA. However, like HIUV, Cybrid also has strong expansion plans. It is adding new capacity on top of its existing base of 25 million m2 per month. This capacity expansion is expected to help Cybrid capture a 15% market share in the total encapsulation segment, according to Cybrid's marketing director Xinjun Li. Cybrid has already a share of 17.5% in the POE segment. "By the end of 2021, we will be second or third largest encapsulation supplier in the world," said Li.

5. Trends in Backsheets

Ideally, for an important process consumable such as a backsheet, which has a sizable influence on costs as well as the reliability of solar modules, developments to reduce costs and enhance reliability must go hand in hand. But the dominance of one over the other changes as per market needs. Currently, module makers are under very high pressure to reduce costs to cope with the price increases from silicon and other processing materials, such as backsheets. Not only have the prices for all components used in backsheets increased, but the rise in transportation and packing costs are also influencing backsheet prices.

Above all, the major influence comes from the fact the prices for PVDF have shot up several-fold. The most popular backsheet in the market is a PVDF film on the outer side and fluorine coating on the inner side with a PET core layer, which has a share of over 55%. In that context, rising PVDF costs are driving module makers to seriously evaluate other alternative structures. CPC is one such promising configuration that is benefiting the most from this situation. Then, coextruded backsheets with their huge potential to reduce costs further are gaining traction or, for that matter, every non-PVDF backsheet configuration.

Another important trend in the backsheet business is the rise of transparent backsheets. Almost every leading backsheet manufacturer is developing a transparent variant of their leading product configuration and seems very positive about the potential of these clear rear covers in bifacial applications, especially with modules getting larger and larger. Regarding larger modules, the notion that backsheets with polyolefin-class inner layers are not capable of withstanding hotspot tests is taking hold, especially voiced by the key promoters of fluorine coatings. Another noteworthy development is more and more companies taking interest in coextrusion as an alternative to lamination.

Using a black grid instead of a complete black backsheet is a trend identified by Cybrid. And of course, ensuring the reliability of the solar modules for 25 or 30 years continues to be an ongoing topic of interest for the entire backsheet industry. This chapter discusses the important developments in the backsheets segment.

5.1 Price Increase of Raw Materials

Sky-high PVDF prices are a burning topic in the backsheet segment. The price of PVDF film almost doubled from 2.5 CNY/m2 in 2020 to 4.5 to 5 CNY/m2 in 2021 as a result of the dramatic rise in the price of resin for PVDF, according to Fumotech's Wei.

Jolywood's Yuan said the price for this resin has increased from 70,000 CNY/ton to 220,000 CNY/ton, an increase of 320%, while ZTT put this range at 60,000 CNY/ton to 180,000 CNY/ton. This price increase is mainly due to a resin shortage arising from increased demand from electrical vehicles, as PVDF is used in lithium-ion batteries. The key stakeholders of the backsheet segment are in regular dialogue with resin makers, according to Cybrid's Li. He estimates that the supply situation could ease by October 2022. By then the damage could be huge and partly irreversible.

First, this is seriously affecting those companies that have been mainly focusing on products based on PVDF, but not only them. The first ones to be affected were PVDF suppliers such as Fumotech, which expects its market share to decrease by 10% over 2020. This is not just a consequence of module makers evaluating other backsheet configurations, but backsheets as a segment also faces tough competition from glass. With glass vendors having dramatically decreased prices, it is a good opportunity for module manufacturers to replace backsheets with glass altogether. In fact, the backsheet segment is expected to fall by about 5 to 10% already in 2021.

On the other hand, Cybrid's Li noted that the degree of price increase for PVDF is not directly reflected in backsheet prices. The final backsheet price went up by 2 to 3 CNY per square meter. "It is still affordable and in fact is at a level seen 3 years ago," he emphasized. While representatives from some module manufacturers we talked to in early 2021 did not agree with this argument, towards the end of the year PV panel prices have tended back towards

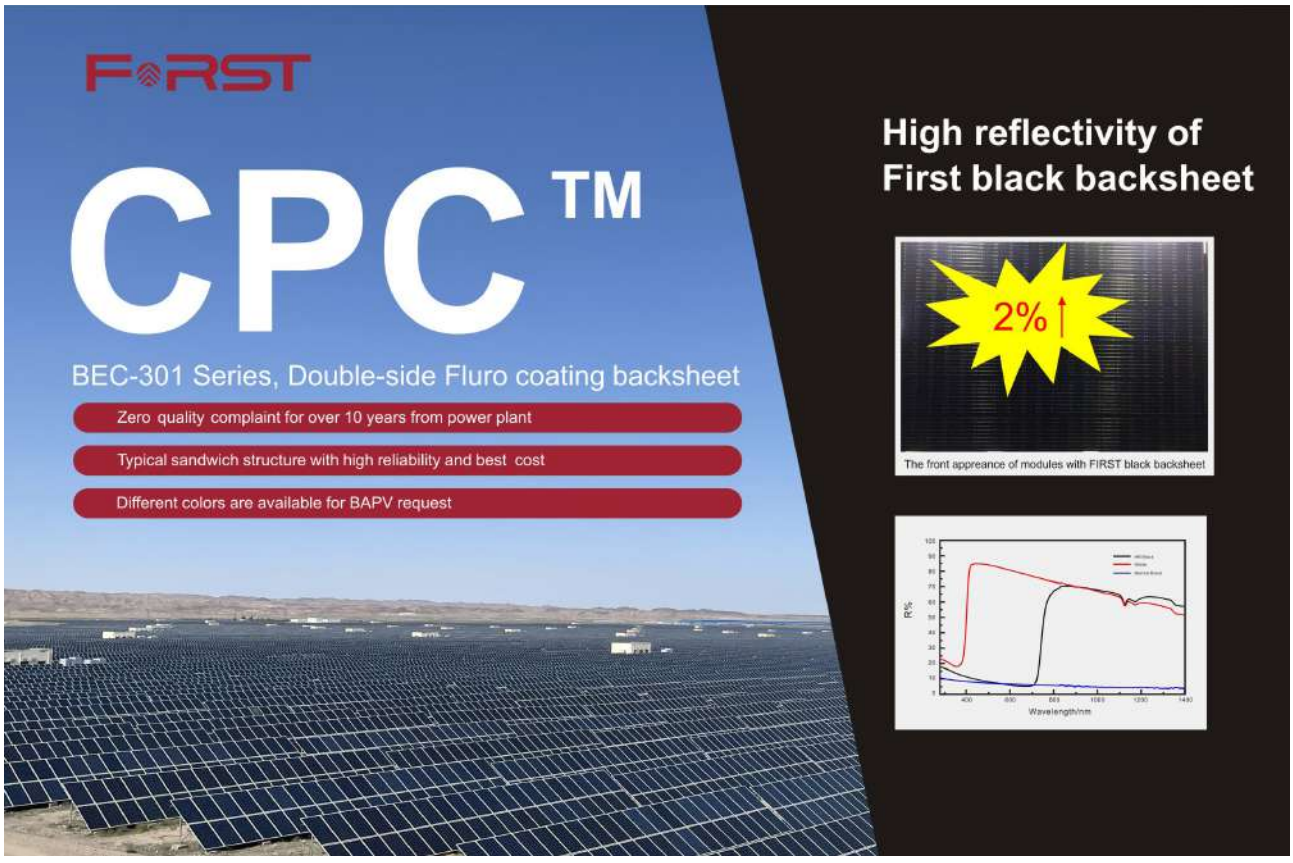
the level they were 3 years ago as well. Although cost reductions are not entirely driven by materials, with technologies such as half cell, MBB and larger wafers playing a major role there, the industry continues to pursue alternative solutions.

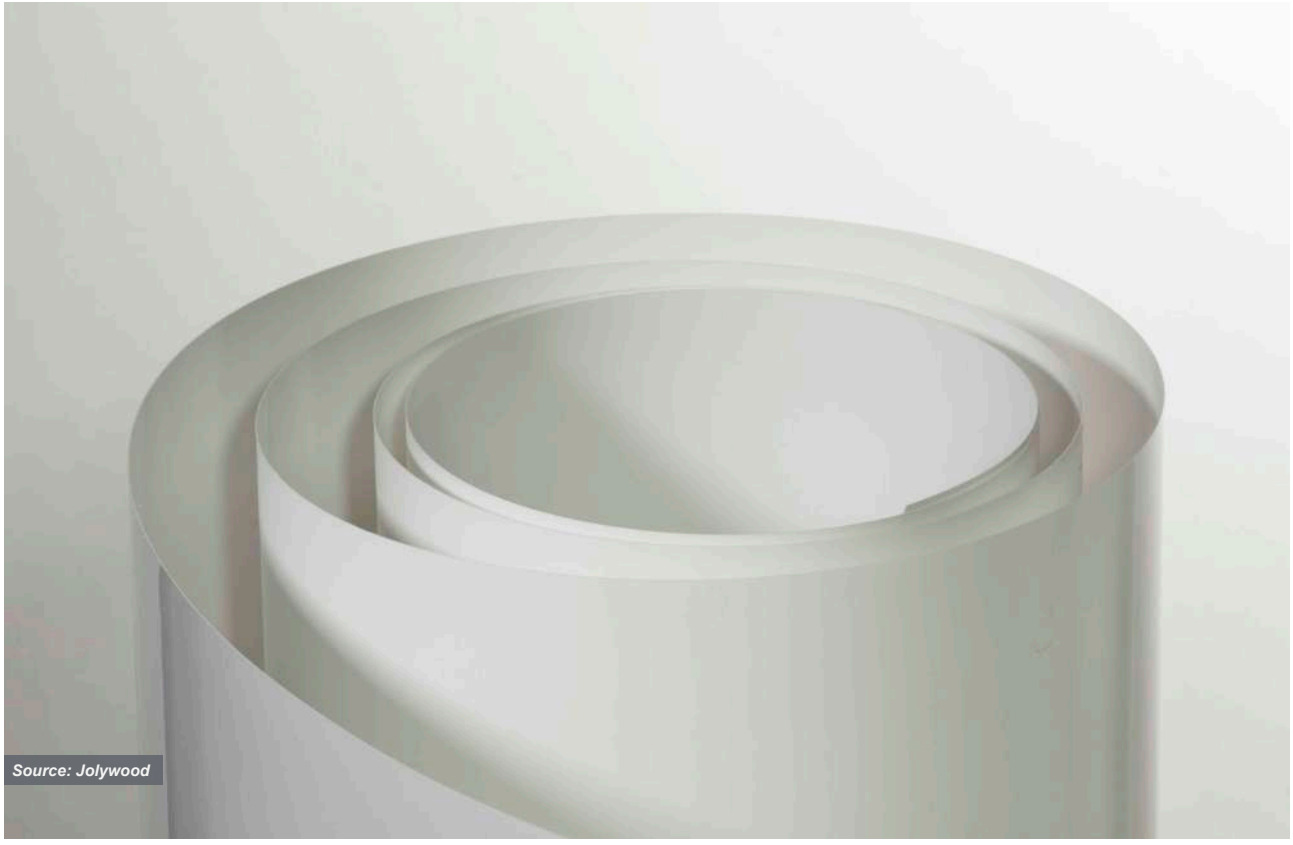
CPC is the most popular alternative, most prominently seen in action at tier 2 module makers, but not limited to. Jolywood is a key promoter of coatings-based products, which it started offering in 2008. As of June 2021, the total FFC double-sided coating backsheet shipments exceeded 350 million m2, or 70 GW in module terms, according to Yuan. “After 14 years of outdoor use and no complaints, the market has started recognizing our products,” he added. The coatings-based configuration also offers other advantages such as glue-less construction and fewer process steps, high production efficiency and improved production yields, ultimately providing outstanding cost performance ratio, according to Jolywood.

Coveme has also developed coating technologies for different backsheet applications, as Manara emphasizes. “The quality of the coating must be really strong and exactly reflect that of the layers in terms of hydrolysis and UV barriers,” she said.

Not just coatings, all PVDF-free structures such as PET based, non-fluorine coatings and coextruded products, including Endurans HPO and all-PP configuration from Borealis, are clearly gaining popularity. Even Tedlar, an expensive fluoropolymer, is seeing increased demand on this account.

The firm believers of films cannot seem to agree that coatings can replace the outer protection layers. Endurans’ Hoek in fact opined that the industry simply resorted to using less and less material, or materials that cost lower, rather than focusing on innovation, both of which pose reliability risks. Fumotech’s Wei also points out that fluorine content of the coatings at 20% is relatively less than that of films, which is 40% for PVDF. As an alternative to PVDF as the outer layer, Fumotech for example is developing a new film that can compete with the price of CPC or even PP, but Wei refrained from providing any details, whereas Cybrid is working on the PPf structure.





Best bargain: Due to the dramatic PVDF price jump, CPC coatings based backsheets benefited a lot, such as products offered by Jolywood.

Not just the prices of PVDF, all raw material prices related to backsheet production have increased in general, albeit not to the tune of PVDF. According to Coveme, the price for PET raw materials increased somewhere in the range of 15% to close to 25%, while the PE film price also increased also 15% to 35% (see graphs on p. 26 for reference).

As a result, backsheet prices have also seen a commensurate increase. Jolywood provided the average reference prices from 2020 and 2021 for the purposes of comparison.

CPC:

- 2020: CNY 9.5 CNY/m^2
- 2021: CNY 12.5 (CNY/m^2)

KPC:

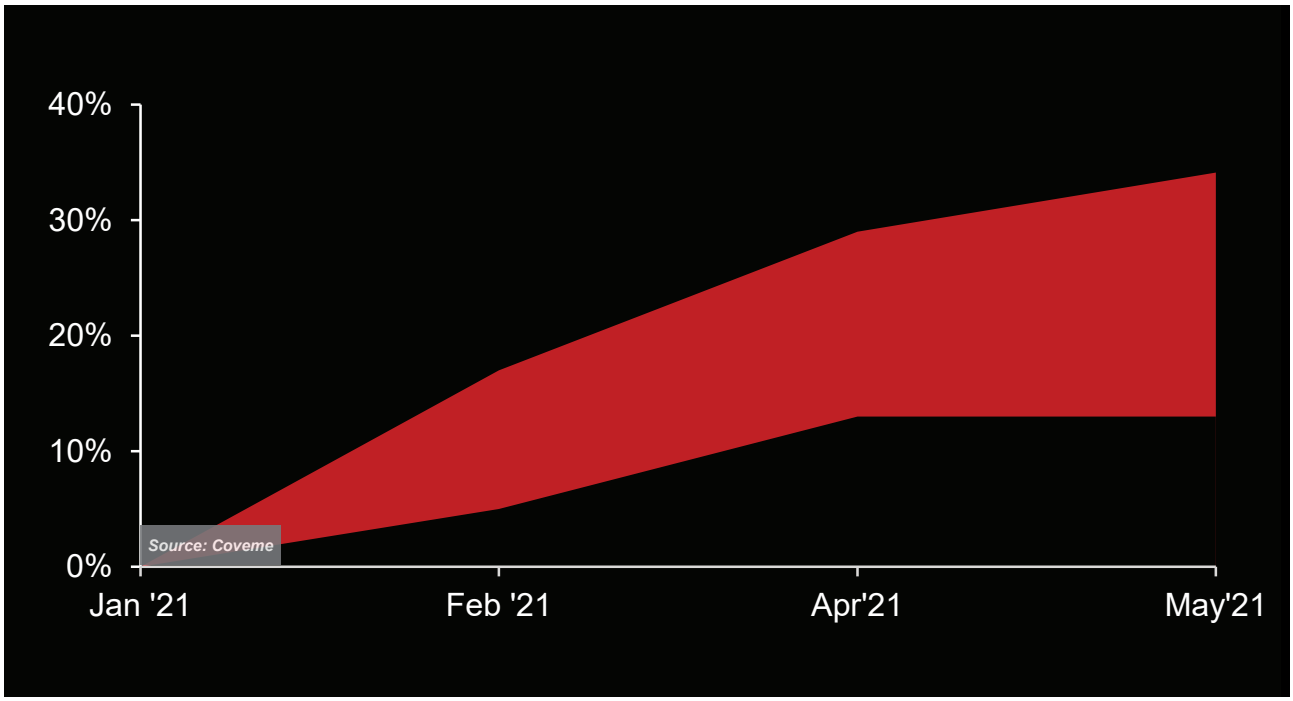
- 2020: CNY 10 CNY/m2
- 2021: CNY 14 CNY/m2

TPC:

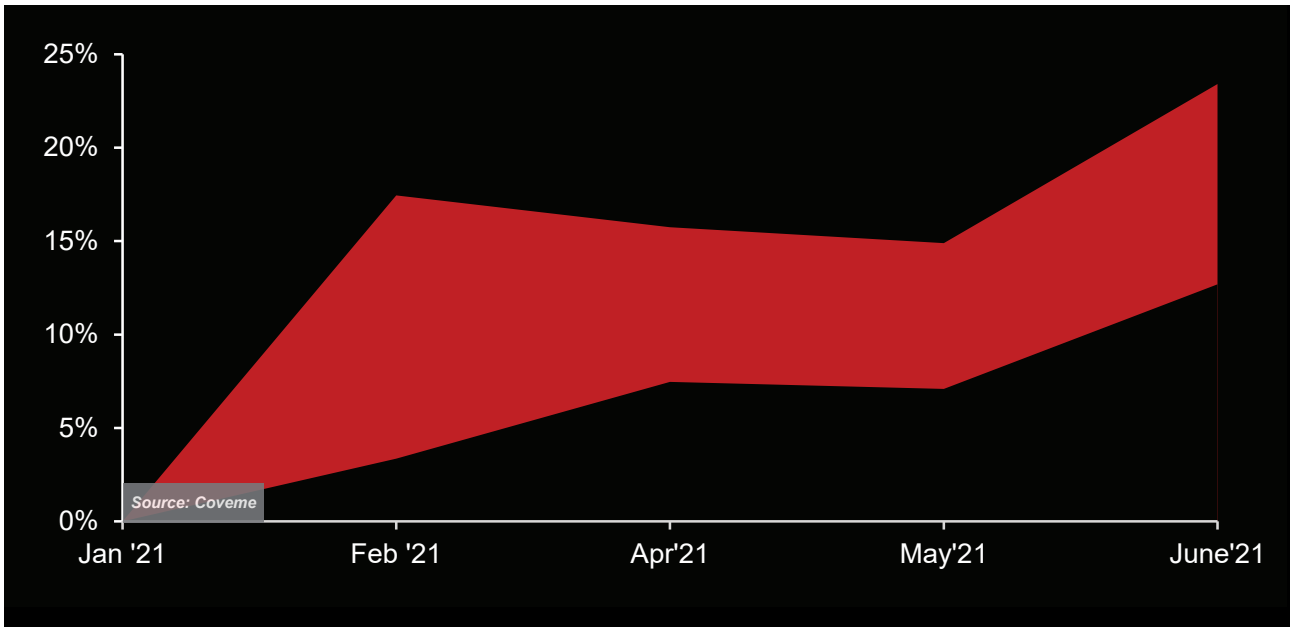
- 2020: CNY 17 - 18 CNY/m^2
- 2021: CNY 17 - 18 CNY/m^2

Declining to quantify the values, Coveme's Manara says that PET-based backsheet prices went up 10 to 15% in 2021 compared to a year earlier. She also emphasizes that CPC remains the most competitive, especially if technologies lead to high productivity, which implies the prices of PET-based backsheets fall in between KPC and CPC. Since Endurans launched its product only in 2020, Hoek says that there is no reference data, but points out that backsheet prices are expected to increase 10 to 20% due to the increase in raw material and logistics costs. "The market is positioning itself on different prices due to cost increases in raw materials, but also to increases in costs throughout the entire supply chain," says Manara.

PE Film Price Trends in H1/2021 – Coveme



PET Film Price Trends in H1/2021 - Coveme



Others too: Not only for PVDF, the other raw materials used in backsheets have also seen significant price increases in 2021. According to Coveme, the PE price increased by up to 35%, while the price for PET increased by up to around 25% in H1/2021.

5.2 Transparent Backsheets

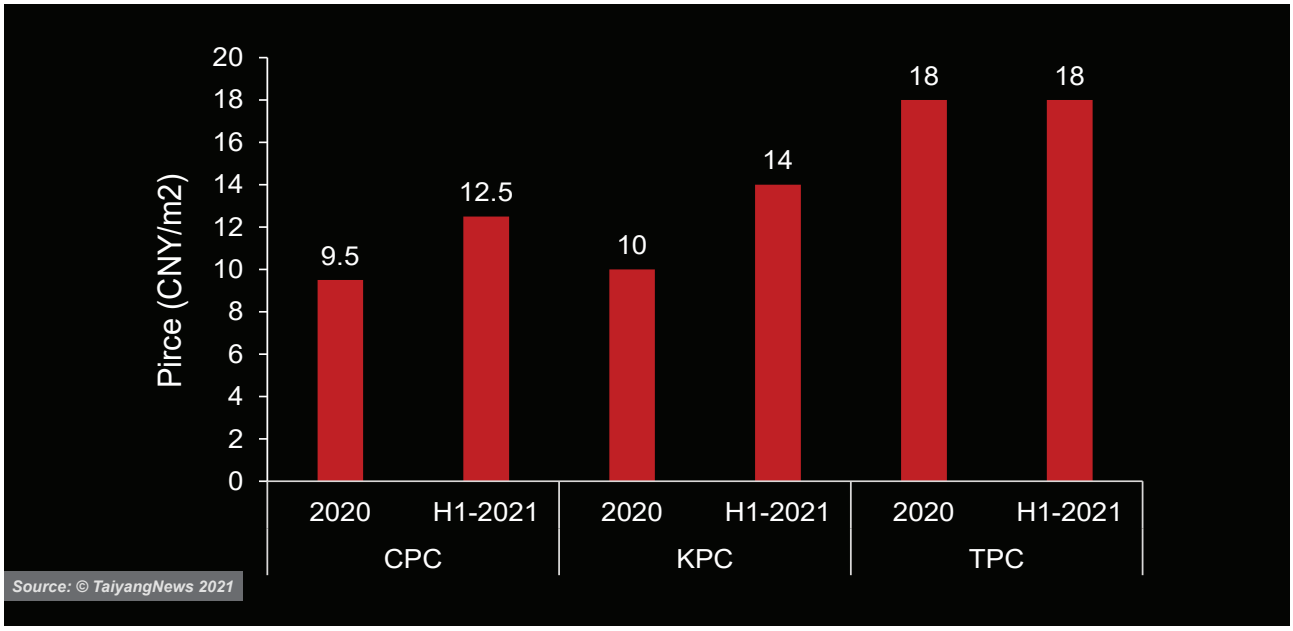
But for prices, transparent backsheets would have been the most interesting topic and it still is the top technological development in the area of backsheets. What has brought about this increased traction and attention to transparent backsheets is their application in a very rapidly developing sector of PV — bifacial. It is a technology that improves the energy yield of the PV system with minimal effort, ultimately reducing LCOE of a PV system. The ease of manufacturing, especially at the cell level, is the key to its widespread appeal. Any advanced technology beyond PERC is naturally bifacial and PERC, as well, can be tweaked to bifacial without involving additional costs.

At the module level, the most important change is naturally to make the rear cover transparent. Glass has been the natural and predominant choice in this regard. 2018-ish, during the commercialization phase of bifacial technology, there was no competent polymer solution available that could meet the needs of bifacial panels. As the bifacial trend took hold, so did the focus on transparent backsheets. Result — now there are reliable clear variants of backsheets available from nearly all leading companies.

In fact, using a transparent backsheet as rear cover of a bifacial module is an interesting alternative to glass. This approach also comes with several advantages. Unlike the heavy glass-glass modules, the polymer-based products weigh the same as standard modules, eliminating any extra care required in transportation, handling and installation. In addition, the manufacturing process, along with other materials used in module making, remains unchanged. This offers the manufacturer the ease of switching production between monofacial and bifacial module varieties depending on market demand.

Conversely, adding an extra glass loader to make glass-glass modules is not an expensive affair these days. Line throughput could favor the transparent backsheet based process, as the glass structure requires longer lamination cycle times compared to polymers. The observed drop in productivity for a plant using a glass rear cover is about 10% which, however, is not attractive enough to lure module makers into polymer based solutions. Using glass requires a change in BOM. It is not as simple as adding a sheet of glass, but it requires a high PID-resistant encapsulant such as POE at least on one side – the rear side for PERC. Unlike glass,

Prices of Backsheet Structures in H1/2021 vs 2020



High, higher, PVDF: In 2021, backsheets generally got pricier compared to 2020, but the rear covers containing PVDF increased the most with a hike of about 40%.

the polymer backsheet modules are “breathable,” which means they allow moisture and free radicals formed, if any, to escape. It also makes sense to use backsheet panels in hot regions, which dissipate heat better than glass, thus helping to lower the cell operating temperature by 5 to 10 °C, making them more efficient.

One of the USPs for glass-glass modules has been the 30-year performance warranty. With its strong track record in reliability tests for mechanical loading and damp heat performance, this structure built enough equity for itself among module makers that it was the go-to solution in applications for very long times of use. Its exclusivity, however, has already been challenged. There are transparent backsheet modules available in the market now that match the 30-year power warranty of glass-glass panels, notably from JinkoSolar and Jolywood. A lot of the credit can be attributed to DuPont — the lone source of PVF Tedlar and a strong advocate of transparent backsheets for bifacial applications. JinkoSolar, one of the 3 world’s largest module makers, was convinced and started offering commercial transparent backsheet modules based on Clear Tedlar with a 30-year power warranty. Following this lead, Jolywood also commercialized the polymer rear cover modules with the 30-year warranty. Jolywood is somewhat different in this context. In addition to being a high-efficiency TOPCon cell and module manufacturer, Jolywood’s core business is supplying backsheets. It is in fact the world’s leading backsheet supplier in 2021, according to shipment data. However, the lower warranty span does not seem to be a showstopper. Talesun and LG, for example, even started offering transparent backsheet modules with a 25-year power warranty. All leading companies have evaluated, tested and also completed the certification process. JA Solar, Suntech and Yingli have already put their transparent backsheets into commercial production, according to Fumotech’s Wei. Jolywood adds a few more names to the list – Chint-Astronergy, Hyundai Solar and Indian module maker Vikram Solar.

The industry and its participants have a thorough understanding of the pros and cons of transparent backsheets versus glass. In other words, there are no pressing issues with transparent backsheets. The selection criterion now simply boils down to costs. This is evident from the fact that during the second half of 2020, when glass was in short supply and the prices were high, the industry rushed towards transparent backsheets, a trend acknowledged by all backsheet suppliers. But of late, with the fall in glass prices, glass has more than found the favor it had lost among the manufacturers. In the long run though, as costs go down, many backsheet makers expect the share of transparent backsheet to rise quickly.


