Lamination: Key to module durability

Lamination is the most important process in making of solar modules. A good laminate ensures long life and durability of PV modules whereas an improper one can lead to early or premature module failures. Understanding the complete process not only helps in producing a better product but also reduces losses like cell breakage, air bubbles and delamination, which mostly occurs due to incorrect processing parameters.

![Figure 1: Typical solar module laminator (El Amrani, Mahrane, Moussa, & Boukennous, 2007)](image)

Majority of module laminators follow the following 3-step process for proper melting and curing of the encapsulant (EVA) and achieving a good quality laminate:

1. Heating of the module lay-up to required temperatures to perform the EVA cross-linking step.
2. Applying a vacuum to remove the air and other volatiles to prevent bubbles.
3. Application of pressure to ensure a good surface contact and adhesion between the different layers of the PV module.

The so-called flatbed laminator consists of a processing chamber that is divided by a flexible (silicon) membrane in an upper and lower chamber. Both chambers can be individually evacuated and the module lay-up is normally heated in the lower chamber by a heating plate (Electric or hybrid).

The process
To dig deeper, the three step process can be further divided into following:

1. **Lay up:** An arrangement of glass-> EVA -> cells -> EVA -> Backsheet, in that order, is prepared for lamination.

2. **Pin lift:** Due to the relative large temperature difference of about 100°C between the heating plate and the PV module lay-up upon insertion, glass warping (curving) of the 3-4mm thick glass is observed. To avoid this glass warping and achieve homogenous heating profile, the flat-bed laminator is equipped with pins that are used to lift the PV module lay-up about 5mm from the heating plate, which results in a more gentle and homogeneous heating of the lay-up.
**Solar module Lamination Process**

**Pin release**
- After EVA softening point.
- Allow for faster and higher temperature heating of modules.

**Vacuum - lower chamber**
- Remove air & other volatiles and avoid bubble formation.
- Too early or high rate suction will result in significant outgassing of required EVA additives.
- Late suction will lead to air inclusion and hence bubble formation.

**Pin lift**
- Avoid glass warping due to high temperature difference.
- Leads to homogenous heating without direct contact.

**Lay up**
- Insertion of cold PV module lay up into laminator.
- A lay up of Glass -> EVA -> cells -> EVA -> backsheet.

**Vent - upper chamber**
- To facilitate improved contact with the heating plate and hence better heat transfer.
- Venting too early can lead to unwanted cell breakage.
- Late venting can lead to shifting of strings or cell swimming phenomenon.

**Cooling step**
- Controlled stopping of chemical reactions.
- Making module ready for post laminations steps.
3. **Vacuum - Upper chamber:** The lower processing chamber of the laminator is evacuated to remove the air and avoid bubble formation. The time of applying a vacuum as well as the rate of evacuation can be varied to optimise the process and hence the end-result. Reducing the pressure too early or at a high rate will result in significant outgassing of the additives in the EVA like adhesion promoters and/or stabilisers, and hence in a decreased quality of the PV modules, whereas applying the vacuum too late will lead to air inclusion and hence unwanted bubble formation.

![Figure 2: Solar module lamination cycle](image)

4. **Pin Release:** After obtaining a homogeneous temperature in the glass plate and crossing the so-called EVA softening point at about 60°C-80°C, the PV module is directly pressed on the heating plate by releasing the pins and the actual EVA cross-linking process is initiated.

5. **Vent - Upper Chamber:** By venting the upper chamber, improved contact & heat transfer takes place between the module lay-up and the heating plate. Here again, care has to be taken when applying the pressure, to what extent and at what rate. Applying the pressure too early increases the chance of unwanted cell breakage whereas applying the pressure too late will most often result in a shift of the cell strings or so-called cell-swimming phenomenon.
6. **Controlled Cooling**: A subsequent controlled cooling step leads to a controlled stopping of the radical induced chemical reactions and completes the lamination cycle making the stable PV module ready for the post-processing steps and testing.

Lamination is a complex process with interplay of a variety of processing parameters like pressure, time and temperature. Systematic research is needed to optimise the lamination process towards the fastest cycle time guaranteeing the highest quality and a robust process window.

As a leading manufacturer of Solar EVA Encapsulants, we at Brij understand this complexity and develop our product with lower rejection rates, higher adhesion strength and controlled crosslinking.

*Switch today and experience the 'Brij Advantage'.*

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*Brij welcomes feedback on whitepapers and its other resources available. Please contact us by email at support@brijfootcare.in or by telephone on +91-98688-83388.*

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**References**
