Adapted version from German original

Environmentally friendly and cost-saving

Atmospheric-pressure plasma technology

Among the great diversity of pretreatment methods in industrial processes the use of environmentally friendly and cost-saving processes is steadily growing in importance in automotive engineering. An innovative plasma technology from Plasmatreat GmbH, Steinhagen, serves not only for the microfine cleaning of surfaces and improving adhesion, but also it is often the sole solution for obtaining strong joints.

1 Introduction

In order to obtain durable and load-bearing adhesive joints between plastics or metals it is first of all necessary to create the right conditions. In automotive engineering an atmospheric-pressure plasma technology is now used globally in over 70 different applications for the pretreatment of plastics, metal, ceramics or glass. Whether applied to windscreens or instrument panels, headlights, seals for electronic components, EPDM profiles or whole car body parts, this plasma technology ensures simple, reliable and solvent-free pretreatment prior to bonding, foaming and painting processes.

2 What is plasma?

Plasma is based on a simple physical principle. As a result of input of energy the states of matter change: solid becomes liquid and liquid turns to gas. If further energy is now supplied to a gas it becomes ionised, i.e. the electrons are given more kinetic energy and leave their atomic shells. Free electrons, ions and molecular fragments are formed. Plasma is produced. Due to its instability, however, this “fourth state of matter” can scarcely be used at normal atmospheric pressure (Fig. 1).

Only the Openair atmospheric-pressure plasma technology developed and patented by Plasmatreat GmbH, Steinhagen, in 1995 opened up new opportunities. By developing and using plasma jets it became possible to integrate this state of matter scarcely used hitherto in industry into production processes and hence make plasma usable “in-line” in industry under normal atmospheric conditions for the pretreatment of the surfaces of materials. On contact with the surfaces of materials the additional energy supplied is transferred to them and so is available for subsequent reactions. In this way surfaces are produced which have ideal properties for coating, printing, adhesive bonding or foaming.

3 Electrically neutral plasma beam

The process is based on a jet principle. In contrast with high-cost low-pressure plasma systems (vacuum chamber) the jets here operate in-line at atmospheric pressure, that is to say under normal atmospheric conditions. They are driven solely by air and high voltage. The emergent plasma beam is electrically neutral and as a result possible applications are greatly extended and simplified (Fig. 2 and Fig. 3). Its intensity is so high that treatment speeds of several 100 m/min can be achieved. The typical rise in temperature of a plastic surface during treatment amounts in this case to $\Delta T < 20$ °C.

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The plasma system is characterized by a threefold action: it activates surfaces by selective oxidation processes, discharges them at the same time and brings about microfine cleaning of the surfaces of metals, plastics, ceramics and glass. In addition, the plasma energy of this system is utilized for depositing layers. By adding a precursor the technique has also been developed further for purposes of providing nanocoatings.

4 Surface tension

Surface tension is the most important measure for evaluating the likelihood of adhesion of an adhesive layer or surface coating. In car body construction for reasons of weight-saving individual subassemblies are now

