

FREQUENTLY ASKED QUESTIONS REGARDING STR's UF EVA

What is UF EVA?

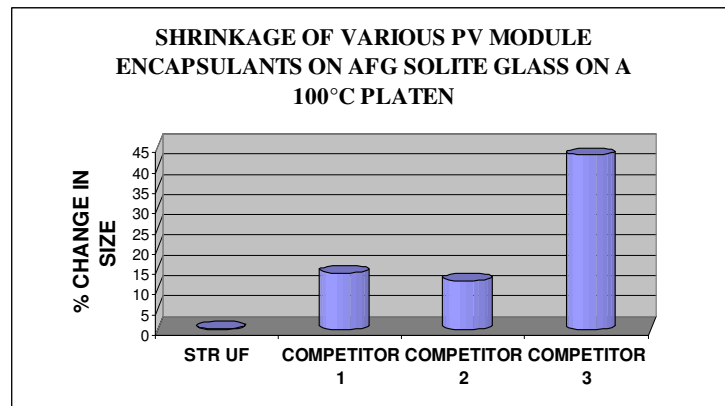
UF stands for **User Friendly EVA** – EVA sheet that handles better and laminates easier.

What makes it UF?

UF is the result of processing that eliminates the residual stresses imparted to the material in the conventional extrusion process along with a unique method of applying a uniform, non-sticky texture.

Why is it more process friendly?

First and foremost, the product does not shrink during lamination. All other encapsulant products on the market do, and the lamination process must be adjusted to overcome this inherent problem with conventionally extruded materials. The less an encapsulant shrinks during lamination, the wider the process window is. This translates to increased throughput and reduced cost.



Second, the UF material has a very uniform and repeatable texture to facilitate de-airing and avoid premature adhesion, which can result in entrapped air. The texture also renders the EVA non-tacky for ease of handling in the lay-up step.

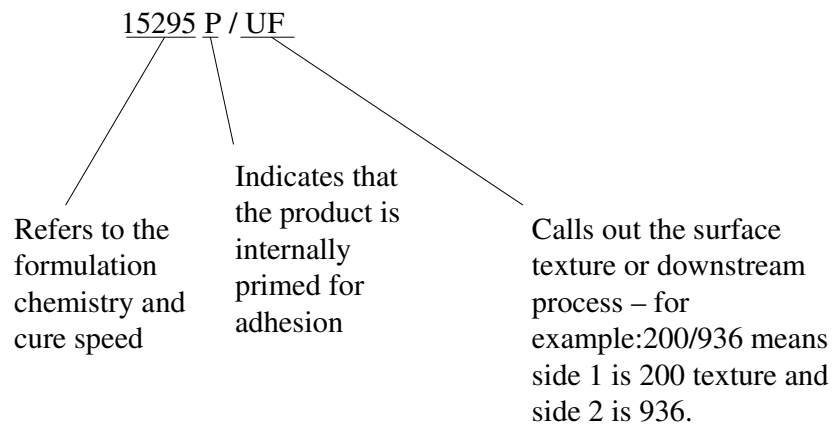
Also, the roll quality of the UF product is second-to-none, enabling automation in unwinding and lay-up, while reducing or eliminating the edge-trimming process.

Are there changes to the formulation?

No. The product going into and coming out of the extruder is exactly the same as it has always been. STR holds the formula of each of our encapsulants absolutely sacred. If we do change or modify a formulation, we assign a new product code and advise our customers of the change, as well as the benefits they can expect. The customer is given the opportunity to switch on the merits of performance. We don't even switch suppliers without notification and prior approval of our customers.

How do we decipher the product code?

The first part of the product code calls out the formulation; it is completely independent of the rest of the code. If it reads “15295P”, then the chemistry is identical to all other products beginning with “15295P”, regardless of what follows in the code.



The “UF” in the example above describes not only the texture, but also the process by which the sheet is finished. UF product can be made with any formulation we offer.

If we switch to the UF product, do we have to re-certify?

No. According to Section 3.0 of the Guidelines for Retest Requirements, published by the Photovoltaic Testing Laboratory at Arizona State University, dated 2/22/99, the following changes trigger a partial re-qualification:

- (Change in Encapsulant System)*
- ***Different Materials***
 - ***Different Additives***
 - ***Change in Edge Seal***
 - ***Different Primer or Method of Priming***
 - ***Modification of Encapsulation Process (Time, Temperature, Pressure)***

Since none of the above applies to a change in texture, and the materials are identical in formulation, switching to the UF EVA will not trigger the need for re-qualification.

