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Plastic
and metal:
**a strong
connection**

MATERIALS TPC-ET with enhanced crystallization rate
INJECTION MOLDING High quality interior components
TECHNOLOGY Lightweight multi-sandwich design



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Plastic & metal A strong connection

An innovative coating process offers a pioneering solution for improving plastic-to-metal bonds in the injection molding industry

1 Over time, corrosive media can cross the interface and penetrate a hybrid component, causing damage and even delamination (Photo Plasmatreat)

The interface between plastic and metal is a risk factor which often proves to be a headache for injection molding manufacturers during the production of hybrid components. Over time, particularly corrosive media can cross the interface and penetrate the component, causing damage and even delamination (Picture 1). Practical experience shows that an injection-molded bond that was originally tight can become untight over time, lose cohesion and ultimately lead to the functional failure of the

components. In many cases, premature adhesive failure is caused by the absorption of moisture in combination with oxygen, which results in subsurface migration at the interface. System partners **Plasmatreat** (Elgin, USA) and **Akro-Plastic** (Niederzissen, Germany) set themselves the task of finding a secure industry solution to this problem.

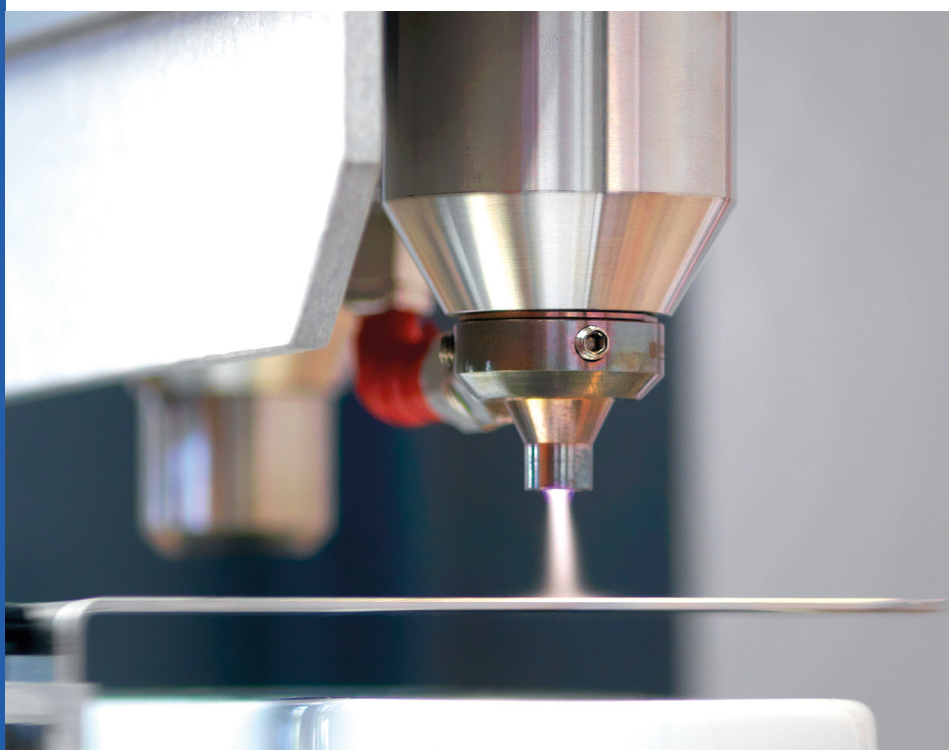
After two years of research, the plasma specialist and the plastics compound manufacturer succeeded in developing a process by the name of Plasma-SealTight. Here, the composition of an anti-corrosive plasma-polymerized layer generated under atmospheric pressure is precisely matched to the recipe for the plastic compound and the process parameters to create a long-time stable, media-tight bond of the injection-molded part.