Source: DuPont

Equating to glass: Based on extensive testing, DuPont was able to convince leading module manufacturers, like JinkoSolar, to offer glass-transparent backsheet modules with 30 years power warranty, matching the offer for glass products.

The cost difference between glass and transparent backsheet at which it starts to make sense for module makers to switch is at least 3/m2 CNY, according to Jolywood's Yuan. Then, the other benefits such as savings in encapsulation (may not be relevant now: see encapsulation section for details) and ease of production play in — motivation enough for module makers to shift to transparent backsheets. A point to be noted here; backsheet prices are very much dependent on the polymer chemistry used for building different layers, also the case with transparent backsheet. And making film-based backsheets requires all components such as the outer protection layer, PET, inner layer if applicable, and glue to be transparent, all while maintaining the same UV protection attributes. All this not only makes for a complex backsheet making process, but it also makes the final product expensive. Film-based transparent backsheets are about 80 to 90% more expensive than their opaque counterparts. For example, the TPC transparent backsheets sold in H2/2021 for about 32 CNY/m2 CNY against 18 CNY /m2 for the opaque one.

Making transparent fluorine coatings based backsheets on the other hand is easy and low cost. Moreover, the base value for opaque CPC backsheets is also low, so making transparent CPC backsheets cost competitive to glass is relatively easy. In H2/2021, the price of a CPC transparent backsheet was pegged at about 20 CNY/m2 while an opaque backsheet of the same configuration costed about 12 to 14 CNY/m2. In comparison, prices for 2 and 3.2 mm glass were 20 CNY /m2 and 24 CNY/m2, respectively, meaning there needs to be a further 15 to 20% cost reduction to make it lucrative.

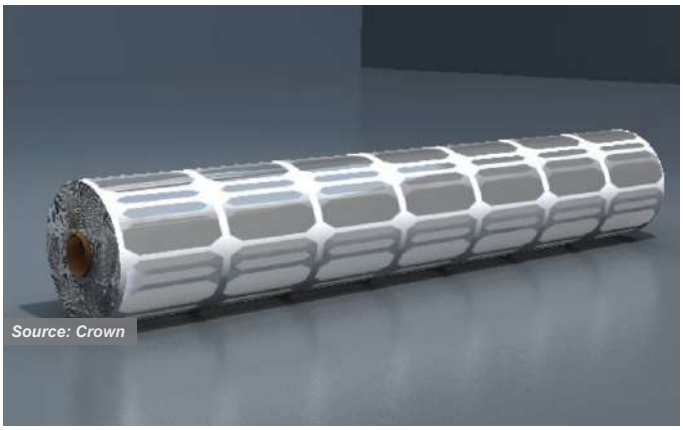
Still, transparent backsheets make a strong business case in a few markets, according to Cybrid's Li. He takes Turkey as an example, where importing glass from China is a costly affair. "For such markets, transparent backsheet is much better," said Li. In addition, Cybrid also sees potential for transparent backsheet in the C&I rooftop markets with flat roofs and moderate weather conditions.

All component suppliers and most backsheet manufacturers are offering solutions suitable for transparent rear covers. Starting with component suppliers, DuPont has been offering Clear Tedlar. Fumotech has developed several generations of transparent PVDF and the product accounted for 20% of its shipments in 2020 and 13% during the first half of 2021. ZTT has started supplying

Source: Jolywood

Pricier than glass: While transparent backsheets have evolved in terms of reliability attributes, their major bottleneck is the price difference to glass, which plummeted recently. The transparent CPC configuration comes closest to glass prices.


Source: Hangzhou First


Source: Crown

In order not to waste the light that hits empty spaces between the cells in a bifacial module, all leading backsheet suppliers are offering products with reflective material. Shown here are products from Hangzhou First (left) and Crown (right).

transparent PVDF with its shipments reaching about 1 million m2 so far. DTF has also added a range of ultra-clear products to its Mylar UVHPET portfolio for bifacial applications. The films are designed to be used as outer, inner or mono layers in transparent backsheets.

Jolywood was one of the first companies to offer transparent backsheet products, based on the TPC configuration, but its main product is CPC. Lucky Film was also one of the frontrunners to bring a transparent backsheet to the market, based on Tedlar. And while Cybrid was mainly promoting its famous KPf structure till 2020, the company has now shifted its focus to coatings-based solutions for transparent backsheets. For applications in extreme weather conditions, for example requiring high abrasion resistance, the company has developed special abrasion-resistant hard coatings that can be applied on top of the regular fluorinated coatings. This additional 5 µm costs 1 CNY/m2 extra over the base CPC price of a backsheet, according to Li. The main products for Coveme for transparent backsheets are PET and Tedlar based, including an option for primer or coating on the cell side.

These are only a few examples, as every major backsheet maker is promoting a transparent variant of its leading backsheet configuration. The only exception is Endurans. According to Hoek, it is one of the products in its development pipeline. While it is not difficult to introduce a transparent backsheet for the company, given its polymer engineering background, Hoek underscores that the high internal

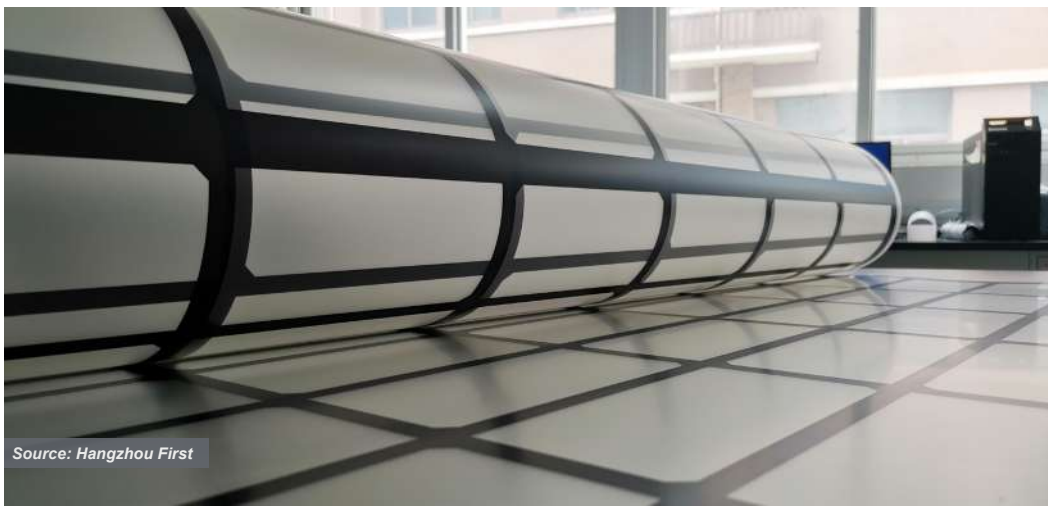
testing standards take time in order for such a product to be endorsed under the Endurans brand.

Apart from the polymer chemistry, the transparent backsheet has another interesting variant that is actually aiming to alleviate one of the inherent limitations of the bifacial technology, i.e., the front power of the bifacial module is less than that of its monofacial variant. The inter-cell spaces of a monofacial module are white, which reflect the light hitting these spaces onto the active surface, enhancing optical gains. Bifacial, with its transparent rear cover, lets the incident light on these inactive areas to simply pass through, thus missing out on any such gains. To overcome this limitation, backsheet makers borrowed an idea that was initially introduced by the solar glass segment. They are offering a tailored product that remains transparent in those areas where the cell will be placed while the inter-cell spacing area is printed with a white reflector. Such backsheets are referred as “grid” and/or “patterned”. This way, a bifacial module looks like a monofacial panel from both the sides and the white reflector assumes the role of reflecting incident light on inter-cell spacing. All major companies are offering such custom-made backsheets tailored to match the different cell sizes and module designs of individual manufacturers. The additional costs for applying grids are about 2 CNY/m2. However, the acceptance for such products varies from company to company. Jolywood, with a share of 70% for grid applied products within its transparent backsheet sales says the industry well received the product. On the other hand, Hangzhou First and Lucky Film have not observed huge demand for such products. Coveme did see an increase in demand in the beginning of 2021, but not so much in the second half.

There is one other variant of the grid backsheet that is getting popular – changing the color of the grid from white to black. This is especially from module makers that are making black modules. Such modules typically employ black backsheets which add to the aesthetics quotient of the backsheet. Since bifacial cells are priced the same as monofacial cells, using a white backsheet is always beneficial versus using black backsheets, as some portion of IR light that passes through the cells can be reflected back when the rear cover is white. Using white backsheet with black grids solves both the purposes – function and form. According to Cybrid’s Li, the approach improves the module power by about 4 W.

5.3 Coextrusion Process

No doubt the backsheet segment is innovative and very dynamic. But these developments are rather limited to the polymer chemistry and finding new configurations in terms of the backsheet structure; regarding the manufacturing process, the segment is rather “old school.” The majority of the backsheets in today’s market are produced with lamination; procuring the different layers of films, mostly externally, and glue them together by means of lamination. Coating, especially when applied on both sides, is a step forward from the lamination method; however, the core film is still procured externally. Coextrusion, on the other hand, offers the ability to produce backsheets directly from resin. The beauty of the process is that it allows the stacking of multiple layers of different polymer chemistries, if needed, in



Source: Hangzhou First

Grid in black: To improve the performance of all-black modules, companies are also offering white backsheets with black grids.

one go. Not only does it simplify the manufacturing process, which has a high cost savings potential, the process is free from glue. That means the coextruded backsheets are free from inter-layer delamination.

There are two kinds of solutions from two different companies. Endurans is offering a final backsheet product. Then, Borealis designed its business model to operate a step above in the supply chain. The Austrian chemical company is supplying resin and encouraging backsheet makers to produce in-house.

As for polymer chemistry, it is relying on polypropylene (PP) in mono material configuration, meaning the produced backsheet stack still has 3 layers, but each layer of PP is modified for a specific role. BISCHOF + KLEIN from Germany has also commercialized a backsheet product based on an all-Pp coextruded backsheet; but the company has not responded to our enquiry as of the publication time of this report.

Borealis calls its solution Quentys and started promoting its solution in two configurations — a PP core layer to replace the PET alone and an all-PP based fully functional backsheet. While the customer can choose what is the best, highest cost benefit can be availed when choosing the co-extruded full PP-backsheet as it avoids any further lamination or coating steps, according to Borealis' business manager for solar, Alper Muraben. Borealis currently supplies a polypropylene compound, not the film itself, leaving backsheet makers in the position to design their own films from the Quentys compound in-house for use on their own production lines. While standard polypropylene can be bought on the market in the form of homopolymers or copolymers, this would not suffice for the requirements of backsheets. Based on long term knowledge and experience Borealis has developed multiple tailor made polypropylene products. According to Muraben, this not only requires a high level of polymer know-how, but also brings in additional costs with it. Borealis is offering ready-to-use polypropylene compounds specifically made and tested according to the requirements of the backsheets, so that manufacturers can run Quentys directly on their lines. This means that the backsheet maker does not have to go through the tiresome process of developing their own compounds. "It is a kick start for the backsheet maker when they want to introduce a new product line," said Muraben. The resulting product has passed all tests required for backsheets. The industry feedback about the performance of the backsheet in different tests is positive, according to Muraben. He quotes water vapor transmission rate, electrical performance and temperature index as examples.

Polypropylene has a long track record in demanding outdoor applications. Borealis has used this experience to develop dedicated compounds that meet the long list of backsheet requirements.. As for the core layer, when compared to the current state of the art (PET), it has low density. What this means is the same performance attributes can be achieved with the use of less material, and the

superior water vapor barrier properties are an added bonus. Apart from the technicalities, Quentys comes with two primary advantages. One is savings in costs due to the superior performance of the PP and the coextrusion process. The other important part is sustainability. According to Muraben, PP is highly recyclable, which is done so in a very large scale; and Borealis, with its wealth of experience in recycling, is focusing on circular economy for plastics. He further emphasized that the all-PP backsheet is a mono material — a common word in packaging. The packaging industry itself is moving away from multilayer packaging; for example, paper on the outer side and plastic on the inside pose problems in sorting and recovery as part of recycling. Based on the experience with other applications Borealis has, mono materials have shown to have the best yield in recycling. Not only the final product, even during the manufacturing, the waste from trim on the edges can be fed back into the extruder. “Mono materials will be preferred in the future,” he underlined.

Borealis is seeing a positive response to its solution from the PV market. The first backsheet makers have already invested in the coextrusion equipment. Some of them are in the final stages of cost and performance optimizations. With Quentys as the backbone, a few backsheet makers are customizing the solution according to their needs and are on the verge of approving the product, said Muraben. Borealis is putting its experience of working with backsheet makers to good use in improving the product further. This is evidenced in the company preparing to launch the second generation of Quentys, which is in testing, according to Muraben. PP is very versatile and currently at the very early stage of optimization, he emphasized, but as it gains more and more market acceptance, there is huge potential for future optimization and cost reductions without compromising on performance.

An inherent limitation of PP is the low melting point, below 165 °C, This limits the lamination temperature of PP based backsheet: It cannot exceed 155 °C. Borealis recommends a lamination temperature of 150 °C. Module makers have to be very careful if they want to go up to 155 °C. However, in the majority of cases at the manufacturers, lamination is done at 145 °C or 150 °C, at maximum, with only a few going beyond this level. Thus believes Quentys is compatible with a major part of the market.

At the backsheet supplier level, Lucky Film is in favor of the technology and the company estimates


Source: Endurans

Fairly different: The backsheets from Endurans not only follow an uncommon structure – polyamide/ polypropylene/ polyolefin, the backsheets are also produced with a special coextrusion process.

it to have big application in next 3 to 5 years. The company is also working on a coextrusion project that is still in the development phase, while the products are expected to hit the market sometime this year, while Lucky Film declined to elaborate on the details of the polymer chemistry it is working on.

Fumotech is yet another Chinese company that is in favor of the coextruded PP structure and is evaluating the technology. Referring to PP coextrusion, Fumotech's Wei said that it is an effective way to reduce the costs, while underscoring the limitations in passing the hot spot test and lamination temperature as shortcomings. Fumotech is working on a coextruded PP solution but given the background of the company as a PVDF supplier, the business model behind the project is a secret, at least for now, as Wei would not provide any details.

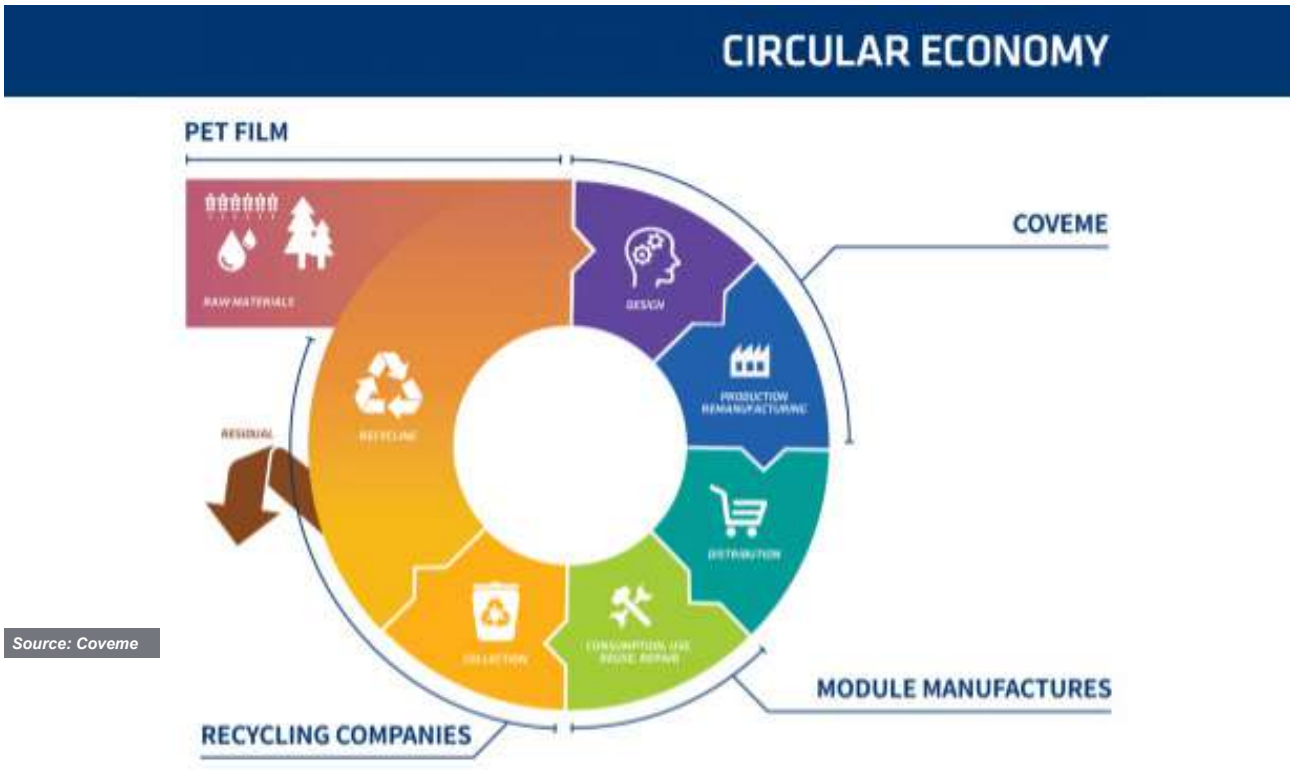
Another strong proponent supplying coextruded backsheets for some time is Endurans, but the company is relying on a slightly different polymer chemistry. The Endurans backsheet is built with 3 different polymer chemistries – Polyamide 12 for outer protection, modified polyolefin as core and a modified polyolefin e-layer. Endurans is also quite upbeat about its selection of polymer chemistry for its backsheet over the typical configurations available in the market. As for the core layer – modified polyolefin –, it is less sensitive to moisture compared to PET and the mechanical properties remain unaltered for longer durations, justifying its usage in extreme outdoor applications. In addition to being cost-competitive with all traditional laminated/coated backsheets, including CPC, Endurans highlights the ease of end-of-life treatment with its product configuration, an often-neglected topic in price/cost discussions. Recycling fluoropolymer backsheets, whether through incineration, pyrolysis, or direct remelting, is technically difficult and thus costly. In contrast, the Endurans HP range is fully recyclable through the lowest-cost option of remelting. The company has been monitoring 9 solar fields in Europe and Asia since 2015 that have its backsheets installed, with zero failures reported so far, according to Endurans' Hoek. "Our backsheets meet, and sometimes even surpass, the highest industry standards; the PVEL stress test is one example," said Hoek.

In addition to Endurans HP backsheets for mainstream modules, the company is also supplying a conductive backsheet under its Endurans CB brand that is targeted at high-end applications. The customer base for this product is currently in Europe and the US, while the company is working to expand into Asia as well.

5.4 Backsheets Made with Recycled Material

Sustainability has always been a topic in solar and, of late, is getting increased attention. It would be more of a concern when the solar modules reach end of life, as modules contain considerable amounts of polymers that eventually require safe passage for disposal. As a first step towards module waste recycling, DTF, in cooperation with Coveme, have launched a range of backsheet films with 33% recycled content which won the Intersolar AWARD in 2021. The development was possible due to the LuxCR process which breaks down the waste material to the starting monomer— the building block for all polyesters — removes contamination, and then rebuilds it into a PET film for PV or any other application, said DTF marketing manager Davies. It is like upcycling the PET waste and blending it with 2/3 virgin material to make PET films used in backsheets. The key here is to make the recycled product's properties identical to one made with 100% virgin material. Additionally, the product also reduces the carbon footprint by 10%, according to Davies.

Coveme's role in the supply chain is a vital one. It takes the PET films made from recycled content and converts them into backsheets to be used by solar module makers. "We absolutely believe that sustainable product design and circular economy models are becoming a must and requests coming from the market confirm this," said Coveme's Monica Manara. As a matter of fact, the company is already offering a 1,000 V DC backsheet with recycled polyester film, which according to Manara has undergone the same qualification test and proved to be equal in performance, as well as in reliability, as the company's standard backsheets. The company also concluded the development activity for a 1,500 V DC version, which is currently under internal evaluation, and expects it to be successful as the earlier one. As a step further, Coveme has also finished a feasibility study of a circular process for the recovery of the PET-based backsheet at the end of life of the solar module. "We proved that the polyester can be separated from the module, taken



Source: Coveme

Fully recyclable: Coveme introduced a backsheet that is made with recycled PET content. It has also completed a feasibility study of a circular process for the recovery of PET based backsheets at the end of a solar module's life, which the Italian company presented at the TaiyangNews Solar Module Innovations Conference in Nov. 2021.

back into a monomer state and used again for PET film production," said Manara, adding, "A closed loop so to speak."

Endurans also highlights the sustainability of its Endurans HP product range, which is "fluorine free" and according to the company has a 30% lower carbon footprint compared to fluorinated backsheets made using the lamination process. It has a positive impact on waste treatment and associated costs at the end of life of modules, said Hoek.

5.5 Larger modules

Like any other part of the supply chain, the backsheet makers also have to upgrade their products to be able to cater to the needs of the larger modules built with larger wafer formats such as M10 and G12. The backsheet makers are required to adapt to the width of these larger module and all leading backsheet suppliers are ready with such upgrades. However, the larger modules put yet another limitation related to the inner layers of the backsheet. According to Cybrid's Li, the structures using polyolefin based inner layers with melting points between 120 and 160 °C have problems in passing the hotspot test due to bubble formation. That's mainly because the modules based on M10 or G12 wafer size have hotspot temperatures higher than melting points of these polymers. Even Lucky Film, which was a strong promoter of polyolefin-based inner layers, observed such products failing IEC hotspot tests, especially with modules built with M10 or G12 cells, while no such side effect has been observed with coatings. Indeed, fluorine-based coatings are found on a major portion of mainstream backsheet configurations today.

6. Trends in Encapsulation

While nothing groundbreaking has happened in the mainstream encapsulation segment, Dow is in the process of developing a very innovative liquid silicone solution for building integrated PV that cures at room temperature with high durability of up to 50 years. On a general note, the major improvements in the encapsulation segment are aimed at providing compatible solutions to advanced architectures such as HJT and TOPCon.

The other developments in the encapsulation segment are going basically in the same direction as for backsheets. This segment of polymer wraps is also severely hit by raw material shortages, leading to spikes in encapsulation material prices. And bifacial is also at the center of most important developments in the encapsulation segment. While EVA's rule in the encapsulation segment has been mostly unchallenged, the special requisites arising from the bifacial segment saw the advent of polyolefins. The coextrusion technology, which has just started making inroads into the backsheets segment, is already very well established in the encapsulation segment to produce multi-layered stacks of encapsulation films, again also mainly for glass-glass bifacial modules.

6.1 Encapsulation Material Price Development

As with any raw materials these days, the prices of encapsulation films have also increased considerably. However, the prices for EVA have been going literally through the roof, owing to short supply of the resin. According to HIUV's Quan, the price went up from 13,000 CNY/ton during the beginning of 2021 to 19,000 CNY/ton during the month of August, putting encapsulation makers under pressure. As for the final product, compared to 2020 average selling price, every mainstream encapsulant's price has gone up by about 30%, as can be seen from the average prices of 2020 and H1-2021 referenced below.

EVA:

- 2020: CNY9.4/m^2
- 2021: CNY12.1/m^2

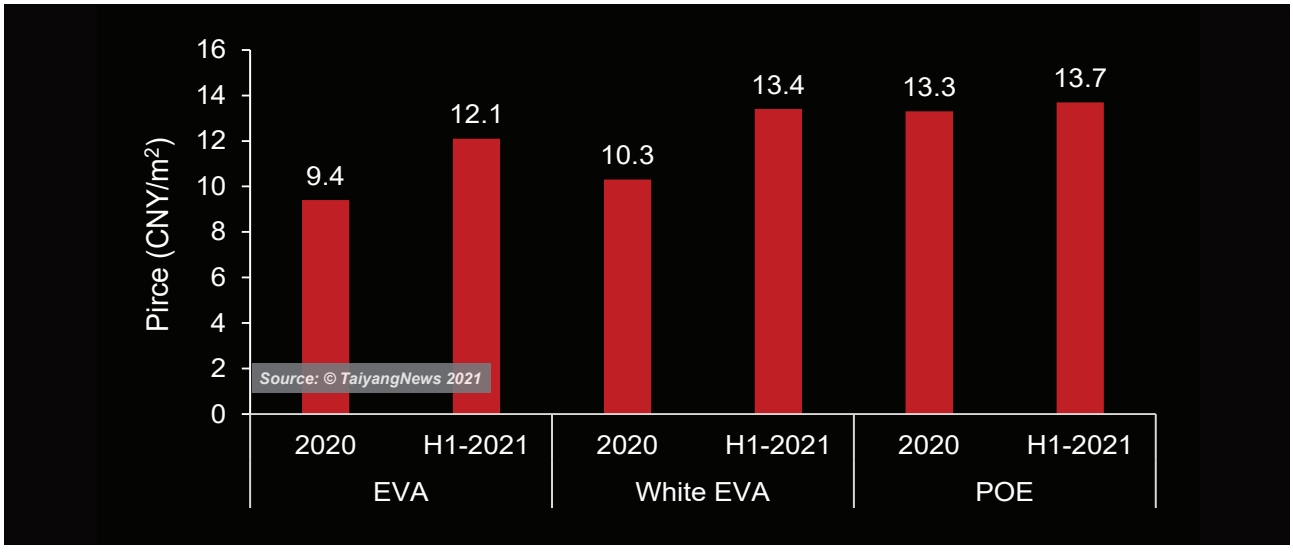
White EVA:

- 2020: CNY10.3/m^2
- 2021: CNY13.4/m^2

POE (EPE):

- 2020: CNY13.3/m^2
- 2021: CNY13.7/m^2

Prices of Encapsulation Structures in H1/2021 vs 2020



Affected by short supply: Due to the price increase of EVA resin, the price of related encapsulants – EVA and white EVA – has increased by about 30% in 2021, while the POE related encapsulants price has increased only marginally.

In September 2021, HIUV announced a big price increase on EVA of up to 35%, citing the rise in input prices with no end in sight. In order to save on EVA consumption, some module makers have even started using the coextruded EPE structure also on the front side of the glass-glass modules. Cybrid's Li expects the short supply situation to ease sometime in 2022.