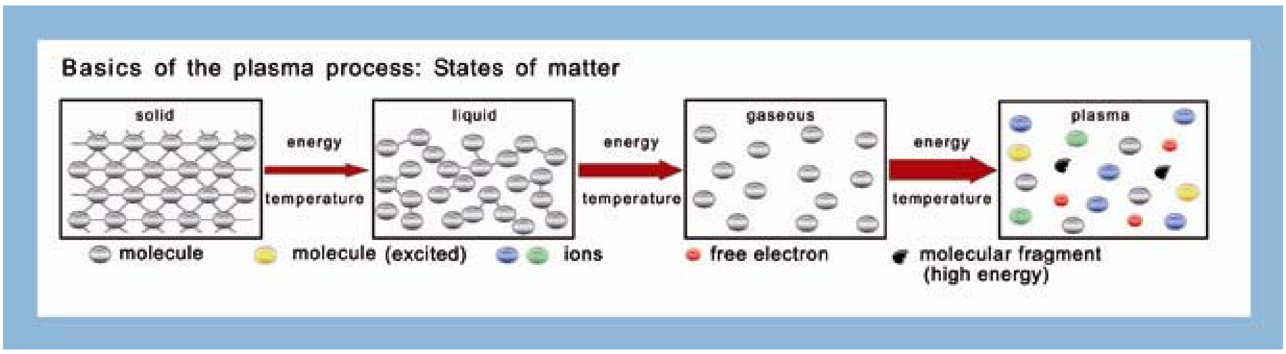
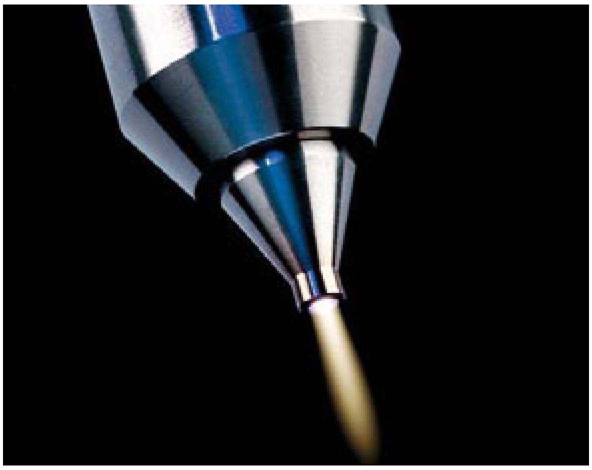


Fig. 1. Plasma – states of matter



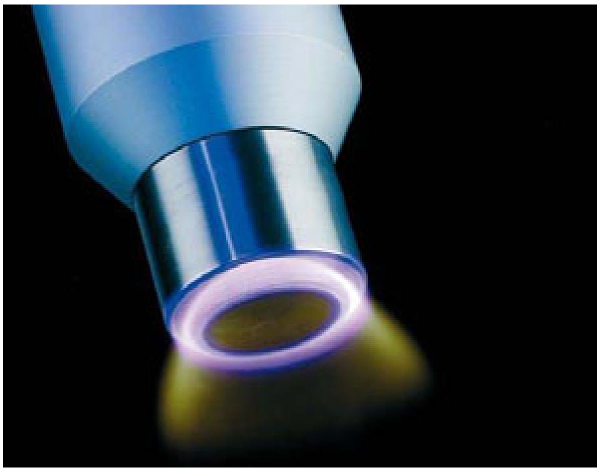


Fig. 2 and Fig. 3 Fine jets having a relatively small exit angle are suitable for treating narrow profiles and complex geometries, while rotary jets operate on surfaces up to 40 mm wide. In the case of relatively large treatment areas several plasma jets are combined with one another.

no longer made of steel or aluminium sheet, but rather of high-performance plastics. The likelihood of a plastic undergoing adhesive bonding depends essentially on its surface tension which should be greater than that of the adhesive. This, however, is frequently not the case and so it becomes necessary to carry out a suitable surface pretreatment. Secure adhesion of a two-pack polyurethane adhesive to SMC or PPO is achieved by pretreatment with plasma. In this way surface tension values of more than 72 mN/m are possible on many plastics (Fig. 4).

A decisive advantage of the technique consists in that hitherto incompatible substrates can be made to adhere to one another so that water-based adhesives, and often UV-based adhesives also, adhere to highly adhesion-resistant surfaces such as nonpolar plastics for example.

5 Plasma instead of primer

To Michael Stege, former specialist consultant for adhesives and sealants in process engineering at Volkswagen AG, the reasons for using the new plasma technology were obvious. For the Golf IV Volkswagen developed an additional bonded door seal for improving driving comfort by damping wind noise. This self-adhesive seal made of EPDM rubber was to be additionally fixed at the ends by means of adhesion points composed of a MS polymer adhesive. To improve the adhesion of the adhesive this rubber has to be pretreated. An absolute requirement was that this should be done by means of a solvent-free and hence environmentally friendly system.