Do we have to change the cycle to use it?

No. You will be able to use the UF product without changing your laminator settings. You may want to change the settings to get the benefit of speed later on, but you can start by dropping it into your existing process.

Why does it cost more?

The UF process requires extra steps to finish the extruded sheet, as well as a more expensive (and robust) release liner. There is a higher capital cost for the equipment needed to produce the product and a longer, more involved set-up routine to get it into production.

We also take more of the trim loss in this process by trimming in line to hold ± 3 mm on the width; in fact, this is shifting all or part of the trim cost back to STR.

On a total cost basis, however, one could certainly make the argument that the UF product is well worth the extra \$0.02 per square foot - at least that's what our customers are telling us.

How can the product be more expensive but less costly?

The UF product invariably reduces the level of rejected panels. We've had customers report significant reductions in rejects due to cell registration, bubbles, and voids. In most cases, these types of module flaws are reduced to a very small fraction of one percent of all products made, and in many cases, totally eradicated.

Reducing rejects, of course, has the potential to more than offset a marginal increase in the cost of the EVA.

Increased throughput also saves money in the big picture by making more productive use of existing equipment, labor, and floor space. Avoiding the need for additional laminators and ancillary equipment preserves precious capital funds.

How can we get increased throughput by switching to UF EVA?

Due to the stability of the UF product, it is able to tolerate more process variation in the laminator. We've learned that the conventional lamination cycle is dictated by two main concerns: de-airing, and curing.

In the de-airing step, the module "lamwich" is heated as the vacuum is drawn. These simultaneous processes actually compete with one another because as the EVA is melting; it's becoming very sticky, and has the potential to entrap air - so the vacuum has to be strong enough to evacuate the air before the EVA melts and traps it (resulting in a bubble). Complicating this delicate balance is the fact that all conventionally produced (non-UF) EVA is shrinking at the same time!

The propensity to shrink must be overcome by adjusting the timing of the cycle to optimize the above parameters: possible but not necessarily simple.

The UF product alleviates the concerns about timing the cycle to compensate for shrinkage. The uniform texture also facilitates de-airing very effectively.

The end result is a material that affords the user more flexibility and less sensitivity to normal process variation in the laminator.

Do you offer UF EVA with fiberglass scrim or TPE attached?

No. Technically, it's possible to make such a construction, but it's really not necessary. This is true because STR's process of laminating the conventional EVA to films such as scrim and TPE yields a dimensionally stable product.

This is the case because our lamination process has many of the beneficial attributes of the UF process, which reduce residual stress. And the films to which we are laminating provide rigidity and dimensional stability.

Making the laminates with the UF process would add cost without benefit – something we think you'd rather avoid.

Are there any drawbacks to using the product?

None.

Are there any other benefits we didn't discuss?

Yes. The UF process is completely dry. No water is used in any step of manufacture. Moisture can interfere with silane bonding to many surfaces including glass and oxidized metals. If you have a moisture-sensitive module design, then the UF is a must.

We don't really have that many complaints about our present material, so why should we be so concerned about shrinkage?

Two very big reasons: First, because your process has been designed to work around the fact that the EVA is distorting. This is likely costing you time in the pump down step that could be eliminated, or it's forcing you to operate at a lower platen temperature to mitigate the effects of shrinkage.

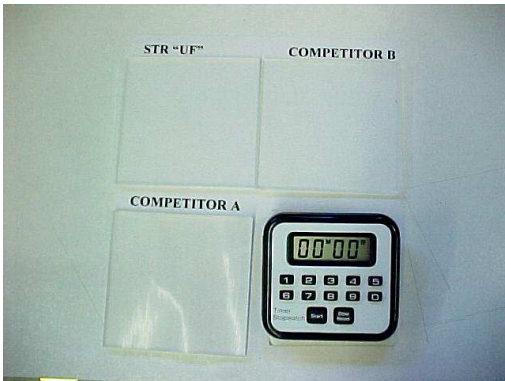
Second, the higher the shrinkage, the more narrow the process window is in the first part of the cycle.

The beginning of the lamination cycle, whether you're laminating and curing in the laminator or post curing in an oven, is the most critical part of the process. Think about it this way – you load the module onto the hot platen, close the lid, and then draw the vacuum in both chambers. Before the press is applied, you've basically spent between four and six minutes with the module sitting on a hotplate WITHOUT the benefit of the diaphragm holding things in place (typically the diaphragm is against the top chamber wall).