Source: Hangzhou First

Price pressure: The most important development for market leading technology EVA has been its increasing price, which is giving way for other encapsulants such as the EPE structure to be used also on the front side.

6.2 EVA & white EVA

No revolutionary developments have taken place in the EVA segment. Surprisingly, PID and white EVA remained the keywords in this segment. There has been a continuous ongoing effort at the product level to improve the PID-resistance attribute of this encapsulation film and every supplier is offering such a product with improved PID resistance. Traditionally, while EVA is transparent, a white variant was brought to the market to be used as the bottom encapsulation layer. The white EVA increases the light reflection from the cell gaps in a finished module, resulting in power gains. Replacing transparent EVA with the white variant on the module's rear side boosts the power output by up to 1%, whereas it could be up to 2% when using bifacial cells. Half-cell based modules can benefit even more due to a relatively lower packing density of cells in a module. While all this is not new, white EVA is now becoming the mainstream. About 70% monofacial modules today use white EVA on the rear side, according to Cybrid's Li. However, in terms of sales and shipments, it has a market share of only 30%, because a solar module requires two films of EVA – one for the front and one for the rear; and transparent products are always the choice for the front side. Making white EVA has its implications on costs, thus also the price is higher – about 20% more expensive than the transparent variant.

HIUV, claiming to be the inventor of white EVA, has made a few improvements in regard to processing thinner wafers. HIUV's Quan explains the problem: The white EVA is slightly different from transparent EVA, in that it is a little harder, which creates stress at the cell edges and busbars during lamination. To counter this, HIUV has come out with a softer multi-layer structure called EWE or EW, where E stands for transparent EVA and W for white EVA. Simply put, the harder white layer is covered on one side or both by the softer transparent EVA to reduce the stress. "We are evaluating it with big module companies to optimize the composition and structure," said Quan.

6.3 Polyolefins – POE, EPE and TPO

With the increased deployment of bifacial modules and EVA some limitations, especially the low PID resistance, its applications are mostly limited to glass-glass modules. Module makers have started looking for encapsulation solutions beyond EVA – and POE fits the bill well. The polymer with superior water vapor barrier and high PID resistance has proved a good fit for glass-glass bifacial modules. POE is free from acid and free radical formation, which was observed with EVA, especially in glass-glass modules. While POE was initially used on both the front and rear, due to its higher costs, its application is now rather limited to the rear

side, especially for PERC bifacial modules. That's because the rear side of the module contributes most to PID due to the presence of aluminum oxide on the rear of the PERC cells.

However, nothing is perfect and so is POE, which has some practical constraints. If not cared for properly, it is very easy to generate bubbles during the lamination process when using POE film. Moreover, the lamination time is longer, requiring roughly 6 minutes more per lamination cycle. When using polyolefin films for an MBB module, the busbars might be slightly displaced during the cooling cycle of the lamination. The adhesion properties of POE to glass is also inferior to that of EVA. To overcome these limitations, encapsulation material suppliers engineered a multilayer construction called EPE, consisting of a thin layer of polyolefin sandwiched between two EVA layers, manufactured via coextrusion. Using POE in the middle increases the resistance to water vapor significantly and also improves anti-PID performance. This way, the 2 outermost EVA layers provide enhanced adhesion to cells and glass, while the middle layer works as a better barrier to moisture ingression. As for lamination time, the coextruded film finds the middle ground at around 450 seconds compared to about 600 and 300 seconds for EVA and single layer POE, respectively. In order to avoid the acid formation, specially developed acid-free EVA is used in EPE configurations. All leading encapsulant suppliers we talked to are of the opinion that the single layer POE will be replaced with the coextruded EPE structure. Indeed, the structure is finding more and more applications, especially with new cell architectures.

HJT with TCO on both sides, for example, has low adhesivity with POE but good adhesion with EVA. But EVA alone is not sufficient to act as the required moisture barrier for long. Thus, HIUV recommends its EPE structure. Jinergy, one among the early developers of HJT in China chose our EPE, said HIUV's Quan. As for TOPCon, Hangzhou First says that the technology is more sensitive to water vapor ingression compared to PERC. So the company recommends the coextruded multilayer EPE for TOPCon bifacial modules, more specifically for the transparent backsheet based one. For glass-glass modules, front side POE and EVA on the back can still be adapted. But a glass-backsheet module requires POE on both sides. Using POE on both sides is not ideal for passing the damp heat test due to poor adhesion to glass, according to Hangzhou First. Also due to the shortage of EVA raw material, several companies are seriously evaluating the possibility of employing an EPE encapsulant also on the front side.

As for the price of EPE, it completely depends on the raw material prices of EVA and POE. Generally, the raw material price of POE is higher than EVA. But given EVA is in short supply currently, the prices of EVA resin are very high and volatile. As for the manufacturing costs, the coextrusion production process for EPE is more complex compared to making a single film. The waste from edge trims in this process cannot be recycled, which drives the costs up. Overall, the costs for making EPE are

slightly higher; however, the final price difference mainly depends on the resin prices of EVA and POE. An interesting development in this context of cost reduction is that encapsulation manufacturers are also weighing the option of reducing the thickness without affecting the performance.

6.4 Thermoplastic Polyolefins

Unlike with backsheets, where Borealis is following a “B to B” approach, in the encapsulation segment the company is taking a “B to C” approach. It is the only company in our overview that is promoting a thermoplastic polyolefin-based encapsulation solution directly to module manufacturers. What makes this Quentys solution from Borealis special is that it is a proprietary non-crosslinking type of encapsulation, whereas the more popular POE and EVA are crosslinking types. The key advantages are low processing temperature and no cross-linking. The solution also helps in reducing the lamination time, emphasizes Borealis. The thermoplastic nature of the material allows module manufacturers to rework on the laminate in case of any defects such as bubble formation. Above all, the material supports low-temperature processing, down to 120 °C. As to the question of stability of thermoplastic PO, Muraben says the reliability is well tested and proven in a double glass configuration.

Modules based on BPO do not feature any creep at normal utilization temperatures. Moreover field tests have been conducted by third parties in deserts in South America and Middle East and demonstrated excellent module performance, according to Muraben. Borealis has also made further developments related to its encapsulation material, specifically for bifacial PERC glass-glass modules. The improved Quentys is aimed at combining the best of both worlds – EVA and POE; essentially the adhesion of EVA and PID resistance of POE. While the new encapsulant has completed internal validation, the results are due. The material is also subject to accelerated testing with HJT technology, the results for which are expected to be out by the end 2021. In parallel, Quentys is also under evaluation for cell structures featuring perovskites, which prefer thermoplastic polyolefins due to a low processing temperature and the absence of peroxides. “Quentys has a wide spectrum of coverage, including the present PERC, advanced HJT and next-generation perovskites,” said Muraben. Borealis expects its customers to benefit from local manufacturing in Europe, especially amid the supply disruptions currently being faced.

Source: Borealis

For HJT and beyond: Due to its low temperature processing ability, the thermoplastic polyolefin encapsulant from Borealis marketed as BPO is finding a place in temperature sensitive applications like HJT, such as this module made by CEA. It’s also a good fit for perovskite technology, according to Borealis.

HIUV's Quan thinks that more than for HJT, thermoplastic polyolefins are better suited for perovskites due to their high water vapor barrier properties and, more importantly, low processing temperature. A few manufacturers have tried lamination temperatures of 140 °C with perovskites with other materials, which is causing considerable loss in efficiency, he said.

6.5 Silicones

Silicone is also an interesting and well-known material used for encapsulation applications. Several variants of silicones have been introduced in the past but with very little success.
Dow has now introduced its DOWSIL 9955, which like most silicones is a poly dimethyl siloxane (PDMS). The difference between this material and other silicones used for encapsulants lies in its curing chemistry, meaning establishing the cross link. According to Guy Beaucarne from the façade engineering and architectural design team of Dow Silicones, DOWSIL 9955 uses a 'unique and proprietary' condensation cure method as against the "additional cure" chemistry in traditional silicone encapsulant technologies. The new material has several advantages, the most notable of which is that it can be cured at room temperature and develop primer-less adhesion at room temperature, he said.

The condensation cure chemistry for silicone is not new and has been used in many products, including traditional silicone sealants, but it is new for transparent encapsulant products. DOWSIL 9955, originally a product developed for construction applications, is now promoted for module encapsulation applications. However, Dow is not directly competing with EVA or POE as both the materials are well established in their respective mainstream applications; but Beaucarne sees some segments where silicone can prove to be advantageous. "BIPV is one example," says Beaucarne. In this scenario, it is best to have the module life matched to the lifetime of other building components, which is typically 50 years, he explains. Beaucarne believes that, given their track record, silicones could provide such longevity when complemented with module technology and other bill of materials. Another potential application is modules for high temperature regions where silicone would provide the required reliability that is needed in such extreme weather conditions.

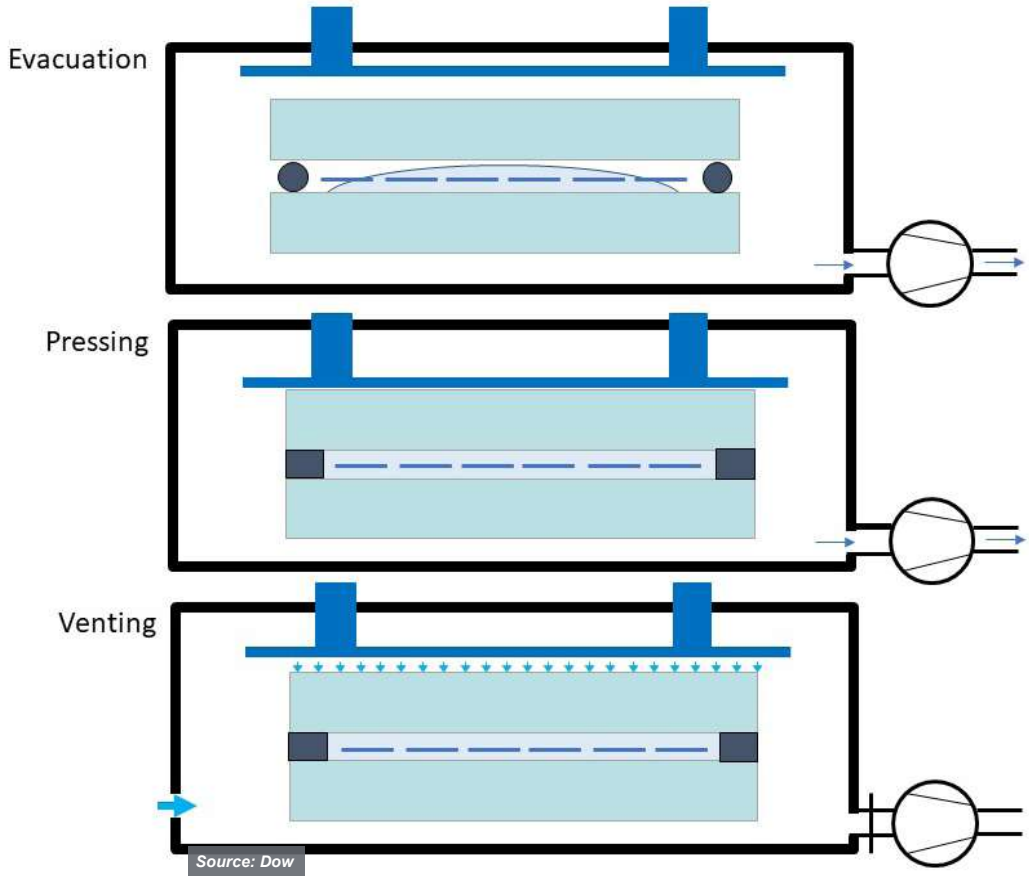
Dow's new solution is not to be confused with the product that has been introduced by Dow Corning many years back but under the PV6212 brand, which along with other silicone materials for PV are now part of the DuPont portfolio.

The DOWSIL 9955 material comes in a liquid form, and it can be used directly by the module maker by stand dispensing, facilitated by its fairly low viscosity, according to Beaucarne. It is not recommended for all module configurations, but primarily for glass-glass modules with a commercially available edge

sealant. Beaucarne did not reveal the names of the module makers that are using DOWSIL 9955. However, while acknowledging that it is still at a very early stage, given the market for silicone-based encapsulant is very small, he believes that the solution has good growth potential with the emergence of PV in countries with harsh weather conditions as well as the emergence of BIPV.

Regarding the change required in production process, the solution eliminates the layup to cut and place the films but requires additional stations to dispense the silicone and edge sealant. The laminators which are generally used for glass-glass modules can also be used. The need for laminator arises due to the requirement of the vacuum and does not require the heating feature. In principle, one can develop a low-cost piece of equipment that can do just the evacuation and pressing. As for the costs, Beaucarne says that the silicones are substantially more expensive than EVA and a little more than POE; however, developing a completely new line keeping in view the strengths of DOWSIL 9955 can potentially reduce processing costs. “I cannot quantify the benefits now,” he says.

While there is no study available to substantiate the 50-year reliability claims of Dow’s latest solution, there are some studies out about modules using silicone as encapsulant. Beaucarne highlighted a recent joint technical research paper presented by Dow in cooperation with the European Commission’s Joint Research Centre in Ispra, Italy, “Material study of photovoltaic modules with silicone encapsulation after long-term outdoor exposure” that showed that silicone has changed only a little after 20 years of operation in outdoor conditions. “We expect a similar level of performance with our 9955,” said Beaucarne.



Silicone solution: Dow’s new silicone solution that can be cured at room temperature helps in simplifying the encapsulation process, as shown in this schematic. While it does not require curing at high temperature, it needs a vacuum.

7. Product Descriptions

This is our 3rd combined market survey on backsheets and encapsulation materials, the two polymer wraps used in solar module manufacturing. Here, we present data for 90 products from a total of 12 companies, including the market leaders in these segments. This compares to 96 products from 14 companies in the previous survey. This part of the report specifically provides detailed descriptions of product specifications plotted against their respective suppliers, who are listed in alphabetical order. The first part covers backsheet products, the second part encapsulation products.

7.1 Backsheets

Backsheets are the rear cover of the module that protect the cell matrix circuit from environmental impacts, which makes them the backbone of module reliability. While there are several variants of backsheets, they can be largely categorized into fluoropolymer and non-fluoropolymer (see detailed specs starting on p.65).

7.1.1 Fluoropolymer-based Backsheets

In this section, we talk about 39 fluoropolymer backsheet products from six suppliers in detail. The products include fluoropolymer-based backsheets that contain fluorine in at least one layer, as well as coating-based backsheets using fluorine. Chinese module makers favor fluoropolymer backsheets in general, where at least the outermost layer contains fluorine.

COVEME: Although a strong promoter of non-fluoropolymers, Coveme has traditionally been a laminator of fluoropolymer-containing Tedlar-based products. The Italian company has repeated its previous listing of 6 products without any changes to their specifications. The entire fluoropolymer range of backsheets from Coveme is based on Tedlar as the outer protective layer and the so-called “primer”, which is nothing but polyethylene as inner layer, both of which are bonded with a PET core film. Interestingly, Coveme is not actively promoting any PVDF based backsheets.

As in the past, Coveme has left most of the specifications blank for its listing. Out of the six products, two are transparent backsheets promoted for bifacial applications and four are opaque. The latest among the range is **dyMat Clr TsL** series of transparent backsheets introduced in 2020 that is offered in two variants—**dyMat Clr TsL 50/158** and **dyMat Clr TsL 50/285**. While what differentiates these two models is the effective thickness of the entire backsheet, the company has not provided the thickness of the individual layers. The former model comes with an effective thickness of 253 µm and the latter 380µm, making them eligible for 1,000 V and 1,500 V respectively. Their ability to limit moisture ingression is however the same at a rate of 2 g/m^2/d. The dyMat Ts 38/125 and dyMat Ts 38/285 are 2019 models with an effective thickness of 221 µm and 281 µm, respectively. The thicker backsheet is eligible for maximum voltage of 1,500 V and has a moisture ingression rate of 2 g/m^2/d, while the leaner one is suitable for 1,000 V that has a moisture barrier property of 3 g/m^2/d. These two backsheets are designed to reflect 75% of light on the EVA side and have a breakdown voltage of 20 KV. These color options for these Tedlar-based backsheets are white and black.

Source: Coveme

Fluor as well: While Coveme is the pioneer and driving force in PET based backsheets, it also sells fluoropolymer based products.

The dyMat TsL 50/250 and dyMat TsL50/285 models share the same backsheet composition and come in a standard white color for the front, while the rear can be opted with either white or black. The **dyMat TSL 50/285**, thicker by 35 µm than the other, is designed for 1,500 V and has moisture barrier properties of 1.7 g/m^2/d. The **dyMat TsL 50/250**, on the other hand, has a 2 g/m^2/d moisture ingression rate and is suitable for a system voltage of 1000 V.

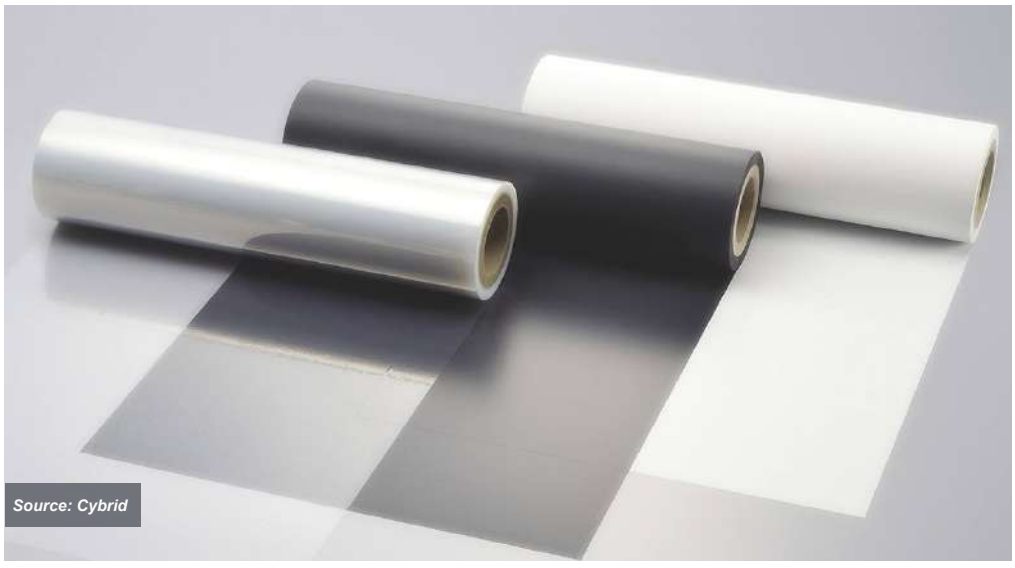
China's Crown, which missed its spot in the previous overview, has provided data for just one product—TPM—that too a 2014 model. The model name also indicates its structure—Tedlar / PET and primer layers—and the company has not provided the thickness of these layers. The product is available in white, black, as well as a transparent variant. The product is designed for a system voltage of 1,000 to 1500 V and has a water vapor permeability of 1.5 g/m2/d. The peel strength of the backsheet with EVA is 40 N/cm, while interlayer adhesion as 15N/cm. Crown specifically highlights that the TPM model is highly compatible with the silicone sealant.

CYBRID: For the leading supplier of the segment, not only is the number of products unchanged since 2019 at eight, but the majority of the specifications also remain unaltered.

Of the eight products listed, six are KPf backsheet based, where "f" denotes fluorine skin, a proprietary fluorine-based coating. Introduced in 2012, KPf is the basic backsheet platform the developed by the company with a 22.5 µm PVDF film as an outer layer and a 4 µm-thin fluorine coating on the cell side, sandwiching the 262 µm thick universal PET core film. The product is designed for a maximum system voltage of 1,000 V and has a water vapor permeability of 2 g/m^2/d. The glossy finish of the inner surface has a rated reflectivity of about 80% within the spectral band of 400 to 1,100 nm. The same backsheet configuration is also offered with Arkema's Kynar film instead of PVDF. However, the company has not mentioned which of the listed products contain the Kynar film.

Cybrid's **KPf (1500)** is tagged with higher resistance to heat and humidity, as well as partial discharge. However, the claim is not reflected in the respective specifications for water vapor permeability and partial discharge, which along with other listed parameters are same as the above KPf. In addition, the listed specifications for its **KPf (H)** are also nearly identical to the two aforementioned models of KPf series models, except that this backsheet has a higher reflectivity of 90%. While not explicitly mentioned in the specification table, the KPf range is offered with a 1,500 V partial discharge as well.

Cybrid also supplies special backsheets for hydrophobic cell architectures, including heterojunction structures and thin-film PV, under the **KPAf** brand name. This backsheet has a completely different configuration. The single-layer PET film is replaced with a stack consisting of a 20-µm thin aluminum sheet inserted between two125-µm thick PET layers. A fluorine skin is then added to the cell side, and PVDF is attached on the airside.



Source: Cybrid

KPf is key: Cybrid offers backsheets with different configurations, but its main product is based on KPf.

These changes increase the effective thickness of the backsheet to 325 µm and bring down the moisture ingression levels considerably to a very low 0.005 g/m^2/d.

fPf is another specialty product from Cybrid. As the name indicates, the PET film is burned with a fluorine skin on either side to make the backsheet transparent for use in bifacial modules. The configuration of this backsheet is also slightly different, in that its effective backsheet thickness is made up of a 280 µm core PET film and 20 µm fluorine coatings on either side.

While the company's **PPf** model should technically be listed in the non-fluoro segment of this survey as its outer protective layer is polyester, it finds itself listed in the fluoro stream owing to its fluorine coating on the cell side. A low-cost solution from Cybrid, PPf is specially promoted for rooftop applications. The backsheet comes with a 50-µm special PET layer with UV protection attributes, a 250-µm core PET layer and a 4-µm coating.

The company's remaining two backsheets do not have a fluorine skin. One has the typical **KPK** configuration, and the other is **KPX** with a 150-µm thick polyolefin inner layer. This product is also promoted as an intermediate solution between KPAf and other products for water vapor barrier properties with a spec of 0.8 g/m^2/d. The rest of Cybrid's product range has a rated water vapor permeability of 2 g/m^2/d. Irrespective of film configuration and composition, mechanical properties for Cybrid's entire product range are identical—80 MPa tensile strength, 100% elongation at break in both the MD and TD directions.

HANGZHOU FIRST: In addition to the ten models listed in the 2020 survey, Hangzhou First has added one more product to the current listing. This new addition—BEC-306D—is a 2020 launched product follows the TPC structure, in which B 25 µm Tedlar film is used as the outer protective layer, PET core layer and fluoroethylene vinyl ether (FEVE) inside coating with an effective thickness of 310 µm. The product is designed for 1,500 V partial discharge and 1.8 g/m^2/d for moisture ingression. It has a tensile strength of 160 Mpa and tear strength of 80 N/mm. Hangzhou First is mainly promoting this product for applications that require high resistance to sand abrasion. The BEC-301 comes with FEVE on both sides and has a thickness of 10 µm on the cell side and 20 µm on the air side, with a 275 µm PET in between, all amounting to an effective thickness of 325 µm. The backsheet is provided with an additional FEVE mesh of 20 µm towards the cell side to fill the cell gaps in bifacial modules using transparent backsheet. The BEC-306 is the Tedlar variant of the above model, where the outer FEVE is replaced with 25 µm PVF film, increasing the effective thickness by 5 µm to 330 µm. Except for these constructional differences, these two backsheets have similar specifications. They are designed for 1,500 V partial discharge with 1.8 g/m^2/d for moisture ingression. Both have a tensile strength of 150 Mpa and tear strength of 80 N/mm with 100% elongation. The EVA peel strength is 10 N/mm.


Source: Hangzhou First

Black & white: For completely black modules, backsheet suppliers are applying black grids and a white backsheet to mimic a fully black look while improving output.

Hangzhou First has primarily been focusing on coating-based solutions for backsheets. Its **KPO BEO-303**, however, is a departure from this philosophy where it does not use any coating at all. It is a PVDF-based backsheet with a polyolefin inner layer with 20 and 80 µm thick films bonded to a 140 µm PET film, respectively. The film has an effective thickness of 280 µm. It is designed for a 1,000 V

partial discharge with a 1.8 g/m^2/d for moisture ingression.

The CPO BEO-301 goes back to the FEVE coatings based construction. It uses coating on one side and polyolefin on the other side of the PET core with respective thicknesses of 5 µm, 80 µm and 155 µm, resulting in a final backsheet thickness of 250 µm. Although there is a slight difference in thickness, the specs for mechanical properties of this backsheet are much like the BEO-303 model. Both have a tensile strength of 100 MPa and tear strength of 80 N/mm in both the MD and TD directions. The dimensional stability and shrinkage are 0.3% in the MD direction and zero in TD direction. Though the EVA peel strength is also same at 15 N/mm, the inner-layer adhesion is slightly stronger for a coating-based product at 0.5 N/mm compared to 0.4 N/mm for completely film-based products. On the other hand, the latter scores a little higher in terms of moisture resistance with 1.8 g/m^2/d as compared to 1.9 g/m^2/d for the coating-based product.

The BEC-301, which outlines the company's basic backsheet configuration, features a 5 µm FEVE coating on the cell side and 20 µm on the air side, while the PET core film has a thickness of 255 µm, resulting in an effective thickness of 280 µm. Originally introduced in 2008, this model has a partial discharge of 1,050 V tested in air and is rated a water vapor permeability of 1.8 g/m²/d. The backsheet has a white outer layer, while the inner side can be either white or black. It has a reflectivity of 80% within the wavelength range of 400 to 700 nm.

The BEC-301 is also offered in two other versions, BEC-301T and BEC-301D. The BEC-301T is a transparent version suitable for bifacial module applications. It follows the same construction down to the individual layers. Apart from being transparent, the major technical difference associated with this model over the BEC-301 is the EVA peel strength of 8 N/mm, about half of the other model at 14 N/mm.

BEC-301D is a thicker backsheet with a final thickness of 300 µm. While the coating thickness is the same—5 µm on the cell side and 20 µm on the air side—a thicker PET film of 275 µm is used. The remaining specifications of this model are the same as those outlined for the basic model, the BEC-301. Similar to the company's other backsheets, except for the transparent version, BEC-301D is also promoted for high adhesion, good weathering resistance, high sand abrasion resistance and high reflectivity. Owing to the fact that it is a relatively thicker backsheet, it is compatible with a higher partial discharge voltage of 1,500 V. The remaining four models listed here are also designed to support a higher system voltage of 1,500 V.