Multifunctional

When creating a boundary layer between two different materials, the challenge is to ensure that the chemical properties achieve simultaneous bonding between the two materials. Plasma-SealTight is a chemical-physical process that creates a covalent bond between different materials by means of layer deposition in atmospheric pressure plasma. The layer bonds with the metal at molecular level and forms such a strong adhesive bond and tight seal with the adapted plastic compounds that it takes on the function of an anticorrosive coating. A precursor in the form of an organosilicon compound is added to the plasma to produce a coating. Due to high-energy excitation within the plasma, this compound is fragmented and deposited on the surface in the form of a vitreous layer. The chemical composition can

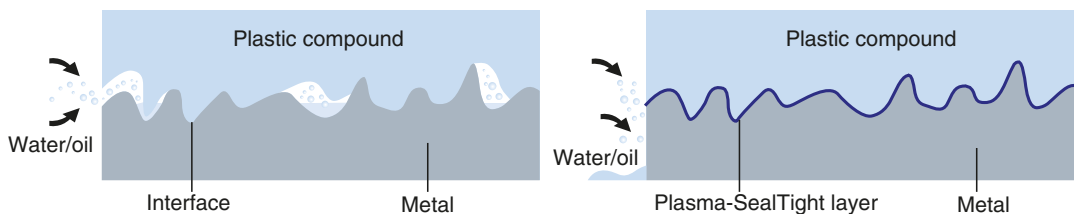
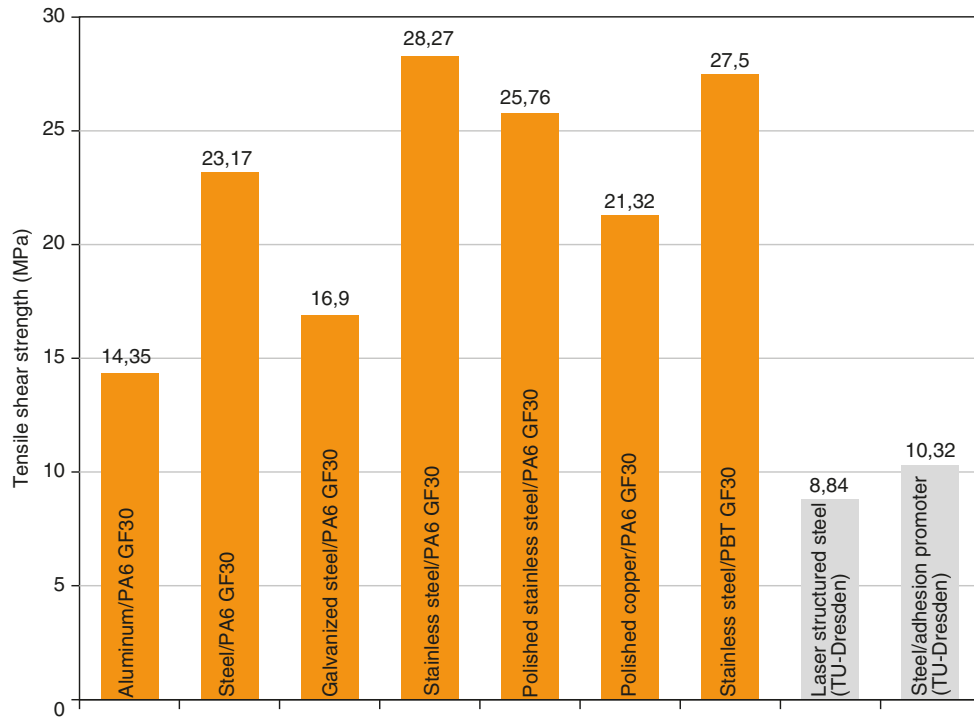
Plasma coating without vacuum

The PlasmaPlus coating technology underpinning this new sealing process was developed around ten years ago by Plasmatreat and the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen. Based on the Openair plasma nozzle technology developed by the plasma company back in 1995 for the microfine cleaning and activation of material surfaces, it enables functional thin-film coatings to be produced in line or externally under atmospheric pressure and thus under completely normal production conditions, thus dispensing with the separate, expensive vacuum chamber needed for low-pressure applications. The process is reliable and one hundred percent reproducible. The dry, environmentally friendly coating method replaces the cleaning and priming steps frequently used in hybrid injection molding. It also eliminates the need for process steps such as intermediate storage and drying, enabling components to be further processed immediately after coating.



