TOWA Europe BV & ECN
in opdracht van RVO

CALIFORNIA

Capturing light for high-efficiency at all incident angles

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Introduction

In California project TOWA Europe B.V. and ECN Solar have explored the potential of TOWA's compression molding technology for application in photovoltaics, and namely improving the power output of PV module by means of improved light-management in a cost-efficient way. The novelty of the approach consists in application of optically active structures on glass using TOWA's high-pressure molding technology, normally applied for encapsulation of electronic components or LEDs. TOWA's molding technology allows application of optically-active structures on a substrate with high level of precision and fine control of the geometry of the structures.

Figure 1
Examples of structures that can be produced using TOWA's compression molding technology.

Summary of activities and results

The joint effort of TOWA and ECN resulted in demonstration of a highly-effective anti-reflection (AR) coating as well as a first test structure allowing the light falling between cells to be diverted to the cells (edge collectors).

In the first phase of the project we examined various PV module configurations, in which TOWA's optical layers could be integrated. This activity consisted in a desk study and a series of brainstorm sessions, in which nine PV module lay-outs or configuration were considered and evaluated using a score matrix. As a result, it has been decided to proceed with development of structured coatings on glass as most promising and also fitting the project scope and timeline. (See Figure 2**Error! Reference source not found.Error! Reference source not found.** and Figure 3)

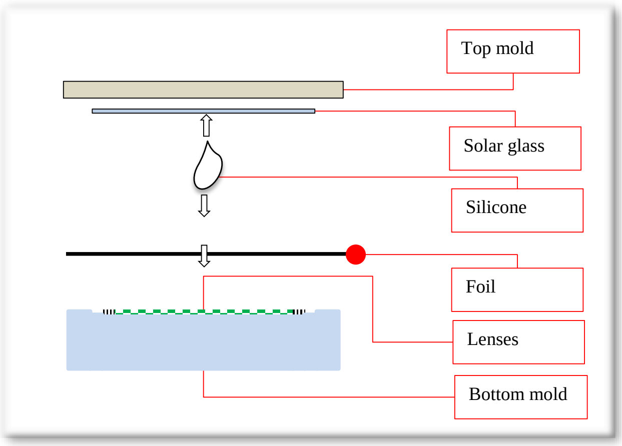

Figure 2
Schematic picture of the principle of compression molding process

In view of a great degree of freedom offered by TOWA's molding technology in terms of shape and size of optically-active structures, quite some effort had been put into identification of most promising structures and their optimization from the performance and manufacturability point of view. As a result of this effort, optically-active structures for an AR coating and edge collectors were proposed. The structures defined in the geometry optimization phase were then translated by TOWA into a modular mold design, which allowed application of AR coating and edge collector structures individually or simultaneously. Main challenge at this stage was translating the proposed structures into an insert design as precisely as possible, but also ensure simple manufacturability. With mold in place, a series of molding trials had been carried out in order to optimize such parameters as molding pressure, vacuum levels, curing time etc. Furthermore, various separator foils had to be tested in order to ensure a proper control of the quality of the molded layers. Finally, TOWA could apply both AR coating and edge collectors on glass substrate (see Figure 4).

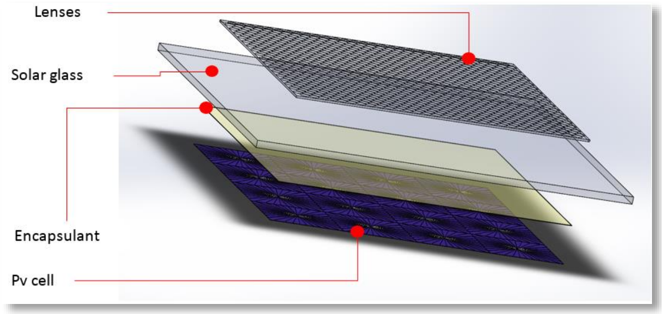

Figure 3
Schematic lay-out of a PV module having an optically active coating on top of glass.

ECN used the coated (molded) glass samples to manufacture and test functional prototypes - single-cell interdigitated back-contact (IBC) modules (see Figure 5). Systematic I-V measurements of the functional prototypes under standard test conditions (STC) and various angles of incidence were carried out using PASAN flash tester. These measurements pointed at a high performance of AR coating (more than 2% in I_{SC} gain for normal incidence) and also a positive effect of the edge collector. For modules having AR coating, the Incident Angles Modifiers (IAM) were calculated from the measurements under different angles. From IAM's (Figure 6) we could conclude that TOWA's AR coating was superior to the commercial coatings tested at ECN, but additional studies are required to properly compare the performance and cost-performance ration of TOWA's coatings with commercially-available solutions.

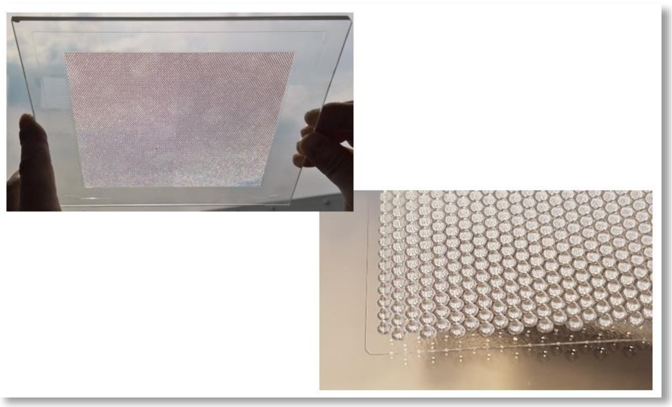

Figure 4
Pictures of optically-active layer with AR function on the solar glass substrate.