After comparing different corona and plasma systems, with particular value being attached to great process latitude, VW chose the rotating plasma jets of the Openair system. Stege reports that the process replaces several working steps when the seals are pretreated with plasma directly before application of the adhesive. As a result of this highly effective measure not only the otherwise essential precleaning of the bonding surfaces but also the application of solvent-based primer just before bonding is eliminated. Furthermore, the process has the great advantage of reproducibility

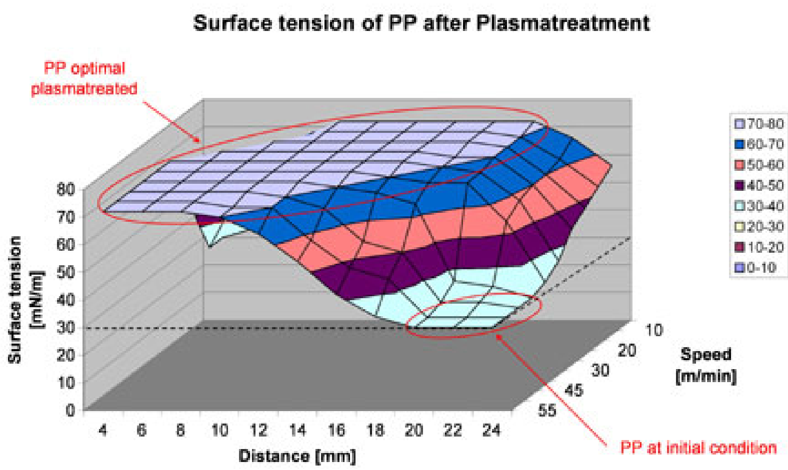


Fig. 4 The diagram shows a plastic surface which has been pretreated with plasma as a function of spacing and speed. After treatment within a broad processing latitude the surface becomes polar and the surface tension rises to >72mN/m

when the installation parameters are precisely monitored. The positive consequences for Volkswagen are that the pot life of a primer no longer needed to be taken into account, there were no longer any emissions of solvent nor any logistical pressures in supply. Since then almost all lines in door production at Volkswagen have been equipped with the plasma system.

6 Painting processes

The painting of car body surfaces, now common throughout the world, to produce a coat of paint composed of individual functional layers will soon change. The objectives here include achieving external paint structures which make the surface harder and hence less susceptible to damage and scratching. The trend for the future is in the direction of what are known as nanopaints. These are usually coating materials which in the fluid processing state consist of particles having diameters of a few nanometres (nm). If produced to be strongly hydrophobic they give rise to a "lotus effect" so that water runs off them. They are much harder and hence substantially more resistant to mechanical damage than conventional paints. Nanopaints have hitherto had only one disadvantage: it has not been possible to make them undergo adhesive bonding (Fig. 5).

In this case also the plasma process developed by Plasmatreat was able to provide a solution for the future. The marked increase in surface tension resulting from the pretreatment has been used to make selected points on the surface of the paint "adhesive-friendly" and so allow intimate bonding to other parts, such as antenna mountings or decorative trim.

Fig. 5 Pretreatment with plasma ensure a flawless visual appearance of the painted surface.

7 Painting in the interior

Switches with laser-etched symbols, high-gloss decorative trim and covers, display windows with a scratchproof coat of paint and glittering fascias, ventilator grilles or handles on glove compartments – plastic parts in the interiors of automobiles today are given the most expensive coats of paint (Fig. 6).

Fig. 6 After injection moulding but prior to painting of instrument module housings, there first ensues microfine cleaning with atmospheric-pressure plasma

Conventional preparatory procedures on SMC, such as sanding down or cleaning with acetone, are not only replaced by plasma treatment but the bonding results are also surpassed. After installation the high-performance thermoplastic and thermoset components fulfil all requirements with regard to lightweight construction, passive safety, mechanical properties and a first class surface. Atmospheric-pressure plasma can be used as a pretreatment process for both the adhesive bonding and the painting of these subassemblies. This is the case, for example, in vehicles made by BMW and Rolls Royce.