The BEC-303 is yet another solution, apart from the above mentioned KPO BEO-303, for module makers that insist on having a fluoropolymer film on the outer side of the backsheet. This backsheet has a 5-µm FEVE coating and a 20-µm thin PVDF film attached to a 275-µm PET sheet, amounting to an effective thickness of 305 µm. The product is offered in white and black. The bond between the EVA and FEVE coatings evaluated via EVA peel strength is given as 14 N/mm, and the peel strength of the inner layers, which is not applicable for purely coating-based products, is given as 0.4 N/mm.

Interestingly, these peel strength-related specifications, and the stated reflectivity of 85%, are also the same for Hangzhou First's another completely coating-free backsheet, the BEF-302. Like many backsheet suppliers, Hangzhou First has also been offering typical backsheet structures with fluoropolymer films on both sides for quite some time. For example, the BEF-302 has been on the market since 2009. The backsheet is formed with two PVDF films, each measuring 30 µm, attached to a 250-µm PET film on both sides. The resulting backsheet has a thickness of 310 µm.

The majority of the mechanical properties for all six listed models are identical. They all have the same tensile strength of 160 MPa in the MD as well as the TD direction. The elongation is 130% in the MD direction and 120% in the TD direction, while the tear strength is 80 N/mm in both directions. The specs given for the dimensional stability and shrinkage are also the same for all models—0.3% in the MD direction and 0% for the TD direction. The water vapor permeability is also the same for the entire range at 1.8 g/m²/d.

While it is acceptable to have such a level of water permeability for the above backsheets, the value is somewhat higher for the **BEAL-304.** This

backsheet comes with an extra layer of aluminum, typically used for better moisture-barrier properties. In addition to the 5 and 20 µm FEVE coatings and 255-µm PET films, this backsheet includes a 20-µm aluminum film, giving the product a total thickness of 305 µm. Similar to other products from the company, this backsheet is also supplied in rolls and sheets, and can be stored at less than 35°C and a relative humidity of 80% for up to one year. The most prominent change that the company's entire product range has seen is its standard width has been increased from 1,260 mm to 1,360 mm.

JOLYWOOD: China's Jolywood, the second leading backsheet supplier in 2020 and most likely to the leader for 2021 has actually consolidated its product portfolio from 8 as listed in the previous survey to 4. Even in its current listing, Jolywood is promoting two transparent backsheets—**FFC-JW30(Plus)** and **TFB-30(Plus)**.

The **FFC-JW30(Plus)** has a double-sided fluoro coating, patented as FFC, applied to a 275 µm PET core. The backsheet configuration is listed by Jolywood as an FFC/PET/FFC backsheet. The coating thickness varies —25 µm on the air side and 15 µm on the cell side for an effective thickness of 315 µm. The weight of the backsheet has been optimized from 395 g/m² to 445 g/m² and. As a result of increasing the core layer thickness from 250 µm to 285 µm, which increases the effective thickness to 310 µm, this backsheet is now eligible to 1,500 system voltage class.

These changes also find their way into another transparent backsheet of the company, **TFB-30(Plus)**. This backsheet now also qualified for 1,500 V system voltage requirement. The weight of this backsheet has increased from 420 to 445 g/m^2, and the film density reduced to 1.39 g/cm from 1.4 g/cm^3. Consequently, this backsheet is slightly thicker at 320 µm. It is protected by a Tedlar outer film with a relatively thin coating of 10 µm applied inside on a 275 µm core.

The other specs for these two transparent backsheets are identical. Both the backsheets have a water vapor permeability of 2.5 g/m^2/d. The tensile strength of 120 MPa and 1% shrinkage of these transparent backsheets is the same in both MD and TD directions, while the elongation is 100% in MD and 90% in TD. All have an EVA peel strength of 4.5 N/mm and inner layer adhesion peel strength of 0.4 N/mm. The dimensional stability is one additional piece of information Jolywood has now disclosed for its complete range, which is at 1% in both the MD as well as in TD directions.

For standard modules, Jolywood is offering two models—one with a double-sided coating and one with film on the air side and coating on the cell side.

Source: Jolywood

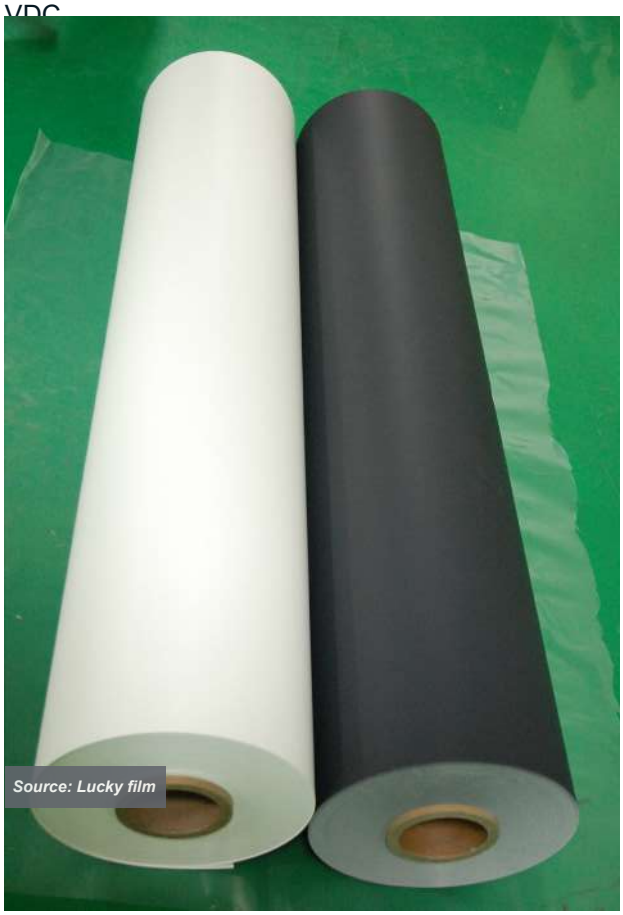
Jolywood is a firm believer in coating based backsheets, which has led the company to the top position among backsheet suppliers in the first half of 2021.

The FFC-JW3010 is now has an additional suffix "(plus)" following a few changes in its physical properties, while the structure remains the same as FFC/PET/FFC. It now features a thicker core of 285 µm, sandwiched between two somewhat atypical coatings—13 µm on the outer side and 12 µm on the inner side. Due to the increase in PET layer thickness by 35 µm, the effective thickness has increased correspondingly to 310 µm. The model is available in white, and while its weight has increased from 395 g/m^2 to 445 g/m^2, the density remains the same 1.44 g/m^3.

Jolywood's previously listed KFB-30 is now upgraded to **KHB-30 (plus)** that is a backsheet with double-sided fluorine protection in a sense that the backsheet employs PVDF films with a 20-µm outer layer and a 15-µm inner coating using Jolywood's FFC coating as an inner layer. The plus most likely refers to the increased PET core thickness of 275 µm, leading to an increased effective thickness of 315 µm. According to Jolywood, this configuration eases the module rework. The company claims the backsheet has good overall UV stability and is free from yellowing.

Lucky Film has provided data for four products compared to three in the earlier edition. The KPCw1 is the new addition to the list, while the model is itself not new to the market being introduced in 2016. The product is based on a KPC structure with PVDF accounting 20 µm, PET for 285 µm and 5 µm coating to the total backsheet thickness of 316 µm. Same as the other products of the company, this backsheet is also supplied in widths ranging from 990 to 1,300 mm. The tensile strength is given as 120 MPa and elongation at break 100%. This backsheet is rated with a water vapor permeability of ≤ 2 g/m²/d and the reflectivity is given as 80%. With a breakdown voltage of 18 kV, the backsheet qualifies for a partial discharge of 1,500 VDC.

Among the listed models in the last overview, the Tedlar-based **TPP1** comes in a combination of polyolefin, PET and PVF with thickness of 60, 230 and 25 µm, respectively, with an effective thickness of 328 µm. The front and rear are white in color and have a smooth finish. Tensile strength and elongation at break are given as 120%. This high heat resistance backsheet has a water vapor permeability of ≤ 2 g/m²/d and the reflectivity is given as 80%. With a breakdown voltage of 18 kV, the backsheet qualifies for a partial discharge of 1,500 VDC.


Source: Lucky film

Fluoro only: All three products provided by Lucky Film are based on fluoropolymer chemistry.

The remaining two products from Lucky Film are coating based and transparent, which makes them suitable for bifacial applications. Both products have the same mechanical properties and exhibit the same performance characteristics, but differ in backsheet composition, thickness and weight. The **Kpct1** is built with 285 µm PET, 20 µm PVDF film and 5 µm coating, while **TPcw1** makes use of 25 µm Tedlar attached to 275 µm PET on the air side and slightly thicker coating of 10 µm on the cell side. Both these products have an effective thickness of 320 µm, breakdown voltage of 16 kV and partial discharge of 1,500 VDC. Water vapor permeability is 2.5 g/m²/d, EVA peel strength is 6 N/mm.

Indian company **Shingi Urja** has provided data for five products, of which two follow a KPE structure, two are CPC and one KPC. The latest ones among them are coatings based backsheets. The main difference among the CPC structured products is the effective thickness of the backsheet. The **Armour PC300BS** is the thicker one at 305 µm. It has tensile strength of 180 MPa and 170 MPa in the MD and TD directions, respectively, and elongation at break is given as 100% in both directions. The backsheet also qualifies for 1,500 V system voltage. It also has a lower water vapor ingression rate of 1.5 g/m²/d compared to that of **Armour PC200BS**, which is rated at 1.8 g/m²/d. This backsheet has an effective thickness of 215 µm that only qualifies for 1,000 V system voltage. The tensile strength given as 160 MPa in MD direction and 150 MPa in TD.

The third product of the 2021 series is only used as inner coating and PVDF as the outer protective layer with a total thickness of 305 µm. Majority of its important mechanical properties and performance characteristics resemble those of Armour PC300BS, namely elongation, partial discharge and water vapor permeability and tensile strength. However, the product has the highest density of 1.41 g/m3 among the company's range and weighs in at 430 g/m².

The remaining two products of the company are 2017 models are built with inner primer layer and PVDF outer layers with PET as core. The **Armour PF300BS** comes with a total thickness of 330 µm and an effective thickness of 230 µm. Tensile strength is given as 160MPa MD, 150MPa TD and elongation at break 100 %. This high heat resistance backsheet has a water vapor permeability of ≤ 1.5 g/m²/d and the backsheet qualifies for a partial discharge of 1,000 VDC. The **Armour PF350BS** is simply a thicker version built on the same template of PVDF / PET / Primer with 370 µm and 320 µm total and effective thicknesses, respectively. Thus, the backsheet also meets requirements for a 1,500 system voltage, but its rated water vapor permeability of 1.5 g/m²d is the same as that of its thinner variant.

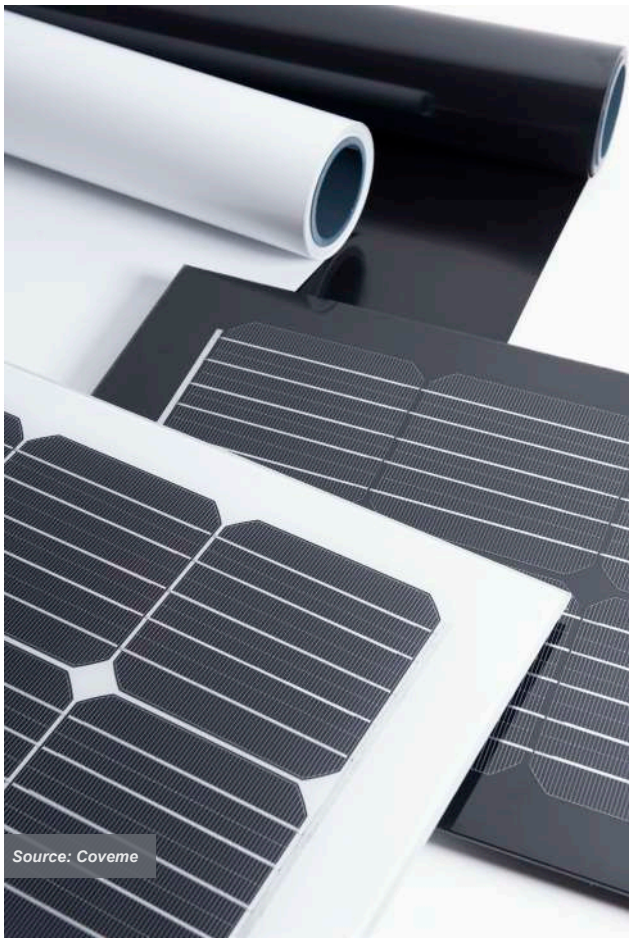
The company's entire backsheet range is supplied in widths of up to 1,350 mm, white in color with black as an option and glossy finish. The reflectivity is also the same for all products, given as 85% referring the visible light. All products are rated with the same inner-layer adhesion of 5 N/mm, a strong adhesion to EVA with 80 N/mm peel strength and rated shrinkage of ≤ 1.5 in MD and ≤ 0.5 % in TD directions.

7.1.2 Non-fluoro-based Backsheets

Non-fluoropolymer-based backsheets are also becoming increasingly interesting, especially in terms of innovation, driven by a growing number of companies joining the stream. Traditionally, non-fluoropolymer-based backsheets have been considered suitable for gentle weather conditions where the UV and moisture content are low. Suppliers, however, are now challenging this thinking and promoting their products for all weather conditions. The majority of non-fluoropolymer backsheet makers emphasize that their products are equally protective and provide comparable weathering protection as fluoropolymers. Sometimes these backsheets also turn out to be a cost effective alternative.

Backsheets with UV-stable PET are most widely used in the non-fluoropolymer segment. Coveme was a leader in this segment with its PET-based solutions in the past. Several companies have since joined the stream with alternative configuration that are free from the halogen. This non-fluoropolymer-based backsheets section features 29 products from six suppliers. AGFA and B+K have not responded to our enquiry and it is not clear if these two companies are still continuing in the backsheets business, while Hangzhou First just omitted the non-fluoropolymers from its listing. This gap is filled by 3 companies—Crown, Cybrid and Shingi Urja.

COVEME: The Italian company has been a pioneer in non-fluoropolymer-based backsheets, which still remains its main focus. Most of its product range is based on a PET/PET/Primer construction. While PET has established itself very well as the ultimate material for the core layer of backsheets, its UV stability has always been questioned. Now although the unsterilized polyester films are indeed prone to UV degradation, Coveme believes that developments in polyester chemistry and advancements in manufacturing processes have enabled the development of UV-durable polyester. Coveme is using primer—a polyethylene-based compound the company claims to have high bonding to EVA—as the inner layer for all of its backsheets.


Source: Coveme

Betting on PET: Coveme's core expertise are backsheets based on PET. The Italian company is promoting a large PET product portfolio of 16 models in this survey.

The company has provided data for 17 products, which is the largest product portfolio for non-fluoropolymer-based backsheets as well as in the entire survey. The company has added four models to its previous listing. Coveme declined to reveal the details for all of the mechanical properties and a few physical properties, and thus left blank in the specifications tables. All the PV-targeted polymer solutions of the company are part of the dyMat series and share the common prefix. We've omitted this common name to help readers easily differentiate between the listed models.

Among the 4 newly introduced 2021 models, two are specially designed for 1,500 V system voltage. These are HDPYE C, and HDPYE C BKHR. Both the products are built on the same composition of two PET layers designed to be on the outer UV proactive layer and core layer and inner coating, and have nearly same specifications with two primary differences—thickness and color. The HDPYE C has an effective thickness of 315 µm and offered in both white and black. The **HDPYE C** BKHR on the other hand comes with a 320 µm thickness and the backsheet is offered in black, still facilitating enhanced reflectance of up to 45%, while the white backsheet supports up to 75% reflectivity.

The other two latest products AHDPYE SPV P and APYE SPV C BKHR are aluminum based, meaning the backsheet configuration consisting an extra layer of aluminum sandwiched between the UV protective PET and core PET to attain very low water vapor permeability of 0.005 g/m^2/d. And the differentiating factors among this pair of products are inner layer composition, thickness and color. The **AHDPYE SPV P** has a thickness of 405 µm built using primer as inner layer, thus benefiting from thickness related aspects such as maximum system voltage of 1,500 V. It has a reflectivity of 82% on the cell side. The other variant, **APYE SPV C BKHR** is based on coating on the cell side and is mainly offered in black color with enhanced reflectivity of 45%. This backsheet is also offered with variable thickness from 237 µm to 277 µm.

Bk HDPYE SPV L: Introduced in 2020, this model is black in color on both the air and the cell sides. This product is useful in making the aesthetically superior total black modules. Therefore, it doesn't come as a surprise that the company is promoting this backsheet for BiPV applications. With a thickness of 370 µm, the model features all the benefits of higher thickness—supporting maximum system voltage of 1,500 V and better moisture barrier properties of 1.8 g/m^2/d.

Coveme has provided data for two 2019 models, both of which are transparent. The **Clr HDPYE CX** now promoted as **Clr HDPYE** is a thicker backsheet with an effective thickness of 370 µm that qualifies the backsheet for a system voltage of 1,500 V. The backsheet is made with the so-called COEX PET, which is nothing but transparent, hydrolysis-resistant and electronic-grade PET on the air side , PET core layer and a clear UV-resistant inner layer. This backsheet limits the moisture ingression rate down to 1.7 g/m²/d.

The **ClrPYE MONO CX** now listed as **ClrPYE MONO**, on the other hand, is based on a monolayer construction. It features special UV resistance technology called bulk technology that provides UV protection across the whole thickness of the single PET layer. With an effective thickness of 268 µm, this backsheet only qualifies for a system voltage of 1,000 V and rated with water vapor permeability of 2 g/m²/d.

Coveme's **PYE 3000 - 3000 L**, with a total thickness of 295 µm, has passed 3,000 hours of damp heat test, which is three times the spec. The backsheet is suitable for a 1,000-V partial discharge and has a moisture ingression rate of 2.5 g/m^2/d. It has a reflectivity of 85% on the cell side. The BkPYE SPV L is an all-black variant, like Bk HDPYE SPV L mentioned above, that is specially designed for building-integrated PV.

Coveme is promoting its **APYE** for PV technologies that demand a high-level moisture barrier, such as for heterojunction and thin film modules that are highly sensitive to water vapor. The backsheet is integrated with a sheet of aluminum to provide high level of protection from moisture ingression. This backsheet, with a thickness of minimum 285 µm and maximum 370 µm, dramatically lowers the water vapor ingression rate to 0.005 g/m^2/d. The company says that, upon request, it can also supply the backsheet with different thicknesses for the aluminum film. The other option with this product is a high reflectance above the standard spec of 75%.

The **PYE SPV-SPV L** is Coveme's best-selling product with more than 50 GW installed worldwide. The company claims it has the best quality-price performance ratio of any backsheet on the market. With an ultimate thickness of 295 µm, this backsheet meets the requirements for a system voltage of 1,000 V and has a rated moisture ingression level of 2.5 g/m^2/d.

The **HDPYE SPV L** is a non-transparent "super thick" model with a total thickness of 370 µm and, as such, supports a maximum system voltage of 1,500 V and better moisture barrier properties of 1.8 g/m^2/d. In addition, this backsheet can be optionally offered with "super high" reflectivity above the given spec of 83%. It is offered in white or black on the air side and only white on the cell side.

The **PYE SPV L 305** is the low thickness variant of the above. As the numerical part of the model name indicates, this PET/PET/Primer composition has an effective thickness of 305 µm. However, Coveme characterizes this backsheet as "extra thick" owing to the fact that it is promoted for 1,000 V system voltage applications. Its water vapor permeability is 2 g/m^2/d and reflectivity is 82%, also the same as the above model.

Coveme is also offering two backsheet models based on a monolayer configuration in a non-transparent variant consisting of PET and primer films. The **MONO L PLUS**, launched in 2017, has a total thickness of 218 µm. This mono product has a relatively high water vapor permeability of 2.2 g/m2/d and is being promoted as suitable for 1,000 V maximum system voltage applications. According to Coveme, this backsheet provides the best price-performance ratio.

Coveme's most interesting backsheet products cannot technically be called backsheets at all. They are mainly promoted as a replacement for the glass front covers. Coveme has developed a so-called "hard coating" applied on top of PET and primers on the cell side. According to Coveme, this product, referred to as totally transparent, uses a new coating technology on the polymer stack, ultimately resulting in "superior" UV, scratch and abrasion resistance that can compete with glass in a few applications. While these products were also featured in our previous survey, Coveme has slightly upgraded the specs of these front sheets.

The ClrFS PYE MONO CX, now promoted as C**lrFS PYE MONO**, is a 1,000-V front sheet with a total thickness of 283 µm and a rated moisture ingression level of 2.5 g/m^2/d. All these parameters have essentially remained the same as the previously listed model. Consequently, the upgrades that called for a new name are not reflected in the specifications table.

The same goes for ClrFS HDPYE L CX as well, which is now listed as **ClrFS HDPYE**, which is a thicker 385 µm version. The additional thickness is built up by adding an extra layer of PET on the air side, on which the "hard coating" is applied. At this thickness, the backsheet apparently qualifies for a DTI of above 300 µm, and is thus rated with a 1,500

V partial discharge. This polymer laminate is also rated with low moisture ingression properties, given as 1.7 g/m^2/d. These two front sheets are rated with a breakdown voltage of 20 kV.

Crown: The company is listing only one backsheet model called as BO-L3, in the non-fluoropolymer backsheet segment. While the company says this 2013-introduced product is a PET based backsheet, the details of the backsheet structure are missing; however, the effective thickness is given as 360 µm. The product is available in white and black for both air and rear side. The backsheet has a tensile strength of 210 MPa, and 50% elongation, while the shrinkage is different in MD and TD directions at 1.5% and 1%, respectively. It has the inner layer and EVA adhesion designated as peel strengths of 15 N/cm and 40 N/cm, respectively. The backsheet supplied with both system voltage classes of 1,000 V and 1,500 V, and rated with 1.5 g/m²/d water vapor permeability.

Cybrid with its main focus on fluoropolymer based backsheets has also provided the data for a non-fluoropolymer product called PPF, which follows a construction of PET / PET / coating with respective thicknesses of 50 µm, 250 µm and 4 µm. This 2019 model has an effective thickness of 304 µm and supplied in width up to 1,320 mm. Cybrid offers this product in white and with glossy, scratch-resistant finish. This backsheet displays a reflectivity of up to 82%. It complies with a 1,500 V partial discharge and is rated with a water vapor permeability of 1.9 g/m²/d.

Endurans Solar: DSM, now part of Endurans, is still promoting and has provided data for two products for the current survey, similar to the previous overview.

The **Endurans HP D06**, launched in 2020, is manufactured using co-extrusion processing using polyolefin polymer chemistry. Endurans calls the configuration as HPO. Endurans HP D06 has an effective thickness of 310 µm. Supplied in white and black, its air side comes in a matt finish, although a shiny and smooth surface can be opted for on the rear side. The backsheet is rated with a dimensional stability as well as shrinkage of less than 1% in both the MD and TD directions. This backsheet is suitable for a partial discharge of 1000 V and displays good moisture barrier properties with a water vapor permeability of 0.8 g/m²/d. In addition, this model has a reflectivity of 93%. The most important differentiation associated with the Endurans products is that the coextruded method of manufacturing makes different layers of a backsheet inseparable, thus avoiding any risk of interlayer delamination of the backsheet.

Most of these physical and mechanical properties are also applicable to another model, the **Endurans HP D15**. The major difference associated with this product is its higher thickness of 350 µm, a lower water vapor permeability of 0.6 g/m²/d, a higher reflectivity of 95% on the EVA side, and the maximum system voltage of 1,500 V. Both products boast a green tag, stating they are “100% recyclable” and 30% lower carbon footprint compared to fluorine-based laminated products.

Source: SVECK

Only one: Crown provided only data for just one non-fluoro based model, that was introduced 9-years back.

Endurans also highlights that its products have higher resistance to sand abrasion, making them suitable for desert applications.

FÉRON: Féron is also highlighting the "fluorine free and recyclable" nature of its products. The German company is now listing six products, similar to the earlier edition. The one thing that's uniform across all of Féron's products is that they are all offered with a standard spec of 1,000 mm, although the company does supply custom widths upon request. Féron is promoting three product groups: coatings on both sides of the PET core film; an E-layer replacing the coating on the cell side; and a core layer with single-side coating.

Introduced in 2018, what's innovative about the core layer with single side coating is that the backsheet features a polyolefin based core layer. This backsheet is offered in two versions. The **CPx 1000** is designed for a maximum system voltage of 1,000 V with a thickness of 176 µm, built with a 170-µm polyolefin core layer and a 10-µm coating. It has a rated tensile strength of 35 MPa in the MD direction and 25 MPa in the TD direction. The tear strength is 17 N/mm and shrinkage is 1.2% in MD, while no shrinkage is observed in TD.

While the above mentioned mechanical properties are exactly the same for the **CPx 1500**, it is rated for a higher system voltage of 1,500 V. And at 355 µm, it is nearly double the thickness of CPx 1000. The rest of the performance characteristics of these backsheets are identical—a breakdown voltage of 15 kV, a water vapor permeability of 1.5 g/m²/d and 90% reflectivity on the EVA side. Féron claims that both backsheets have passed the 15,000-hour Xenon test according to ISO 4892-2 norms and 8,000 hours for the damp heat test. While there is no color choice apart from white with this backsheet, the 1000 V product is also supplied in black.

The **neoX CPE** series is based on a coating/PET/E-layer structure. The **neoX CPE 300/50** consists of a non-fluorine-based UV and weathering protection coating of 10 µm on the air side of the 300 µm PET film, to which a 50-µm primer (E-layer) film is attached. The backsheet has an effective thickness of 365 µm. It is also the heaviest in the range at 495 g/m². In the respective MD and TD directions, the backsheet has a tensile strength of 150 MPa and 140 MPa, 170% and 140% elongation, tear resistance of up to 11 N/mm and 18 N/mm force, and shrinkage of 1.5% and 0.5%. The adhesion to EVA is given in terms of a peel strength of 7 N/mm, which is the same for the other CPE product as well as the CPC product range. The intra-layer peel strength, which is nothing but the degree of adhesion between PET and the primer film, is 1.5 N/mm. A thick PET core film of 300 µm qualifies this backsheet to be used in the 1,500 V system voltage class. The product also shows good moisture barrier properties with an allowed ingression of 1.9 g/m²/d.

