Locally Selective Functional Layers with Atmospheric Plasma

New Plasma Technology for Functional Surfaces

A new atmospheric plasma technology and winner of the Industry Award 2012 offers a wealth of locally selective, different functional nanocoatings for material surfaces. What was previously possible only under vacuum can now be achieved under normal pressure in a continuous, in-line production process.

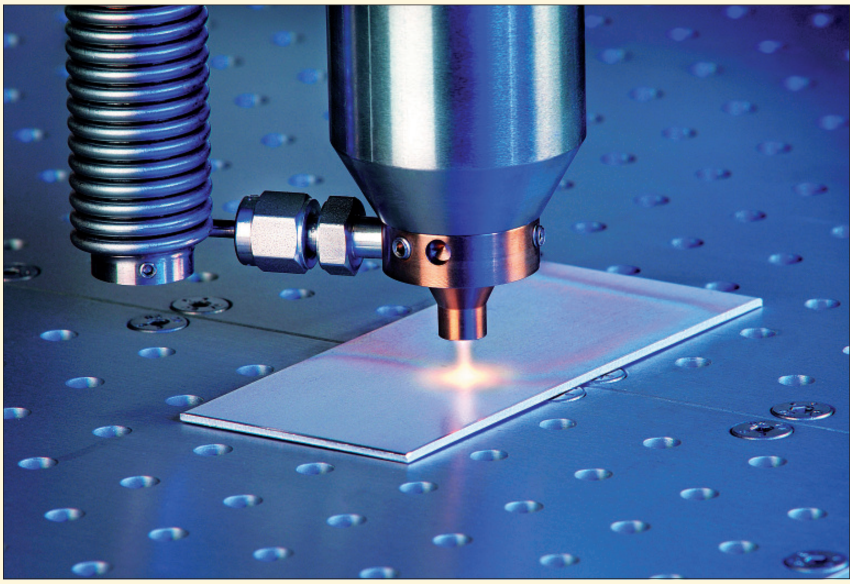

Figure 1
Locally selective plasma coating under atmospheric pressure: the chemical composition can be varied according to the application to obtain the best results for a variety of different materials

The process is based on the Openair plasma jet technology developed by Plasmatreat GmbH which has been used throughout the world for almost 20 years. This system is characterised by a threefold action: it activates surfaces by selective oxidation processes, discharges them at the same time and brings about microfine cleaning of materials such as metals, plastics, ceramics and glass. A particular feature of this technology is that the plasma is potential-free, which greatly increases the range of possible applications. The intensity of the plasma is so high that processing speeds of several 100 m/min can be achieved. It also offers economic benefits: the jet systems are designed for in-line integration by the user, i.e. they can be integrated directly into a new or existing production line, and they are compatible with robotic systems.

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Plasma coating under normal pressure

In addition to the functions described above, this plasma system is also used for functional coating (Figure 1). Until recently this coating process could only be performed under vacuum. Plasmatreat, in close collaboration with the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen, has spent the last few years developing an innovative process called PlasmaPlus, which for the first time enables a nanocoating to be applied to material surfaces under normal atmospheric conditions. In recognition of its work in developing this simpler, far quicker and more cost-effective process, the company was this year granted the Industry Award 2012 in the "Production and Mechanical Engineering" category. Fraunhofer researchers Dr. Jörg Ihde and Dr. Uwe Lommatzsch received the Joseph von Fraunhofer Prize at almost the same time.

At the heart of the process is a plasma nozzle which conceals a highly complex coating system (Figure 1). The process is environmentally friendly, needing nothing other than compressed air, electricity and a precursor,

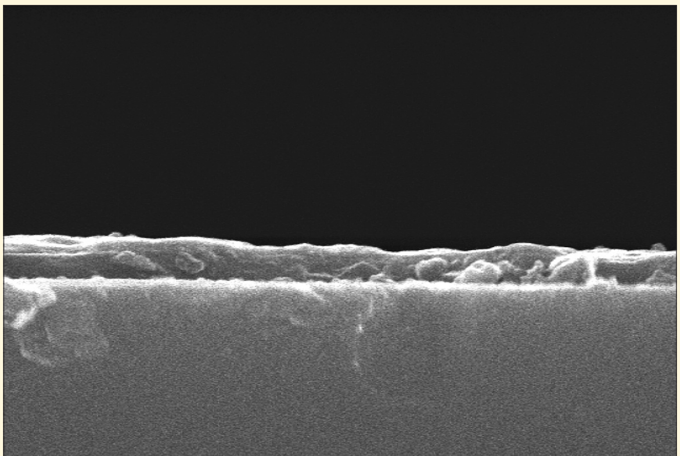

Figure 2
The image shows a cross-section through an approximately 100 nm thick PlasmaPlus coating (SEM 50,000x magnification)
Source: Saint-Gobain

