

Symbiosis between metal and plastic

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An innovative plasma sealing technology combined with application-specific thermoplastic compounds now makes it possible to achieve particularly strong, media-tight joints between hybrid injection molding components.

Une vitrification novatrice au plasma associée à des composants thermoplastiques spécifiques à chaque application permet maintenant d'interconnecter de manière particulièrement forte et étanche des composants hybrides moulés par injection.

Eine innovative Plasmaversiegelung in Kombination mit anwendungsspezifischen Thermoplast-Compounds ermöglicht jetzt den besonders starken und mediendichten Verbund von Spritzguss-Hybridbauteilen.

Joining thermoplastic compounds to metal is state-of-the-art in injection molding. However, the interface where the different materials meet is still regarded as a risk factor. If not properly sealed, it provides a permanent pathway for the ingress of water, air or other media. In many cases, premature adhesion failure of such components is caused by the absorption of moisture in combination with oxygen, which results in subsurface migration at the interface. Water ingress in this boundary area leads to corrosion of the metal, which often results in complete functional failure.

The plasma sealing technology «Plasma-SealTight» developed by Plasmatreat and Akro-Plastic offers a completely new approach to ensuring a very strong, media-tight hybrid joint (Fig. 1). Here,

the composition of an anti-corrosive plasma-polymerized layer generated under atmospheric pressure, the recipe for the plastic compound and the process parameters are precisely matched to create a long-time stable, media-tight bond of the injection-molded part.

Plasma coating without vacuum

The new plasma sealing process is based on the «PlasmaPlus» technology developed around ten years ago by Plasmatreat and the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen. This discovery made it possible to produce functional thin-film coatings for the first time under atmospheric pressure and thus under completely normal production conditions inline or externally, dispensing with the costly separate 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.

Multi-functional with millimeter precision

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 adherent joint and tight seal



Fig. 1: 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 materials. (Pictures: Plasmatreat GmbH)

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 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 (Fig. 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, Plasmatrete 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 facilitates adhesion to metal and metal oxide, silicon oxide is responsible



Fig. 2: The metal part (left) can be overmolded with the thermoplastic compound (right) immediately after atmospheric pressure plasma coating to produce a strong joint.

Overview of the «Plasma-SealTight» process Innovation and cost reduction:

- safe, globally available industry solution
- in-line use in the injection molding production line (no external transport routes)
- greatest possible process reliability and consistent reproducibility
- high potential for developing new material combinations
- area-selective, high-speed pretreatment

Increasing component quality

- significant improvement of adherent joints
- corrosion protection of metal inlay
- media-tightness in the joint interface
- highly precise and reproducible compounding process ensures consistent product quality

Sustainability

- complete elimination of solvents, primers and acids
- no VOC emissions
- very low use of chemicals (precursors)
- high energy efficiency due to low energy consumption of the plasma unit
- high energy efficiency due to the elimination of transport routes for semifinished components
- high energy efficiency due to the elimination of drying processes for semifinished components

for the barrier effect and media tightness. The organic components in the layer (functional groups) are responsible for the adherent joint with the polymer.

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

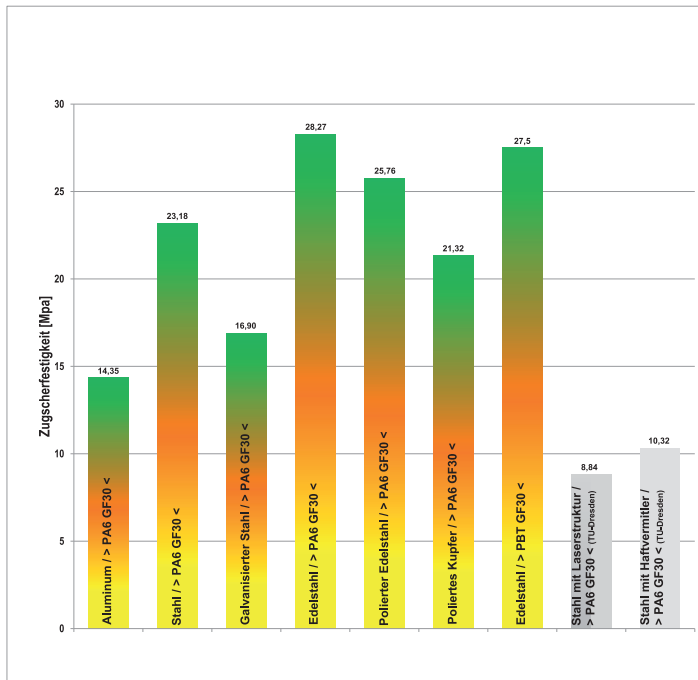


Fig. 3: The «Plasma-SealTight»-joints achieved maximum tensile shear strengths which far exceeded those of test specimens coated with adhesion promoter or laser-structured test specimens.

different coefficients of linear expansion of plastic and metal on the one hand, and the chemical-physical adherent joint with the plasma polymer layer on the other. When all the criteria have been evaluated and adjusted, the atmospheric pressure plasma-coated metal can be overmolded immediately with the thermoplastic compound to produce a strong joint without the need for any additional resources or measures (Fig. 2).

