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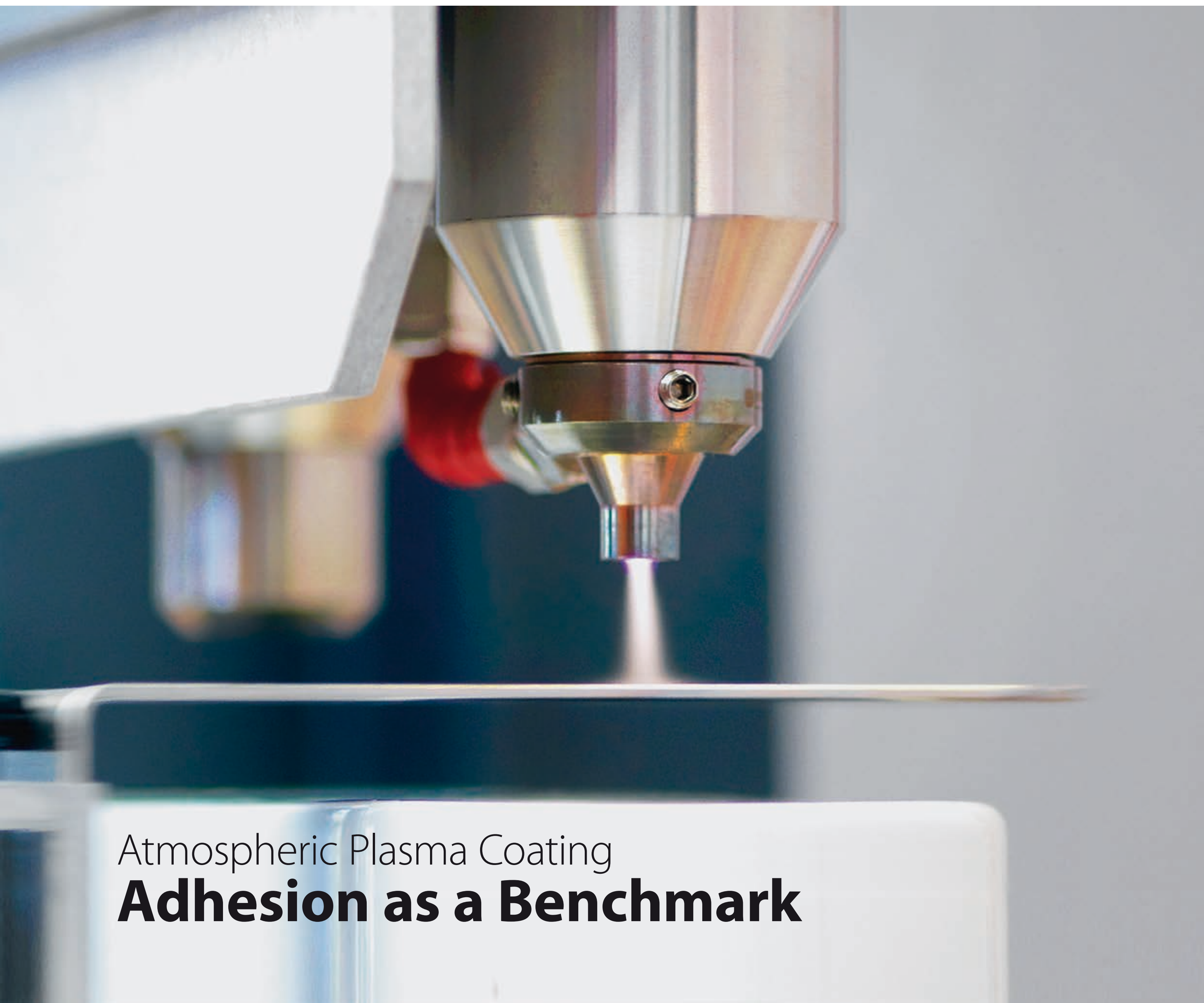
Automotive Finishing
The Route to High-Tech Manufacturing

