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Adhesives and Sealants
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Adhesion from the
Plasma Nozzle

Adhesion from the Plasma Nozzle

Only a vision just 25 years ago, plasma from the nozzle now sets the standards for the pretreatment of material surfaces prior to bonding in virtually every sector of industry around the world. Automotive engineering in particular has benefited from the atmospheric pressure plasma process first integrated into series production in the mid-90s.

Inès A. Melamies

The industry had long been waiting for an alternative to wet chemical cleaners and adhesion promoters for series production. Growing demands in the nineties for environmentally friendly, safe in-line pretreatment processes called for new methods which did not require wet chemicals and were at the same time more process-reliable and cost-effective. With the development of Openair-Plasma technology in 1995 followed ten years later by the Plasma-Plus coating technology jointly patented with the Fraunhofer IFAM in Bremen, Christian Buske, founder of the Westphalian technology developer and systems engineer Plasmatreat, more than granted this wish. He created one of the most effective and environmentally friendly processes for the fine cleaning, simultaneous activation and functional nanocoating of material surfaces. According to the company, today they no longer merely produce individual jets systems, they construct entire high-tech plasma cells (*Figure 1*) for users throughout the world.

Plasma jet technology

Plasma jet technology created a dry, very rapid pretreatment process which enables the area-selective – in other words targeted at a specific area of the component – pretreatment of series-produced components in a continuous production process. The nozzles run entirely on compressed air, high-voltage and a process gas if required, so the process is environmentally friendly. The plasma is produced inside the nozzles by an intensive, pulsed arc discharge and conditioned at the nozzle outlet. A targeted flow of air along the discharge path separates parts of the plasma and transports them via the nozzle head to the surface of the material being treated. The shape of the nozzle head determines the geometry of the emitted beam. Depending on the nozzle geometry, Openair-Plasma can be applied in a working range of 3 mm (for static nozzles) up to a treatment width of approx. 100 mm (for rotating double nozzle systems).

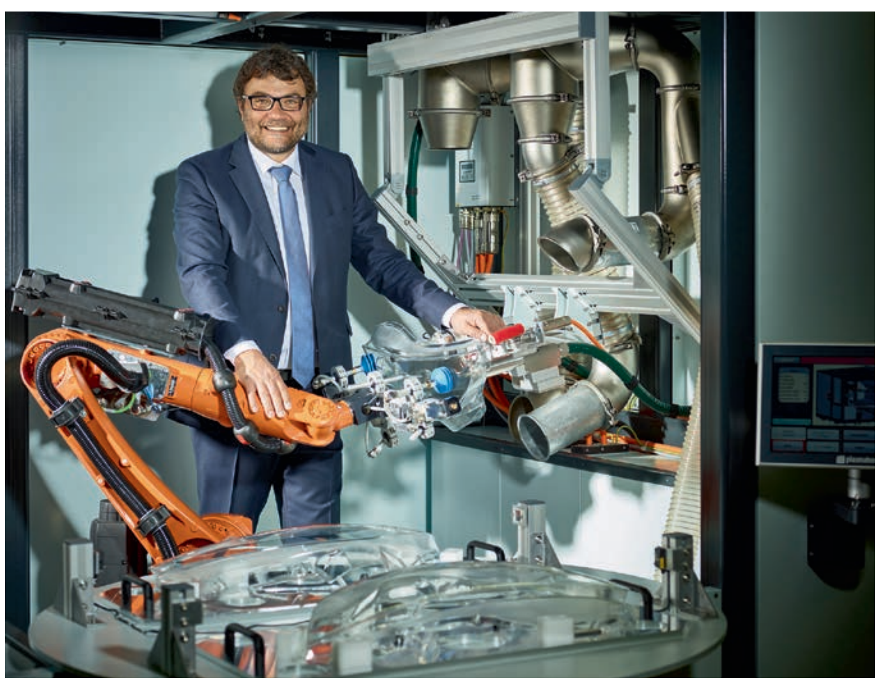

Figure 1 > Hi-tech in Westphalia: Plasmatreat founder Christian Buske inside one of the latest generation plasma cells for pretreating plastic car headlight lenses

Figure 2 > Nozzle combination: Inline plasma treatment in the continuous extrusion process for EPDM profiles

Several nozzles can be combined in line for the pretreatment of large areas such as composite panels or in the extrusion process for EPDM profiles (*Figure 2*).

Surface energy

"Surface energy" is the keyword when it comes to wettability and adhesion. It largely determines whether the desired adhesion to the substrate is actually achieved. Good wettability is conditional on the material surface being ultra-clean and the surface energy of the solid material being higher than the surface tension of the liquid adhesive or paint. Layers of dust deposits, grease, oils and other contaminants can often compromise the naturally high level of surface energy in metals and glass, thereby impairing wettability. But cleaning with plasma restores it in seconds. Plastics such as polypropylene or polyethylene which require pretreatment due to their low surface energy and resulting poor adhesive characteristics benefit especially from the high activation power of plasma, as well as the cleaning effect.

Plasma activation

Activation means a reactive surface change at molecular level which results in entirely new adhesive characteristics. The surface is activated 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 which form a permanent bond with the reactive components of the adhesive (*Figure 3*). The process makes the previously non-polar substrate polar and significantly increases its surface energy, thus facilitating homogenous wettability. This significantly improves the adhesion of the adhesive.

