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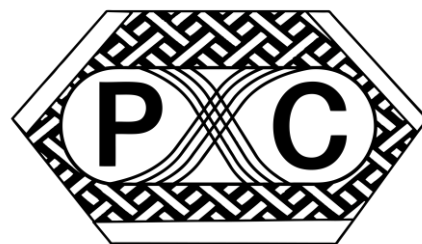
PROCEEDINGS

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ATMOSPHERIC PRESSURE PLASMA OPTIMIZES ADHESION PROCESSES ON PLASTIC SURFACES IN THE AUTOMOTIVE INDUSTRY

ATMOSFÉRICKÁ PLASMA OPTIMALIZUJE PROCESY LEPENÍ NA POVRCHU PLASTŮ V AUTOMOBILOVÉM PRŮMYSLU

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For non-polar plastics, surface activation is essential to ensure the reliable, long-time stable adhesion of adhesive bonds and coatings. The reason why an adhesive or paint does not readily adhere to clean plastic surfaces is generally because the surface energy is too low. Plasma can quickly remedy this problem. The automotive industry is using Openair-Plasma[®] jet technology as an environmentally friendly and particularly cost-effective means of satisfying the industry's strict technical and quality requirements.

Pro zajištění dlouhodobě spolehlivé adheze lepidel a povlaků na nepolárních plastech je nezbytná aktivace povrchu. Důvodem, proč lepidlo nebo lak nepřilne na čistý povrch plastu je obecně velmi nízká povrchová energie. Plasma může tento problém rychle napravit. V automobilovém průmyslu je využívána technologie Openair-Plasmové trysky jako ekologický a zejména úsporný způsob, jak splnit přísné technické a kvalitativní požadavky tohoto odvětví.

KEYWORDS

Atmospheric pressure plasma, surface pre-treatment, surface cleaning, surface activation, adhesion, surface energy

INTRODUCTION

The most likely cause for the inability of clean and additive-free plastics to be bonded or painted effectively is their low polarity and resultant low surface energy. This is the most important measure for determining the probable adhesion of an adhesive layer or paint. For non-polar plastics, surface activation is essential to ensure the reliable, long-term stable adhesion of adhesive bonds and coatings. When a plastic's surface energy is too low, atmospheric pressure plasma can remedy this problem within seconds. The automotive

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industry is using Openair-Plasma® jet technology as an environmentally safe and particularly cost-effective means of satisfying the industry's strict technical and quality requirements.

A QUESTION OF SURFACE ENERGY

With the development of its atmospheric plasma jet inline technology over twenty years ago, the German systems engineer Plasmatrete created a solution which the industry had long been seeking: an alternative to wet-chemical pretreatment processes for material surfaces. Growing demands in the nineties for environmentally friendly, safe processes called for new methods which did not require wet chemicals and were at the same time cost-effective and process-reliable. Now used throughout the world, Openair-Plasma® technology offered a highly effective pretreatment process based on jet technology that enables the area-selective, thus partial pretreatment of mass-produced components in a fully automated and continuous production process.

Non-polar plastics require an essential pretreatment before downstream processes such as bonding, painting, printing or foaming. This is because their lack of polarity causes them to have low surface energy. Reliable adhesion is conditional on the surface energy (mJ/m^2) of the solid material being higher than the surface tension (mN/m) of the liquid coating applied, such as adhesive, paint or ink. Plasma treatment even allows substrates previously regarded as incompatible to be bonded to one another without using primers, whereby water-based and often even UV adhesives provide long-time stable adhesion once the surfaces have been activated.



Fig.1 (Photo: Plasmatrete GmbH)

Triple effect: Openair-Plasma® rotating nozzle for microfine cleaning, electrostatic discharging and simultaneous activation of a plastic surface

TRIPPLE EFFECT

Openair-Plasma® (Fig.1) performs three operations in a single step lasting only a matter of seconds: The plasma emitted from the nozzle at extremely high speed simultaneously brings about the microfine cleaning, electrostatic discharging and activation of the plastic surface – a reactive change at molecular level. Activation is achieved through the chemical and physical interaction of the plasma with the substrate. When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix. Functional groups are created at the surface

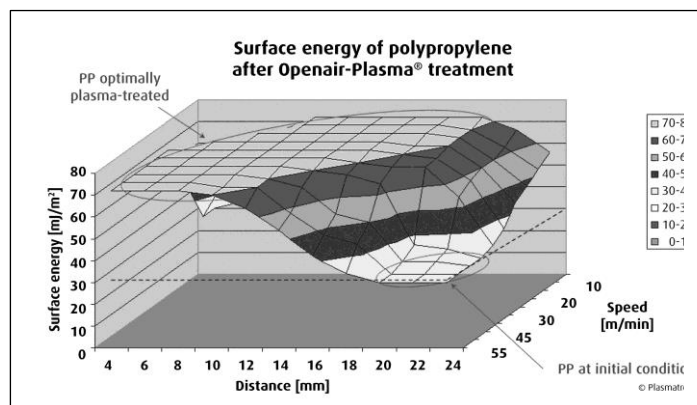


Fig.2 (Image: Plasmatrete GmbH)

