Troubleshooting with cold plasma

The rain/light sensor reflects incoming light beams while measuring the light refraction. Transparent LSR forms the cover layer for adhesion to the glass pane

Material compatibility. A problem with the adhesion of liquid silicone rubber to polycarbonate would have almost led to a loss of the planned production with a sensor manufacturer in Baden-Württemberg. It was only thanks to the prompt introduction of an atmospheric plasma process that on-time production became possible.

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The design of a car rain/light sensor with package consists of various plastic material layers which must adhere to one another precisely and all over the surface. Even the tiniest air bubbles can initiate malfunctioning of the wiper so that it would also become active in sunshine.

The Swabian family-owned company Weber-Formenbau GmbH & Co. KG in Esslingen specializes in demanding multi-component injection-molded parts for the automotive, medical and electronics industry. One of their showcase products is the complex polycarbonate optics of rain/light sensors which they manufacture for a large automotive supplier in an injection molding process **(cover picture)**. But producing the plastic optics alone is not enough given that such a sensitive component must additionally be well protected, say enclosed, on the one hand and a cover layer for adhesion to the windshield (see info box) is required on the other.

INCOMPATIBLE MATERIAL COMBINATIONS

Since the production of sensor components involves several production steps due to their complexity, the Essling-located company expanded their plastic component production areas and invested in new injection molding machinery. In a first machine, the polycarbonate lenses are produced from three components. With an overall length of just less than 3cm, these fiber optics cover both the sensor function for daylight and the sensor function for water **(Fig. 1)**.

Fig. 1. The highly complex polycarbonate optics of the sensors is manufactured in a three-component injection molding process (figures: Plasmatreat)

Fig. 2. The PC lenses are initially overmolded with a PBT package

Fig. 3. Section view: Portion of the LSR coating on the left, still uncoated lenses on the right

After a comprehensive visual inspection of each single unit, the pre-molded parts are overmolded, in the next production step, with PBT in a

Fig. 4. View into the injection molding machine: The Openair plasma beam impinges with almost ultrasonic speed on the polycarbonate lenses. Microfine cleaning and strong activation impart new adhesion properties to the plastic material

two-component injection molding machine where the PBT serves as a kind of package which laterally tightly encloses the PC optics **(Fig. 2)**. The viewing faces of the small PC optics remain free during this process. In the next production step, the entire PC/PBT face is sprayed with a coating of transparent LSR (Liquid Silicone Rubber) which forms the contact face to the windshield **(Fig. 3)**. Since rain/light sensors have to be detachable, and therefore re-usable, in the event of windshield fracture, the LSR must afford good adhesion to the PBT packing and the PC lenses.

But exactly this production step turned out to be a problem: The LSR, injected as the last component to provide adhesion to the windshield, was repelled by the surface of the polycarbonate lenses. The subsequent inspection revealed tiny air bubbles that could have well affected the light refraction so that the sensor would have received undesired rain pulses.

As Elvira Postic, managing partner of Weber-Formenbau and grandchild of the company founder, recalls: "Nine hundred sensors were due to be delivered within a few weeks only, so we immediately got to work seeking the cause and a solution to the adhesion problem." But neither a modification of the polycarbonate nor tests with various adhesion-reinforcing silicones brought about a remedy. It was only when Clemens Trumm, Manager Application Development Center at Momentive Performance Materials, and the University of Esslingen were consulted on an advisory basis that they realized that the lack of wettability of polycarbonate was due to the PC surface itself, and not to the LSR. The surface energy was too low. Apart from that, adhesion defects were generated by localized contaminations of the coatings. Trumm made the suggestion to treat the component surface with atmospheric plasma and recommended Plasmatreat, a company located in Steinhagen, Westphalia.

COLD PLASMA IMPROVES THE ADHESION PROPERTIES

The Openair plasma technology developed by Plasmatreat in 1995 for the pretreatment of material surfaces is in worldwide use today. Unlike low pressure plasma, this process does not require a vacuum chamber but operates under completely normal atmospheric conditions. The intensity of "cold" plasma is so high that processing speeds of several 100 m/min can be achieved **(Fig. 4)**. The heating typically undergone by typical plastic surfaces is less than 30 °C during treatment. The system is characterized by a triple effect: It activates the surface by targeted oxidation processes, discharges the surface at the same time and leads to microfine cleaning. The activation results in a distinct increase of the surface energy so that completely new adhesion properties can be generated.