New Powder Coating Line
Plant sets new Standards of Productivity and Flexibility

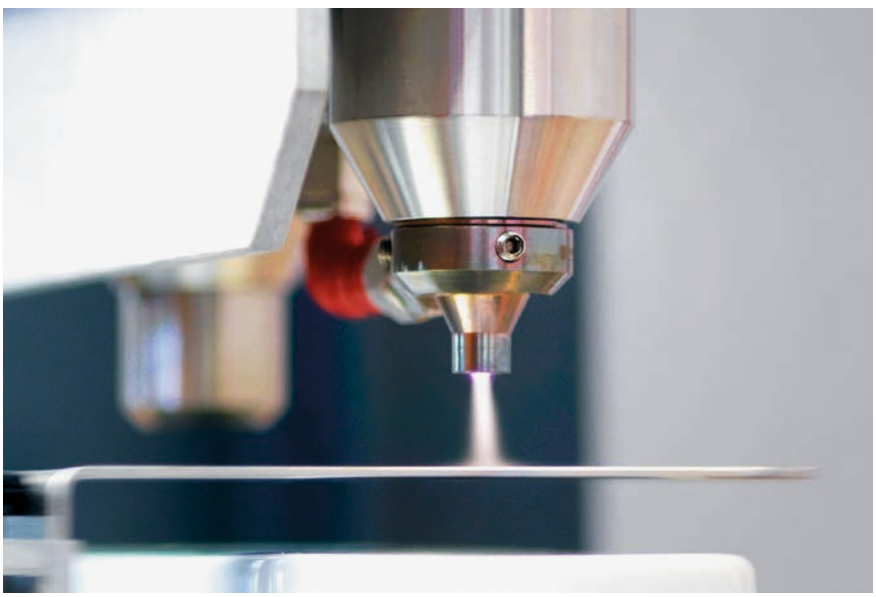
Wet Blasting Machine
Perfectly Prepared for Coating



Atmospheric Plasma Coating
Adhesion as a Benchmark

Adhesion as a benchmark

A new environmentally-safe systems solution based on atmospheric plasma coating not only promises a particularly strong, media-tight plastic-to-metal bond in the injection molding process, but also a very cost-effective solution.



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The newly developed chemical-physical coating process enables the area-selective application of functional nanocoatings in milliseconds and the formation of covalent bonds between different materials

The bonding of thermoplastic compounds to metal is state-of-the-art in injection molding and used in many industrial applications. However, the interface where the completely 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 a plastic-to-metal bond.

Practical experience shows that even an injection-molded bond that was originally tight can become untight over time, subsequently leading to failure of the component function and delamination. In many cases premature adhesive failure is caused by the absorption of moisture in combination with oxygen, resulting in subsurface migration at the interface. Water ingress in the boundary area leads to corrosion of the metal and in most cases to complete functional failure.

Plasma-SealTight (PST) – a plasma sealing technology developed by Plasmatreat and Akro-Plastic – now offers a completely new approach to achieving a particularly strong, media-tight hybrid bond Here, the composition of a plasma polymer 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.

Plasma under normal pressure

The PlasmaPlus coating technology – on which the new process is based – was developed about ten years ago by Plasmatreat and the Fraunhofer Institute IFAM. Based on its sister technology Openair plasma, developed by Plasmatreat in 1995 for the ultrafine cleaning and activation of material surfaces, PlasmaPlus allows functional thin-film coatings to be applied to material surfaces under atmospheric pressure rather than in a separate vacuum chamber under low pressure; in other words, inline or externally, under completely normal production condition. The process is secure and one hundred percent reproducible. The dry and environmentally friendly method entirely replaces cleaner and primer processes often used in hybrid injection molding. It also dispenses with the need for process steps such as intermediate storage and drying, enabling parts to be further processed after coating.