2 The chemical-physical Plasma-SealTight process enables the area-selective deposition of functional nanocoatings in milliseconds and thus the creation of covalent bonds between different material (Photo Plasmatreat)

3 Comparison: The Plasma-SealTight bonds achieved maximum tensile shear strengths which far exceeded those of test specimens coated with adhesion promoter or laser-structured test specimens (Photo Plasmamatreat)



4 If water penetrates the boundary layer of the plastic-to-metal bond, it can lead to corrosion, failure of the component function or even delamination (left). The plasma polymer layer (right) fills every cavity, leaving the water no opportunity to penetrate the boundary layer. The covalent bond thus provides corrosion protection (Photo Plasmamatreat)

be varied according to the application to ensure that optimum functionalization is obtained for any given material. A further advantage of the process is its great flexibility. In particular, the coating thickness and process speed can be precisely matched to a specific level of corrosion protection. Without doubt, the special advantage of this process over other coating techniques is the fact that layer deposition is area-selective, i.e. the nozzle technology enables it to be targeted with pinpoint accuracy to a precisely defined location, even at very high processing speeds (Picture 2). A 100nm thin coating is deposited in milliseconds,

whereas it would take around one to two minutes to do this using low-pressure plasma (vacuum chamber) and localized selection would not be an option. By developing new precursors and extensively adapting the plasma parameters, Plasmamatreat has succeeded in selectively incorporating several functions into a single layer in the Plasma-SealTight process. These functions include good bonding to the metal surface, enhanced corrosion resistance, acting as a media and oxidation barrier and adhesion-promoting properties for plastics through the creation of functional chemical groups. Whilst the silicon contained in the layer

Plastic recipes

When formulating recipes for their plastics, manufacturers have to take into account many characteristics of the subsequent product stipulated by the customer – mechanical, electrical, thermal and chemical properties, the plastic's fire rating and its general properties such as density and moisture absorption. Each plastic matrix is modified through the addition of additives, fillers and reinforcing materials. It is these components of the recipe that turn a base plastic into an application-specific plastic compound.

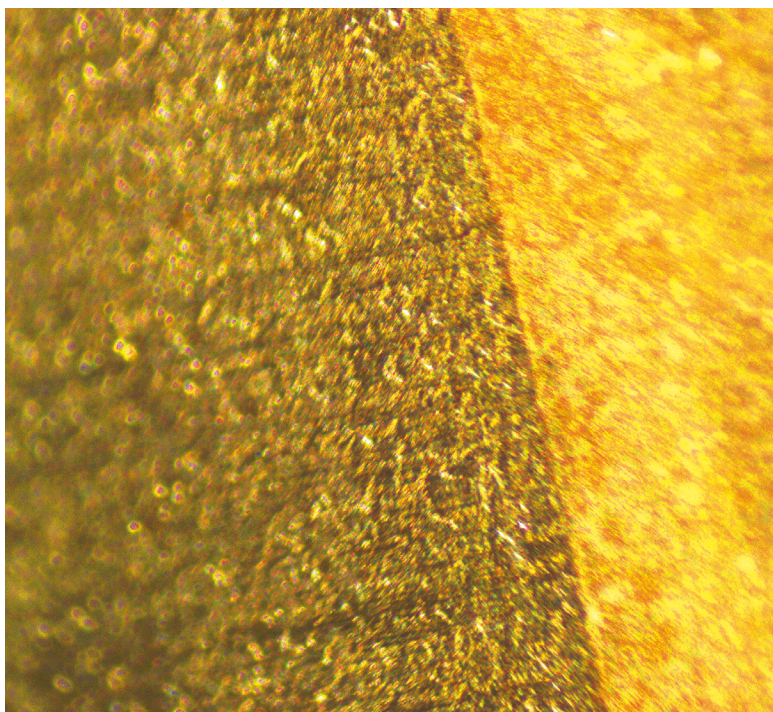
To guarantee consistent product quality and thus the functioning of subsequent components, the manufacturer must have an extremely precise and reproducible compounding process. Akro-Plastic specializes in complex, customized adaptations of plastic properties. Having developed its own compounding technology, it can satisfy the above-mentioned requirements for functional integrity and quality internationally regardless of the production location and so took on the task of creating a compound with specific properties for the project. The chemical recipe had to take account of two main aspects; the different coefficients of linear expansion of plastic and metal on the one hand, and the chemical-physical adhesive bond with the plasma polymer layer on the other.

