A knight in shining (plasma-)armour

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A problem with the adhesion of liquid silicone rubber to polycarbonate would almost have resulted in failing to undertake production of an auto part with a sensor manufacturer in southern Germany. Thanks to the prompt introduction of an atmospheric plasma process, on-time production was once again a possibility.

The design of a car rain/light sensor within an overall pack necessitates various plastic material layers which must adhere to one another exactly and over the entire surface. Even the tiniest air bubbles can bring about malfunctioning of the wiper resulting in its becoming active in sunshine.

Family-owned company Weber-Formenbau GmbH & Co. KG in Esslingen, in the south of Germany, specializes in producing multi-component injection-moulded parts for the automotive, medical and electronics industry. One of its showcase products is a complex, polycarbonate optics, rain/light sensor which they manufacture using an injection moulding process, for a large automotive supplier. Production of the plastic optics (a sensitive component) must, in addition, include both protection in an enclosure, on the one hand, and a cover layer used to adhere to the windshield, on the other.

Incompatible material combinations

Since the production of sensor components involves several production steps and because of their complexity, Weber-Formenbau expanded its plastic component production areas and invested in new injection moulding machinery. In the first machine, the polycarbonate lenses are produced from three components. With an overall length of just less than 3 cm, these fibre optics cover both the sensor function for daylight and the sensor function for water (see Figure 1).

After a comprehensive visual inspection of each single unit, the pre-moulded parts are overmoulded, in the next production step, with polybutylene terephthalate (PBT) in a two-component injection moulding machine where the PBT serves as a kind of package which laterally tightly encloses the PC optics (see Figure 2). The viewing faces of the small PC optics remain free during this process.

In the next production step, the entire polycarbonate (PC)/PBT face is sprayed with a coating of transparent liquid silicone rubber (LSR) which forms the contact face to the windshield (Figures 3 and 4). 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.

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

In the case study under analysis,it was precisely this production step which 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 false rain pulses.

Figure 2: The PC lenses are initially overmoulded with a PBT package

Figure 3: Section view: portion of the LSR coating on the left, still uncoated lenses on the right

Figure 4: The fully coated rain sensor

As Elvira Postic, managing partner of Weber-Formenbau and grandchild of the company's founder, recalled: "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 Centre 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 that the component surface be treated with atmospheric plasma and recommended the German plasma specialist Plasmatreat, in Steinhagen.

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 (see Figure. 5). The heating normally 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. Trials at Plasmatreat have revealed that the surface energy of many nonpolar plastic materials can be 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.

