BUSINESS UNIT
MICROTECHNOLOGY

1

MONO-FRACTIONAL RECYCLING OF ALL MATERIALS IN PHOTOVOLTAIC MODULES

THE TASK

Photovoltaic modules are a key element of energy policy and reality that is driven by the desire to generate energy with environment-friendly methods, decentralized and from renewable resources. With a growing installed capacity of photovoltaic modules, the demand for recycling older modules increases as well. Recycling and reuse are not only necessary for environmental reasons, they also make economic sense. In particular, the ultrapure front glass panel is a valuable product. The modules also contain valuable materials such as copper, indium and selenium, which can be directly recycled for the European market and thus minimize risks associated with import and raw materials sourcing.

The conventional recycling method is to shred and melt down the modules. Due to cross contamination issues, this method limits the reuse to lower value products such as bottle glass. Alternative chemical or thermal processes require too much energy rendering these options undesirable. Thus a non-destructive technology is required to open the laminated glass system so that the module can be completely recycled and sorted by front and backside glass plates, metals and polymer foils.

Fraunhofer IWS engineers aim to develop a solution which separates in a damage-free manner the photovoltaic multilayer laminated composite which is also usable over larger dimensions. The goal is to 100 percent recycle the sorted components and reuse them in high value products.

OUR SOLUTION

Photovoltaic modules are laminated glass panel systems. The electricity generating metal-semiconductor layers are encapsulated between rigid backside and high-quality frontside glass panels to be stable in demanding weather conditions. The durable bond between the glass panels is ensured by laminating the entire area with polymer foil. The laminate is extremely strong and poses a great challenge for recycling.

The idea is to weaken the large sized laminate by depositing a precisely defined amount of energy in between the bonded glass panels. The aim is to use laser radiation to waken this zone so that front- and backside glass panels can be separated from each other without the need for much mechanical force. The solution is required to provide process safety and an economically feasible throughput. A laser-optical and mechanical hybrid technology was developed, which features high speed and on-the-fly processing.

RESULTS

A laser-based solution requires sufficient transmission of front- or backside glass panel (depending on processing strategy) and sufficient energy absorption in between the glass panels. Thus, laser systems were selected that radiate at near-infrared wavelengths, penetrating the glass without much losses but being almost completely absorbed in the metallic or semiconducting layer. This process offers the basic capability to deposit the energy at the right location inside the multilayer laminate.

However, the laminate needs to be uniformly weakened in the interface without locally overheating the material. The by far more challenging task is to combine the laser system technology with the processing regime. The thermally induced cracking of the flat glass panels and thus their destruction has to be avoided. For this reason, the lasers are operated in pulsed mode. Typical pulse lengths of several tens of nanoseconds were combined with fast laser velocities of up to 3 m s^{-1} to minimize the probability of local overheating of the material. During the laser pulse the metal-semiconductor layer explosively evaporates over an area that is even larger than the focal spot of the laser. Even if the laminate was not completely covered over the entire area, it was sufficiently weakened to separate the panels.

Laser parameters (e. g., focal length, pulse repetition rate) and processing parameters (e. g., line scanning with the focused laser beam, distance of the lines, type and strength of the mechanical separation force) were deliberately tuned to adapt the process to successfully separate typical solar module types.

The hybrid approach was consequently developed for on-the-fly processing. This way the photovoltaic modules can be recycled in a continuous inline process. Subsequently the metal-semiconductor layer and the polymer foils become accessible to chemical processing steps. Technologically challenging is the processing of special areas such as the edges where there is no photovoltaic active layer to absorb the laser radiation. Here too were solutions developed with adapted wavelengths and alternative mechanical process variations.

This hybrid process to separate the front- and backside glass panels is the first and economically absolutely necessary processing step to sort and recycle all the components of photovoltaic modules. Processing speeds were demonstrated to be as high as 0.75 m^2 min^{-1}, and the process is scalable.

The laser based process produces high quality recycled raw materials that can add value to other manufactured goods. Thus the process is a source of providing rare raw materials. The approach is principally usable to recycle other types of laminated systems as well.

The Free State of Saxony's Ministry for Economy and Labor funded the effort through its central development agency SAB (FKZ 100192199/2936).

1 Mechanically shredded photovoltaic modules

2 Separating of photovoltaic module laminates by laser induced interface weakening

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