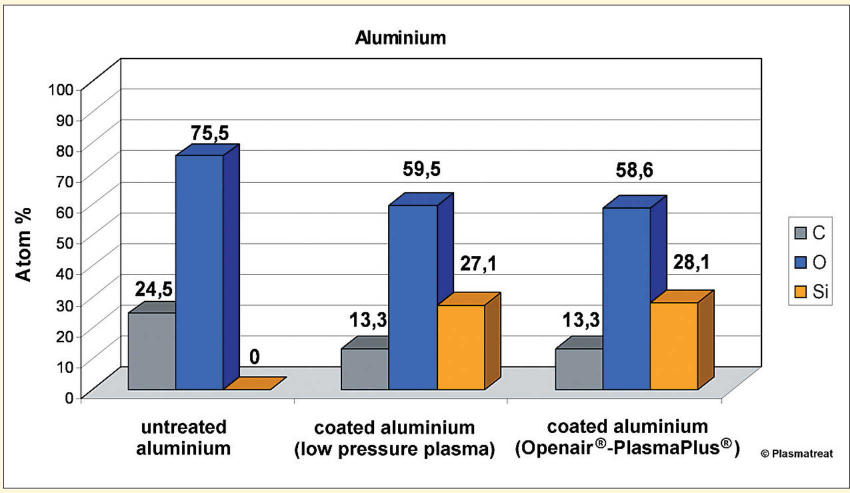

Figure 3 Composition of the coatings produced by PlasmaPlus

which is added to the plasma to create the coating. Due to the high-energy excitation in the plasma, this compound is fragmented and deposited on a surface as a vitreous layer (Figure 2). The chemical composition can be varied according to the application to achieve the best results on a variety of different materials.

Apart from in-line use, the main advantage of PlasmaPlus compared with other systems is the locally selective coating technique. The use of a plasma jet enables the coating to be applied in a highly targeted manner which makes efficient use of resources. Processes can be controlled in such a way that coatings which confer different functions, such as corrosion protection, adhesion, or even anti-adhesion, can be applied using the same nozzle (Figure 3). This means that only very small quantities of coating material are required, and very varied materials or material combinations can be applied.

Research goals and applications

Plasma coating makes it currently already possible to create hydrophobic surfaces that repel water. Surfaces treated in this way are also dirt-repellent and self-cleaning without requiring any mechanical cleaning action. Barrier or diffusion coatings created using plasma are an important focus of research. They are considered a reliable protection for food, beverage and medicinal packaging and provide an effective barrier to carbon dioxide, oxygen and water. They can be applied to all types of plastics and enable the production of barrier films or PET bottles with a CO_2 barrier.

The award-winning PlasmaPlus process can already be used to apply photocatalytically-active titanium-dioxide coatings. When exposed to sunlight and moisture, these coatings have a self-cleaning and germicidal effect. This application is of particular interest for coating medical and sanitary products since it allows manual cleaning intervals to be extended or omitted altogether. Another Plasmatreat research topic is the deposition of antimicrobial coatings containing silver.

Plasmatreat is also intensively researching and developing techniques to improve rubber-to-metal and plastic-to-metal bonding in hybrid injection moulding. This involves applying nanocoatings with active adhesion to the metal surface, then moulding the plastic component onto the surface. In the future, depositing adhesion-promoting coatings with the PlasmaPlus process will provide an alternative to solvent-based primers in automobile manufacturing.

Plasma coating has been successfully used as a universal release treatment for injection moulding tools for the past two years. It provides exceptional anti-adhesion characteristics for a variety of different polymer and rubber-based mould materials. This anti-adherent effect is due entirely to plasma polymerisation on the mould surface. Thanks to this environmentally friendly process, wet chemical release agents are no longer required, nor is it necessary to demount moulds for re-coating, since old coats no longer have to be removed. New coatings can now be applied directly to the mould in situ.

Up to now, the solar industry has used polymer coatings in the µ range to achieve the corrosion protection required for solar panels. The new process relies on atmospheric plasma polymerisation to achieve the same level of protection, albeit with a considerably smaller layer thickness in the nanometre range, which greatly reduces the light absorption of the coating.

It is also possible to apply atmospheric plasma coatings to complex 3-D components using the PlasmaPlus process based on Openair plasma technology. The coating material even reaches areas that are difficult to access like deep groove geometries or undercuts. This makes it possible to completely coat populated circuit boards on or under the components.

