Selective plasma coating of metal surfaces

Atmospheric-pressure plasma ensures corrosion resistance

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Whether for corrosion protection, as an adhesion agent prior to bonding, or for ease of surface cleaning - a newly developed method allows for selective coating of metal surfaces with different functionalized layers based on atmospheric-pressure plasma technology.

Higher requirements on the corrosion resistance of, for example, bonded metallic components, demand innovative solutions. One of the global players from the subcontractors to the automotive industry was faced with the challenge of retrofitting an enhanced anticorrosive treatment for an aluminium component into an existing production line. The use of the atmospheric-pressure plasma coating process makes this possible.

Figure 1: What was previously only achievable in the vacuum chamber is now possible in-line under normal atmospheric pressure: The functional coating of aluminium components. (Photo: Plasmatreat)

Nanocoating at atmospheric pressure

Until just recently plasma polymerization was a process that could only be carried out in vacuum. However, in close collaboration with the research institute Fraunhofer IFAM, Plasmatreat developed and patented a new technology allowing for a nanometre thick coating of material surfaces at atmospheric pressure (Figure 1). It is barely three years ago that this technique found its way into an industrial application for the very first time. A special feature of this process is its high cost efficiency, since in contrast with low-pressure techniques, it does not require a low-pressure chamber.

The principle of this method is based on the fact that an organosilicon compound is admixed with the atmospheric-pressure plasma to produce a layer. Due to the high-energy excitation in the plasma, this compound is fragmented and deposited as a vitreous layer on the surface to be treated. The chemical composition can be varied according to the type of application to achieve the best possible results on the various materials.

Corrosion protection of aluminium

Using this system, for example, as a corrosion protection for aluminium surfaces, brings about a number of advantages: In contrast with other coating techniques, it is suited for in-line use on the one hand and for the solution of selective coating tasks on the other. The anticorrosive effect is particularly marked in aluminium alloys. The layer is capable of protecting aluminium against direct salt spray (DIN 50021) for several days without the visual appearance of the metal being affected. By means of plasma from a jet system, corrosion protection is applied without contact with the surface of the aluminium (Figure 2).

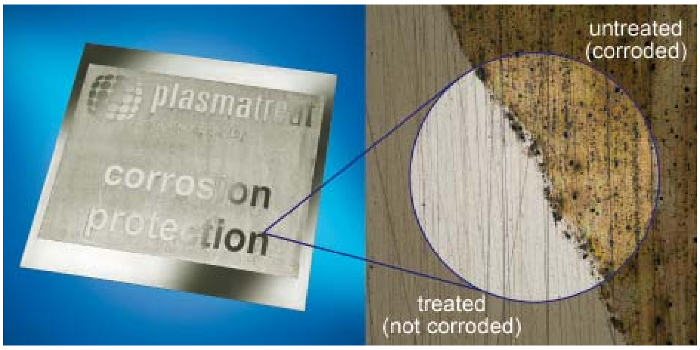

Figure 2: Under the microscope the area protected by the new method exhibits no sign of corrosion even after direct exposure to the salt spray test for 96 hours. (Photo: Plasmatreat)

TRW Case Study at a glance

Openair plasma offers TRW the following advantages:

- Highly efficient anti-corrosion coating
- High resistance against environmental conditions
- New quality standards for the components
- Local application of the coating with no effect on critical areas
- Long-term stable adhesion of the adhesive
- Environmentally friendly process
- Little space required by the plasma installation
- Subsequent integration into the process chain
- Low maintenance effort
- Short cycle times
- No need for removing the coatings before the recycling process

Since the new method operates under normal atmospheric pressure, it does not require a vacuum to deposit a layer.

Other special features of the process are its environmental friendliness and its great flexibility: In particular the film thickness and the speed of the process can be matched in line with requirements to the anticorrosive effect needed (Figure 3).

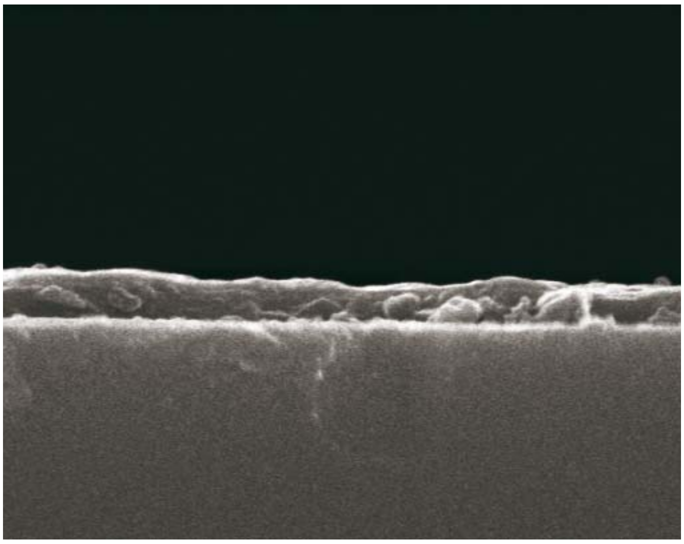

Figure 3: Cross-section through an approx. 100 nm thick layer (50 000 times magnification by scanning electron microscope) (Photo: St Gobain)

Typical processing speeds vary from 5 to 30 m/min. Directly after application of the coating, the component can be processed further. The coating affords not only high resistance to corrosion but also a stable, peel-resistant substrate for adhesives and sealants. The process is furthermore very environmentally friendly and there is no need for disposal or treatment of chemicals.