Vision and challenge

Whilst the use of PlasmaPlus technology soon became standard for bonding and

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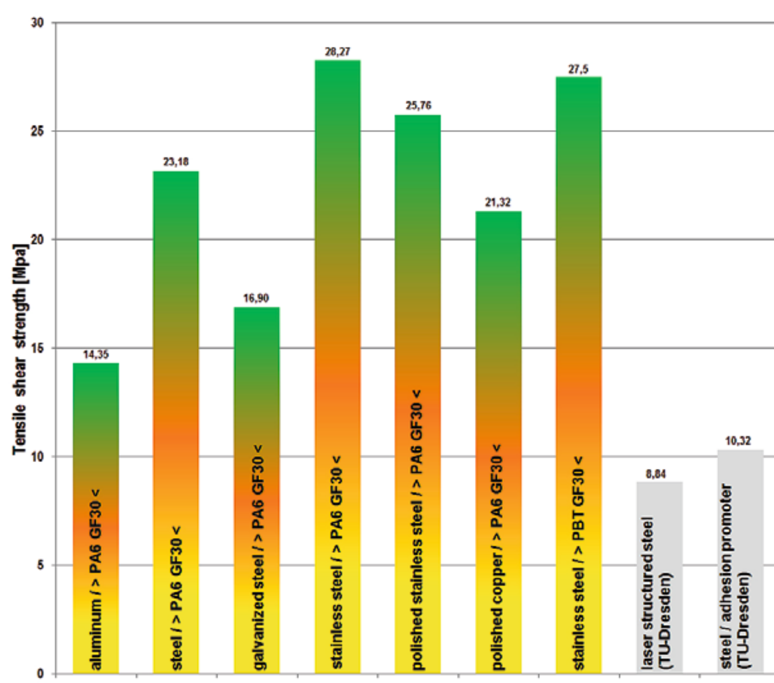
The penetration of water through the boundary layer of a plastic-to-metal bond due to poor adhesion leads to corrosion of the metal and in most cases, to complete functional failure.

painting processes, its use in hybrid injection molding remained a vision until very recently. Leonhard Enneking, who for ten years has been 2-component specialist, key account manager and project manager at Plasmatreat, had long been seeking a suitable plastics manufacturer to form a system partnership with. The suitable candidate not only had to be willing to tackle this exciting topic with him in-depth, but would also have to be capable of implementing it rapidly into the production process at a later date. He found the right partner in Akro-Plastic.
Following preliminary trials, strategic market analysis was undertaken in the first year to explore the barriers to market entry and the most important topics for users. On the basis of this analysis, it was decided to focus initially on technical plastics in general and thermoplastics (polyamides) in particular, since these play an important part in most technically based industrial and automotive applications. "The challenge", says Enneking "was to develop a new functional coating on the one hand, and a complete industrial solution on the other". Achieving this goal required not only a stable process and suitable consumables; the chemical composition and processing properties of the new plasma coating also had to be reliable, ergonomic and sustainable, i.e. user-friendly, low-odor and environmentally safe. This was the high standard they aspired to when the system partners began the actual test phase for their future project in 2015.

Multi-functional and millimeter precise

The creation of a boundary layer between two dissimilar materials presents the developers with a major challenge, since the chemical properties of the layer call for the creation of a simultaneous bond between different materials. The task becomes even more complex if the materials belong to different groups, as is the case here with metal and plastic.
PlasmaPlus 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, in combination with the



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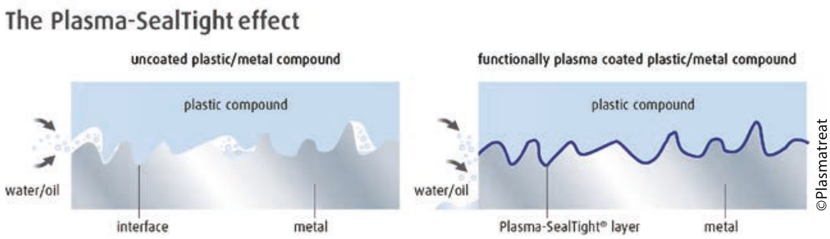
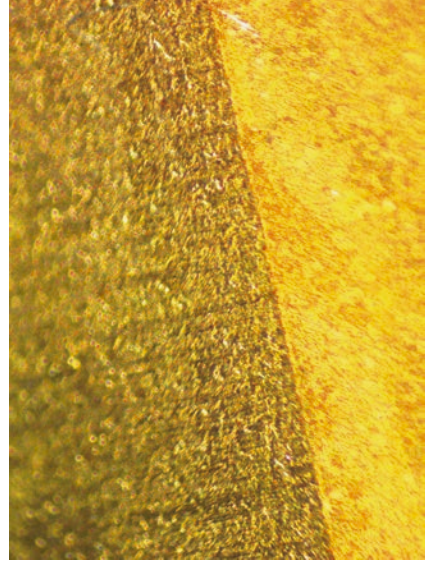
Comparison: The maximum tensile shear strengths of Plasma-SealTight bonds are well above the maximum values obtained from laser-structured test specimens or ones coated with an adhesion promoter.