The anti-corrosion coating provided by atmospheric plasma polymerisation is particularly effective with aluminium alloys. It can protect the aluminium from direct salt spray (DIN 50021) for several days without affecting the visual appearance of the metal (Figures 4 and 5). The jet system

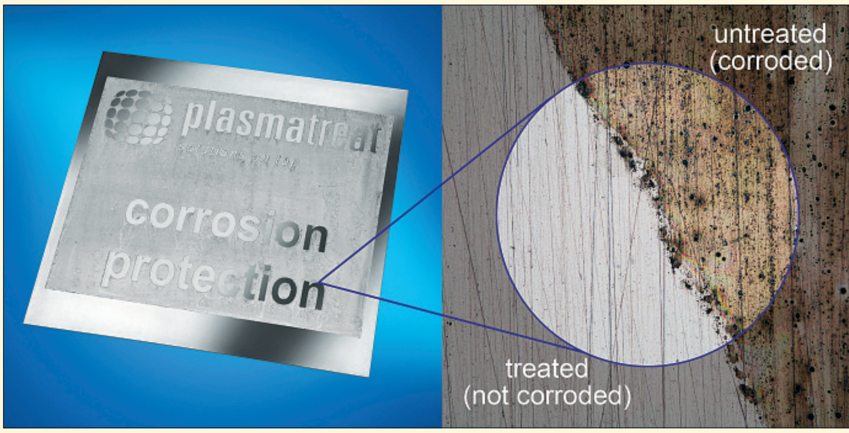

Figure 4 The area protected by the PlasmaPlus coating shows no signs of corrosion even after a 96 hour salt spray test

SWAAT-Test	Test duration [hours]			
	50	250	500	750
Without corrosion protection	leak-proof	leaky	leaky	leaky
Anticorrosion grease sprayed on	leak-proof	leak-proof	leak-proof	leaky
Coating with PlasmaPlus® plasma	leak-proof	leak-proof	leak-proof	leak-proof

Figure 5

Leak testing using the salt spray test (green: housing shows no signs of leakage; red: housing is leaky: corrosion on the flange with penetration to inside)

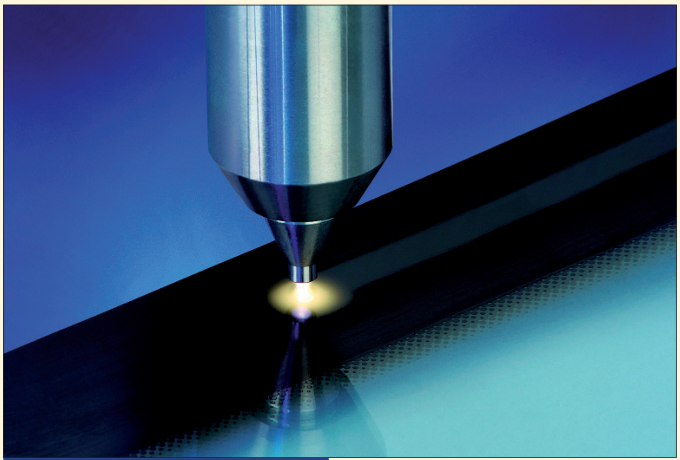

Figure 6

Openair-Plasma for microfine cleaning of the surface of the glass prior to coating with PlasmaPlus

uses the plasma to apply the corrosion protection to the aluminium surface without actually coming into contact with it.

TRW Automotive uses PlasmaPlus technology to coat motor pump housings for power steering systems in a continuous production process. The plasma polymer coating enables the company to achieve a far superior seal than would have been possible with the techniques used previously (Figure 5).

It is state of the art throughout the automotive industry to use direct glazing to bond front and rear windshield directly to the car body. However, it is also state of the art to use solvent cleaners and primers to reliably bond the adhesive to the ceramic screen print. Plasmatreat has teamed up with American company Ford Automotive to develop a solution for direct glazing that uses plasma technology to create an environmentally friendly pre-treatment which eliminates VOC emissions. The plasma is used in two stages: to remove any hydrocarbon residues from the surface (Figure 6) and to apply a nano-coating which modifies the surface of the glass with silanes using PlasmaPlus coating technology.

Summary

PlasmaPlus nanocoating under atmospheric pressure allows for substances tailored to specific applications to be deposited deep into the nanostructures of the material surface. This produces a highly effective functional coating and gives the materials completely new surface characteristics. The ability to manufacture products with selectively functionalised surfaces has added an entirely new dimension to innovation capability.