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Milestone regarding a Highly Circular Module

1.1 Selection of materials for processing highly circular modules

TNO has compiled a 'Bill of Materials' for module manufacturing based on a selection of biobased and circular PV materials. The materials are used for manufacturing mini modules and testing material compatibility and durability. In a later stage process compatibility with the Meyer Burger pilot technology will be developed together with partner CSEM.

Commercially available glass plates and backsheet will be sourced by TNO. A criteria for circularity addresses the application of closed loop and mono design materials. For the project the following materials are chosen:

- Bio-based encapsulant by partner Padanaplast to be tested and evaluated on module level;
- NCR will provide wafers made with partly recycled silicon offcuts from their own mono-Si process;
- TNO will source 'Mono designed' circular backsheet;
- As an alternative to backsheet and as a reference a glass rear sheet will be used.

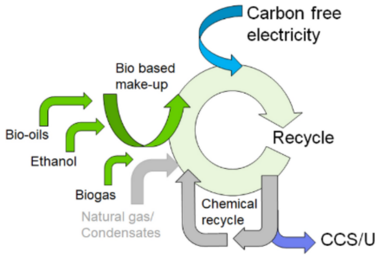
Bio based encapsulant

Large scale PV panel production in the EU based on non-fossil materials requires novel concepts for the production of encapsulant, backsheet and probably polymer based transparent front-sheet for light weight panel applications. In this project TNO investigates together with the partners polymer materials suitable for PV panel application, obtained from Advanced Bio based Circular (ABC) sources. This non-fossil based polyolefin is a fully closed loop material and could be an appropriate choice for sustainable PV panel production.
In terms of polymer re-use, at end of life, novel material choices are required to exchange the non-circular concepts. Based on resilience requirements of the EU critical raw material act, circular production processes are strongly anticipated. At present, circular (closed loop) polymer materials are not applied in Asian made PV panels permitting an opportunity for product improvement in the EU.

Project partner Padanaplast developed Polidiemme XL-Elastomer, an encapsulant that has the option to be manufactured from bio- oil (particularly palm oil). Oils originating from biomass can serve as sustainable non-fossil based raw material to produce olefine encapsulant and backsheet material.

Ideal for the production of olefines, is a direct feed of bio oils to either steam cracking or a catalytic cracking process. Major challenge is the vastly different composition of bio oils, in particular the presence of variable amounts of oxygen. Co-feeding with a petroleum based feedstock can provide a partial solution, however only low amounts of high-oxygen content bio-oil are miscible with the petroleum based feedstock, and therefore feeding to fixed-bed systems such as hydrotreater in large volumes is problematic.

Vegetable oils, animal fats or triglyceride based biomass residues have relatively low oxygen content (≤ 10 wt. %) compared to lignocellulosic bio oils and thus can be easier processed in a milder hydrotreatment process. Particular examples of bio oils suitable for mild hydro deoxidation (HDO) upgrading are palm oil and crude tall oil from coniferous wood pulping. Hydrotreatment of vegetable oils has been performed in commercial scale for production of renewable diesel and jet fuels over the last two decades. Hydrotreatment of triglyceride vegetable oils results in renewable naphtha and propane, which can be subjected to steam cracking and propane dehydrogenation (PDH) process, respectively. Resulting green ethylene and propylene can then be used for polyolefin and polypropylene production, as has been demonstrated on commercial scale. Advantage of hydrotreated bio oils as a feedstock is the possibility to use existing infrastructure such as cracker and PDH plants for the green olefin production. The annual vegetable oil production volume is 200 Mt as of 2021.



Conceptual paths to minimum carbon emissions and fossil carbon contents in olefins: bio replacement (green), carbon emission free energy (blue), carbon loss minimization (grey) and carbon emission capture (purple)

Wafers from reused off-cut silicon

Project partner NCR provides silicon wafer material for the production of the heteroJunction solar cells. After the formation of the round silicon ingot, off-cut material from dicing (square wafering) is used and refed into the polysilicon melt.