facilitates adhesion to metal and metal oxide, silicon oxide is responsible for the barrier effect and media tightness. The organic components in the layer (functional groups) are responsible for the adhesive bond with the polymer.

Strong adhesion

For the test phase the company focused on a glass fiber-reinforced type PA6 GF30 plastic for the base compound, which was modified as testing progressed. Around 3500 test specimens of the different metals and modified plastic compounds were tested, during which time the plasma layer was continuously optimized in terms of both adhesion and protection against corrosive media. The desired cohesive fracture of the plastic was achieved with steel, stainless steel, polished stainless steel and polished copper. High tensile shear strength values were obtained with these metals (Picture 3). A mixed fracture was obtained

5 The micrograph shows a clear distinction between the plasma-coated, corrosion-free metal surface (left) and the uncoated, corroded area (right) (Photo Plasmatreat)



6 The turnkey, fully automated PTU1212 plasma cell contains everything the plasma process needs and can be connected to any conventional injection molding machine (Photo Plasmatreat)



with aluminum and galvanized steel. A cohesive fracture of the plastic was also obtained with other combinations such as steel and stainless steel overmolded with the thermoplastics PA66 GF30, PA6 GF50, PA66+PA6 GF30 and PBT GF 30. Artificial ageing tests showed good levels of strength here too.

Media-tight

Water can easily penetrate the boundary layer and spread across the surface of materials that do not have a chemically bonded connection. The plasma seal prevents this effect by filling the microscopic cavities like a fine mist, bonding to the metal surface and forming a corrosion-proof barrier (Picture 4) The aim of the media tightness and corrosion resistance tests was to discover the extent to which the required bond strength is weakened by artificial ageing. Tests on plasma-treated metals showed that the layer forms a barrier against water, saline

solutions and gases and thus prevents the subsurface migration of these media. A stainless steel test specimen demonstrates these findings; it was plasma-coated under atmospheric conditions on one half only, fully overmolded with PA6 GF30 and then placed in a corrosive medium for several weeks. On removal, the plastic was mechanically removed and the metal was tested. There was a clear distinction between the uncoated, now badly corroded area and the plasma-coated, corrosion-free metal surface (Picture 5). Investigations of oil and other media tightness are currently under way, with preliminary tests already showing promising results.

Technical implementation

In automating the coating process, the plasma company focused on designing a multi-component pretreatment system which is compact and easy to integrate into a continuous production line.

The company achieved its goal with the development of the turnkey, fully automated PTU1212 plasma cell (Picture 6), unveiled for the first time at K 2016. The cell, which can be adapted to suit any conventional injection molding machine, makes the process faster and at the same time allows for the continuous flow production of mass-produced plastic-to-metal components. It contains everything the process needs, from the generator, robot, control technology, PCU plasma control unit and plasma jets to cables and consumables. The plasma system itself has two separate plasma nozzles. A robot – or with the two smaller variants, an XY axis system – guides the metal inlay initially beneath the Openair plasma beam, which removes any contamination from its surface at molecular level, thus restoring its original good wetting behavior. The functional coating is applied immediately afterwards from the second plasma nozzle.

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