When the foil fails to stick

Atmospheric pressure plasma as troubleshooter in touch foil bonding

1 The center stack of the Ford Lincoln MKZ's central console. The touch foil concealed behind sliders is pretreated with atmospheric pressure plasma to ensure bubble-free lamination

ELECTRONIC/AUTOMOTIVE_PLANT AND EQUIPMENT – bubbles forming in the boundary layer is a dreaded yet familiar phenomenon in foil adhesion: The adhesive bond between the touch foil and the new polycarbonate 3D control panel, despite initially appearing to bond reliably, failed the climatic test at a South German automotive component supplier. The manufacturer turned to atmospheric pressure plasma to safeguard series production.

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. German automotive component supplier Preh, which is part of Joyson Electronics, made this discovery during the developmental phase of a new control system for the Ford Lincoln MKZ. Known as the center stack, this control system lies at the heart of the central console and packs a variety of functions into the tightest of spaces »1. The lower half of the center stack has sliders with capacitive touch functions 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 »2. The foil has multiple layers of screen-printed electronic circuitry containing all the specific electrical functions »3. The adhesive bond initially seemed satisfactory until an unexpected problem arose during the climatic test.

Adhesion fails in the climatic test

Adhesion tests in the automotive industry are conducted under extreme conditions and a climatic test represents a formidable challenge for a foil adhesive bond. It simulates 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 100 hours in the climatic chamber at 85 °C and 85% air humidity. But when the panel was removed from the climatic chamber, large bubbles had formed in the boundary layer between the plastic substrate and the foil. The contact adhesive of the adhesive backing had detached in these areas. Delamination like this would cause subsequent functions to fail. To remedy the problem, the company initially looked for alternative adhesives ranging from simple industrial glues to OCAs (optical clear adhesives), and subjected them to a variety of tests. The simple adhesives produced large bubbles, the high-tech adhesives produced smaller bubbles, but the problem remained the same – the adhesive film lifted.

Researching the cause

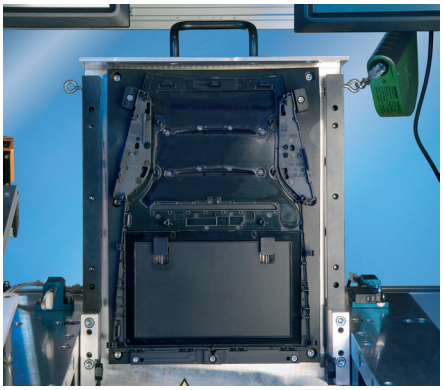
Once it became clear that changing the adhesive was not going to solve the problem, the focus turned to the component itself, the polycarbonate panel. The most likely cause of bubble formation was thought to be a release of gases from additives in the plastic due to intense warming during the climatic 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. The company opted for the Openair plasma technology developed by Plasmatreat.

Triple action plasma treatment

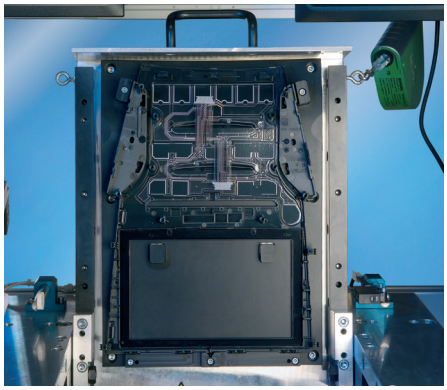
The process is based on the development of plasma nozzles. This highly effective and environmentally friendly pretreatment method requires only air as the process gas and electrical energy. Unlike low-pressure plasma, atmospheric pressure plasma works under completely normal air conditions and so does not require a vacuum chamber. The dry pretreatment process can easily be integrated in-line into new or existing production lines or even used externally. The process performs three operations in a single step lasting only a matter of seconds: It simultaneously brings about the microfine cleaning, electrostatic discharging and area-selective activation of the plastic surface. This triple action is more effective than conventional pretreatment systems.