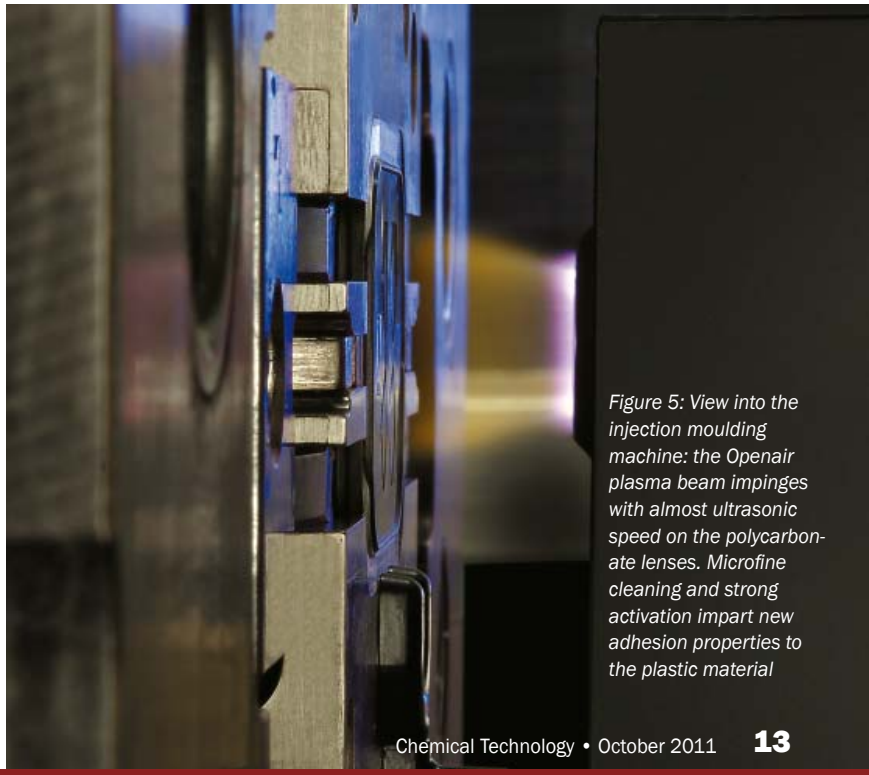


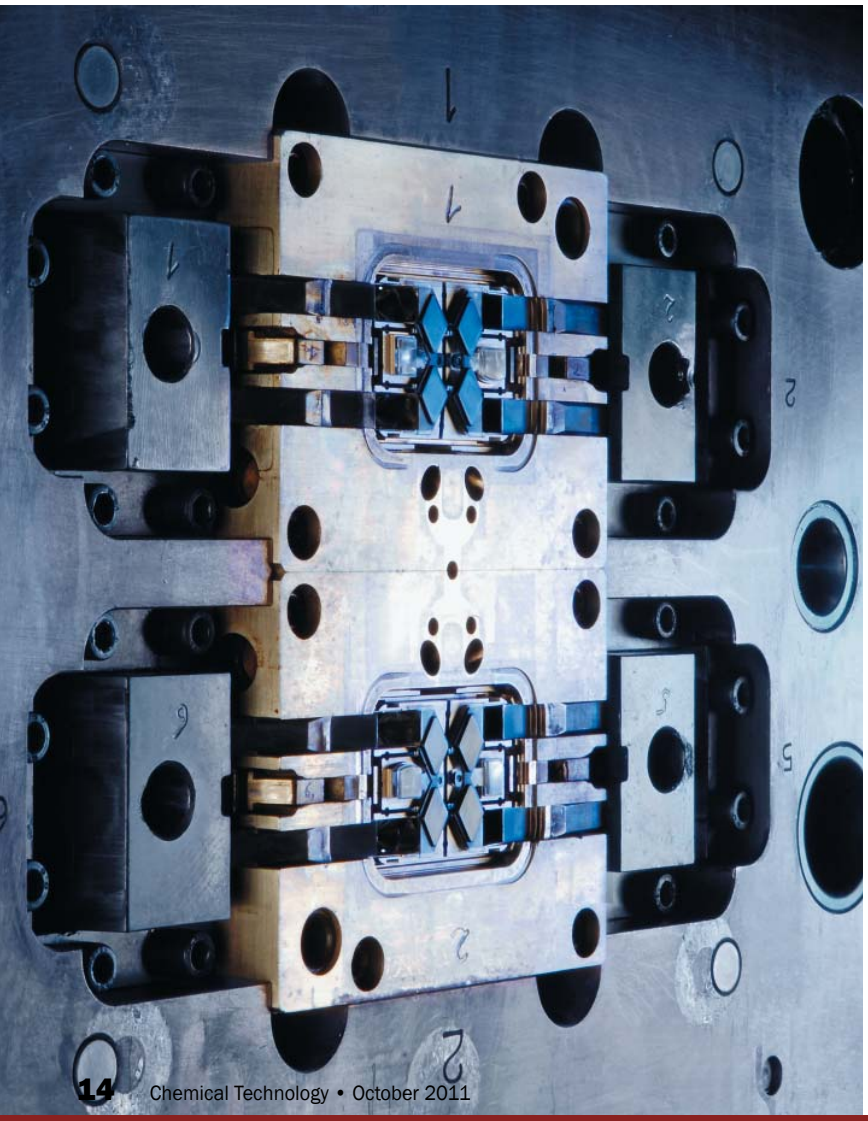
Figure 5: View into the injection moulding machine: the Openair plasma beam impinges with almost ultrasonic speed on the polycarbonate lenses. Microfine cleaning and strong activation impart new adhesion properties to the plastic material

Problem solving under time pressure

Weber-Formenbau was left with only five days before delivery of the final components. After a test run on 100 components in Plasmatreat's South Branch laboratory, which was carried out at short notice, overmoulding with LSR proved to be successful without any troubling effects. The optical inspection left no room for interpretation: not a single air inclusion; the silicone adhered perfectly to the polycarbonate. A further 800 components were subjected to the same pretreatment on the next day - with the same positive result.

The injection moulder, in order to enable direct component treatment in the tray, was provided the following day with a rental system. At the same time a plant concept for offline component treatment was developed since the desired integration of the plasma plant could apparently not be achieved because all the processing sides of the injection moulding machine were in use. Joachim Schüßler, Head-of-Sales-Germany at Plasmatreat, explained: "A situation we are, unfortunately, frequently faced with, is as follows: a new process unexpectedly does not work properly and our technology is harnessed to provide a remedy with inline pretreatment. When looking at the new machine we often find that there is no space left for installing the system."

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



Rain sensor functioning

In principle, the daylight beam falling on the windshield passes through the rain sensors lens 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 the car is being driven, the lower the light intensity measured by the diode and the stronger the pulses the sensor is sending to the vehicle's automatic wiper control system.

Integrated plasma system

In the case of Weber-Formenbau, an integration solution was, however, found in co-operation with the German engineering specialist KIKI Ingenieurgesellschaft mbH, Malsch and the injection moulding machine manufacturer Arburg GmbH + Co KG, Loßburg.

The machine base area was adapted and the plasma nozzle placed to enter the tool in a downward manner from the machine bed - rather than from upwards as usual. The two cavities were moved by means of a rotary unit. The overmoulding process of the PC optics with PBT was performed in the upper cavity (see Figure 6). After rotation, the already overmoulded components located in the lower cavity are treated with plasma using a pneumatic motion system.

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

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. Elvira Postic is convinced of the effectiveness of the pretreatment process:

Figure 7: The nozzle of type RD 1004 has been integrated into the fully automated injection moulding 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 in its safety and and in its 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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