The **neoX CPE 150/50**, introduced in 2015, uses a rather thin core PET film of 150 µm as opposed to 300 µm with neoX CPE 300/50. And except for properties linked to thickness, rest of the specifications are identical for both the products. This backsheet has an effective thickness of 215 µm and can withstand a maximum voltage of 1,000 V. It also has a relatively high moisture ingression rate of 3.1 g/m²/d.

The **neoX CPC 300** is a 2016 model that belongs to the third product group of the company, which uses coatings on both sides. This 330 µm thick backsheet uses a 310-µm core PET film, which is coated with 10 µm on both sides. It has a rated weight of 460 g/m² and a density of 1.43 g/cm³. Féron offers this product in white on the air side, and in choices of white or black on the cell side, as well as a smooth and scratch-resistant finish, which is true for all CPC and CPE product series. It complies with a 1,500 V partial discharge and is rated with a water vapor permeability of 1.9 g/m²/d.

The **neoX CPC 150**, with a 150-µm PET film, is designed for 1,000 V system voltages. It has the lowest barrier for water vapor ingression among the company's backsheets with the given permeability of 3.9 g/m²/d. Similar to the other CPC and CPE product range, this backsheet displays a reflectivity on the EVA side ranging between 80% and 90%. According to Féron, all these four models have passed 25,000 hours of Xenon tests and 3,000 hours of damp heat testing.

Shingi Urja: The company is offering two products as part of its non-fluoropolymer offering. Both the products are 2017 models based on PET / PET / primer configuration. The **Armour PO300BS** has

an effective thickness of 170 µm. The polymer composite shows a good moisture barrier property with a rated transmission of 1.5 gm/m^2/d. The backsheet comes with a color option between white and black on the outer side, while the inner side is always white with a reflectivity of 85%, and meets the 1,000 V class requirement.

The **Armour PO350BS** has a 350 µm core layer with an effective thickness 300 µm. The product has a tensile strength of 170 MPa and 160 MPa, and shrinkage of 1.5% and 0.5% in MD and TD directions respectively, while the elongation is the same in both directions at 100%. This backsheet displays a reflectivity of up to 85%. It complies with a 1,500 V partial discharge, while rated water vapor permeability of 1.5 g/m²/d is also the same for the company's other backsheet product.

7.2 Encapsulation films

Encapsulation materials play a dual role in a solar module. In addition to contributing to the module reliability, with its influence on optical properties, the encapsulation material can also influence electrical properties of the solar modules. Their main function is to provide electrical insulation and cushion the solar cells embedded into the module. EVA has been the material of choice probably since the inception of solar modules and has been enjoying a monopoly status. While there were several alternative materials proposed for this application, none of them were able to gain any meaningful share.

However, advanced module concepts, such as bifacial, demand solutions other than EVA. In fact, manufacturers have responded to the demand and today offer effective alternatives to EVA for advanced applications. Our market survey on encapsulation materials is divided into two parts—EVA and non-EVA based products. Seven manufacturers have responded to our enquiry, providing data for 23 products.

7.2.1 EVA Products

The EVA section of the survey lists 14 products from five companies, of which seven are from the market leader Hangzhou First, three models from another well-known company in the field, HIUV, two models from Sveck and one each from Crown and Cybrid.

Crown: The company has provided data for one EVA based encapsulant, ISARD, introduced in 2016. This product is offered with a standard thickness of 0.3 to 0.8 µm. It is supplied in a standard width of 2,200 mm. The density of this fast-cure EVA is given as 0.948 g/cm³ and comes with a tensile strength of 16 MPa. This EVA product supports laminating temperatures of 140 to 150°C. As for the lamination cycle time, 5 to 6 minutes is recommended for vacuum and between 10 and 12 minutes for press time. The crosslinking is accomplished at a temperature window of 140 to 150°C.

Cybrid: The leading supplier of the backsheet has also ventured into the supply of encapsulation products. Interestingly, the company has been offering T11, an EVA based encapsulation product, since 2014. This model is built with a vinyl acetate content of 28% and 75% gel content. This fast-cure EVA product has a thickness range of 200 µm to 800 µm and a width of 980 mm. It has a tensile strength of 12 MPa and elongation of 450% in both the MD and TD directions, and shrinkage of 3% and 1.5%, respectively. The adhesion to glass is given as 60 N/cm and bonding to backsheet is 40 N/cm. It has a rated reflectivity of 91% referring to a wavelength band of 380 to 1,100 nm. The refractive index is between 1.48 and 1.49 and a volume resistivity of 1 x 10^{15} ohm.cm, and a water absorption rate of 0.1%.

HANGZHOU FIRST: This Chinese company is the market leader in the encapsulation segment. As it did in the previous survey, Hangzhou First has provided data for seven EVA models, whose specifications have also remained unaltered except in tensile strength, which is same for the entire range at 160 MPa irrespective of direction. The most recent among the listed ones are the two 2017 models—**Su406** and **Su806**. This pair of products represents the company's "super fast cure" range. That means the encapsulants support a faster cycle time in module manufacturing. While the recommended vacuum time during the lamination process with these two products is the same as that of fast-cure variants at 3 to 6 minutes, the press time is between 5 and 10 minutes, 1 to 5 minutes less than the fast-cure versions. These two models differ from each other in UV permeability; while the Su406 is totally UV transparent, the Su806 blocks light below 360 nm.

The remaining five listed products are part of the fast-cure EVA range of the company. Among these, the **F806W** is somewhat special in its application. Launched in 2015, this model is a white EVA, meaning it is designed specifically for the rear side of the module. It helps reflect the sunlight that falls on the inter-cell spacing, giving it a second chance to get absorbed. It has a rated reflectivity of 90% referring to a wavelength band of 400 to 1,100 nm. The F806W comes with a standard thickness of 450 µm and is 980 mm in width. It has an elongation of 400% in both the MD and TD directions and shrinkage of 5% and 2%, respectively. Adhesion to the glass is given as 60 N/cm, and 40 N/cm is its bonding strength to the backsheet. The processing conditions are apparently the same as the other fast-cure products, as the EVA covering the rear of the module has to be co-processed with the one on the front side, as is the case with all of the "fast cure" models. The product is specially designed to avoid any overflow of white pigment to the front side during the lamination process.

F406PS and **F806PS** are another pair of specialty products from Hangzhou First that was introduced in 2014. The "PS" suffix denotes snail-trail resistance, while the differentiating factor among these two is the standard thickness and UV cut-off. While the F406PS is supplied in a standard thickness of 500 µm and has no UV cut-off, the F406PS is offered at 450 µm and stops sunlight below 360 nm from entering the module. These two EVA products are rated with a slightly higher tensile strength of 16 MPa when compared to the previous level of 12 MPA and an elongation rated at 450% in both the TD and MD directions. However, shrinkage of 3% in the MD direction is double the TD at 1.5%. As for the chemical properties, these encapsulation films have a vinyl acetate content of 28% and 75% gel content. The adhesion strength to glass is 60 N/cm and bonding to backsheet is given as 40 N/cm. These two models are fast-cure versions that support similar processing conditions—lamination temperature between 140 and 160 °C, requiring vacuum time of 3 to 6 minutes and a press time of 6 to 12 minutes.

These specifications given for mechanical and chemical properties, as well as processing conditions, are exactly the same for another pair of


Source: Hangzhou First

The ruler: Hangzhou First, having its legs in both backsheets and encapsulation segments, is the unprecedented leader of the later with over 50% market share.

One exception is that the press time range is 6 to 14 minutes. The main difference between these two models is their UV transmittance. While the F406P comes with no UV cut-off, the F806P filters out light below 360 nm wavelength. The standard thickness is also different. While the F406P has a rated thickness of 500 µm, the F806P is supplied with a thickness of 450 µm. The width for both the models is 980 mm, while the remaining parameters are identical. When compared to the previous edition, the tensile strength for these models has also increased up to 16 MPa.

Hangzhou First's entire range of EVA films is PID-resistant; and with the exception of white EVA, they all have identical performance attributes. The remaining six models are rated with a light transmittance of 91% at a wavelength band of 380 to 1,100 nm, a refractive index between 1.48 and 1.49, a volume resistivity of 1 x 10^{14} ohm-cm and a water

absorption rate of 0.1%.

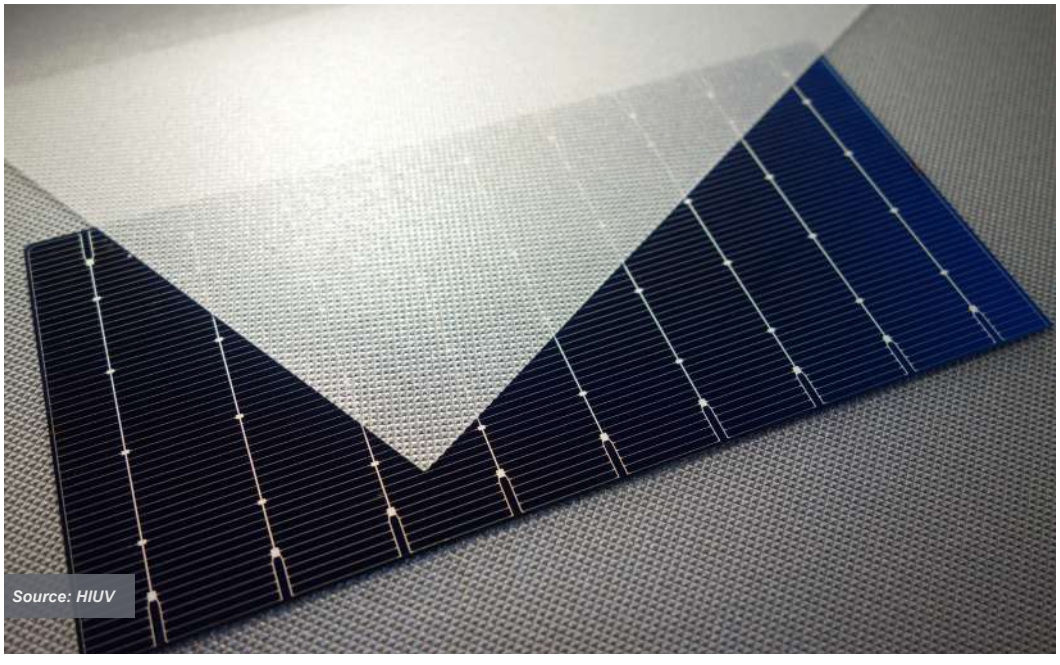
HIUV: Another leading company of the segment, HIUV has provided data for three models, each with specific applications. The company actually differentiates applications at the product level based on the layer they are applied to in the module wrap and the products have not undergone any changes from the previous listing.

The **S201MT1** is specially designed for the glass side of the laminate. It is offered in standard thickness of 600 µm and width of 985 mm. But as with all of the other EVA suppliers, HIUV is offering a wide range of dimensions suitable for any special requirements. The density is given as 0.96 g/m^3. These physical properties are the same for all of HIUV's three listed models.

The **S201MT2** is the model promoted for rear-side encapsulation. Similar to the other models, it also comes with a surface finish of double frosted and pyramid embossing to enhance the light trapping. In terms of mechanical properties, all the three encapsulants listed in this section are exactly the same, with a tensile strength of 18 Mpa and 500% elongation in the MD as well as in TD direction; and shrinkage in the TD of 2% compared to 4% in the MD. The bonding to glass is 60 N/cm, which is only relevant for glass-glass modules, and a 50 N/cm adhesion strength to the backsheet. They are also identical in terms of performance attributes—limiting the water vapor absorption to less than 0.1% in weight, a volume resistivity of 1x10^{15}, and a refractive index of 1.48. As with the front EVA S201MT1, this rear encapsulant is also transparent, and both are rated with a light transmittance of 91% at a wavelength band of 380 to 1,100 nm. However, this EVA placed at the rear of the laminate is designed to protect UV exposure below 360 nm. These two complementing products exhibit "good PID suppressing properties," according to HIUV.

The **S201W** is also designed for the rear side, but it is a white EVA for enhanced optical performance of the module. The films supplied under this label are specially treated with electron beam pre-crosslinking technology to avoid any overflow of white pigment on to the front side. This product comes with a different tensile strength of 16 MPa. Like the other two, this product also belongs to the fast-cure class, meaning the processing conditions are the same for HIUV's entire product range. The EVA product range supports laminating temperature of 140 to 170°C. As for the lamination cycle time, 5 to 7 minutes is recommended for vacuum and between 9 and 11 minutes for press time. The crosslinking is accomplished in a temperature window of 135 to 150°C. The film has a vinyl acetate content of 28.5% and 80 to 95% gel content. This EVA model comes with a slightly lower volume resistivity of 1 x 10^{14}.

SVECK: One among top 3 EVA suppliers, SVECK



Source: HIUV

Application specific: HIUV is promoting 3 models, each designed for different applications – one is for the glass side, two are for the rear of which one is a white EVA product.

has provided data for two EVA-based encapsulants, one more than the previous listing. The CO-556 product launched in 2020 product that comes with a standard thickness of 450 µm. This product is offered with higher widths of up to 1,320 mm to support the processing larger modules based on larger wafer formats and has a tensile strength to 6 MPa. This latest production of the company supports laminating temperatures of 148 to 153°C, 6 to 7 minutes for vacuum and between 12 and 15 minutes for press time. The crosslinking is accomplished at a temperature window of 148 to 153°C. This EVA model comes with a volume resistivity of 1 x 10^{14} ohm.cm.

SV-15296P/SV-15297P, introduced in 2014, is the second model promoted by SVEC in the current survey. This product is offered with a standard thickness of 450 µm, with an option to choose the thickness from a range of 400 and 800 µm. It is supplied in a standard width of 985 µm, and widths from 970 to 1,150 mm are also possible. The density of this encapsulant is given as 0.95 to 0.96 g/cm³ and comes with a different tensile strength of 12 MPa. The EVA product range supports laminating temperatures of 138 to 150°C. As for the lamination cycle time, 3 to 6 minutes is recommended for vacuum and between 5 and 10 minutes for press time. The crosslinking is accomplished at a temperature window of 138 to 150°C. The film has a vinyl acetate content of 28.5% and 80 to 95% gel content. This EVA model comes with a slightly lower volume resistivity of 1 x 10^{14} ohm.cm.

7.2.2 Non-EVA products

The non-EVA part of the survey received responses from 5 suppliers that have provided data for eight products in total.

BOREALIS: The Austrian company has provided data for two products—**BPO8828F** and **BPO8828S**, but consolidated in one column of the survey table. Available in choices of transparent and white, both the products are part of its Quentys range of encapsulation solutions, which is based on thermoplastic and non-crosslinking film polymer chemistry that enables module rework as and when necessary. It is offered with a 400 to 600 µm thickness and 990 mm width as standard with the thickness range from 990 to 1250 mm and the company is open to making other dimensions if such a demand arises. The polyolefin film has a density of 0.945 g/cm^3. The tensile strength of the products is given as 18 MPa and shrinkage of 3% in both the MD and TD directions, while elongation data has not been provided. Except for the supported lamination temperature range of 120 to 170°C, the company has not provided any other processing conditions,


Source: SVECK

Captive consumption: With SVECK being part of module company RISEN Energy group, a notable chunk of its encapsulants production is used for inhouse panel assembly.

only noting that they depend on "BOM & laminator type." The light transmittance of the film is estimated to be 89% for wavelengths between 400 and 1,150 nm for a 450-µm film laminated between 1-mm glass slides and cuts off UV portion of solar light spectrum below 300 nm. The reflectivity for the white version is the same as the transmittance, i.e. 89% at 400 to 1,150 nm. It has a refractive index of 1.49 and 1 x 10^{15} ohm.cm volume resistivity. Notably, the shelf life of Quentys BPO 8828F at one year is double that of any other encapsulant listed in the survey.

CYBRID: The market leader of this segment is now promoting the next generation of non-EVA based encapsulation solution called **T22h**. While there is no significant change in the naming over the previous model T22, the current product is a coextruded film containing EVA and POE. It is expected to bring the best of both worlds of EVA and POE for glass-glass module makers. It is a fast-cure product offered in both transparent as well as white versions, depending on whether the module is bifacial or not. T22h has a rated tensile strength of 5 MPa and elongation of 500% in both directions. Cybrid's product supports a lamination temperature of 145°C and cycle time of 20 minutes, for which 5 minutes is recommended for vacuum, while press time is given as 10 minutes. The encapsulant exhibits the same bonding to the glass and backsheet with adhesion strength of 60 N/mm. With respect to optical properties, the product is rated with a 91% light transmittance between the wavelengths of 385 and 1,100 nm. The T22h coextruded encapsulant has the highest volume resistivity of $2x10^{16}$ among the products listed in this section of the survey.

HANGZHOU FIRST: The top EVA supplier is again listing two polyolefin models, **TF4** and **TF8**, in the non-EVA section of the survey. The polyolefin product range also follows the same differentiation logic as Hangzhou First applied in the EVA listing, i.e. with and without a UV cut-off. The company claims that the TF4 has absolutely no UV cut-off, while the TF8 has a cut-off at 360 nm. Both have a light transmittance of 90%, referring to a wavelength band of 380 to 1,100 nm. The products are supplied in a 450-µm thickness and 980 mm width as standard and are rated with a tensile strength of 10 MPa and 500% elongation. The product range supports a lamination process temperature from 140 to 160°C with 4 to 6 minutes recommended for vacuum and 11 to 20 minutes of press time. The polymers have the same gel content of 60%. These two models of the company have not undergone any major changes since our last listing.

HIUV: Another leading EVA supplier, HIUV, is listing two non-EVA models—**P507**—, same as our

Source: SVECK

POE portfolio: Like other leading encapsulation material suppliers, SVECK is also promoting POE based encapsulation solutions for bifacial applications

previous listing and P506M. The P507 is a three-layer coextruded polyolefin film; to be specific, a polyolefin film sandwiched between the two EVA films. The main advantage of the product according to HIUV is its ability to reduce the cycle time in the lamination process from 25% to 35%. HIUV also claims that the product reduces the chance of bubble formation during the lamination process.

P506M, although newly listed in the current survey, is a 2018 model of single layer POE sheet. Both the products support a lamination temperature of 140 to 170°C with 5 to 7 minutes recommended for vacuum and 9 to 11 minutes of press time. The other specifications of these composite film are identical to the others. Supplied in a standard thickness of 500 µm and 985 mm width, they have a slightly higher density of 0.92 g/cm^3 and 0.9 g/cm^3 respectively. Both the products are offered in a transparent form with double-frosted surface finish. **P507** has a tensile strength of 12 MPa in both directions and exhibits a 60 N/cm adhesive strength to glass and 50 N/mm with the backsheet. The stack has a 91% transmittance for wavelengths between 380 and 1,100 nm. P506M has 85% transmittance for wavelengths between 380 and 1,100 nm.

SVECK: Another leading EVA supplier, SVECK, is listing one non-EVA encapsulant in the survey. The **SE-556 SE-557**, introduced in 2015, is POE based. Supplied in a standard thickness of 500 µm and 985 mm width, the company is also ready to offer the product in other dimensions—400 to 900 µm thickness and width ranges between 970 and 1,150 mm. The module using this POE encapsulation material is recommended to process with a vacuum time of 5 to 7 minutes and press time of 11 to 13 minutes. It supports a lamination temperature range of 140 to 160°C. The SE-556 SE-557 is offered in transparent form with double-frosted surface finish. It has a tensile strength of 18 MPa in both directions and exhibits a 70 N/cm adhesive strength to glass and 50 N/mm with the backsheet. The POE film has a 91% transmittance for wavelengths between 380 and 1,100 nm and water absorption of 0.05% weight. The product is rated with refractive index of 1.48 and 1 x 10^{15} ohm.cm volume resistivity.

8. Conclusions

2021 was everything but boring in the field of backsheets and encapsulation. A positive note for this segment is a continued solar market growth – and several product innovations to address the module manufacturer's needs. On the other hand, backsheets now have a true competitor in glass.

In the past, glass and backsheets rarely crossed paths as far as module making is concerned; and when they did, it was for a little piece of the PV cake called bifacial. But what used to be a small niche segment of PV has now become mainstream at close to 20% in 2020 – and is rapidly gaining ground, expected to reach a global market share of over 50% within this decade. Making a bifacial module involves a special encapsulation scheme and a transparent rear cover. The choice of glass was natural, but only until transparent backsheets were introduced a few years ago. After a slow start, these backsheets were in high demand in 2020, when glass prices started to shoot up. But backsheet makers were in for disappointment with the glass price rally lasting only briefly – and was basically solved after capacities were rapidly expanded. In short, technically speaking, transparent backsheets appear to have been evolved to be a reliable rear cover, while the major constraint remains – price, although todays difference to glass of only about 15% leaves hope for the polymer side.

The recent developments for PVDF, which owned over half of the market among different backsheet materials in 2020, were also not on the positive side for backsheets. During 2021, PVDF's prices went north dramatically as it also attracted strong demand from the storage industry, which made the formerly low-cost material much less attractive for solar. In fact, the PVDF developments helped the 'comeback' of glass for the rear cover, but at the same time, this opened a window for other backsheet materials.

Among the configurations that have come to the forefront to take the place of PVDF based backsheets is CPC, which seems to be benefiting the most for the moment, but also Tedlar has regained popularity. The non-fluoropolymer segment is also seeing some traction; pure PE or PP based backsheets are superior when it comes to environmental concerns and recycling – a topic that is quickly gaining importance in Europe these days. However, it remains to be seen how quickly PVDF resin suppliers expand capacities to address solar's demand. If available in large enough quantities, PVDF still has a cost advantage over its polymer peers.

In times of rising material prices, the pressure is high to find other ways of cost reduction – and there is indeed quite some activity. An interesting alternative to the current state of the art of making these polymer stacks is coextrusion. The manufacturer's response, though, has been mixed so far. The first products based on all-PP based coextruded backsheets are expected to hit as soon as the end of the first half of 2022.

The high raw material prices are also affecting the encapsulation segment – here it is incumbent EVA for which prices have skyrocketed in 2021. Technologically, there is no revolution on the horizon in EVA developments, but high-reflective white EVA is increasingly preferred for the rear of a module. With the teething issues addressed, this material will take a big chunk of rear side encapsulation. There is also further notable development in the POE segment. POE is becoming the rear encapsulant of choice in bifacial modules, addressing the shortcomings of EVA, but it also brings up other concerns such as bubble formation, longer processing times and difficulties with the MBB layout. The coextruded EPE structure – a EVA sandwich with a POE layer in the middle – developed as an alternative to pure POE is gaining ground. The stack is expected to become the mainstream solution for rear side encapsulation of glass-glass bifacial modules. Unlike in backsheets, coextrusion is very much welcomed here. The same approach is also used to fuse transparent and white EVA to make it further process-friendly, especially when using larger and thin wafers.

While not new but perhaps overshadowed by EVA's strong dominance, silicones for encapsulation are now trying a comeback with an interesting USP – very long reliability of around 50 years. The

target market this time around is not mainstream applications but the still very small though emerging segment of BIPV. The logic is to match module life to that of other building components. What it holds for the future remains to be seen, but for sure the important field of backsheets and encapsulation as a key to reliable power generation with solar modules is not boring at all these days.

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9. Interview

Amid the material shortage and consequent prices hikes, backsheets and encapsulation materials, the key polymer wraps used in module making are increasingly gaining importance. TaiyangNews talked to Xinjun Li, marketing director of Cybrid, one of the two world leading backsheet suppliers. Counting on its strong footprint in the backsheets segment, Cybrid also has ambitious plans to become a key encapsulation materials supplier.

XINJUN LI, MARKETING DIRECTOR, CYBRID

Xinjun Li has a strong academic and research background including a Ph.D in polymer science and prior experience in packing and special plastics at a leading polymer company. He is associated with Cybrid since 2016 in various positions. He was in charge of backsheet and encapsulation materials R&D for 5 years and is now the marketing director at Cybrid.

TaiyangNews: Cybrid is one among few companies that supply all polymer wraps needed for solar module manufacturing. How do you see the market development for these two segments – backsheets and encapsulation?

Xinjun Li: *Cybird is a functional polymer material expert. We have strong R&D background in making polymer films based on which we have developed the world's leading backsheet configuration KPf. We also eventually developed an encapsulation solution for PV. But in addition to PV, we also supply our products to various other industries.*

As for backsheets, it now has a new competitor in glass. Lower glass prices, coupled with increase in all polymer prices in general, will lead to an increase in the share of glass in 2021. A significant increase in PVDF prices has increased the price of PVDF-based backsheets more prominently. But we think this is temporary and it will be back to normal as the materials supply situation improves.

The encapsulation segment is more diversifying. More and more white EVA is used in standard modules. And POE is becoming the choice for rear encapsulation of the bifacial modules.

TaiyangNews: What are the most important trends in backsheets?

Xinjun Li: *The biggest change in 2021 was the high price of PVDF, which has almost doubled. The price increase is mainly due to the shortage of the resin used for PVDF production. This again is mainly due to the increased demand from electrical vehicles, as PVDF coating is used in lithium-ion batteries. All this has meant that PVDF is in a short supply situation.*

TaiyangNews: When do you think the situation would be normal again?

Xinjun Li: *We are working in close cooperation with the resin suppliers and feeding them with market intel. If they don't act fast, they may lose the whole PV backsheet market, because there are alternatives available already. One is the CPC structure that is free from PVDF. While the tier 1 module makers are still using the KPf structure, tier 2 companies are already shifting to coating based solutions to save on costs. PET based backsheet is another alternative. The resin makers have acknowledged the situation and are increasing their production capacities. However, our estimate is that the situation will not change much till October 2022.*

TaiyangNews: Won't it be too late?

Xinjun Li: *What you have to note here is that the price of PVDF has doubled, but not the final backsheet. And the price increase is not just*

the result of PVDF alone; the prices for all other materials such as PET and glues used in the backsheet have also increased. The final price for PVDF backsheets have gone up by 2 to 3 CNY/m2. It is still affordable. In fact, prices are the same as 3 years ago.

TaiyangNews: Larger modules based on larger wafer formats have been the trend in the industry for some time; what is the impact of this development on backsheets?

Xinjun Li: *Such modules require changes to backsheet dimensions and we were equipped to address such demands long back. However, these larger modules are now bringing in a configurational limitation. A few companies, not Cybrid of course, are promoting polyolefin based inner layers. Configurations such as KPO, KPM and KPE fall into this category. These backsheets are failing in hotspot tests for high power modules based on M10 and G12 cells. The reason is simple: the melting point of these films, which is typically between 120 and 165 °C, is lower than the hotspot test temperatures. The fluorine inner coatings based backsheets such as our KPf are able to pass such tests without any issues. Most of the leading companies are refraining from using backsheets with inner polyolefin films in high power modules. I can say it's sort of an unofficial ban.*

TaiyangNews: How is the transparent backsheet segment doing?