The figure shows a non-polar plastic surface that was pretreated as a function of distance and speed with plasma. Treatment renders the surface polar and the surface energy rises to $>72 \text{ mJ}/\text{m}^2$ (72 dyne) with a large process window.

which form a permanent bond with the reactive components of the adhesive. The process makes the previously non-polar substrate polar and significantly increases its surface energy (Fig.2). The result is homogeneous wettability of the substrate and a long-time stable adhesion of the adhesive or coating even under challenging load conditions. The rise in temperature of plastic surfaces during this type of plasma treatment is typically $\Delta T < 30^{\circ}\text{C}$.

APPLICATION IN THE AUTOMOTIVE INDUSTRY

STRUCTURAL BONDING

Nowadays the superstructures of modern commercial vehicle are mostly fully bonded. Among other things, this increases their inherent strength and payload as well as reducing their weight. The requirements for structural bonding are high and can only be achieved with a reliable pretreatment process.

Europe's leading trailer manufacturer Schmitz Cargobull gave up using organic solvents for pretreating the composite sandwich panels of large refrigerated superstructures (Fig. 3) many years ago. The refrigerated semitrailers are self-supporting systems, the entire modular structure is assembled without bolts and rivets. By bonding the large-format panels in aluminum profile rails, the system becomes self-supporting. The areas of the panel surface to which the adhesive is applied are pretreated with environmentally friendly atmospheric pressure plasma to enhance the durability and tightness of the adhesive bond. Four Openair-Plasma® treatment stations with 32 plasma nozzles, some rotating and some static, have successfully replaced conventional pretreatments such as mechanical keying or activation with environmentally harmful solvents in this production.



Fig.3 (Photo: Schmitz Cargobull AG)
Structural bonding: Europe's leading semitrailer manufacturer gave up using organic solvents for pretreating composite panels prior to bonding several years ago using atmospheric pressure plasma instead.

MASK-FREE PRETREATMENT OF INSTRUMENT PANELS

Pretreatments using flame technology require labor-intensive masking of instrument panels before they can be filled with foam. The use of Openair-Plasma® technology by automotive component supplier SMP Deutschland for the cockpit of the Audi Q5 showed that it could be done without masking. This instrument panel is composed of three layers of material: a long-glass-fiber-reinforced plastic substrate, a PUR foam layer and a molded PVC skin, known as a 'slush skin'.



Fig.4 (Photo: Plasmamatreat GmbH)

The robot-controlled plasma rotary nozzles carry out an area-selective treatment of the instrument panel. By scanning the geometry of the instrument panel true-to-contour, they eliminate the need for masking before foaming.

The structural parts are made from injection-molded polypropylene (PP). Pretreatment is essential with this type of non-polar plastic to facilitate subsequent adhesion processes.

The Plasmatreat system equipped with three robot-controlled patented rotating nozzles operates at a flow rate of approximately 250 m/s. As a result, even complex geometries such as tiny recesses and undercuts can be effectively activated. A particular benefit is the true-to-contour scanning of the plastic surface. For the manufacturer, the advantages of the plasma process were clear: The area-selective application was a key deciding factor; pinpoint precision meant that masking was no longer required (Fig.4). The fact that the “cold plasma” does not damage the long-glass-fiber-reinforced polypropylene surface, the system is highly process-reliable and reproducible and the technology as a whole significantly reduces operating costs were further plus points.

PRETREATMENT OF PLASTIC BODY ASSEMBLIES

In order to save weight in vehicle body construction, individual assemblies are now made from high-performance plastics which are glued together. The plasma treatment not only replaces conventional methods of pretreating the SMC (Sheet Molding Compound) – such as sanding or cleaning with acetone – it also produces superior bonding results. After assembly, the plasma-treated high-performance thermoplastic and thermoset components meet all the requirements in terms of lightweight construction, passive safety, mechanical properties and a “Class A” finish.

The plasma process is also particularly effective on fiber composite materials such as carbon fiber-reinforced plastic (CFRP) or glass fiber-reinforced plastic (GFRP). Nowadays automotive parts such as vehicle roofs, trunk lids or hoods are molded from CFRP. Release agents are required to remove the complex individual parts safely from the molds after production. After demolding, components from these release agents remaining on the surface must be laboriously removed. With atmospheric pressure plasma cleaning, on the other hand, any residual release agents are completely broken down and eliminated in seconds before bonding (Fig.5).