8 Two-component injection moulding

The creation of functional, visually attractive plastic components with a good feel to the touch for automobile interiors requires lengthy, cost-intensive and labour-intensive assembly which often renders production uneconomical and less reliable. A base support manufactured from a rigid component (such as PP, PA or ABS) is overlaid with a flexible material (such as leather, synthetic leather, PU or TPU slash skin). Here the pleasant feel to the touch is achieved, on the one hand, by means of the material and, on the other hand, by "back-foaming" with a flexible component. A problem frequently remaining in doing so is that when the door inner lining

Fig. 7 Adjusting wheel from Müller Technik: Only pretreatment with Openair plasma has made it possible to obtain a strong joint between a rigid polypropylene (inside) and a flexible, easy-grip TPU injection-moulded outer sheathing.

Fig. 8 Demonstration of the selective mode of action of a plasma polymer layer: the logo and inscription areas on an aluminium plate after 96 hour exposure to the salt spray test.

later comes into contact with greasy or oily cosmetics (such as hand cream or suntan lotion) the flexible component may become detached. Plasma pretreatment suppresses this effect (Fig. 7).
A far more low-cost and also reliable method consists in producing a part directly, ready for dispatch, in a two-component injection moulding machine. Corresponding trials have already been carried out with positive results at Müller-Technik, Steinfeld. In doing so the Openair method allows normally uncombinable plastics to be joined together. The base support is injection moulded in the machine and after plasma treatment immediately overmoulded with a flexible component. As a result manual handling of individual parts is rendered superfluous and the part falls out of the machine “in the finished state” after each cycle.

9 Plasma coating without vacuum

The adhesive bonding of aluminium is state of the art. Nevertheless, when conventional pretreatment methods are used considerable expense is incurred for durably bonding aluminium surfaces especially when exposed to corrosive media such as moisture and salt (Fig. 8). Wet-chemical methods such as chromate coating or anodising are usually employed to meet the high requirements. These, however, are cost-intensive batch processes which, furthermore, are extremely questionable from an ecological point of view.
Even until quite recently plasma coating was a process which could only be implemented in a vacuum chamber. In close collaboration with the Fraunhofer IFAM, Bremen, Plasmatreat has now developed a new patented technology called PlasmaPlus. This is a plasma polymerisation process with which, according to information from the company, for the first time in the world

Cost efficiency compared

Surface treatment with atmospheric-pressure plasma compared with low-pressure plasma and other methods has the following advantages

- In contrast with low-pressure methods atmospheric-pressure plasma technology is more efficient since the pretreatment process makes do without a costly vacuum chamber and takes place in-line in the production line under completely normal atmospheric conditions.
- The number and size of parts treated at low pressure, i.e. in a vacuum, are limited by the chamber required. For pretreatment production processes have to be interrupted and assembly is usually carried out manually.
- Openair atmospheric-pressure plasma technology is without restriction compatible with robots and capable of in-line integration. The system can be very easily integrated 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-like products, as in the coil coating process, nor large-area pretreatments prior to bonding processes can be implemented.
- Chemical treatments require consumables and often leave behind residues that are difficult and very expensive to dispose of. The plasma technology described completely replaces chemicals in the cleaning process.
- Mechanical pretreatment methods (scoring) are very difficult to implement reliably and also operate with consumable materials.
- The only constraint is that atmospheric-pressure plasma technology, however, is not suitable when surfaces are not accessible to the atmospheric-pressure plasma beam due to complicated geometries or when the production layout is already designed for chamber processes.

nanometre thick plasma coatings can be applied to the surfaces of materials at atmospheric pressure.
The anticorrosive action is particularly effective on aluminium alloys as the latest application at TRW Automotive, Germany, in the process for plasma coating aluminium pressure housings for motor pump units shows. The layer is able to protect the aluminium for several days in the direct salt spray test (DIN 50021) without the visual appearance of the metal being affected.

10 Summary

Scarcely any bounds are set to the versatility of application of the in-line plasma system described here. Key advantages include its reliability and quality in the production process. Conventional pretreatment methods such as cleaning using wet chemicals are completely displaced by the plasma process and, furthermore, the number of working steps is reduced. This gives rise to significant cost savings in production. Requirements such as simple integration into process workflows and compatibility of the treated plastic surfaces with cathodic dip coating are just as well fulfilled as requirements for environmental compatibility.

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