Xinjun Li: *We spent a lot of time in reducing costs and improving the performance of the transparent backsheet. In fact, they are robust enough, and now it's just a matter of costs. This is also evident from what happened in 2020 with several module makers turning to transparent backsheets when glass prices were high. Most of the leading module makers even finished all the testing procedures. But as glass prices dropped considerably since the start of 2021, they again moved back to glass.*

Looking at the current situation, transparent backsheets did not reach a big share in 2021 and will not do so in the coming months. As far as Cybrid is concerned, our focus is on overseas module makers. For example, in countries like Turkey, the transport of glass from China is very expensive. Importing glass also attracts additional duties. For such markets, transparent backsheets make a lot of sense in terms of costs.

In the end, our competitors aren't other backsheet suppliers, but it is glass.

TaiyangNews: How do you plan to win over glass?

Xinjun Li: *As I said earlier, today's transparent backsheets are robust enough in terms of quality. We have to ensure that the price gap between the transparent backsheet and glass is close enough where it starts making sense for module makers. In the current situation, we cannot do it with PVDF-based structures, and that's not just because of the high PVDF price. The transparent variant of PVDF is more expensive than the standard variant, and on top, we have to pay for the special transparent glues. On the other hand, coatings have good potential for cost reduction. FPf coatings meet the requirements in roof application without high humidity. For modules that have to serve in tough weather conditions, we can apply a 5 µm hard coating on the outer side of the coating, i.e., double coating on the outer side. We call these backsheets as 'Skin Cocktail' backsheets.*

TaiyangNews: What would be the additional price for such hard coatings?

Xinjun Li: *About 1 CNY/m2.*

TaiyangNews: How is the progress with grid backsheets?

Xinjun Li: *The white grid applied transparent backsheets are increasingly preferred. However, there is an interesting development in this area as well. We have a white backsheet with black grid for those modules makers that want to produce black modules.*

TaiyangNews: What is the benefit of using such a grid when the backsheet is opaque?

Xinjun Li: *Black grid on white backsheet is used to replace a total black backsheet. Using a black grid on a white backsheet gives a module the stunning appearance of a black module. To the question of*

the purpose of a white backsheet itself, companies are making glass-backsheet modules also with bifacial cells. A portion of IR light that would pass through the cells reflects back when using the white backsheet compared to a black rear cover. This way, you can increase the power output of a black module by at least 4 W compared to using a total black one.

TaiyangNews: What is your opinion about the recyclability of backsheets, especially given the backdrop that a few companies are commercializing backsheets made with recycled PET?

Xinjun Li: *We are also working in the direction of green backsheets. We already have a product, which is PPf that is offered in two variants – one comes with a fluorine based inner coating and another one has a fluorine free inner coating.*

As for other products in the market, there is a wrong notion in the market that all PET based products are green and fluorine based are not. The leading PET based configuration has a polyolefin-based compound as the inner layer, which is hard to decompose in nature. In case of Cybrid's products, even with the fluorine coating, which are just 4 µm, they decompose easily compared to polyolefin film based backsheets, for example PPE structures. PET needs around 100 years decompose, but coextrusion backsheets are using polyolefins (PP, PE), which need million years to decompose. From this pointed of view, I would recommend PET backsheets with inner layers other than polyolefins.

TaiyangNews: How are you positioned in the encapsulation material segment?

Xinjun Li: *By the end of 2021, as the entire capacity of Cybrid comes online, we will take 15% of the market share. We will be among the top 3 in the world. As for POE films, we are the biggest supplier in the market; however, for the coextruded structure, our presence is definitely there, but we are far from claiming leadership.*

TaiyangNews: Are you focusing on all encapsulation materials or just POE related?

Xinjun Li: *We are among the top 4 encapsulation players in the world since September 2021. We supply EVA, white EVA, EPE and POE in market. We mainly supply EVA + white EVA for glass\ backsheet modules, and EVA+ EPE for glass/glass modules. So the key product for us is EVA. As for high efficiency technologies, we recommend EPE+ POE for TOPCon and EPE + EPE for HJT modules.*

TaiyangNews: So, what are the most important trends you see in the encapsulation segment?

Xinjun Li: *In bifacial double glass modules, the encapsulation material of choice for the front is EVA and coextruded EPE for the rear. For glass-backsheet modules, the front side is transparent EVA and about 70% of the market switched to white EVA for the rear side.*

TaiyangNews: Thank you for the interview.

10. Product Specifications Table

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Coveme**	**Coveme**	**Coveme**
Product name	**dyMat TsL 50/250**	**dyMat TsL 50/285**	**dyMat Ts 38/125**
Available since	2013	2017	2019
Backsheet composition	PVF / PET / Primer*1	PVF / PET / Primer*1	PVF / PET / PVF
Physical properties			
Thickness of each layer	–	–	–
Effective thickness	345 ± 5% µm	380 ± 5% µm	221 ± 5% µm
Width	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm
Weight	–	–	–
Density	–	–	–
Color options - front / rear	White	White	White / black
Colors options - rear	White / black	White / black	White / black
Surface finish	–	–	–
Mechanical properties			
Tensile strength (MD/TD)	–	–	–
Elongation (MD/TD)	–	–	–
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	–	–	–
Shrinkage (MD / TD)*1	–	–	–
EVA peel strength	–	–	–
Peel strength of inner layers	–	–	–
Performance characteristics			
Breakdown voltage	> 20 kV	> 20 kV	> 20 kV
Partial discharge	> 1,000 VDC	> 1,500 VDC	> 1,000 VDC
Water vapor permeability	< 2 g/m²d *2	< 1.9 g/m²d *2	< 3 g/m²d *1
Reflectivity (EVA Side)	> 75%	> 82%	> 75%
Flame spread index	< 100	< 100	< 100
Ideally suited for:	Field Installation	Field Installation	Field Installation
The most important benefits	• Tedlar based backsheet • Suited for 1,000 VDC systems • DTI > 150 µm	• Tedlar based backsheet • Suited for 1,500 VDC systems • DTI > 300 µm	• Tedlar based backsheet • Two Tedlar layers • Suited for 1,000 VDC systems • DTI > 150 µm
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	40 °C / 65% RH	40 °C / 65% RH	40 °C / 65% RH
Shelf life	2 years	2 years	2 years
Special notes			
***1 at 150°C for 30 min**	*1 Available also with fluoro based Coating instead of Primer *2 at 38 °C 90% RH	*1 Available also with fluoro based Coating instead of Primer *2 at 38 °C 90% RH	*1 at 38 °C 90% RH

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Coveme**	**Coveme**	**Coveme**
Product name	**dyMat Ts 38/285**	**dyMat Clr TsL 50/158**	**dyMat Clr TsL 50/285**
Available since	2019	2020	2020
Backsheet composition	PVF / PET / PVF	PVF / PET / Primer*1	PVF / PET / Primer*1
Physical properties			
Thickness of each layer	–	–	–
Effective thickness	281 ± 5% µm	253 ± 5% µm	380 ± 5% µm
Width	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm
Weight	–	–	–
Density	–	–	–
Color options - front / rear	White / black	Transparent	Transparent
Colors options - rear	White / black	Transparent	Transparent
Surface finish	–	–	–
Mechanical properties			
Tensile strength (MD/TD)	–	–	–
Elongation (MD/TD)	–	–	–
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	–	–	–
Shrinkage (MD / TD)*1	–	–	–
EVA peel strength	–	–	–
Peel strength of inner layers	–	–	–
Performance characteristics			
Breakdown voltage	> 20 kV	> 20 kV	> 20 kV
Partial discharge	> 1,500 VDC	> 1,000 VDC	> 1,000 VDC
Water vapor permeability	< 2 g/m²d *1	< 2 g/m²d *2	< 2 g/m²d *2
Reflectivity (EVA Side)	> 75%	–	–
Flame spread index	< 100	< 100	< 100
Ideally suited for:	Field Installation	Field Installation	Field Installation
The most important benefits	• Tedlar based backsheet • Two Tedlar layers • Suited for 1,500 VDC systems • DTI > 300 µm	• Tedlar based backsheet • Totally transparent - 1,000VDC • DTI > 150 µm • Particularly indicated for bifacial cell PV and BIPV	• Tedlar based backsheet • Totally transparent - 1500VDC • DTI > 300 µm • Particularly indicated for bifacial cell PV and BIPV
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	40 °C / 65% RH	40 °C / 65% RH	40 °C / 65% RH
Shelf life	2 years	2 years	2 years
Special notes			
***1 at 150°C for 30 min**	*1 at 38 °C 90% RH	*1 Available also with fluoro based Coating instead of Primer *2 at 38 °C 90% RH	*1 Available also with fluoro based Coating instead of Primer *2 at 38 °C 90% RH

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Crown**	**Cybrid**	**Cybrid**
Product name	**TPM**	**KPF**	**KPF1500**
Available since	2014	2012	2012
Backsheet composition	PVF / PET / Primer	PVDF / PET / Fluorine skin film	PVDF / PET / Fluorine skin film
Physical properties			
Thickness of each layer	–	22.5 / 262 / 4 µm	22.5 / 262 / 4 µm
Effective thickness	325 µm	295 µm	295 µm
Width	Customer width	< 1,100 mm	< 1,100 mm
Weight	–	420 ± 10% g/m²	420 ± 10% g/m²
Density	–	1.42 g/cm³	1.42 g/cm³
Color options - front / rear	White / black / transparent	White	White
Colors options - rear	White / black / transparent	White	White
Surface finish	–	Glossy	Glossy
Mechanical properties			
Tensile strength (MD/TD)	≥ 350 / ≥ 350 N/cm	80 / 80 MPa	80 / 80 MPa
Elongation (MD/TD)	≥ 100 / ≥ 100 %	100 / 100 %	100 / 100 %
Tear strength (MD/TD)	≥ 4 / ≥ 4 N/cm	–	–
Dimens. stability (MD/TD)*1	–	1.5% / 1%	1.5% / 1%
Shrinkage (MD / TD)*1	≤ 1.5% / ≤ 1.0%	0.8% / 1%	0.8% / 1%
EVA peel strength	≥ 4 N/mm	60 N/mm	60 N/mm
Peel strength of inner layers	≥ 1.5 N/mm	4 N/mm	4 N/mm
Performance characteristics			
Breakdown voltage	≥ 18 KV	17 kV	17 kV
Partial discharge	1,000 / 1,500 VDC	1,000 VDC	1,000 VDC
Water vapor permeability	≤ 1.5 g/m²d *1	2 g/m²d	2 g/m²d
Reflectivity (EVA Side)	–	≥ 80%*1	≥ 80%*1
Flame spread index	–	34	34
Ideally suited for:	–	–	–
The most important benefits	• Excellent quality stability • Wet and heat ageing resistance • UV resistance stability • Excellent adhesion between backsheet and EVA • Excellent adhesion adaptability between backsheet and silicone sealant	• Excellent UV stability on both sides • High resistance to sand blasting • High weatherability and durability	• High resistance to heat and humidity • Excellent partial discharge • Excellent UV blocking
Packaging & Storage			
Packaging	–	Roll, sheet	Roll, sheet
Storage conditions	Dry sealed conditions can be kept for a year, and placed in dry environment after opened.	20 - 40 °C / 40% - 60% RH	20 - 40 °C / 40% - 60% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**		*1 Referring to 400 - 700 nm	*1 Referring to 400 - 700 nm

FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	Cybrid	Cybrid	Cybrid
Product name	**KPF(H)**	**KPAF**	**FPF**
Available since	2012	2012	2012
Backsheet composition	PVDF / PET / Fluorine skin film	PVDF / PET / AL / PET / Fluorine skin film	Fluorine skin film / PET / Fluorine skin film
Physical properties			
Thickness of each layer	22.5 / 262 / 4 µm	22.5 / 125 / 20 / 125 / 4 µm	20 / 280 / 20 µm
Effective thickness	295 µm	325 µm	320 µm
Width	< 1,100 mm	< 1,100 mm	< 1,100 mm
Weight	420 ± 10% g/m²	420 ± 10% g/m²	420 ± 10% g/m²
Density	1.42 g/cm³	1.42 g/cm³	1.42 g/cm³
Color options - front / rear	White	White	White
Colors options - rear	White	White	White
Surface finish	Glossy	Glossy	Glossy
Mechanical properties			
Tensile strength (MD/TD)	80 / 80 MPa	80 / 80 MPa	80 / 80 MPa
Elongation (MD/TD)	100 / 100 %	100 / 100 %	100 / 100 %
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	1.5% / 1%	1.5% / 1%	1.5% / 1%
Shrinkage (MD / TD)*1	0.8% / 1%	0.8% / 1%	0.8% / 1%
EVA peel strength	60 N/mm	60 N/mm	60 N/mm
Peel strength of inner layers	4 N/mm	4 N/mm	4 N/mm
Performance characteristics			
Breakdown voltage	17 kV	17 kV	17 kV
Partial discharge	1,000 VDC	1,000 VDC	1,000 VDC
Water vapor permeability	2 g/m²d	0.005 g/m²d	2 g/m²d
Reflectivity (EVA Side)	≥ 90%*1	≥ 80%*1	≥ 80%*1
Flame spread index	34	34	34
Ideally suited for:	–	–	–
The most important benefits	• Excellent UV stability on both sides • High reflectivity • High weatherability and durability	• The lowest WVTR, suitable for HJT and CIGS module • High resistance to sand abrasion • High weatherability and durability	• Transparent backsheet for Bi-facial PV • Excellent UV stability on both sides • High weatherability and durability
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	20 - 40 °C / 40% - 60% RH	20 - 40 °C / 40% - 60% RH	20 - 40 °C / 40% - 60% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**	*1 Referring to 400 - 700 nm	*1 Referring to 400 - 700 nm	*1 Referring to 400 - 700 nm

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Cybrid**	**Cybrid**	**Cybrid**
Product name	**PPf**	**KPK**	**KPX**
Available since	2013	2009	2012
Backsheet composition	PET / PET / Fluorine skin film	PVDF / PET / PVDF	PVDF / PET / PO
Physical properties			
Thickness of each layer	50 / 230 / 4 µm	30 / 250 / 30 µm	22.5 / 262 / 150 µm
Effective thickness	295 µm	345 µm	435 µm
Width	< 1,100 mm	< 1,100 mm	< 1,100 mm
Weight	460 ± 10% g/m²	500 ± 10% g/m²	420 ± 10% g/m²
Density	1.46 g/cm³	1.45 g/cm³	1.42 g/cm³
Color options - front / rear	White	White	White
Colors options - rear	White	White	White
Surface finish	Glossy	Glossy	Glossy
Mechanical properties			
Tensile strength (MD/TD)	80 / 80 MPa	80 / 80 MPa	80 / 80 MPa
Elongation (MD/TD)	100 / 100 %	100 / 100 %	100 / 100 %
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	1.5% / 1%	1.5% / 1%	1.5% / 1%
Shrinkage (MD / TD)*1	0.8% / 1%	0.8% / 1%	0.8% / 1%
EVA peel strength	60 N/mm	60 N/mm	60 N/mm
Peel strength of inner layers	4 N/mm	4 N/mm	4 N/mm
Performance characteristics			
Breakdown voltage	16 kV	17 kV	17 kV
Partial discharge	1,000 VDC	1,000 VDC	1,000 VDC
Water vapor permeability	2 g/m²d	2 g/m²d	0.8 g/m²d
Reflectivity (EVA Side)	≥ 80%*1	≥ 85%*1	≥ 80%*1
Flame spread index	34	34	34
Ideally suited for:	High temp. and high humidity area	–	–
The most important benefits	• Cost-effective product • Good weatherability and high reflectivity with fluorinated treatment; • Low water vapor transmission rate	• Excellent UV stability on both sides • High resistance to sand abrasion • High weatherability and durability	• Excellent UV stability on both sides • Suitable for high humidity area • High weatherability and durability
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	20 - 40 °C / 40% - 60% RH	23 ± 10 °C / 55 ± 15% RH	20 - 40 °C / 40% - 60% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**	*1 Referring to 400 - 700 nm	*1 Referring to 400 - 700 nm	*1 Referring to 400 - 700 nm

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Hangzhou First**	**Hangzhou First**	**Hangzhou First**
Product name	**Firstbacksheet BEC-301 TM**	**Firstbacksheet BEC-306 TM**	**FirstKPO BEO-303**
Available since	2019	2019	2018
Backsheet composition	FEVE(MESH) / FEVE / PET / FEVE	FEVE(MESH) / FEVE / PET / PVF	PO / PET / PVDF
Physical properties			
Thickness of each layer	20 / 10 / 275 / 20 µm	20 / 10 / 275 / 25 µm	80 / 140 / 20 µm
Effective thickness	325 µm	330 µm	280 µm
Width	1,260 mm	1,260 mm	1,360 mm
Weight	440 g/m²	450 g/m²	390 g/m²
Density	1.4 g/cm³	1.4 g/cm³	1.4 g/cm³
Color options - front / rear	Transparent	Transparent	White
Colors options - rear	White / black (MESH)*1	White / black (MESH)*1	White
Surface finish	Smooth	Smooth	Smooth
Mechanical properties			
Tensile strength (MD/TD)	150 / 150 MPa	150 / 150 MPa	100 / 100 MPa
Elongation (MD/TD)	100 / 100 %	100 / 100 %	100 / 100 %
Tear strength (MD/TD)	80 / 80 N/mm	80 / 80 N/mm	80 / 80 N/mm
Dimens. stability (MD/TD)*1	0.5% / 0.5%	0.5% / 0.5%	0.3% / 0%
Shrinkage (MD / TD)*1	0.5% / 0.5%	0.5% / 0.5%	1.5% / 1%
EVA peel strength	10 N/mm *2	10 N/mm *2	15 N/mm
Peel strength of inner layers	NA	NA	> 0.4 N/mm
Performance characteristics			
Breakdown voltage	20 kV	20 kV	20 kV
Partial discharge	1,500 VDC	1,500 VDC	1,000 VDC
Water vapor permeability	1.8 g/m²d	1.8 g/m²d	1.8 g/m²d
Reflectivity (EVA Side)	80% (white mesh)	80% (white mesh)	80%
Flame spread index	–	–	9.8
Ideally suited for:	–	–	–
The most important benefits	• 90% High transmittance • Excellent weather-resistance • Good adhesion with EVA/ POE	• 92% High transmittance • Excellent weather-resistance • Good adhesion with EVA/ POE	• High reflectivity/high adhesion • Excellent weather-resistance • Better cost performance
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	< 35 °C / 80% RH	< 35 °C / 80% RH	< 35 °C / 80% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**	*1 BEC-301T (no mesh) TYPE *2 POE peel strength	*1 BEC-306T(no mesh) TYPE *2 POE peel strengthx	

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Hangzhou First**	**Hangzhou First**	**Hangzhou First**
Product name	**FirstCPO BEO-301**	**Firstbacksheet BEC-301**	**Firstbacksheet BEC-301T**
Available since	2018	2008	2016
Backsheet composition	PO / PET / FEVE	FEVE / PET / FEVE	FEVE / PET / FEVE
Physical properties			
Thickness of each layer	80 / 155 / 5 µm	5 / 255 / 20 µm	5 / 255 / 20 µm
Effective thickness	250 µm	280 µm	280 µm
Width	1,360 mm	1,360 mm	1,360 mm
Weight	360 g/m²	410 g/m²	410 g/m²
Density	1.4 g/cm³	1.4 g/cm³	1.4 g/cm³
Color options - front / rear	White	White / black	Clear
Colors options - rear	White	White / black	Clear
Surface finish	Smooth	Smooth	Smooth
Mechanical properties			
Tensile strength (MD/TD)	100 / 100 MPa	160 / 160 MPa	160 / 160 MPa
Elongation (MD/TD)	100 / 100%	130 / 120%	130 / 120%
Tear strength (MD/TD)	80 / 80 N/mm	80 / 80 N/mm	80 / 80 N/mm
Dimens. stability (MD/TD)*1	0.3% / 0%	0.3% / 0%	0.3% / 0%
Shrinkage (MD / TD)*1	0.3% / 0%	0.3% / 0%	0.3% / 0%
EVA peel strength	15 N/mm	14 N/mm	8 N/mm
Peel strength of inner layers	> 0.5 N/mm	NA	NA
Performance characteristics			
Breakdown voltage	18 kV	20 kV	20 kV
Partial discharge	1,000 VDC	1,050 VDC	1,050 VDC
Water vapor permeability	1.9 g/m²d	1.8 g/m²d	1.8 g/m²d
Reflectivity (EVA Side)	80%	80%*1 / 70%*2	80%
Flame spread index	47.8	47	47.8
Ideally suited for:	–	–	–
The most important benefits	• High reflectivity/high adhesion • Excellent weather-resistance • Better cost performance	• High reflectivity/high adhesion • Excellent weather-resistance • High sand abrasion resistance	• High adhesion • Excellent weather-resistance • High sand abrasion resistance
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	< 35 °C / 80% RH	< 35 °C / 80% RH	< 35 °C / 80% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**		*1 (white) Referring to 400 - 700 nm	

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Hangzhou First**	**Hangzhou First**	**Hangzhou First**
Product name	**Firstbacksheet BEC-301D**	**Firstbacksheet BEC-303**	**Firstbacksheet BEF-302**
Available since	2013	2010	2009
Backsheet composition	FEVE / PET / FEVE	FEVE / PET / PVDF	PVDF / PET / PVDF
Physical properties			
Thickness of each layer	5 / 275 / 20 µm	5 / 275 / 20 µm	30 / 250 / 30 µm
Effective thickness	300 µm	305 µm	310 µm
Width	1,360 mm	1,360 mm	1,360 mm
Weight	420 g/m²	420 g/m²	420 g/m²
Density	1.4 g/cm³	1.4 g/cm³	1.4 g/cm³
Color options - front / rear	White / black	White / black	White / black
Colors options - rear	White / black	White / black	White / black
Surface finish	Smooth	Smooth	Smooth
Mechanical properties			
Tensile strength (MD/TD)	160 / 160 MPa	160 / 160 MPa	160 / 160 MPa
Elongation (MD/TD)	130 / 120%	130 / 120%	130 / 120%
Tear strength (MD/TD)	80 / 80 N/mm	80 / 80 N/mm	80 / 80 N/mm
Dimens. stability (MD/TD)*1	0.3% / 0%	0.3% / 0%	0.3 / 0%
Shrinkage (MD / TD)*1	0.3% / 0%	0.3% / 0%	1.5% / 1%
EVA peel strength	14 N/mm	14 N/mm	14 N/mm
Peel strength of inner layers	NA	> 0.4 N/mm	> 0.4 N/mm
Performance characteristics			
Breakdown voltage	20 kV	20 kV	20 kV
Partial discharge	1,500 VDC	1,500 VDC	1,500 VDC
Water vapor permeability	1.8 g/m²d	1.8 g/m²d	1.8 g/m²d
Reflectivity (EVA Side)	80%*1 / 75%*2	85%*1 / 75%*2	85%
Flame spread index	47.8	9.8	9.8
Ideally suited for:	–	–	–
The most important benefits	• High reflectivity/high adhesion • Excellent weather-resistance • High sand abrasion resistance	• High reflectivity/high adhesion • Excellent weather-resistance • High sand abrasion resistance	• High reflectivity/high adhesion • Excellent weather-resistance • High sand abrasion resistance
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	< 35 °C / 80% RH	< 35 °C / 80% RH	< 35 °C / 80% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**	*1 (white) Referring to 400 - 700 nm	*1 (white) Referring to 400 - 700 nm	

FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	Hangzhou First	Hangzhou First	Jolywood
Product name	**Firstbacksheet BEAL-304**	**Firstbacksheet BEC-306D**	**FFC-JW30(plus)**
Available since	2015	2020	2014
Backsheet composition	FEVE / PET / AL / FEVE	FEVE / PET / PVF	FFC / PET/ FFC
Physical properties			
Thickness of each layer	5 / 255 / 20 / 20 µm	5 / 275 / 25 µm	25 / 275 / 15 µm
Effective thickness	305 µm	310 µm	315 ± 5% µm
Width	1,180 mm	1,360 mm	≤ 1,200 mm
Weight	430 g/m²	440 g/m²	445 g/m²
Density	1.4 g/cm³	1.44 g/cm³	1.41 g/cm³
Color options - front / rear	White / black	White / black	White / black / transparent
Colors options - rear	White / black	White	White / black / transparent
Surface finish	Smooth	Smooth	Smooth
Mechanical properties			
Tensile strength (MD/TD)	160 / 160 MPa	160 / 160 MPa	≥ 120 / ≥ 120 Mpa
Elongation (MD/TD)	130 / 120%	130 / 120%	≥ 100 / ≥ 90%
Tear strength (MD/TD)	80 / 80 N/mm	80 / 80 N/mm	–
Dimens. stability (MD/TD)*[1]	0.3% / 0%	0.3% / 0%	≤ 1% / ≤ 1%
Shrinkage (MD / TD)*[1]	0.3% / 0%	0.3% / 0%	≤ 1% / ≤ 1%
EVA peel strength	14 N/mm	14 N/mm	≥ 4.5 N/mm
Peel strength of inner layers	> 0.4 N/mm	> 0.4 N/mm	NA
Performance characteristics			
Breakdown voltage	20 kV	20 kV	≥ 18 KV
Partial discharge	1,500 VDC	1,500 VDC	≥ 1,500 VDC
Water vapor permeability	1.8 g/m²d	1.8 g/m²d	≤ 2.5 g/m²d
Reflectivity (EVA Side)	80%	85 %*[1] / 7 %*[2]	≥ 85%*[1]
Flame spread index	47.8	2.1	8.8
Ideally suited for:	–	–	1,500V modules
The most important benefits	• High reflectivity/high adhesion • Excellent weather-resistance • High moisture barrier	• High reflectivity/high adhesion • Excellent weather-resistance • High sand abrasion resistance	• A membrane-adhesive integrated structure (FFC/ PET/FFC) with fluorine coating on both sides • Application method: plasma chemical modification and Fluoro-Silicon surface grafting • Suitable for 1,500 V system
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Rolls or stacked pre-cut sheets
Storage conditions	< 35 °C / 80% RH	< 35 °C / 80% RH	0 - 35 °C / 70% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**		*1 (white) Referring to 400 - 700 nm *2 (black) Referring to 900 -1500 nm	*1 referring to 400 - 700 nm