The results were compared to two types of reference modules having flat glass combined with black background (encapsulant) and flat glass combined with white background (white encapsulant) (see Figure 5).

As one of the important practical implications, TOWA's AR coating should allow replacement of modules having white background with black background (e.g., from aesthetical considerations) without loss, or even some gain, in annual yield. On the other hand, the power output and annual yield of a standard module having white background can also be significantly improved by applying TOWA's AR coating.

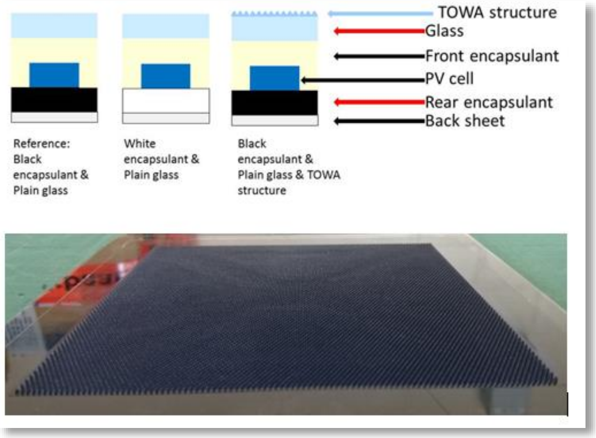

Figure 5
Single-cell laminate lay-outs manufactured and tested (top) and picture of an IBC module made with glass coated with TOWA AR coating (bottom).

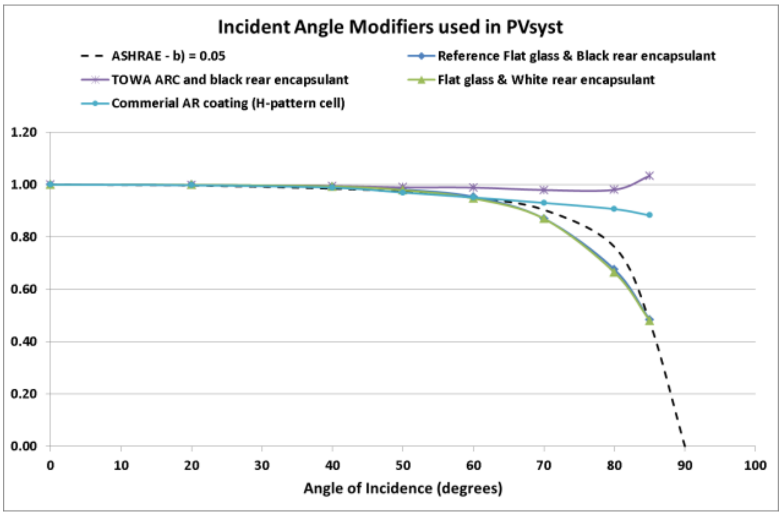

Figure 6
Measured Incident Angle Modifiers (IAMs) for a fixed azimuth, compared to the standard ASHRAE– b_0=0.05 used in annual yield simulations; also included is a previously measured IAM for a commercial AR coating. The IAM for TOWA's AR coating hardly changes in broad range of angles of incidence.

Preliminary reliability studies, which consisted in thermal cycling and damp heat exposure of the coated glass samples, point at good weathering characteristics of the coatings in terms of visual appearance, retention of adhesion and optical transmission.

As an important overall achievement, in this project we took the complete route from defining optically active structures by means of ray tracing, then translating the theoretically-defined geometries to a mold design to producing coatings on glass, the experimental evaluation of the developed coatings, and finally calculation of the impact of the developed structured on the annual yield for a typical residential PV system. In this project we could demonstrate technical feasibility and potential of the TOWA's technology. Further technical development and detailed cost assessment of the proposed technology will be addressed in a follow-up project.

Partners

TOWA, founded in 1979, has always pursued development of new products and innovation in Semiconductor manufacturing.
Technology with the goal of achieving win-win relationships with their customers by working directly on joint development projects, and the establishment of service centers in the world's major semiconductor producing regions. These efforts let to developing a firm foundation to meet the needs of the technical evolution in the semiconductor field by "providing the products and services that our customers require.

Recently also the LED manufacturing technology for devices such as interior lights, Flat Panel Display Backlight for TV and for Automobile applications became part of The TOWA equipment portfolio. The transfer molding and compression molding technology, developed by TOWA has become the leading technology in the fields of Semiconductor packaging and LED manufacturing.

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ECN Solar Energy, with its staff of over 70 scientists and engineers, offers a wide range of R&D activities on PV materials and -processing technologies, cell- and module design. These are available for transfer and implementation on laboratory-, pilot- and production scale. ECN's extensive facilities for characterization and solar cell- and module processing are well suited to study almost all R&D issues currently relevant for the PV industry. Lifecycle analyses for newly developed processes are evaluated to determine the environmental impact of these new processes.

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