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LARGE AREA MICRO STRUCTURING OF TRANSPARENT MATERIALS

THE TASK

Building complementary functions into single objects is certainly appreciated by the end user but also poses an interesting task for designers and manufacturers. The field of functional lighting offers a variety of intriguing concepts. Lights have to be designed to fit a certain shape and to illuminate the desired area according to color and brightness specifications. They also have to meet mechanical stability specifications, need to be energy efficient and should be free of maintenance requirements. And finally they should have an attractive design.

An interesting task was the development of a lighting solution for luggage racks in trains. The solution had to combine spot and area illumination with the requirement for safe luggage storage. The concept was to have a transparent and large area self-illuminating luggage rack, which offers the traveler a selectable choice of lighting conditions. This thrilling idea implies a number of challenges for the manufacturer. For example, LED spotlights have to be integrated as well as OLED area lighting. The necessary electrical pathways must be invisible so that the luggage can be seen without impairment.

A possible solution is based on using panes of glass coated with transparent conductive oxides (TCO). The dimension of a self-illuminating luggage rack is 1 m x 0.4 m. The task is to structure the TCO layers providing safe power to all electrical components while avoiding parasitic leakage currents.

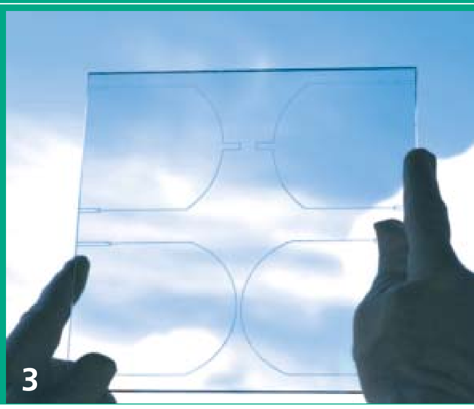
The separation of the conducting paths in the TCO coatings should be invisible and not damage the glass substrate. A luggage rack consists of two glass panes, which are bonded together by a polyurethane foil via hot pressing. This foil has to be structured as well to work for the lighting design.

OUR SOLUTION

The selective structuring of a transparent coating on a transparent substrate is in itself challenging. The approach is to use short pulsed UV and ultra-short pulsed IR laser radiation. Both offer excellent depth control of the ablation process. The absorption of the TCO coating is higher than that of glass in the UV and IR spectral ranges, which benefits this process.

An additional aspect is the need for creating most accurate microscopic structures across a large area. Typical process areas for laser micro machining systems are about 100 x 100 mm^2. Approaching this challenge by stitching smaller sections to cover the large working areas is limited due to optical pincushion and barrel distortions. Such distortions cause disruptions in the areal coverage leading to malfunction.

A new micro structuring machine was used to overcome these issues. This machine has ultra-accurate axes systems with enormously precise scanning field correction (Fig. 2).



RESULTS

The feasibility of the laser processing approach was demonstrated first with smaller samples. A short pulsed nanosecond laser of 355 nm wavelength was applied to electrically disconnect TCO areas, which can conduct electricity to an LED (Fig. 3).

Even better results were achieved with the ultra-short pulsed picosecond laser at 1064 nm wavelength. Skillfully selected laser parameters lead to a complete removal of the TCO along the desired path without any damage done to the glass substrate. Therefore it was decided to use this laser when transferring the process to the final dimensions of 1 m x 0.4 m.

The complete structure had to control 6 OLED areas and 2 spotlight LEDs. The first step was to obtain the exact position of the glass pane. Then the complete structure was laser-machined by stitching together a total of 40 100 x 100 mm^2 segments. This way it was possible to structure the first 50 % of the area of the glass pane. Then the pane was rotated 180° and realigned to process the remaining segments.

The processing of the adhesive polyurethane foil followed the same principle. The objective is to cut out sections for areal and spotlights. To create an eye-catching design element the partner's company logo was machined into the center part of the TCO coating.

The laser track width is only 40 µm but it was sufficient to completely separate the TCO coating across all contour segments. This was also verified and documented by inspecting the sections with a microscope.

Traditionally "micro structuring" and "accuracy over large areas" are mutually exclusive constraints. However, this project demonstrated that both objectives could be simultaneously achieved. Combining process and systems know-how made it possible to create almost invisible functional structures in transparent coatings on transparent substrates.

1 Large area laser micro-structured TCO coated glass substrate

2 Micro structuring system with two scanner heads to process large workpieces

3 UV laser structured surface for feasibility testing

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