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 (Fig. 3). A mixed fracture was obtained 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.

Mediendicht

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 (Fig. 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 (Fig. 5). Investigations of oil and other media tightness are currently under way, with preliminary tests already showing promising results.

Technical implementation

The coating process became mechanized with the development of the turnkey, fully automated

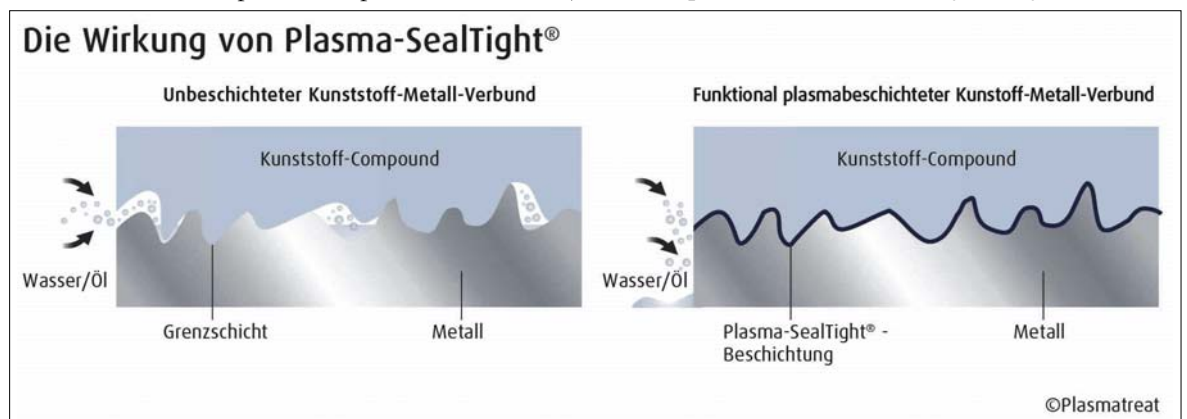


Fig. 4: If water penetrates the boundary layer of the plastic-to-metal joint, it can lead to corrosion, failure of the component function or even delamination (left). The plasma polymer layer (right) fills every cavity, leaving the water no opportunity to penetrate the boundary layer. The covalent bond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

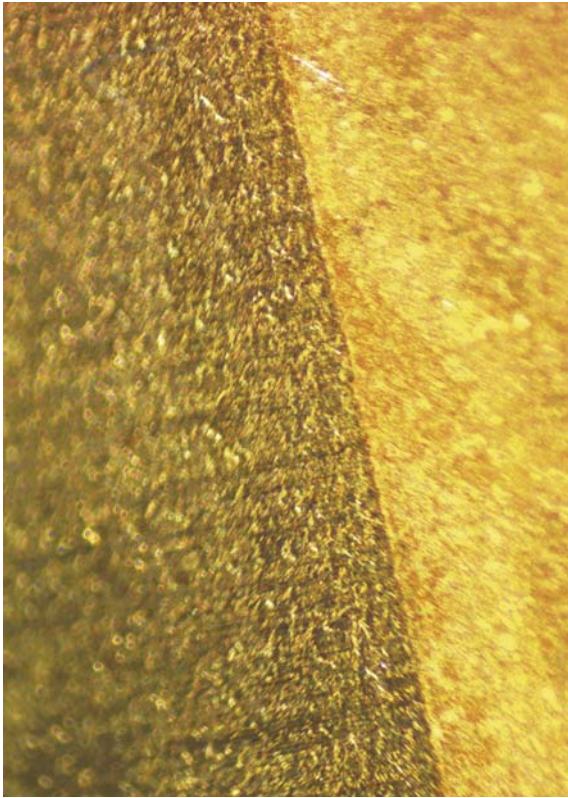


Fig. 5: The micrograph shows a clear distinction between the plasma-coated, corrosion-free metal surface (left) and the uncoated, corroded area (right).

PTU1212 plasma cell (Fig. 6). 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.

Summary

This innovative coating process offers a pioneering solution for improving plastic-to-metal joints in the

injection molding industry. The system partnership between the two specialists provides users with a particularly high degree of security for customized requirements. According to data from the manufacturers, the new process ensures greater product quality in addition to a reliable, reproducible and cost-effective production process, whilst at the same time being completely environmentally benign.



Fig. 6: The turnkey, fully automated PTU1212 plasma cell contains everything the plasma process needs and can be connected to any conventional injection molding machine.

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