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Jolywood**	**Jolywood**	**Jolywood**
Product name	**TFB-30(plus)**	**FFC-JW3010(plus)**	**KFB-30(plus)**
Available since	2017	2010	2011
Backsheet composition	PVF / PET / FFC	FFC / PET / FFC	PVDF / PET / FFC
Physical properties			
Thickness of each layer	25 / 275 / 10 µm	13 /285/ 12 µm	20 / 275 / 15 µm
Effective thickness	320 ± 5% µm	310 ± 5% µm	315 ± 5% µm
Width	≤ 1,200 mm	≤ 1,200 mm	≤ 1,200 mm
Weight	445 g/m²	445 g/m²	445 g/m²
Density	1.39 g/cm³	1.44 g/cm³	1.45 g/cm³
Color options - front / rear	White / transparent	White	White
Colors options - rear	White / transparent	White	White
Surface finish	Smooth	Smooth	Smooth
Mechanical properties			
Tensile strength (MD/TD)	≥ 120 / ≥ 120 Mpa	≥ 120 / ≥ 120 Mpa	≥ 120 / ≥ 120 Mpa
Elongation (MD/TD)	≥ 100 / ≥ 90%	≥ 100 / ≥ 90%	≥ 100 / ≥ 90%
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	≤ 1% / ≤ 1%	≤ 1% / ≤ 1%	≤ 1% / ≤ 1%
Shrinkage (MD / TD)*1	≤ 1% / ≤ 1%	≤ 1% / ≤ 1%	≤ 1% / ≤ 1%
EVA peel strength	≥ 4.5 N/mm	≥ 4.5 N/mm	≥ 4.5 N/mm
Peel strength of inner layers	≥ 0.4 N/mm	NA	≥ 0.4 N/mm
Performance characteristics			
Breakdown voltage	≥ 18 KV	≥ 18 KV	≥ 18 KV
Partial discharge	≥ 1,500 VDC	≥ 1,500 VDC	≥ 1,500 VDC
Water vapor permeability	≤ 2.5 g/m²d	≤ 2.5 g/m²d	≤ 2.5 g/m²d
Reflectivity (EVA Side)	≥ 85%*1	≥ 85%*1	≥ 85%*1
Flame spread index	0.8	27.4	1.4
Ideally suited for:	1,500V modules	1,500V modules	1,500V modules
The most important benefits	• Double-sided fluorine structure (PVF/PET/FFC), integrating Tedlar and FFC FFC fluorocarbon inner coating technology, easier for module rework, no delamination • Excellent in UV resistance, non-yellowing	• A membrane-adhesive integrated structure (FFC/ PET/FFC) with fluorine coating on both sides • Application method: plasma chemical modification and Fluoro-Silicon surface grafting • Higher performance and lower cost	• Double-sided fluorine structure (PVDF/PET/FFC), integrating PVDF film and FFC • FFC fluorocarbon inner coating technology, easier for module rework, no delamination • Excellent in UV resistance, non-yellowing
Packaging & Storage			
Packaging	Rolls or stacked pre-cut sheets	Rolls or stacked pre-cut sheets	Rolls or stacked pre-cut sheets
Storage conditions	0 - 35 °C / 70% RH	0 - 35 °C / 70% RH	0 - 35 °C / 70% RH
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**	* 1 referring to 400 - 700 nm	* 1 referring to 400 - 700 nm	* 1 referring to 400 - 700 nm

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Lucky Film**	**Lucky Film**	**Lucky Film**
Product name	**TPP1**	**KPCw1**	**KPCt1**
Available since	2018	2016	2019
Backsheet composition	PO / PET / PVF	Coating / PET / PVDF	Coating / PET / PVDF
Physical properties			
Thickness of each layer	60 / 230 / 25 µm	5 / 285 / 20 µm	5 / 285 / 20 µm
Effective thickness	328 µm	316 µm	320 µm
Width	990 - 1,300 mm	990 - 1,300 mm	990 - 1,300 mm
Weight	450 ± 20 g/m^2	440 ± 20 g/m^2	440 ± 20 g/m^2
Density	–	–	–
Color options - front / rear	White	White	Transparent
Colors options - rear	White	White	Transparent
Surface finish	Smooth	Smooth	Smooth
Mechanical properties			
Tensile strength (MD/TD)	≥ 120 / 120 MPa	≥ 120 / 120 MPa	≥ 100 / 100 MPa
Elongation (MD/TD)	≥ 120 / 120%	≥ 100 / 100%	≥ 100 / 100%
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	–	–	–
Shrinkage (MD / TD)*1	≤ 1% / ≤ 1%	≤ 1% / ≤ 1%	≤ 1% / ≤ 1%
EVA peel strength	≥ 6 N/mm	≥ 6 N/mm	≥ 6 N/mm
Peel strength of inner layers	≥ 0.4 N/mm	≥ 0.4 N/mm	≥ 0.4 N/mm
Performance characteristics			
Breakdown voltage	≥ 18 kV	≥ 18 kV	≥ 16 kV
Partial discharge	≥ 1,500 VDC	≥ 1,500 VDC	≥ 1,500 VDC
Water vapor permeability	≤ 2 g/m²d	≤ 2 g/m²d	≤ 2 .5 g/m²d
Reflectivity (EVA Side)	≥ 80%	≥ 80%	–
Flame spread index	–	–	–
Ideally suited for:	1,500 V modules	1,500 V modules	1,500 V bifacial modules
The most important benefits	• High heat resistance • High insulative • High weather resistance	• High heat resistance	• High transmittance • Light weight • High weather resistance
Packaging & Storage			
Packaging	Roll, Sheet	Roll, Sheet	Roll, Sheet
Storage conditions	Room temperature	Room temperature	Room temperature
Shelf life	1 year	1 year	1 year
Special notes			
***1 at 150°C for 30 min**			

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Lucky Film**	**Shingl**	**Shingl**
Product name	**TPCw 1**	**Armour PF300BS**	**Armour PF350BS**
Available since	2019	2017	2017
Backsheet composition	Coating / PET / PVF	PVDF / PET / Primer	PVDF / PET / Primer
Physical properties			
Thickness of each layer	10 / 275 / 25 µm	330 µm ± 5%	370 µm ± 5%
Effective thickness	320 µm	230 µm	320 µm
Width	990 - 1,300 mm	Up to 1,350 mm	Up to 1,350 mm
Weight	435 ± 20 g/m^2	425 g/m²	490 g/m²
Density	–	1.29 g/cm³	1.32 g/cm³
Color options - front / rear	Transparent	White	White
Colors options - rear	Transparent	White / black	White / black
Surface finish	Smooth	Glossy	Glossy
Mechanical properties			
Tensile strength (MD/TD)	Coating / PET / PVF	> 160 / 150 MPa	> 180 / 170 MPa
Elongation (MD/TD)	≥ 100 / ≥ 100%	> 100 / 100%	> 100 / 100%
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	–	–	–
Shrinkage (MD / TD)*1	≤ 1% / ≤ 1%	≤ 1.5% / ≤ 0.5%	≤ 1.5% / ≤ 0.5%
EVA peel strength	≥ 6 N/mm	> 8 N/mm	> 8 N/mm
Peel strength of inner layers	≥ 0.4 N/mm	> 0. 5 N/mm	> 0. 5 N/mm
Performance characteristics			
Breakdown voltage	≥ 16 kV	> 18 kV	> 18 kV
Partial discharge	≥ 1,500 VDC	≥ 1,000 VDC	≥ 1,500 VDC
Water vapor permeability	≤ 2.5 g/m²d	< 1.5 g/m²d	< 1.5 g/m²d
Reflectivity (EVA Side)	–	> 85% (visible light)	> 85% (visible light)
Flame spread index	–	< 100	< 100
Ideally suited for:	1,500 V bifacial modules	Ground mounted projects	Ground mounted projects
The most important benefits	• High transmittance • Light weight • High weather resistance	• High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI	• High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI
Packaging & Storage			
Packaging	Roll, Sheet	Ambient	Ambient
Storage conditions	Room temperature	–	–
Shelf life	1 year	24 months	24 months
Special notes			
***1 at 150°C for 30 min**			

FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Shingi**	**Shingi**	**Shingi**
Product name	**Armour PFC300BS**	**Armour PC200BS**	**Armour PC300BS**
Available since	2021	2021	2021
Backsheet composition	PVDF / PET / Coating	Coatng / PET / Coating	Coatng / PET / Coating
Physical properties			
Thickness of each layer	305 µm + 5%	215 µm + 5%	305 µm + 5%
Effective thickness	305 µm	215 µm	305 µm
Width	Up to 1,350 mm	Up to 1,350 mm	Up to 1,350 mm
Weight	430 g/m²	290 g/m²	410 g/m²
Density	1.41 g/cm³	1.35 g/cm³	1.37 g/cm³
Color options - front / rear	White	White	White
Colors options - rear	White / black	White / black	White / black
Surface finish	Glossy	Glossy	Glossy
Mechanical properties			
Tensile strength (MD/TD)	> 180 / 170 MPa	> 160 / 150 MPa	> 180 / 170 MPa
Elongation (MD/TD)	> 100 / 100%	> 100 / 100%	> 100 / 100%
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*[1]	–	–	–
Shrinkage (MD / TD)*[1]	≤ 1.5% / ≤ 0.5%	≤ 1.5% / ≤ 0.5%	≤ 1.5% / ≤ 0.5%
EVA peel strength	> 8 N/mm	> 8 N/mm	> 8 N/mm
Peel strength of inner layers	> 0. 5 N/mm	> 0. 5 N/mm	> 0. 5 N/mm
Performance characteristics			
Breakdown voltage	> 18 kV	> 18 kV	> 18 kV
Partial discharge	≥ 1,500 VDC	≥ 1,000 VDC	≥ 1,500 VDC
Water vapor permeability	< 1.5 g/m²d	< 1.8 g/m²d	< 1.5 g/m²d
Reflectivity (EVA Side)	> 85% (visible light)	> 85% (visible light)	> 85% (visible light)
Flame spread index	< 100	< 100	< 100
Ideally suited for:	Ground mounted projects	Roof top installations	Ground mounted projects
The most important benefits	• High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI	• Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI	• High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI
Packaging & Storage			
Packaging	Ambient	Ambient	Ambient
Storage conditions	–	–	–
Shelf life	24 months	24 months	24 months
Special notes			
***1 at 150°C for 30 min**			

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS			
Company	**Coveme**	**Coveme**	**Coveme**
Product name	**dyMat PYE SPV - SPV L**	**dyMat PYE SPV L 305**	**dyMat PYE 3000 - 3000 L**[*1]
Available since	2010	2016	2010
Backsheet composition	PET / PET / Primer	PET / PET / Primer	PET / PET / Primer
Physical properties			
Thickness of each layer	–	–	–
Effective thickness	295 ± 5% µm	305 ± 5% µm	295 ± 5% µm
Width	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm
Weight	–	–	–
Density	–	–	–
Colour options - front / rear	White	White	White
Colours options - rear	White / black	White	White / black
Surface finish	–	–	–
Mechanical properties			
Tensile strength (MD/TD)	–	–	–
Elongation (MD/TD)	–	–	–
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)[*1]	–	–	–
Shrinkage (MD / TD)[*1]	–	–	–
EVA peel strength	–	–	–
Peel strength of inner layers	–	–	–
Performance characteristics			
Breakdown voltage	> 20 kV	> 20 kV	> 20 kV
Partial discharge	> 1,000 VDC	> 1,000 VDC	> 1,000 VDC
Water vapor permeability	< 2.5 g/m²d[*1]	< 2 g/m²d[*1]	< 2.5 g/m²d[*2]
Reflectivity (EVA Side)	> 82%	> 82%	> 85%
Flame spread index	< 100	< 100	< 100
The most important benefits	• Most selling product • Best price-quality ratio • More then 50 GW installed worldwide	• Extra thick > 300 µm • UL Type 1 compliant • Super high reflectant version available	• Resist Over 3,000h DHT
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	40°C / 65% RH	40°C / 65% RH	40°C / 65% RH
Shelf life	2 years	2 years	2 years
Special notes			
***1 at 150°C for 30 min**	*1 at 38°C 90% RH	*1 at 38°C 90% RH	*1 over 3,000 hours of DHT *2 at 38°C 90% RH

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS				
Company	**Coveme**	**Coveme**	**Coveme**	**Coveme**
Product name	**dyMat PYE MONO L PLUS**	**dyMat BkPYE SPV L**	**dyMat HDPYE SPV L**	**dyMat Bk HDPYE SPV L**
Available since	2017	2015	2016	2020
Backsheet composition	PET / Primer	PET black / PET / Primer	PET / PET / Primer	PET black / PET / Primer
Physical properties				
Thickness of each layer	–	–	–	–
Effective thickness	218 ± 5% µm	295 ± 5% µm	370 ± 5% µm	370 ± 5% µm
Width	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm
Weight	–	–	–	–
Density	–	–	–	–
Colour options - front / rear	White	Black	White	Black
Colours options - rear	White / black	Black	White / black	Black
Surface finish	–	–	–	–
Mechanical properties				
Tensile strength (MD/TD)	–	–	–	–
Elongation (MD/TD)	–	–	–	–
Tear strength (MD/TD)	–	–	–	–
Dimens. stability (MD/TD)*1	–	–	–	–
Shrinkage (MD / TD)*1	–	–	–	–
EVA peel strength	–	–	–	–
Peel strength of inner layers	–	–	–	–
Performance characteristics				
Breakdown voltage	> 17 kV	> 20 kV	> 21 kV	> 21 kV
Partial discharge	> 1,000 VDC	> 1,000 VDC	> 1,500 VDC	> 1,500 VDC
Water vapor permeability	< 2.2 g/m²d *1	< 2 g/m²d *1	< 1.8 g/m²d *1	< 1.8 g/m²d *1
Reflectivity (EVA Side)	> 90%	–	> 83%	–
Flame spread index	< 100	< 100	< 100	< 100
The most important benefits	• High quality monolayer PET with UV and HR stabilization across whole width • Best performance price-quality Optimized for new IEC norms	• Black on air side and cell side • Particularly indicated for BIPV	• 1,500 VDC - DTI > 300 µm • Super high reflectant version available • Best performance price-quality for 1,500 VDC	• Black on air side and cell side • 1,500 VDC - DTI > 300 µm • Particularly indicated for BIPV
Packaging & Storage				
Packaging	Roll, sheet	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	40°C / 65% RH	40°C / 65% RH	40°C / 65% RH	40°C / 65% RH
Shelf life	2 years	2 years	2 years	2 years
Special notes				
***1 at 150°C for 30 min**	*1 at 38°C 90% RH	*1 at 38°C 90% RH	*1 at 38°C 90% RH	*1 at 38°C 90% RH

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	Coveme	Coveme	Coveme	Coveme
Product name	**dyMat HDPYE C**	**dyMat HDPYE F**	**dyMat HDPYE C BKHR**	**dyMat APYE**
Available since	2021	2021	2021	2008
Backsheet composition	PET / PET / Coating	PET / PET / Coating	PET / PET / Coating	PET / Al / PET / Primer*1
Physical properties				
Thickness of each layer	–	–	–	–
Effective thickness	315 ± 5% µm	315 ± 5% µm	320 ± 5% µm	285 - 370 ± 5% µm
Width	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm
Weight	–	–	–	–
Density	–	–	–	–
Colour options - front / rear	White / black	White / black	White / black	White / black
Colours options - rear	white / black	white / black	black HR	White / black
Surface finish	–	–	–	–
Mechanical properties				
Tensile strength (MD/TD)	–	–	–	–
Elongation (MD/TD)	–	–	–	–
Tear strength (MD/TD)	–	–	–	–
Dimens. stability (MD/TD)*1	–	–	–	–
Shrinkage (MD / TD)*1	–	–	–	–
EVA peel strength	–	–	–	–
Peel strength of inner layers	–	–	–	–
Performance characteristics				
Breakdown voltage	> 20 kV	> 20 kV	> 20 kV	> 20 kV
Partial discharge	> 1,500 VDC	> 1,500 VDC	> 1,500 VDC	> 1,000 VDC
Water vapor permeability	< 2.5 g/m²d *1	< 2.5 g/m²d *1	< 2.5 g/m²d *1	< 0.005 g/m²d *2
Reflectivity (EVA Side)	> 75%	> 75%	> 45%	> 75%
Flame spread index	< 100	< 100	< 100	< 100
The most important benefits	• 1,500 VDC - DTI > 300 µm • Fluorine-free coating	• 1,500 VDC - DTI > 300 µm • Coating Fluoro based	• 1,500 VDC - DTI > 300 µm • Coating Fluoro based	• Extra moisture barrier • Different Al thickness available • Different PET and primer thickness available • Super high reflectant version available
Packaging & Storage				
Packaging	Roll, sheet	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	40°C / 65% RH	40°C / 65% RH	40°C / 65% RH	40°C / 65% RH
Shelf life	2 years	2 years	2 years	2 years
Special notes				
***1 at 150°C for 30 min**	*1 at 38°C 90% RH	*1 at 38°C 90% RH	*1 at 38°C 90% RH	*1 opt. 9, 20 and 50 µm Al; *2 at 38°C 90% RH

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	Coveme	Coveme	Coveme	Coveme
Product name	**dyMat AHDPYE SPV P**	**dyMat APYE SPV C BKHR**	**dyMat Clr PYE MONO**	**dyMat Clr HDPYE**
Available since	2021	2021	2019	2019
Backsheet composition	PET / Al / PET / Primer*1	PET / Al / PET / Coating*1	PET / Primer	PET / PET / Primer
Physical properties				
Thickness of each layer	–	–	–	–
Effective thickness	405 ± 5% µm	min 237 ± 5% max 277 µm ± 5%	268 ± 5% µm	370 ± 5% µm
Width	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm	50 - 1,500 mm
Weight	–	–	–	–
Density	–	–	–	–
Colour options - front / rear	White / black	White / black	Transparent	Transparent
Colours options - rear	White / black	black HR	Transparent	Transparent
Surface finish	–	–	–	–
Mechanical properties				
Tensile strength (MD/TD)	–	–	–	–
Elongation (MD/TD)	–	–	–	–
Tear strength (MD/TD)	–	–	–	–
Dimens. stability (MD/TD)*1	–	–	–	–
Shrinkage (MD / TD)*1	–	–	–	–
EVA peel strength	–	–	–	–
Peel strength of inner layers	–	–	–	–
Performance characteristics				
Breakdown voltage	> 20 kV	> 20 kV	> 20 kV	> 20 kV
Partial discharge	> 1,500 VDC	> 1,000 VDC	> 1,000 VDC	> 1,500 VDC
Water vapor permeability	< 0.005 g/m²d *2	< 0.005 g/m²d *2	< 2 g/m²d *1	< 1.7 g/m²d *1
Reflectivity (EVA Side)	> 82%	> 45%	–	–
Flame spread index	< 100	< 100	< 100	< 100
The most important benefits	• Extra moisture barrier • Different Alu thickness available • 1,500 VDC - DTI > 300 µm	• Extra moisture barrier • Different Alu thickness available • Different PET thickness available • Super high reflectant black in IR	• Totally transparent High quality COEX PET with UV and HR stabilization • High UV resistance • Particularly indicated for BIFACIAL cell PV and BIPV	• Totally transparent High quality COEX PET with UV and HR stabilization • 1,500 VDC - DTI > 300 µm • High UV resistance • Particularly indicated for BIFACIAL cell PV and BIPV
Packaging & Storage				
Packaging	Roll, sheet	Roll, sheet	Roll, sheet	Roll, sheet
Storage conditions	max. temperature: 40°C max. R.H.: 65%	40°C / 65% RH	40°C / 65% RH	40°C / 65% RH
Shelf life	2 years	2 years	2 years	2 years
Special notes				
***1 at 150°C for 30 min**	*1 opt. 9, 20 and 50 µm Al; *2 at 38°C 90% RH	*1 opt. 9, 20 and 50 µm Al; *2 at 38°C 90% RH	*1 at 38°C 90% RH	*1 at 38°C 90% RH

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	Coveme	Coveme	Crown
Product name	**dyMat ClrFS PYE MONO**	**dyMat ClrFS HDPYE**	**BO-L3**
Available since	2018	2018	2013
Backsheet composition	Hard Coating / PET / Primer	Hard Coating / PET / PET / Primer	PET
Physical properties			
Thickness of each layer	–	–	360 µm
Effective thickness	283 ± 5% µm	385 ± 5% µm	360 µm
Width	50 - 1,500 mm	50 - 1,500 mm	–
Weight	–	–	–
Density	–	–	–
Colour options - front / rear	Transparent	Transparent	White/ black
Colours options - rear	Transparent	Transparent	White / black
Surface finish	–	–	–
Mechanical properties			
Tensile strength (MD/TD)	–	–	≥ 210 / ≥ 210 Mpa
Elongation (MD/TD)	–	–	≥ 50% / ≥ 50%
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	–	–	–
Shrinkage (MD / TD)*1	–	–	≤ 1.5% / ≤ 1.0%
EVA peel strength	–	–	≥ 40 N/cm
Peel strength of inner layers	–	–	≥ 15 N/cm
Performance characteristics			
Breakdown voltage	> 20 kV	> 20 kV	≥ 18 kV
Partial discharge	> 1,000 VDC	> 1,500 VDC	1,000 / 1,500 VDC
Water vapor permeability	< 2.5 g/m²d *1	< 1.7 g/m²d *1	≤ 1.5 g/m²d
Reflectivity (EVA Side)	–	–	–
Flame spread index	< 100	< 100	–
The most important benefits	• Totally transparent frontsheet • Enhanced UV resistance • New Coating technology • Scratch and abrasion resistant • Matt and glossy version	• Totally transparent frontsheet • 1,500 VDC - DTI > 300 µm • Enhanced UV resistance • New Coating technology • Scratch and abrasion resistant • Matt and glossy version	• Excellent quality stability • Humidity and heat aging resistance • UV resistance stability • Excellent adhesion between backsheet and EVA • Excellent adhesion adaptability between backsheet and silicone sealant
Packaging & Storage			
Packaging	Roll, sheet	Roll, sheet	3 inch tube core, PE moisture-proof bag, Safety bracket, Outer carton packaging.
Storage conditions	40°C / 65% RH	40 °C / 65% RH	Dry sealed conditions can be kept for a year, and placed in dry environment after opened
Shelf life	2 years	2 years	1 year
Special notes			
***1 at 150°C for 30 min**	*1 at 38°C 90% RH	*1 at 38°C 90% RH	

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	Cybrid	Endurans Solar *(formerly DSM)*	Endurans Solar *(formerly DSM)*
Product name	**PPF**	**Endurans™ HP D06**	**Endurans™ HP D15**
Available since	2019	2020 *1	2020 *1
Backsheet composition	PET//ad//PET/f	HPO - Co-extruded High Performance Polyolefin	HPO - Co-extruded High Performance Polyolefin
Physical properties			
Thickness of each layer	50 / 8 /250 / 4 µm	–	–
Effective thickness	304 µm	310 µm	350 µm
Width	Up to 1,320 mm	–	–
Weight	434 g/m²	–	–
Density	1.439 g/cm³	–	–
Colour options - front / rear	White	White / black	White / black
Colours options - rear	White	White / black	White / black
Surface finish	Glossy & scratch resistant	Air side: matt; rear: shiny, smooth	Air side: matt; rear: shiny, smooth
Mechanical properties			
Tensile strength (MD/TD)	175 / 165 MPa	–	–
Elongation (MD/TD)	125% / 110%	–	–
Tear strength (MD/TD)	–	–	–
Dimens. stability (MD/TD)*1	–	< 1% / < 1%	< 1% / < 1%
Shrinkage (MD / TD)*1	≤ 0.8% / ≤ 0.5%	< 1% / < 1%	< 1% / < 1%
EVA peel strength	> 80 N/mm	Cannot peel off	Cannot peel off
Peel strength of inner layers	NA*1	Cannot peel off	Cannot peel off
Performance characteristics			
Breakdown voltage	20 kV	22 kV*2	24 kV*2
Partial discharge	> 1,500 VDC	> 1,000 VDC*2	> 1,500 VDC*2
Water vapor permeability	< 1.9 g/m²d	0.8 g/m²d*2	0.6 g/m²d*2
Reflectivity (EVA Side)	82%*2	93% *2,*3 for white	95% *2,*3 for white
Flame spread index	10	NA	NA
The most important benefits	• No risk of delamination due to mono-layer structure • High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • One-step manufacturing for cost down roadmap • Meets latest IEC 61730-1 on DTI without excessive thickness	• Best Performance-Cost ratio for all climates • Excellent moisture barrier, suitable for a wide range of modules • Outstanding UV resistance and mechanical properties • No delamination • Superior sand abrasion properties for desert application • Fully recyclable • Does not contain toxic materials • 30% lower carbon footprint *3	• Best Performance-Cost ratio for all climates • Excellent moisture barrier, suitable for a wide range of modules • Outstanding UV resistance and mechanical properties • No delamination • Superior sand abrasion properties for desert application • Fully recyclable • Does not contain toxic materials • 30% lower carbon footprint *3
Packaging & Storage			
Packaging	100, 200, 400 m*3 & sheets	–	–
Storage conditions	–	≤ 30 °C / ≤ 50% RH	≤ 30 °C / ≤ 50% RH
Shelf life	1.5 years	1 year	1 year
Special notes			
***1 at 150°C for 30 min**	*1 Monolayer backsheet; *2 Referring to 380 - 1,100 nm / ISO 9050; *3 Standard	*1 based on HPO technology platform; *2 Typical value; *3 Referring to 380 - 1100 nm	*1 based on HPO technology platform; *2 Typical value; *3 Referring to 380 - 1100 nm

