PRETREATMENT OF ADHESIVE SURFACES

Plasma rescues adhesion crisis

A supplier had a problem. Despite initially appearing to bond reliably, a touch foil applied to a polycarbonate 3D control panel failed the rigorous climatic test demanded by an automotive manufacturer. Bubbles formed in the boundary layer between the plastic substrate and the foil. Rescue came in the form of a pretreatment with atmospheric pressure plasma.

INÈS A. MELAMIES

The most likely cause for the inability of additive-free plastics to be bonded or coated effectively, or indeed at all, despite having clean surfaces, is their low polarity and resultant low surface energy. This is ultimately the most important measure for determining the probable adhesion of an adhesive layer, paint or coating. If the surface energy of a plastic is too low, the material surface will require activating. The unexpected failure of an apparently successful adhesive bond sometimes comes to light only when a stress test is performed, for example a climatic test. Automotive component supplier Preh had to make this discovery during the developmental phase of a new control system. The Preh Group, part of Joyson Electronics, develops and manufactures climate control and driver control systems, sensors, ECUs and instruments for all well-known vehicle manufacturers.


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Figure 1: The adhesive bond between the PET touch foil and the new 3D control panel of the Ford Lincoln MKZ failed the climatic test. This problem was ultimately solved by using atmospheric pressure plasma.

When in early 2011 Preh received an order to produce a control system for the new Ford Lincoln MKZ, it was decided that one of the three versions would be manufactured in Bad Neustadt, the German headquarters of this globally active company. Known as the “center stack”, this control system lies at the heart of the central console packaging functions into the tightest possible space (Figure 1).

It combines climate control and infotainment functions, including telephone, navigation, radio and music systems in connection with temperature control. The lower half of the center stack has sliders with capacitive touch function for volume and fan adjustment as well as touch sensitive areas with corresponding icons for other functions.

A laminator is used to bond the PET touch foil complete with adhesive backing to the back of the injection molded polycarbonate panel of the center stack. The foil is equipped with multilayers of

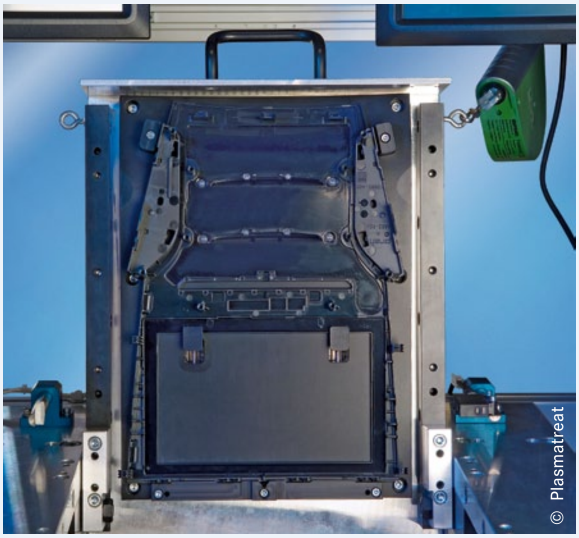

Figure 2: Polycarbonate panel in the laminator prior to applying the touch foil.

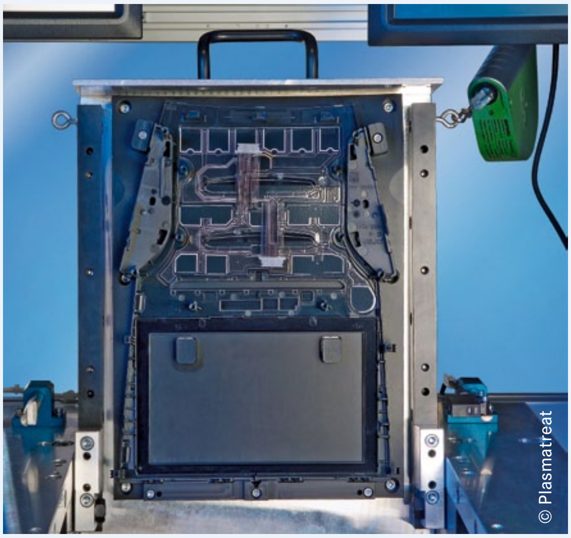

Figure 3: The PET foil complete with adhesive backing receives several layers of printed circuit containing all the electrical functions.

screen-printed circuit, which already contain the specific electrical functions (Figures 2 and 3). The adhesive process was deemed successful until a problem unexpectedly arose during the climatic test.