Fig. 5. Sophisticated integration solution: A pneumatic motion system moves the plasma nozzles from downwards into the injection molding section of the machine

Trials at Plasmatreat have revealed that the surface energy of many nonpolar plastic materials can be even increased to over 72 mN/m which is an optimal precondition for adhesion in the bonding process. Thanks to this technique, it is furthermore possible to achieve adhesion between incompatible plastic materials without bonding, simply by using plasma.
The process of surface discharge also brings about cleaning effects which far exceed those of conventional systems. Here, the user does not only benefit from the high electrostatic discharging effect of a free plasma beam but also from its emission speed near ultrasonic speed, as a result of which loosely adhering particles are also effectively removed from the surface besides providing microfine cleaning.

PROBLEM SOLVING UNDER TIME PRESSURE

Weber-Formenbau were left with exactly as little as five days up to the delivery of proper components. After a test run on 100 components in Plasmatreat's South Branch laboratory, which was carried out at short notice, spraying with LSR proved to be successful without any disturbing effects. The optical inspection left no room for interpretation: Not a single air inclusion, the silicone adhered perfectly to the polycarbonate. A further eight hundred components were subjected to the same pretreatment on the next day - with the same positive result.

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The injection molder, in order to enable direct component treatment in the tray, was supplied with a rental system on the subsequent day. At the same time a plant concept for initially offline component treatment was developed due to the fact that the desired integration of the plasma plant could apparently not be realized on the spot since all processing sides in the injection molding machine had been occupied. Joachim Schüßler, Head of Sales at Plasmatreat, explains: "A situation we are, unfortunately, frequently faced with: A new process does not work properly against expectations, and our technology is to provide remedy with inline pretreatment. When looking at the new machine we often find that there is no space left for installing the system."

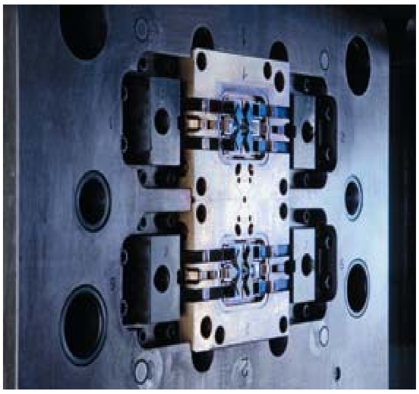

Fig. 6. Pre-molded parts ready for being overmolded with PBT in the upper cavity of the machine

INTEGRATED PLASMA SYSTEM

In the case of Weber-Formenbau, an integration solution was, however, found in co-operation with KIKI-Automations GmbH & Co. KG, Oberkirch, and the injection molding machine manufacturer Arburg GmbH + Co KG, Loßburg. The machine was converted in the area of the machine base, and the plasma nozzle now enters the tool from downwards from the machine bed (**Fig. 5)** - rather than from upwards as usual. The two cavities are moved by means of a rotary unit. The overmolding process of the PC optics with PBT is performed in the upper cavity. After rotation, the already overmolded components located in the lower cavity are treated with plasma using a pneumatic motion system **(Fig. 6)**. Thereafter, the silicone is sprayed on. The inline process only takes a few seconds. The xy motion system positioned in the machine base is moved into the working range of the tool. A plasma nozzle of type RD1004

! Light as a Switch

In principle, the daylight beam inciding on the windshield passes through a lens of the rain sensor and is reflected by the former. The reflection is detected by a photodiode which optoelectronically measures the light refraction. If the glass pane is dry, the entire light is reflected relatively uniformly (total reflection) and passed on to the photodiode. Water drops or water films on the glass, by contrast, disturb the reflection. The more the rain wets the glass surface whilst driving, the lower the light intensity measured by the diode and the stronger the pulses the sensor is sending to the automatic wiper control system.

type can thereby move over the adhesion area and activate the surface of the PC optics for long-term stable adhesion to LSR **(Fig. 7)**.

Fig. 7. The nozzle of type RD 1004 has been integrated into the fully automated injection molding process

CONCLUSION

The above application example shows that manufacturers would be well advised to consider the option of automated pretreatment of plastic surfaces right from the start when planning a new production line since the permanent optimization of materials can substantially modify their composition and, as a consequence, their adhesion properties. In the case of the Esslingen-located sensor manufacturer, the production crisis could be quickly averted by the use of the plasma process and thanks to the dedicated service by the supplier. Elvira Postic is convinced of the effectiveness of the pretreatment process: "With the employment of the Openair technique, we could not only completely eliminate the adhesion problem but also substantially reduce the rejection rate." Besides its high effectiveness, the Plasmatreat technique excels above all by its safety and reproducibility in the production process. Conventional pretreatment methods such as cleaning with wet chemicals or mechanical methods can be completely replaced, harmful emissions avoided and production steps saved by this plasma technique.
Weber-Formenbau records a monthly production rate of about 120,000 rain/light sensors to date and has meanwhile put a third plasma plant from Steinhagen into operation.

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