During cleaning the high energy level of the plasma fragments the structure of organic substances on the surface of the material and removes all traces of contamination even from sensitive substrates, i.e. it cleans to a microfine level. The high electrostatic discharge action of the free plasma beam has an added benefit for the user: Fine particles of dust in the air are no longer attracted to the surface. This effect is further reinforced by the very high outflow rate of the plasma, which ensures that even particles loosely adhering to the surface are removed. The use of this plasma technology eliminates the need for an additional pretreatment such as manual wiping with alcohol, brushing or rinsing.

Non-polar plastics generally have a low surface energy between < 28 and 40 dyne – too low for liquid adhesive or paint to fully wet the surface. The surface energy of these types of plastic must be increased initially by activation, since experience shows that only surface energies of around 42 dyne or above offer the right conditions for adhesion. When the plasma hits a plastic surface (in this case the polycarbonate panel), groups containing oxygen and nitrogen become incorporated into the non-polar polymer matrix. This modifies and activates the surface, causing a significant increase in the surface energy. 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.



»2 The polycarbonate panel in the laminator prior to applying the touch foil



»3 There are several layers of printed electronics on the adhesive-backed PET touch foil

The functional hydroxyl, carbonyl, carboxyl and ether groups that arise (as well as the oxygen compounds of nitrogen) form strong chemical bonds with the adhesives and paints and so help to enhance adhesion.

Subsequent processes such as coating, adhesion or printing can be carried out immediately after the 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. By developing special rotary nozzles with a particularly gentle action, the manufacturer succeeded in discharging the electrical potential present in the plasma to such an extent that the plasma beam hitting the surface is virtually potential-free, thus enabling even sensitive electronic components to be treated.

Total foil adhesion

Preliminary laboratory tests were very encouraging. Surface energy increased from 25 dyne in the untreated state to over 50 dyne following plasma treatment; in other words, it more than doubled. However, whether this would be enough to prevent bubble formation and delamination of the foil remained to be seen. The specification tests went well and the 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 more than four days' storage under extreme temperature and high humidity, 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 surface was cleaned to a microfine level; plasma activation – and this was critical – ensured that the plastic surface 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.

Facts for design engineers

- Adhesion problems can easily be overcome by pretreating plastic components with atmospheric plasma

Facts for purchasers

- Short process times and easy integration into fully automated manufacturing systems make the atmospheric pressure plasma pretreatment appealing

Tacts for quality assurance managers

- By combining plasma pretreatment with precise reproducibility, the process guaranteed a high degree of process reliability, thereby satisfying the vehicle manufacturer's specifications

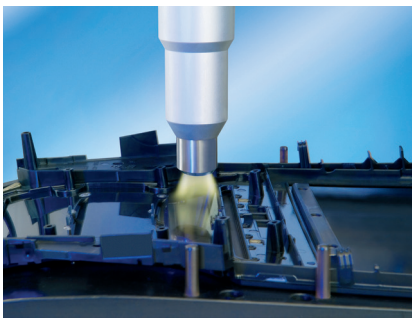
Further Informationen

Plasmatreat GmbH [1]
www.plasmatreat.de
Preh GmbH [2]
www.preh.de

Author: Inès A. Melamies, journalist, Facts4You
Contact: Peter Langhof, market and project manager[1], Martin Geis, production engineer [2]

Plasma in the workflow

The Openair plasma system integrates seamlessly into the semi-automated production line. The production cells arranged in a semicircle are assembled manually. First the chrome trims for the sliders are fixed by thermal staking to the polycarbonate panel, which is injection molded in-house. Pretreatment with atmospheric pressure plasma comes next. An RD1004 rotary nozzle controlled by a 3-axis robot selectively distributes the plasma on the inside of the panel, targeting the exact area where the foil will subsequently be applied. The rotating jet reaches every part of the 3D contour. It takes just 10 seconds to complete deep-pore cleaning and activation of the plastic surface. Every 2 minutes, a treated component is removed and a new one inserted. The touch foil is applied to the panel immediately after plasma treatment. As this approach ensures good initial adhesion, the press can be quickly reopened, which reduces cycle times.



The plasma system is space-saving. A patented rotary nozzle distributes the plasma on the inside of the panel only in those areas where the foil will subsequently be applied