Delamination during climatic testing

The automotive industry is renowned for performing adhesive tests under extreme conditions. A climatic test represents a formidable challenge for a foil adhesive bond, since the climatic chamber is set up to simulate the long-term behavior of the product under severe environmental conditions. The aim is to reveal product weaknesses which have not previously been identified. The Ford specification required the adhesive bond to withstand one hundred hours in the climatic chamber at 85 °C and 85 % air humidity. When the housing was removed from the climatic chamber, the developers found themselves faced with a very unwelcome, but familiar phenomenon associated with foil adhesion: Large bubbles had formed in the boundary layer between the plastic substrate and the foil where the contact adhesive of the adhesive backing had detached. Martin Geis, production engineer at Preh explains: “Delamination like this would ultimately cause functions to fail. To solve the problem we initially looked for alternative adhesives, ranging from simple industrial adhesives to OCAs (optical clear adhesives), and subjected them to a variety of tests.” The simple adhesives produced large bubbles, the high-tech

Figure 4: The center stack production line arranged in a semicircle: Peter Langhof (Plasmatreat) accompanied by Martin Geis and Markus Lederman (Preh) supervising the plasma process (from left).

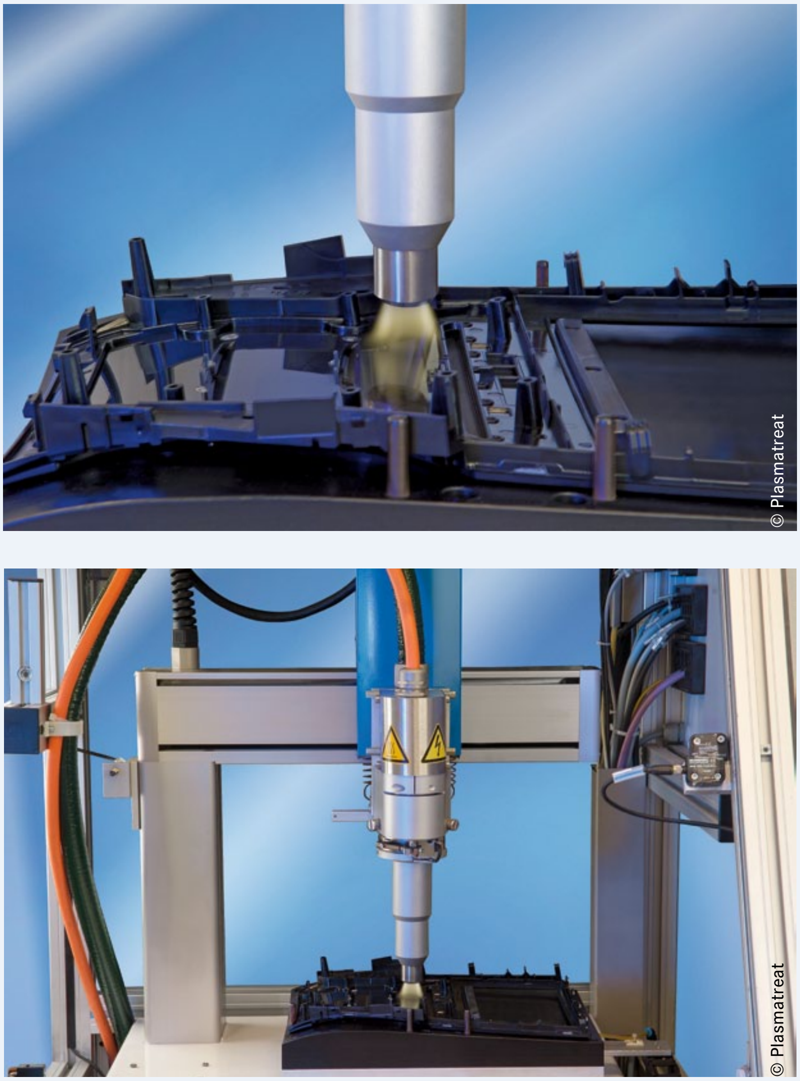

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Figure 5: A rotary nozzle selectively distributes the plasma on the inside of the panel where the foil will subsequently be applied.

adhesives produced smaller bubbles, but the problem remained the same: The adhesive film lifted.

Troubleshooting

Tracking down new adhesives and evaluating them was very time-consuming, and time was pressing on. Once it became clear that no amount of different adhesives was going to provide a solution, the focus turned to the component itself, the PC panel. The most likely cause of bubble formation was thought to be a release of gases from additives in the plastic due to intense warming in the climatic test or air moisture diffusing to the boundary layer. Air pockets caused by invisible dust particles could not be ruled out either. However, since changing the panel material was not an option, there was only one solution: an effective pretreatment of the plastic surface.

When it came to choosing a pretreatment method, Preh knew just where to turn. The company had acquired its first atmospheric pressure (AP) plasma system back in 2002 for microfine cleaning and activating sensor circuit boards prior to printing. Other systems for different production processes soon followed. Martin Geis: “Our laboratory in Bad Neustadt has a small plasma system so we sent our PC panel there for a preliminary plasma test.”

Pretreatment in an instant

Almost 20 years ago Plasmatreat developed atmospheric pressure (AP) plasma technology, a highly effective pretreatment process requiring nothing other than air and electrical energy, which is now used throughout the world.