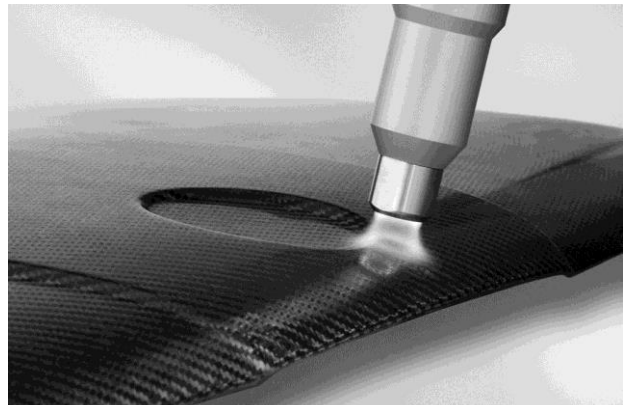


Fig 5 (Photo: Plasmatreat GmbH)
Openair-Plasma® cleaning eliminates in seconds any release agents remaining on the surface after demolding a CFRP component.

SEALING VEHICLE HEAD LAMPS

Hella, a leading automotive component supplier for lighting technology and electronic products, decided back in 1995, i.e. the year the technology was first placed on the market, to purchase a plasma jet system for pretreating their vehicle headlamps. With these components, the adhesive bond between the polycarbonate lenses and their polypropylene housings must satisfy extremely strict sealing requirements.

Even the slightest leak would result in moisture penetration leading to impairment of the lens, which in turn would adversely affect the beam angle of the light. Hella Australia uses the

plasma to clean the grooves in the polypropylene (PP) housing before applying a 2-component silicone adhesive and to activate the non-polar material at precisely defined locations (Fig. 6). As a result, the surface energy of the PP increases from 35 mJ/m² to over 72 mJ/m². This has the effect of improving the adhesive characteristics of the subsequent bond to ensure seal tightness.

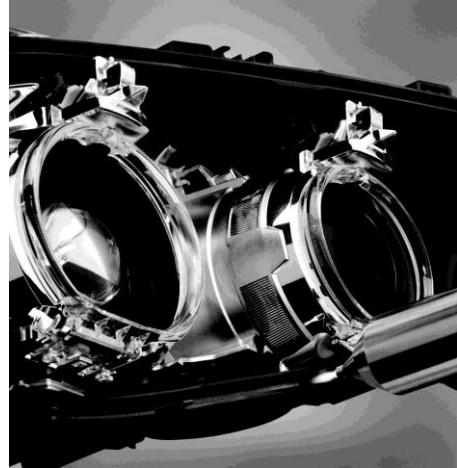


Fig. 6 (Photo: Plasmatreat GmbH)
Vehicle headlamps must satisfy extremely strict sealing requirements. To prevent moisture penetrating the housing, the PP plastic grooves are cleaned and activated with atmospheric pressure plasma prior to bonding.

DISPENSING WITH PRIMERS BEFORE PAINTING

TRW Automotive Electronics & Components pretreats millions of switches for car interiors a year with the atmospheric pressure plasma jet technology prior to painting. A high degree of process reliability is top priority and this is achieved through the computer-controlled and screen-monitored system provided by Plasmatreat. Throughput has tripled since the company started using a new water-based painting line with integrated plasma system and stopped using primers completely (Fig.7). Furthermore, not only has a complete run incorporating six operations been dropped, according to TRW, they have also been able to save a great deal of time and 90% of the energy costs compared with the previous cleaning systems, drying process and primer activation.



Fig. 7 (Photo: Plasmatreat GmbH)
At TRW Automotive, Germany, throughput has tripled since the company started using a water-based painting line with integrated plasma system and stopped using wet chemical primers completely.

BUBBLE-FREE TOUCHSCREEN BONDING

Touchscreens provide the driver with information about the vehicle, navigation system, GSM data and much more besides. The potting between the glass cover and the TFT screen must be completely bubble-free and have good adhesive characteristics.

This calls for a very clean surface with extremely high surface energy. Bavarian automotive component supplier Preh found that patented plasma rotary nozzles satisfied these requirements in the production of their central console control systems. A laminator is used to bond the PET touch foil complete with adhesive backing to the back of the injection-molded polycarbonate panel of the center stack. The foil is supplied with multiple layers of screen-printed electronic circuitry. Bubbles forming between the foil and the carrier during the climatic test were successfully removed by pretreating the PC panel with Openair-Plasma[®] (Fig. 8).

CONCLUSION

Scarcely any bounds are set to the versatility of application of the eco-friendly technology described here. Conventional pretreatment methods such as cleaning and activating using wet

chemicals are completely displaced by the high quality plasma process and some working steps are rendered unnecessary. Apart from its effectiveness, the atmospheric plasma jet technology includes high process speed, high process reliability, one hundred percent robot compatibility and accurate process reproducibility. The computer monitored inline technology offers easy integration into process operations and signal chaining to higher and lower-ranking control units, as well as cost-efficiency and satisfying requirements for total environmental compatibility.

Fig. 8 (Photo: Preh GmbH)

The polycarbonate panel on the car's center stack is pretreated with atmospheric pressure plasma to obtain a bubble-free touch foil bond.



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