During this period, the lamwich is heating up and the EVA is free to move. We've taken a series of photographs to help explain why this is critical.



The Apparatus: A temperature-controlled hotplate set at 212°F (100°C) – which is mild compared to the maximum platen temperature. If repeated at a higher temperature, a more significant change between UF and the competitive materials is observed. This temperature represents the approximate average glass temperature, considering bowing off the platen and the lack of convective heat transfer in a vacuum.



The Test: Samples of various EVA's are cut to match the exact shape of a piece of 3mm thick AFG Solite glass (with stipple pattern). The glass is put onto the hotplate and the EVA samples are quickly aligned with the edges of the glass so that shrinkage can be observed. The timer is started as soon as the samples are put on the hotplate. The paper is used to identify the samples and facilitate loading onto the hotplate.



After 17 seconds: Everything is aligned and the glass is beginning to heat up. You are looking at clear EVA on clear glass – somewhat difficult to photograph but certainly a simulation of reality nonetheless. We'll get a little closer with the camera later on. At this point in an actual laminator, the cover is probably still open and some modules are still being loaded.



At 44 seconds: Just a quick shot of the apparatus again with the temperature controller in view. We are stabilized at about 100°C. The temperature uniformity of the platen is very good – within a couple of degrees across the surface.



At 1 minute 15 seconds: We are beginning to see Competitor A (“the A sample”) EVA distorting badly along the upper and lower edge of the sample. The B sample is shrinking from the left and right edges, and growing past the upper and lower edges of the glass. The UF dimensions are unchanged. By now in the real cycle, the top is closed and the vacuum is being drawn.



At 1 minute 49 seconds: A close-up view of the edges reveals 2 mm of shrinkage on the B sample, about 8 mm shrinkage on the A sample, and none on the UF.



At 2 minutes 37 seconds: Sample A is badly distorted along the top border of the glass, and has shrunk about 3.5 mm from the bottom edge. It exhibits growth along the left and right edges. This sample is also puckering a bit off the surface of the glass. Sample B continues to shrink and the UF sample remains unchanged.



At 3 minutes: Sample B has progressed to 3 mm along the left side and roughly 2 mm along the right side. The EVA is extending past the top of the sample (near the lettering on the paper).



At 3 minutes 41 seconds: Sample A has shrunk up to 10 mm on the bottom edge. Sample B has progressed to 4 mm along the left edge and about 1.5 mm along the right edge. The UF is still unchanged. The EVA at this point is sticking to the glass.



At 5 minutes 8 seconds: The UF EVA remains aligned with the edges all the way around the sample, with only a slight movement in the lower right hand corner of the glass (a surface tension effect). Sample A has distorted significantly and unevenly along all four edges (up to about 37%), while sample B exhibited relatively even shrinkage along two edges (about 12%) and growth along the other two edges. By this point in the lamination cycle, the press is on and the diaphragm is exerting pressure on the lamwich. As you can see from this test however, considerable distortion of the competitor's encapsulants may occur prior to the press coming on.

It is important to note that the competitive samples used as part of this experiment are commercially available EVA sheets provided to the PV industry for the express purpose of laminating modules. They are of equal thickness to the UF sample used. No pretreatment of any of the samples other than cutting to size, by trimming around the glass with a razor knife, was performed.

Will we be the first company to adopt it?

We have been making the UF product line since 1997. Each year, more of our customers adopt this material and presently it accounts for a significant percentage of our sales. One should consider that we are also making a significant amount of laminated products such

as EVA/TPE, EVA/TP, EVA/TPT, and EVA/Scrim, which are all used as the back layer of encapsulant; meaning only 50 – 60% of our sales are available to convert to UF. So it's by far, the dominant choice of materials for the front layer of encapsulant and accounts for significant use in back of the cells as well (for those who choose not to use the multilayer laminated constructions).

Over the last 12 months, we've shipped more than 10 million square feet of UF product to companies in the USA, Europe, Japan, China, Australia, Africa – virtually into every major PV marketplace.

The product has been well tested and proven. It's been used in modules that have passed IEC 61215, made by several different companies.

For more information about our encapsulant materials (including sample requests), please contact a customer service representative at STR Extruded Products at 860 749 8371 (phone), 860 749 8234 (Fax), or by e-mail using the address posted on our company website at www.strus.com