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS

Company	FERON	FERON	FERON	FERON
Product name	**CPx 1000**	**CPx 1500**	**neoX CPE 300/50**	**neoX CPE 150/50**
Available since	2018	2019	2016	2015
Backsheet composition	Coating / PO	Coating / PO	Coating / PET / E-Layer	Coating / PET / E-Layer
Physical properties				
Thickness of each layer	10 / 170 µm	10 / 340 µm	10 / 300 / 50 µm	10 / 150 / 50 µm
Effective thickness	176 µm	355 µm	365 µm	215 µm
Width	1,000 mm or on request	1,000 mm or on request	1,000 mm or on request	1,000 mm or on request
Weight	170 g/m²	340 g/m²	495 g/m²	285 g/m²
Density	0.96 g/cm³	0.96 g/m³	1.32 g/cm³	1.32 g/cm³
Colour options - front / rear	White / black (air side)	White (air side)	White (air side)	White (air side)
Colours options - rear	White / black (cell side)	White (cell side)	White / black (cell side)	White / black (cell side)
Surface finish	Smooth & scratch resistant	Smooth & scratch resistant	Smooth & scratch resistant	Smooth & scratch resistant
Mechanical properties				
Tensile strength (MD/TD)	35 / 25 MPa	35 / 25 MPa	150 / 140 MPa	150 / 140 MPa
Elongation (MD/TD)	600% / 600%	600% / 600%	170% / 140%	170% / 140%
Tear strength (MD/TD)	17 / - N/mm	17 / - N/mm	11 / 18 N/mm (tear resistance)	11 / 18 N/mm (tear resistance)
Dimens. stability (MD/TD)*1	–	–	–	–
Shrinkage (MD / TD)*1	1.2% / 0.0%	1.2% / 0.0%	1.5% / 0.5%	1.5% / 0.5%
EVA peel strength	4 N/mm	4 N/mm	7 N/mm	7 N/mm
Peel strength of inner layers	– *1	– *1	≥ 1.5 N/mm *1	≥ 1.5 N/mm *1
Performance characteristics				
Breakdown voltage	> 15 kV	> 15 kV	> 20 kV	> 15 kV
Partial discharge	> 1,000 VDC	> 1,500 VDC	> 1,500 VDC	> 1,000 VDC
Water vapor permeability	1.5 g/m²d	1.5 g/m²d	1.9 g/m²d	3.1 g/m²d
Reflectivity (EVA Side)	90% *2	90% *2	80 - 90% *2	80 - 90% *2
Flame spread index	NA	NA	NA	NA
The most important benefits	• 15,000 hr Xenon ISO 4892-2 • DTI conformity • DHT > 8,000 hrs	• 15,000 hrs Xenon ISO 4892-2 • DTI conformity • DHT > 8,000 hrs	• 25,000 hrs Xenon ISO 4892-2 • DTI conformity • DHT > 3,000 hrs	• 25,000 hrs Xenon ISO 4892-2 • DTI conformity • DHT > 3,000 hrs
Packaging & Storage				
Packaging	On customer request	On customer request	On customer request	On customer request
Storage conditions	5 - 40°C / 30 - 70% RH	5 - 40°C / 30 - 70% RH	5 - 40°C / 30 - 70% RH	5 - 40°C / 30 - 70% RH
Shelf life	1 year	1 year	1 year	1 year
Special notes				
***1 at 150°C for 30 min**	*1 Inseparable (mono-film) *2 Solar weighted acc. IEC 62805-2	*1 Inseparable (mono-film) *2 Solar weighted acc. IEC 62805-2	*1 PET-E-layer *2 Solar weighted acc. IEC 62805-2	*1 PET-E-layer *2 Solar weighted acc. IEC 62805-2

NON-FLUOROPOLYMER BASED BACKSHEET PRODUCTS				
Company	**FERON**	**FERON**	**Shingi**	**Shingi**
Product name	**neoX CPC 300**	**neoX CPC 150**	**Armour PO300BS**	**Armour PO350BS**
Available since	2016	2015	2017	2017
Backsheet composition	Coating / PET / Coating	Coating / PET / Coating	PET / PET / Primer	PET / PET / Primer
Physical properties				
Thickness of each layer	10 / 310 / 10 µm	10 / 150 / 10 µm	300 µm	350 µm
Effective thickness	330 µm	170 µm	170 µm	300 µm
Width	1,000 mm or on request	1,000 mm or on request	Up to 1,350 mm	Up to 1,350 mm
Weight	460 g/m²	245 g/m²	370 g/m²	470 g/m²
Density	1.43 g/cm³	1.44 g/cm³	1.233 g/cm³	1.233 g/cm³
Colour options - front / rear	White (air side)	White (air side)	White	White
Colours options - rear	White / black (cell side)	White/black (cell side)	White / black	White / black
Surface finish	Smooth & scratch resistant	Smooth & scratch resistant	Glossy	Glossy
Mechanical properties				
Tensile strength (MD/TD)	180 / 1,950 MPa	190 / 190 MPa	> 160 / 150 MPa	> 170 / 160 MPa
Elongation (MD/TD)	205% / 180%	160% / 140%	> 100% / 100%	> 100% / 100%
Tear strength (MD/TD)	33 / 173 N/mm	13 / 13 N/mm	–	–
Dimens. stability (MD/TD)*1	–	–	–	–
Shrinkage (MD / TD)*1	1.5% / 0.5%	1.5% / 0.5%	1.5% / 0.5%	1.5% / 0.5%
EVA peel strength	7 N/mm	7 N/mm	> 8 N/mm	> 8 N/mm
Peel strength of inner layers	– *1	– *1	> 5 N/cm	> 5 N/cm
Performance characteristics				
Breakdown voltage	> 20 kV	> 15 kV	> 18 kV	> 18 kV
Partial discharge	> 1,500 VDC	> 1,000 VDC	≥ 1,000 VDC	≥ 1,500 VDC
Water vapor permeability	1.9 g/m²d	3.9 g/m²d	< 1.5 g/m²d	< 1.5 g/m²d
Reflectivity (EVA Side)	80 - 90% *2	80 - 90% *2	> 85% (visible light)	> 85% (visible light)
Flame spread index	NA	NA	< 100	< 100
The most important benefits	• 25,000 hrs Xenon ISO 4892-2 • DTI conformity • DHT > 3,000 hrs	• 25,000 hrs Xenon ISO 4892-2 • DTI conformity • DHT > 3,000 hrs	• High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI • One-step manufacturing for cost down, high productivity and lower production losses roadmap	• High reflectivity • Excellent UV and hydrolysis resistance across entire material thickness • Meets latest IEC 61730-1 on DTI • One-step manufacturing for cost down, high productivity and lower production losses roadmap
Packaging & Storage				
Packaging	On customer request	On customer request	100, 200 linear meter	100, 200 linear meter
Storage conditions	5 - 40°C / 30 - 70% RH	5 - 40°C / 30 - 70% RH	Ambient	Ambient
Shelf life	1 year	1 year	24 months	24 months
Special notes				
***1 at 150°C for 30 min**	*1 Inseparable (mono-film); *2 Solar weighted acc. IEC 62805-2	*1 Inseparable (mono-film); *2 Solar weighted acc. IEC 62805-2		

EVA BASED ENCAPSULATION PRODUCTS

Company	Crown	Cybrid	Hangzhou First	Hangzhou First
Product name	**ISARD 2180**	**T11**	**Su406**	**Su806**
Available since	2016	2014	2017	2017
Curing class	Fast cure	Fast cure	Super fast cure	Super fast cure
Physical properties				
Standard thickness / range	300 - 800 µm	200 - 800 µm	500 / 200 - 800 µm	450 / 200 - 800 µm
Standard width / range	≤ 2,200 mm	980 / 200 - 1,320 mm	980 / 200 - 2,200 mm	980 / 200 - 2,200 mm
Density	0.948 g/cm³	0.95 - 0.96 g/cm³	0.95 - 0.96 g/cm^3	0.95 - 0.96 g/cm^3
Color	–	Clear	Clear	Clear
Surface finish	–	Embossed	Embossed	Embossed
Mechanical & chemical properties				
Tensile strength (MD/TD)	≥ 16 / ≥ 16 Mpa	> 12 / > 12 MPa	> 12 / > 12 MPa	> 12 / > 12 MPa
Elongation (MD/TD)	≥ 400% / ≥ 400%	> 450% / > 450%	> 450% / > 450%	> 450% / > 450%
Shrinkage (MD/TD)	< 3% / < 1.5%	< 3% / < 1.5%	< 3% / < 1.5%	< 3% / < 1.5%
Adhesive strength to glass	≥ 70 N/cm	> 60 N/cm	> 60 N/cm	> 60 N/cm
Adhesive strength to backsheet	≥ 40 N/cm	> 40 N/cm	> 40 N/cm	> 40 N/cm
Processing conditions				
Lamination temperature	140 - 150°C	140 - 170°C	140 - 170°C	140 - 170°C
Vacuum time	5 - 6 min	3 - 6 min	3 - 6 min	3 - 6 min
Press time	10 - 12 min	7 - 10 min	5 - 10 min	5 - 10 min
Crosslinking temperature window	140 - 150°C	140 - 170°C	140 - 170°C	140 - 170°C
VA Content	–	28 ± 2%	28 ± 2%	28 ± 2%
Gel Content	≥ 75%	> 75%	> 75%	> 75%
Performance characteristics				
Light transmittance	≥ 80% / 280 - 380 nm*1	> 91% / 1,100 - 380 nm	> 91% / 1,100 - 380 nm	> 91% / 1,100 - 380 nm
UV cut-off	–	–	NA	360 nm
Refractive Index	–	1.48 - 1.49	1.48 - 1.49	1.48 - 1.49
Reflectivity (rear EVA)	–	NA	NA	NA
Volume Resistivity	> 1.0*10^{15} Ohm.cm	> 1*10^{15} Ohm.cm	> 1*10^{15} Ohm.cm	> 1*10^{15} Ohm.cm
Water absorption at 20°C for 24 h	–	< 0.1 wt%	< 0.1 wt%	< 0.1 wt%
The most important benefits	• Can effectively prevent the risk of PID components • The best light transmittance to ensure efficiency of power generation components • Excellent adhesion retention after aging	• Short lamination • PID resistance • High transmittance	• Short lamination • PID resistance • High transmittance	• Short lamination • PID resistance • UV cut-off
Delivery & Storage				
Packaging	150 m/roll normally	Roll, Vacuum packing, PE bags	Rolls	Rolls
Storage conditions	≤ 30°C / ≤70% RH	0 - 30°C / < 60% RH	0 - 30°C / < 60% RH	0 - 30°C / < 60% RH
Shelf life	6 Months	6 Months	6 Months	6 Months
Special notes				
	*1 ≥ 91% / 380 - 1,100 nm			

EVA BASED ENCAPSULATION PRODUCTS

Company	Hangzhou First	Hangzhou First	Hangzhou First	Hangzhou First
Product name	**F806W**	**F406PS**	**F806PS**	**F406P**
Available since	2015	2014	2014	2013
Curing class	Fast cure	Fast cure	Fast cure	Fast cure
Physical properties				
Standard thickness / range	450 / 200 - 800 µm	500 / 200 - 800 µm	450 / 200 - 800 µm	500 / 200 - 800 µm
Standard width / range	980 / 200 - 2,200 mm	980 / 200 - 2,200 mm	980 / 200 - 2,200 mm	980 / 200 - 2,200 mm
Density	1 - 1.02 g/cm^3	0.95 - 0.96 g/cm^3	0.95 - 0.96 g/cm^3	0.95 - 0.96 g/cm^3
Color	White	Clear	Clear	Clear
Surface finish	Embossed	Embossed	Embossed	Embossed
Mechanical & chemical properties				
Tensile strength (MD/TD)	> 16 / > 16 MPa	> 16 / > 16 MPa	> 16 / > 16 MPa	> 16/ > 16 MPa
Elongation (MD/TD)	≥ 400% / ≥ 400%	> 450% / > 450%	> 450% / > 450%	> 450% / > 450%
Shrinkage (MD/TD)	< 5% / < 2%	< 3% / < 1.5%	< 3% / < 1.5%	< 3% / < 1.5%
Adhesive strength to glass	> 60 N/cm	> 60 N/cm	> 60 N/cm	> 60 N/cm
Adhesive strength to backsheet	> 40 N/cm	> 40 N/cm	> 40 N/cm	> 40 N/cm
Processing conditions				
Lamination temperature	140 - 160°C	140 - 160°C	140 - 160°C	140 - 160°C
Vacuum time	3 - 6 min	3 - 6 min	3 - 6 min	3 - 6 min
Press time	6 - 14 min	6 - 12 min	6 - 12 min	6 - 14 min
Crosslinking temperature window	135 - 165°C	135 - 165°C	135 - 165°C	135 - 165°C
VA Content	26 ± 2%	28 ± 2%	28 ± 2%	28 ± 2%
Gel Content	> 75%	> 75%	> 75%	> 75%
Performance characteristics				
Light transmittance	< 10% / 1,100 - 380 nm	> 91% / 1,100 - 380 nm	> 91% / 1,100 - 380 nm	> 91% / 1,100 - 380 nm
UV cut-off	NA	NA	360 nm	NA
Refractive Index	NA	1.48 - 1.49	1.48 - 1.49	1.48 - 1.49
Reflectivity (rear EVA)	> 90% / 1,100 - 400 nm	NA	NA	NA
Volume Resistivity	> 1*10^{14} Ohm.cm	> 1*10^{15} Ohm.cm	> 1*10^{15} Ohm.cm	> 1*10^{15} Ohm.cm
Water absorption at 20°C for 24 h	< 0.2 wt%	< 0.1 wt%	< 0.1 wt%	< 0.1 wt%
The most important benefits	• High reflectivity • White • No white over flow	• Snail trail resistance • PID resistance • High transmittance	• Snail trail resistance • PID resistance • UV cut-off	• PID resistance • High transmittance • Excellent durability
Delivery & Storage				
Packaging	Rolls	Rolls	Rolls	Rolls
Storage conditions	0 - 30°C / < 60% RH	0 - 30°C / < 60% RH	0 - 30°C / < 60% RH	0 - 30°C / < 60% RH
Shelf life	6 Months	6 Months	6 Months	6 Months
Special notes				

EVA BASED ENCAPSULATION PRODUCTS

Company	Hangzhou First	HIUV	HIUV
Product name	**F806P**	**S201MT1**[*1]	**S201MT2**[*1]
Available since	2013	2012	2012
Curing class	Fast cure	Fast cure	Fast cure
Physical properties			
Standard thickness / range	450 / 200 - 800 µm	600 / 300 - 1,200 µm	600 / 300 - 1,200 µm
Standard width / range	980 / 200 - 2,200 mm	985 / 300 - 2,100 mm	985 / 300 - 2,100 mm
Density	0.95 - 0.96 g/cm^3	0.96 g/cm^3	0.96 g/cm^3
Color	Clear	Transparent	Transparent
Surface finish	Embossed	Double frosted; pyramid embossing	Double frosted; pyramid embossing
Mechanical & chemical properties			
Tensile strength (MD/TD)	> 16/ > 16 MPa	≥ 18 / ≥ 18 Mpa	≥ 18 / ≥ 18 Mpa
Elongation (MD/TD)	> 450% / > 450%	≥ 500%	≥ 500%
Shrinkage (MD/TD)	< 3% / < 1.5%	≤ 4% / ≤ 2%	≤ 4% / ≤ 2%
Adhesive strength to glass	> 60 N/cm	≥ 60 N/cm	≥ 60 N/cm
Adhesive strength to backsheet	> 40 N/cm	≥ 50 N/cm	≥ 50 N/cm
Processing conditions			
Lamination temperature	140 - 160°C	140 - 170°C	140 - 170°C
Vacuum time	3 - 6 min	5 - 7 min	5 - 7 min
Press time	6 - 14 min	9 - 11 min	9 - 11 min
Crosslinking temperature window	135 - 165°C	135 - 150°C	135 - 150°C
VA Content	28 ± 2%	28.5 ± 2%	28.5 ± 2%
Gel Content	> 75%	80 - 95%	80 - 95%
Performance characteristics			
Light transmittance	> 91% / 1,100 - 380 nm	≥ 91% / 380 - 1,100 nm	≥ 91% / 380 - 1,100 nm
UV cut-off	360 nm	≤ 250 nm	≤ 360 nm
Refractive Index	1.48 - 1.49	1.48	1.48
Reflectivity (rear EVA)	NA	NA	NA
Volume Resistivity	> 1*10^{15} Ohm.cm	≥ 1*10^{15} Ohm.cm	≥ 1*10^{15} Ohm.cm
Water absorption at 20°C for 24 h	< 0.1 wt%	≤ 0.10 wt%	≤ 0.10 wt%
The most important benefits	• PID resistance • UV cut-off • Excellent durability	• Excellent weather ability • Excellent anti-PID performance • No snail tracks • High light transmittance • High laminate yield	• Excellent weather ability • Excellent anti-PID performance • No snail tracks • High light transmittance • High laminate yield
Delivery & Storage			
Packaging	Rolls	Roll, Vacuum packing, carton	Roll, Vacuum packing, carton
Storage conditions	0 - 30°C / < 60% RH	≤ 35°C / ≤ 75% RH	≤ 35°C / ≤ 75% RH
Shelf life	6 Months	6 Months	6 Months
Special notes			
		*1 Transparent top EVA	*1 Transparent bottom EVA

EVA BASED ENCAPSULATION PRODUCTS

Company	HIUV	SVECK	SVECK
Product name	**S201W**[*1]	**CO-556**	**SV-15296P/SV-15297P**
Available since	2013	2020	2014
Curing class	Fast cure	Fast cure	Fast cure
Physical properties			
Standard thickness / range	500 / 300 - 1,200 µm	450 - 800 µm	450 / 400 - 800 µm
Standard width / range	985 / 300 - 2,100 mm	985 - 1,320 mm	985 / 970 - 1,150 mm
Density	1 g/cm3	–	0.95 - 0.96 g/cm³
Color	White	Clear	Clear
Surface finish	Double frosted	Embossed	Embossed
Mechanical & chemical properties			
Tensile strength (MD/TD)	≥ 16 / ≥ 16 Mpa	≥ 6 Mpa	> 12 / > 12 MPa
Elongation (MD/TD)	≥ 500%	≥ 400%	> 550% / > 550%
Shrinkage (MD/TD)	≤ 4% / ≤ 2%	< 3% / < 2%	< 3% / < 1.5%
Adhesive strength to glass	≥ 60 N/cm	> 70 N/cm	> 60 N/cm
Adhesive strength to backsheet	≥ 50 N/cm	> 50 N/cm	> 60 N/cm
Processing conditions			
Lamination temperature	140 - 170°C	148 - 153°C	138 - 150°C
Vacuum time	5 - 7 min	6 - 7 min	3 - 6 min
Press time	9 - 11 min	12 - 15 min	5 - 10 min
Crosslinking temperature window	135 - 150°C	148 - 153°C	138 - 150°C
VA Content	28.5 ± 2%	–	28 ± 2%
Gel Content	80 - 95%	> 70%	> 80%
Performance characteristics			
Light transmittance	NA	≥ 80% / 280 - 380 nm[*1]	> 91% / 1,100 - 380 nm
UV cut-off	NA	280 nm	280 nm
Refractive Index	NA	1.48	1.48
Reflectivity (rear EVA)	≥ 91 / 380 - 1,100 nm	-	360 nm
Volume Resistivity	≥ $1*10^{14}$ Ohm.cm	≥ $1*10^{15}$ Ohm.cm	≥ $1*10^{15}$ Ohm.cm
Water absorption at 20°C for 24 h	≤ 0.10 wt%	< 0.1 wt%	< 0.1 wt%
The most important benefits	• EB pre-crosslinking technology without overflow & fold • General laminating process • High reflectivity • Excellent weather ability • High laminate yield	• Solve the bubble issues during lamination • <5% loss under 85% temperature 85% humidity • 18 min lamination time in total	• 280 - 380 nm wavelength light transmission over 85% • <5% loss under 85% temperature 85% humidity • 12 min lamination time in total"
Delivery & Storage			
Packaging	Roll, Vacuum packing, carton	Roll, Vacuum packing, carton, stacked	Roll, Vacuum packing, carton, stacked
Storage conditions	≤ 35°C / ≤ 75% RH	≤ 30°C / ≤ 60% RH	23 ± 2°C / –
Shelf life	6 Months	6 Months	6 Months
Special notes			
	*1 white EVA	*1 ≥ 91% / 380nm - 1100 nm	

NON-EVA BASED ENCAPSULATION PRODUCTS

Company	Borealis	Cybrid	Hangzhou First
Product name	**Quentys BPO 8828F, BPO8828S, BPO8828UV**	**T22h**	**TF4**
Available since	2016	2017	2015
Material	Polyolefin	Polyolefin (EVA/POE Co extrusion)	Polyolefin
Curing class	Thermoplastic*1	Fast	Fast cure
Physical properties			
Standard thickness / range	400 - 600 µm / Flexible	–	450 / 200 - 800 µm
Standard width / range	990 - 1,250 mm / Flexible	990 - 1,350 mm	980 / 200 - 2,200 mm
Density	0.945 g/cm³	0.88 g/cm^3	0.87 g/cm^3
Color	White / clear	White / clear	Clear
Surface finish	Embossed	Embossed	Embossed
Mechanical & chemical properties			
Tensile strength (MD/TD)	> 18 MPa	≥ 5 Mpa	> 10 / > 10 MPa
Elongation (MD/TD)	–	≥ 500%	> 500 / > 500%
Shrinkage (MD/TD)	< 3%	≤ 3%	< 2% / < 1%
Adhesive strength to glass	> 100 N/cm	≥ 60 N/cm	> 60 N/cm
Adhesive strength to backsheet	> 40 N/cm	≥ 60 N/cm	> 40 N/cm
Processing conditions			
Lamination temperature	120 - 170°C	145°C	140 - 160°C
Vacuum time	Depending on BOM & laminator type	5 min	4 - 6 min
Press time	Depending on BOM & laminator type	10 min	12 - 20 min
Gel Content	NA	≥ 80%	> 60%
Performance characteristics			
Light transmittance	> 89% / 400 - 1,150 nm*1	≥ 91% / 385 - 1,100 nm	> 90% / 1,100 - 380 nm
UV cut-off	< 300 nm, for BPO8828UV 375 nm	–	NA
Refractive index	1.49	1.4	1.49
Reflectivity (rear film)	> 89% / 400 - 1,150 nm	–	–
Volume resistivity	> 1 x 10^{15} Ohm.cm	≥ 2 x 10^{16} Ohm.cm	> 1 x 10^{15} Ohm.cm
Water absorption at 20°C for 24 h	–	–	< 0.1 wt %
The most important benefits	• No crosslinking required • Very short lamination cycle • Superior reliability in the field, high power retention • Fully recyclable film • Enables easy module recycling	• –	• Low WVTR • Long term PID resistance • Excellent durability • High transmittance
Delivery & Storage			
Packaging	Rolls packed in plastic & cardboard boxes	Roll (150 / 200 m)	Roll
Storage conditions	< 35°C / 60% RH	0 - 30°C / ≤ 55% RH	0 - 30°C / < 60% RH
Shelf life	6 - 12 Months	≤ 6 Months	6 Months
Special notes			
	*1 non-crosslinking *2 450 µm film with 1 mm glass		

NON-EVA BASED ENCAPSULATION PRODUCTS				
Company	**Hangzhou First**	**HIUV**	**HIUV**	**SVECK**
Product name	**TF8**	**P507**	**P506M**	**SE-556 SE-557**
Available since	2015	2017	2018	2015
Material	Polyolefin	3-layer coextruded POE*1	POE*1	POE
Curing class	Fast cure	Fast cure	Non - crosslinking	Fast cure
Physical properties				
Standard thickness / range	450 / 200 - 800 µm	500 / 300 - 1,200 µm	500 / 300 - 1,200 µm	500 / 400 - 900 µm
Standard width / range	980 / 200 - 2,200 mm	985 / 300 - 2,100	985 / 300 - 2,100	985 / 970 - 1,150
Density	0.87 g/cm^3	0.92 g/cm^3	0.9 g/cm^3	0.87 g/cm^3
Color	Clear	Transparent	Transparent	Transparent
Surface finish	Embossed	Double frosted	Double frosted	Embossing
Mechanical & chemical properties				
Tensile strength (MD/TD)	> 10 / > 10 MPa	≥ 12 / ≥ 12 Mpa	–	≥ 18 / ≥ 18 Mpa
Elongation (MD/TD)	> 500 / > 500%	≥ 500%	–	≥ 500%
Shrinkage (MD/TD)	< 2% / < 1%	≤ 4% / ≤ 2%	≤ 4% / ≤ 2%	≥ 3% / ≥ 2%
Adhesive strength to glass	> 60 N/cm	≥ 60 N/cm	≥ 60 N/cm	≥ 70 N/cm
Adhesive strength to backsheet	> 40 N/cm	≥ 50 N/cm	≥ 50 N/cm	≥ 50 N/cm
Processing conditions				
Lamination temperature	140 - 160°C	140 - 170°C	140 - 170°C	140 - 160°C
Vacuum time	4 - 6 min	5 - 7 min	5 - 7 min	5 - 7 min
Press time	12 - 20 min	9 - 11 min	9 - 11 min	11 - 13 min
Gel Content	> 60%	≥ 70%	< 5%	≥ 70%
Performance characteristics				
Light transmittance	> 90% / 1,100 - 380 nm	≥ 91% / 380 - 1,100 nm	≥ 85% / 380 - 1,100 nm	≥ 91% / 380 - 1,100 nm
UV cut-off	360 nm	≤ 250 nm	≤ 360 nm	≥ 280 nm
Refractive index	1.49	1.48	1.48	1.48
Reflectivity (rear film)	–	NA	NA	NA
Volume resistivity	> 1 x 10^{15} Ohm.cm	≥ 1 x 10^{15} Ohm.cm	≥ 1 x 10^{15} Ohm.cm	≥ 1 x 10^{15} Ohm.cm
Water absorption at 20°C for 24 h	< 0.1 wt%	≤ 0.05 wt%	≤ 0.05 wt%	≤ 0.05 wt%
The most important benefits	• Low WVTR • Long term PID resistance • Excellent durability • UV cut-off	• Three layer co-extrusion POE (structure: EVA /POE / EVA) • Excellent weather ability • Excellent anti-PID performance • Use for P-PERC; N-TopCON;N-HJT • Save 25%~35% laminating time, boost production capacity • High laminate yield with less bubbles	• Use for thin film PV modules like: CIGS, CdTe: Perovskite • Excellent stable and weather ability • High laminate yield with less bubbles	• Excellent weather ability • Excellent anti-PID performance • No snail tracks • Excellent durability • Low shrinkage rate
Delivery & Storage				
Packaging	Roll	Roll, vacuum packing, carton	Roll, vacuum packing, carton	Roll, vacuum packing, carton
Storage conditions	0 - 30 °C / < 60% RH	≤ 35 °C / ≤ 75% RH	≤ 35 °C / ≤ 75% RH	≤ 30 °C / ≤ 60% RH
Shelf life	6 Months	3 Months	6 Months	6 Months
Special notes				

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