Water penetrating the boundary layer of the plastic-to-metal bond can lead to corrosion, failure of the component function or even delamination (left). However, the plasma polymer layer (right) prevents this by filling every available cavity, leaving the water no opportunity to penetrate the boundary layer. Thus the covalent bond acts as a corrosion-proof barrier.



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

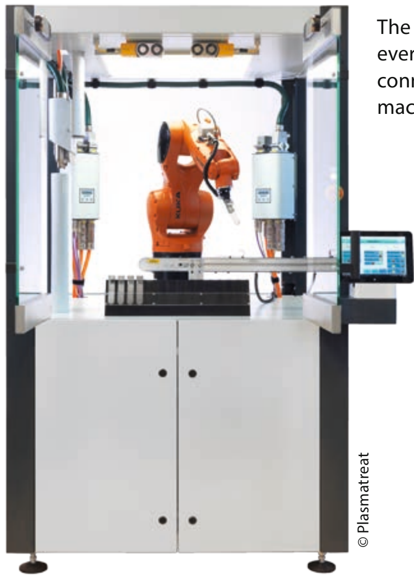
adapted plastic compound, it forms such a strong joint and tight seal that it takes on the function of an anticorrosive coating.
A precursor in the form of an organosilicon compound is added to the plasma to produce a coating. Due to high-energy excitation within the plasma, this compound is fragmented 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. A 100Nm thin coating, for instance, can be 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, the plasma specialists succeeded in selectively incorporating several functions into a single layer. 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 for the barrier effect and media tightness. The organic components in the layer (functional groups) form the adhesive bond with the polymer.

Adaptation of the plastic compounds

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. The company developed its own compounding technology to enable the above-mentioned requirements for functional integrity and quality to be met internationally regardless of the production location, and took on the task of creating a plastic compound with specific properties for the project. Edgar Düvel, formerly with Akro-Plastic, now Global Market Segment Manager at Plasmatreat, explains what it comes down to: “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.”

Bond strength in the test phase

For the test phase the team focused on a glass fiber-reinforced type PA6GF30 plastic for the base compound, which was modified as testing progressed. Around 3500 test specimens of the different metals and modified plastic compounds have been tested to date, during which time the PlasmaPlus layer has been continuously optimized in terms of both adhesion and protection against corrosive media.



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

Media tightness

The aim of the tests carried out to date on the media tightness and corrosion resistance of plasma-coated metals was to discover to what extent the bond strength obtained is weakened by the exposure test. The results showed that the layer forms a barrier against water, salt solutions and gases and thus prevents the migration of these media.
Example: One half of a metal test specimen was plasma-coated under atmosphere. The whole part was 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.
Investigations of oil and other media tightness are currently under way, with preliminary tests already showing very promising results. For example, during the first exposure test in engine oil, a customized test component (brass/plasma sealing layer/ PA6 GF30) showed no signs of leakage even after 1600 hours. A plasma-coated brass test specimen overmolded with PBT GF30 remained tight even after 2000 hours of exposure. The test cycles in both tests were eventually discontinued as the stipulated number of test hours had been significantly exceeded.

Technical implementation

In automating this innovative 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 fully automatic PT1200 plasma cell, which can be adapted to suit any conventional injection molding machine. This unit makes the process faster and at the same time allows for a continuous flow production of injection molded plastic-to-metal components for series production. The cell 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 on a molecular level, restoring its initial good wetting capability. 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 bonds 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 the manufacturers, the new process also ensures greater product quality and a reliable, reproducible and cost-effective production process, whilst at the same time being completely environmentally benign. //

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