Plasma coating in the automotive sector

The atmospheric plasma coating process described here was used for the first time in an industrial application by TRW Automotive, world market leader in the development of integrated safety systems for the automotive industry. The company has employed the PlasmaPlus technique for applications with highest requirements for resistance against environmental conditions such as corrosion resistance, thermal resistance and splash water resistance, since early in 2007.

The task was to reliably protect an aluminium pressure die cast motor pump housing for a power-assisted steering system against corrosion. These units are integral components of servo steering systems for a multitude of vehicles and subjected to high reliability requirements. The corrosion protection is achieved by selective in-line coating of the bonded joints on the metallic component surfaces with atmospheric-pressure plasma.

The coating ensures greatest possible protection against penetration of moisture. In this way it can be safely avoided that microscopically small leaks occur causing corrosion and resulting in a short-circuit and failure of the power-assisted steering system. Coating with atmospheric-pressure plasma therefore assumes a key role here (see Table 1).

Subsequent integration into the process chain

In new developments when all quality requirements are known, implementation with the aid of appropriate influencing factors, such as design, process chain planning or anticorrosion measures, etc, is achievable using commonly available technical solutions. Incomparably more difficult are subsequently arising customer demands in projects already underway with existing global process chains. In such cases commonly available technical solutions are frequently no longer capable of integration or this can only be done by making enormous changes in association with high investment costs. Moreover, changes in production processes including reconstruction measures give rise to downtimes in production. Nevertheless, due to new demands from a customer and renowned automotive manufacturer, TRW decided in 2006 to take

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

Table 1: Leak-proofness check by the salt spray (SWAAT) test:
Green: Housing shows no leaks
Red: Housing is leaky (corrosion on flange with breakthrough towards the inside)

the challenge. The possibilities for protecting a current TRW generation C motor pump unit having an aluminium pressure diecast housing against environmental effects were limited to the following options: improvement of the material, anodization, passivation or plasma coating at low or atmospheric pressure.

- A: Improving the material, ie, interfering with the quality of the aluminium material, is a dramatic change since this is also typically accompanied by other effects, such as a decrease in tensile strength. This would have entailed completely new product validation involving great effort and costs.
- B: Much the same applies to the anodization. The formation of the coating on the surface on which the principle of this method is based results in significant changes in dimensions and therefore in an impact on the fitting system. The lamellar structure also carries risks with regard to contamination of the hydraulic steering system and critical changes in friction at highly stressed screwed joints. Anodization, therefore, would also make extensive product validation necessary.
- C: Passivation affords good protection against corrosion and has the advantage that no layer of appreciable thickness is formed. However, its heat resistance was not sufficient for the applications and internal production processes at TRW so that this method had to be excluded as well.
- D: The possibility of low-pressure plasma finally presumes some readiness to invest in corresponding plant technology. When there is a requirement for high capacity and/or complicated component geometries, high investment costs may be necessary.

All variants considered so far have one thing in common: they are highly cost-intensive and would have to be capable of integration into the process chain in such a way that quality control would lie in the responsibility of global suppliers. Subsequent quality control on finished components ready for delivery is very costly and considerably reduces the reliability of the process (see also the Cost efficiency comparison).

Figure 4: Prior to plasma coating TRW motor pump housings are pre-cleaned with Openair plasma to a microfine level.

Surface pre-treatment and coating with Openair atmospheric-pressure plasma compared to low-pressure plasma and other methods:

- Compared to low-pressure methods, the atmospheric-pressure plasma technology is far more efficient since the pre-treatment process does not require a costly low-pressure chamber and takes place in-line in the production line under normal air conditions.
- Components treated at low pressure, ie, in a vacuum, are limited in size and number by the constraints of the required chamber. Production processes must be interrupted for pre-reatment, and assembly is usually carried out manually.
- The described atmospheric-pressure plasma technology is suitable for robotic and in-line applications without restriction. The system can be very easily integrated 'inline' into new or already existing production lines. Production rates are increased by a significant multiple and the deployment of manpower is considerably reduced.
- With low-pressure plasma neither cleaning processes for strip materials, as in the coil coating process, nor large-area pre-treatment for adhesive bonding processes can be implemented.
- Atmospheric-pressure plasma technology is compatible with the use of robots.
- Chemical treatments require consumables and often leave behind residues that are difficult and very costly to dispose of. The Openair process completely replaces chemical methods used for fine pre-cleaning purposes.
- Mechanical pre-treatment methods (scoring) are very difficult to implement reliably and also operate with consumables.

Atmospheric-pressure plasma technology is not suitable, however, when surfaces are not accessible to the atmospheric plasma beam due to very complex geometries or when the production approach is already designed for chamber-based processes.

Conclusion

Compared to other corrosion protection methods, the green atmospheric-pressure plasma coating process could be integrated into TRW's final assembly with little expense and without disturbances in production. At the same time the process could be ideally incorporated into the in-house quality assurance processes (Figure 4).

Due to the possibility of applying plasma coatings selectively, critical areas remain unaffected so that new validations are not necessary. The low investment and maintenance costs are also of advantage. The low requirement for space and maintenance effort together with short cycle times were further criteria for the integration into the application described here.