Plastics Compounding Platform and the Formulation Development of PV Module Packaging Materials in CSEM

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A compounding platform has been established in CSEM to develop the formulation of plastics for various applications, especially for the packaging materials of the PV modules. This platform opens up not only the possibility to develop reliable, processable and versatile packaging materials to meet the customized demands for special applications like BIPV, but also provides the possibility to study in-depth the degradation mechanism of PV encapsulant and thus to improve the life time of PV modules.

The reliability of PV modules, i.e. their life time, is critical for the further reduction of the levelized cost of PV electricity. A typical PV module mainly consists of front cover, stringed cells and back cover. For the structural integrity, those components are boned with two layers of adhesive, commonly referred as the encapsulant. These thin encapsulants, normally 0.4-0.5 mm thick, bare multiple important functionalities within the module, like the mechanical bonding, optical in-coupling, UV blocking, water/oxygen barrier, etc. Moreover, their stability under the combinational effects of light, heat and moisture possesses significant impact on the reliability of PV modules [1]. The mostly used encapsulant in the past decades has been based on poly (ethylene-vinyl acetate) (EVA). It has been observed that EVA encapsulants of different grades from different manufacturers exhibit distinct outdoor reliability. The composition of the EVA base resins used therein is often similar, which has 26-32% of Vinyl Acetate. Therefore, the key factor causing the different reliability is the formulation. This is also true for the Polyolefin (PO)-based encapsulant, which is considered as a major alternative to EVA.

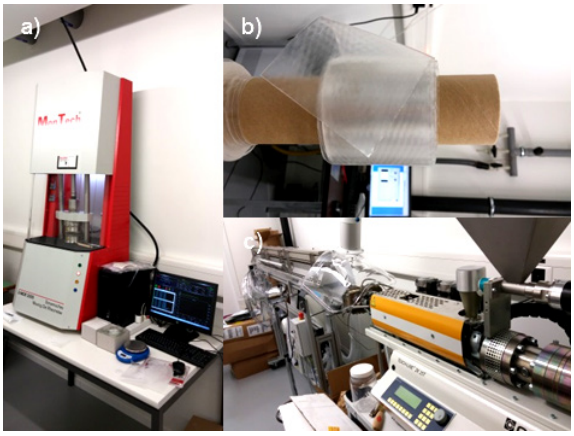

Figure 1: The compounding platform in CSEM. a) D-MDR 3000; b) compounder; c) extruded PO encapsulant.

Given the importance of mastering the formulation of PV encapsulants, CSEM has established a formulation development platform in house, to better serve the needs in various projects related to PV module technology. The platform includes mainly the following facilities (see Fig.1):

- Dr. COLLIN GmbH, TEACH-LINE twin-screw compounder ZK 25 x 24 L/D with co-rotating screws of 25 mm in diameter and 24D in length. Its max. throughput ranges from 0.3 to 4.0 kg/h. It is equipped with a slot die with adjustable opening width and a cooling belt system.
- Inversina 3D tumbler mixer
- Montech Dynamic Moving-Die Rheometer 3000
- Mettler Toledo DSC 1 Differential Scanning Calorimetry
- Chemical analysis facility (e.g. FTIR, GC/LC-MS, Raman, GPC, NMR, …) partly in collaboration with external partners
- Extensive accelerating lifetime testing facilities: climate chambers to implement tests like damp heat, thermal cycling, humidity freeze, etc.; climate chamber with one-Sun irradiation to perform the test of UV+ damp heat; UV chamber; Ovens; highly accelerated damp heat testing setup (high-pressure cooker test)

Moreover, supply channels of base resins and additives have been built with multiple national and international chemical companies.

The compounding platform in CSEM can steadily extrude packaging foil of 0.1 to 2.5 mm thick with the maximum width of 12 cm. Extrusion processes have been developed for common grades of EVA and PO base resins for PV application.

At the moment, the compounding platform is supporting a few projects (internal, industrial and CTI). The examples of the applications are specified as following:

- Colourful PV-grade EVA encapsulant for applications in the BIPV field. Here the colour, stabilization and crosslinking additive packages are optimized for the selected EVA base resins to develop an encapsulant compatible with the building norms.
- PO-based packaging material for advanced PV module solution. Here besides the optimization of additive packages, the selection of a proper PO base resin with desired material properties (optical, rheological, UV stability, adhesion, …) is critical for its processability and module reliability.
- Degradation mechanism study of PV encapsulants. Here with the capability of adjusting the material composition, it is possible to investigate the degradation mechanism of the encapsulants, especially for EVA. One focus is to understand the mechanism behind the yellowing and acetic acid production in EVA encapsulant under different environmental conditions.

Furthermore the expertise on the packaging material analysis has also been developed within the platform.

[1] H.-Y. Li, "Open the black box: understanding the encapsulation process of photovoltaic modules", Ph.D dissertation, EPFL 2013