The plasma process operates in-line under normal atmospheric conditions. Peter Langhof, marketing manager and Preh project manager at Plasmatreat, explains: “Our process performs three operations in a single step lasting only a matter of seconds: It simultaneously brings about the microfine cleaning, electrostatic discharging and activation of the plastic surface. This triple action far outweighs anything conventional pretreatment systems can achieve. The resulting homogeneous wettability of the material surface and long-time stable adhesion of the adhesive bond or coating is achieved even under the most challenging load conditions.” Non-polar plastics generally have a low surface energy between < 28 and 40 dyne, which is too low for liquid adhesive or paint to fully wet the surface. With these types of plastic, the surface energy must be increased by activation, since experience shows that only surface energies from 38 to 42 dyne offer the right conditions for adhesion.

Gently does it

Subsequent processes such as coating, adhesion or printing can be carried out immediately after plasma treatment. The surface of the material is exposed to the high-speed plasma for too short a time for components to sustain either thermal or other damage. Furthermore, the plasma process is virtually potential-free, which greatly extends its applicability, especially in the electronics sector. “For electronic or other sensitive components”, the plasma expert goes on to explain, “we use patented rotary nozzles with a particularly gentle rotary action, which distribute the pretreatment action evenly across the surface of the component.”

When the plasma hits a plastic surface, such as the polycarbonate panel, groups containing oxygen and nitrogen become incorporated into the non-polar polymer matrix. This modifies the surface. Energy-rich radicals, ions, atoms and molecular fragments present in the plasma release their energy at the surface of the material that is being treated and thus initiate chemical reactions which bring about this effect. The functional hydroxyl, carbonyl, carboxyl and ether groups that are produced form strong chemical bonds with the adhesives and coatings and so help to enhance adhesion.

Success with plasma

Preliminary laboratory tests with AP plasma were very encouraging. Surface tension measured using test inks increased from 25 dyne in the untreated state to over 50 dyne following plasma treatment. However, whether this would be enough to prevent bubble formation and delamination of the foil remained to be seen. Numerous specification tests went well and the atmospheric plasma process was found to be process-reliable and one hundred percent reproducible. But the climate test – the ultimate test of adhesion – still lay ahead.

This time when the polycarbonate panel was removed from the climatic chamber after four days’ storage under extreme temperature and high humidity, the developers breathed a sigh of relief. Markus Ledermann, manufacturing technology engineer at Preh, recalls: “There was not a bubble to be seen. With the foil adhesion fully intact, the adhesive bond had met the stringent requirements.” A subsequent functional climatic test of the fully assembled center stack went equally well. Not only did plasma cleaning ensure that the surfaces were cleaned to a micro-fine level; Plasma activation – and this was critical – ensured that the plastic surfaces formed a much stronger bond with the adhesive. The adhesive bond between the foil and the panel was now so strong that gases emitted from the plastic or air humidity within the foil no longer had the power to penetrate the boundary layer.

Plasma in the workflow

In October 2011, the automotive component supplier started series production. The plasma system purchased for this purpose was seamlessly integrated into Bad Neustadt’s semi-automated production line. The production cells arranged in a semicircle are assembled manually (Figure 4).

First the chrome trims for the sliders are fixed to the polycarbonate panel, which is injection molded in-house, by thermal staking. Pretreatment with atmospheric pressure plasma comes next. A rotary nozzle controlled by a three-axle robot selectively distributes the plasma on the inside of the panel where the foil will subsequently be applied. The rotating jet reaches every part of the 3D contour (Figure 5).

It takes just 10 seconds to complete deep-pore cleaning and activation of the plastic surface. Every two minutes, a treated component is removed and a new one inserted. The production line incorporates a control system which individually monitors every stage of the operation. The touch foil is applied to the faceplate immediately after plasma treatment. As this approach ensures good initial adhesion, the press can be quickly reopened, which allows short cycle times.

Summary

The process which combined plasma activation with optimum reproducibility guaranteed a high degree of process reliability, thereby satisfying the vehicle manufacturer’s demanding specifications. When asked about the maintenance costs after using the plasma system for two years, Martin Geis replied: “There’s nothing to say, it hasn’t been necessary yet.” He describes his working relationship with the plasma systems engineer as being one based on mutual trust and respect right from the outset. Over 150,000 plasma-treated center stacks leave the Bad Neustadt factory every year. The touch foil must be able to withstand at least one hundred thousand cycles, equivalent to an average service life of ten years, before showing any signs of weakness. Only the high quality level can satisfy this stringent requirement. ■

More information on this topic

Plasmatreat GmbH
D-33803 Steinhagen
Tel.: +49 (0) 5204 / 9960-0
peter.langhof@plasmatreat.de

or

Preh GmbH
D - 97616 Bad Neustadt a. d. Saale
Tel +49 (0) 9771 92-0
martin.geis@preh.de

The Author

Inès A. Melamies
(+49 (0)2224 989 7588,
info@facts4you.de)
is owner of the press agency
Facts4You in Bad Honnef.