This process includes sawing and grinding the ingots into square or semi-square bricks. First, the ingot is sectioned into suitable lengths and the top and tail part are removed (cropping). This is followed by moving the ingot to the squaring saw, where the sides, also called wings, are removed. These off-cuts (top, tail and wings) can make up as much as a third of the total ingot weight, and the ability to reuse this material is crucial. In addition to the tops, tails and wings, cut off material that does not meet the required quality is also selected. This could be due to visual damages and defects or other parameters like resistivity, lifetime and oxygen content. NCR opts to reuse as much as possible of the material, and to avoid any unnecessary handling and processing that can potentially increase the impurity level of the material. After cleaning the material it is crush into suitable pieces. The large pieces are directly stapled in the crucibles, while wings are typically crushed into small pieces that can also be used for recharging. Recharging is done through a quartz tube which will get clogged if the pieces are too large. High amounts of recycled material in recharging can have detrimental effects on the crystallization process and quality. The crushing increases the surface area and gives rise to impurities. However, enough material has to be crushed to be able to consume the produced amount and not interfere with the silicon product quality. Typically 30% recycled material is added to the feedstock for crystal pulling. NCR recycles approximately 85% of the off-cuts where some is lost during crushing. Almost 10% of the crushed volume is turned into fines and dust which is not suitable for reuse. The other major loss is due to sorting out material that is suspected to have high amount of impurities.

Circular backsheet material

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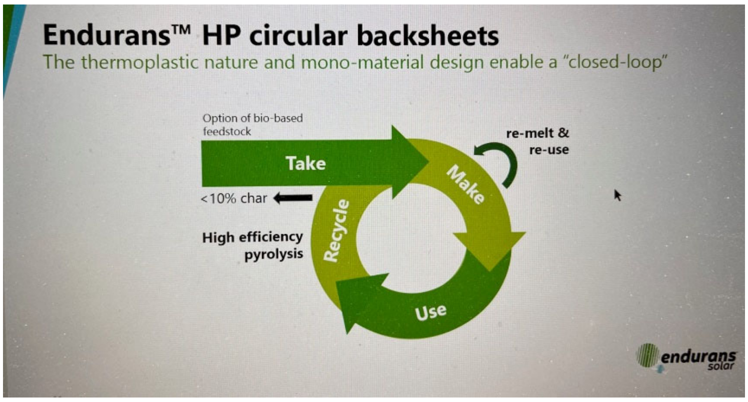
TNO sources mono design backsheet featuring closed loop capability. This backsheet, manufactured by the company Endurans solar Solutions comprises three layers of modified polyolefin to protect the module from UV, humidity and to guaranty electrical isolation. The three layers containing the polyolefin sandwich are coextruded omitting adhesive material between the layers. In comparison with standard backsheet consisting of PVF, PET and adhesives it is comprehensible that a mono material sandwich has an advantage when it comes to recycling. During production the polyolefin waste from foil size cutting can be directly reused for extrusion of new backsheet. In an end of life situation this backsheet can be fully reused aided by a pyrolysis step that offers harvesting of monomers for the production of modified polyolefins. By applying polyolefins the use of harmful PFAS (fluoropolymers) is avoided.



Glass/glass option

As an alternative to backsheet and one of the Meyer Burger options to manufacture bi-facial modules, a glass front and glass rear module version will be tested. Glass is inherently a closed loop material however solar glass is distinguished as low iron glass providing a higher transparency. For this reason solar glass should be recycled separately from other glass.

1.2 Mini module manufacturing and durability tests

With the selected and sourced materials TNO will manufacture mini-modules comprising 1 to 8 cells to demonstrate and evaluate compatibility of the single materials and durability. A test series in accordance with the IEC 61215 test protocol for damp heat and temperature cycling will be executed.

The final goal for this WP subsection is to develop processing compatibility with the Meyer Burger pilot technology. In addition ULIEGE will evaluate how the highly circular BOM impacts the overall LCA of the PV panels and TNO will evaluate the impact on resource availability.

Reference:

Next generation of polyolefin plastics: improving sustainability with existing and novel feedstock base
Alexander Reznichenko & Ali Harlin, SN Applied Sciences volume 4, Article number: 108 (2022)

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