Plasma technology solves critical adhesion problems

Cold plasma improves adhesion properties

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A GERMAN manufacturer of automotive rain and light sensors which operate windscreen wipers was encountering problems with the adhesion of liquid silicone rubber to polycarbonate, a situation which would almost certainly have led to major production losses. The timeous introduction of an atmospheric plasma process to bond these dispirate materials made on-time production possible.

The design of the sensor comprises various plastic material layers which must stick to one another precisely, as even the smallest air bubbles could cause a malfunction.

The family-owned company Weber-Formenbau GmbH & Co. KG in Esslingen, South Germany specializes in demanding multi-component injection-moulded 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 moulding process.

Adding complexity to the manufacturing of these sensors is the need to protect and thus enclose the sensitive components, and provide a cover layer which will stick to the windscreen (see info box).

Incompatible material combinations

Since the production of sensor components involves several production steps, Weber-Formenbau expanded their plastic component production areas and invested in new injection moulding machinery. One of these machines produces the polycarbonate lenses from three components. With an overall length of just less than 3cm each, these fibre optics cover both the sensor function for daylight and the sensor function for water **(Fig. 1)**.

After a comprehensive visual inspection of each single unit, the pre-moulded parts are overmoulded in the next production step with PBT in a two-component injection moulding machine where the PBT serves as a kind of package which tightly encloses the PC optics on each side **(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 and 4)**. Since rain/light sensors have to be detachable, and therefore re-usable, in the event of the windscreen breaking, the LSR must allow good adhesion to the PBT packing and the PC lenses.

But it was exactly this production step that 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. An inspection revealed that there were tiny air bubbles that could have affected light refraction, and the sensor would have received undesired rain pulses.

Elvira Postic, MD of Weber-Formenbau said: “900 sensors were due to be delivered within a few weeks, so we immediately got to work looking for the cause and a solution to the adhesion problem.” But neither a modification of the polycarbonate nor tests with various adhesion-reinforcing silicones proved to be the answer.

It was only when Clemens Trumm, manager Application Development Centre at Momentive Performance Materials, and the University of Esslingen was 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. Adhesion defects were also caused by localized contamination of the coatings.

Trumm suggested treating the component surface with atmospheric plasma and

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

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

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

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

Fig. 4. The fully coated rain sensor

recommended the German plasma specialist Plasmatreat, Steinhagen.

Cold plasma improves the adhesion properties

The Openair plasma technology developed by Plasmatreat in 1995 for the pre-treatment of material surfaces is used worldwide today. Unlike low pressure plasma, this process does not need a vacuum chamber but operates under completely normal atmospheric conditions.

The intensity of 'cold' plasma is so high that processing speeds of several 100 mN/min can be achieved **(Fig. 5)**. The heating typically undergone by typical plastic surfaces is less than 30 °C. 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 micro fine cleaning.

The activation results in a distinct increase of the surface energy so that completely new adhesion properties can be generated. Trials at Plasmatreat have revealed that the surface energy of many nonpolar plastics can be increased to over 72 mN/m, an optimal precondition for adhesion in the bonding process. Thanks to this technique, it is also possible to achieve adhesion between incompatible plastics without bonding, simply by using plasma.

The user benefits not only from the high electrostatic discharging effect of a free plasma beam, but also from its ultrasonic emission speed which effectively removes all loose and micro fine particles from the surface.

Problem solving under time pressure

Weber-Formenbau were left with just five days to deliver the finished components. After testing 100 components in Plasmatreat's laboratory, spraying with LSR proved to be successful without any negative side effects. There was not a single air bubble and the silicone stuck perfectly to the polycarbonate. A further 800 components were subjected to the same pre-treatment the next day - with the same positive result.

In order to allow direct component treatment in the tray, the injection moulder was supplied with a rental system the next day. At the same time a plant concept for initially offline component treatment was developed because the desired integration of the plasma plant could not be done on the spot since all processing sides in the injection moulding machine were occupied. Joachim Schüßler, head of sales for Germany at Plasmatreat, explained: "Unfortunately this is a situation we are often faced with. Our technology provides a remedy with inline pre-treatment. When looking at the new machine we often find that there is no space left to instal the system."

Integrated plasma system

However, in the case of Weber-Formenbau, an integration solution was found in co-operation with German engineering specialist kiki Ingenieurgesellschaft mbH and injection moulding machine manufacturer Arburg GmbH + Co KG, Loßburg. The machine was converted and the plasma nozzle now enters the tool downwards from the machine bed - rather than from upwards as would normally be the case. The two cavities are moved by a rotary unit. The overmoulding process of the PC optics with PBT is performed in the upper cavity **(Fig. 6)**. After rotation, the already overmoulded components in the lower cavity are treated with plasma using a pneumatic motion system. The silicone is sprayed on afterwards. 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 type RD1004 plasma nozzle can move over the adhesion area and activate the surface of the PC optics for long-term stable adhesion to LSR **(Fig. 7)**.

Conclusion

This application example shows that manufacturers would be well advised to consider the option of automated pre-treatment of plastic surfaces when planning a new production line as 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 was quickly averted by the use of the plasma process and thanks to the dedicated service by the supplier.

"With the Openair technique, we not only completely eliminated the adhesion problem but also substantially reduced the rejection rate," said Elvira Postic.

Weber-Formenbau produces approximately 120,000 rain/light sensors a month and has placed a third plasma plant from Steinhagen into operation.

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Rain sensor functioning

In principle, the daylight beam landing 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 opto-electronically 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.

Fig. 5. View into the injection moulding 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

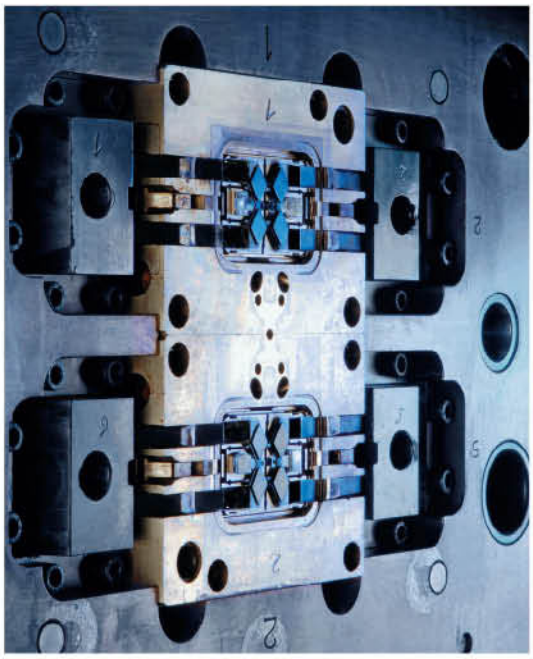

Fig. 6. Pre-moulded parts ready for being overmoulded with PBT in the upper cavity of the machine

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