Plasma coating

PlasmaPlus coating technology allows functional plasma-polymer nanocoatings to be deposited with pinpoint precision under normal pressure (instead of in a vacuum) in continuous production processes. It can be used to generate product-specific coatings for different materials and to deposit them on the surface in milliseconds, where they bond covalently with the substrate. A precursor in the form of an organosilicon compound is added to the plasma to produce this type of coating. High-energy excitation within the plasma fragments this compound and deposits it on the surface in the form of a vitreous coating. One key point for the user is that the chemical composition can be varied according to the application to ensure that optimum results are obtained for any given material. Today the process is most notably used in the automotive industry and in solar technology as an adhesion promoter and for corrosion protection for aluminum components.

Plasma in automotive engineering in preparation for 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.

Schmitz Cargobull gave up using organic solvents for pretreating the sandwich panels of large refrigerated superstructures (*Figure 4*) 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 ap-

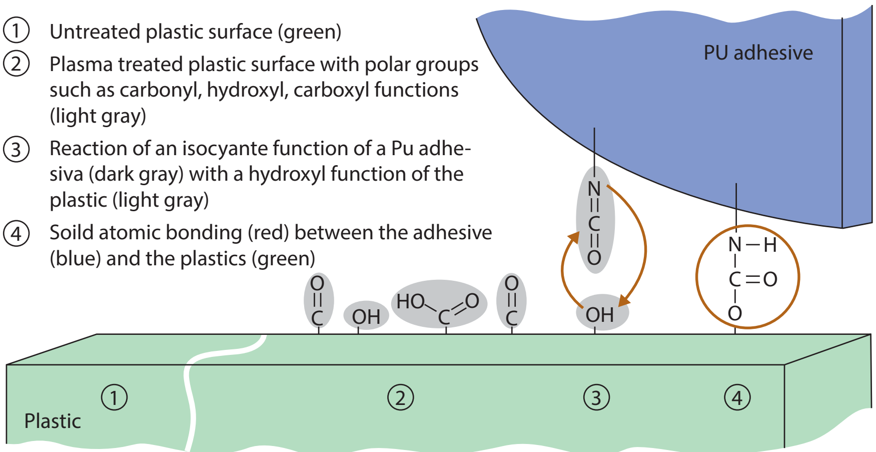

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Figure 3 > The surface is activated through the chemical and physical interaction of the plasma with the substrate. When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix.

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Figure 4 > The panel surfaces of the self-supporting refrigeration system are pretreated with environmentally friendly Openair-Plasma to enhance the durability and tightness of the adhesive bond.

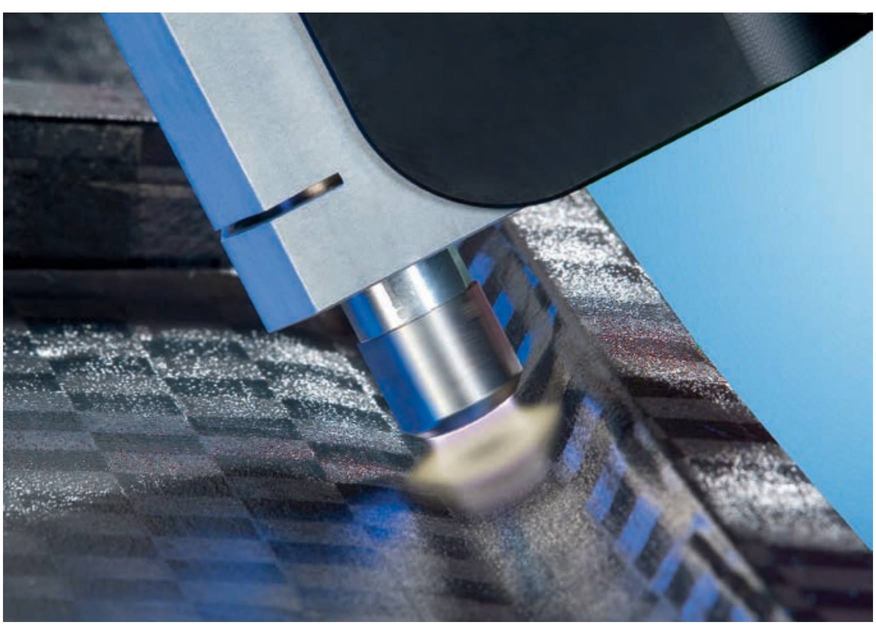

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Figure 5 > The plasma process is also particularly effective on fiber composite materials and for pretreating CFRP prepregs before bonding.

plied 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.

Plasma in vehicle body construction

Ever-increasing demands for efficient production processes, resource conservation and lightweight, energy-saving construction present significant challenges to the automotive industry which can no longer be overcome using conventional sheet metal construction methods. So to save weight in vehicle body construction, individual assemblies - now made from high-performance plastics - are glued together. The plasma treatment not only replaces conventional methods of pretreating SMC (Sheet Molding Compound) – such as sanding or cleaning with acetone – it also produces superior bonding results. The plasma process is also particularly effective on fiber composite materials such as carbon fiber-reinforced plastic (CFRP) or glass fiber-reinforced plastic (GFRP) and with the prepregs – the pre-impregnated semifinished products made from them (*Figure 5*). It is increasingly common for parts such as vehicle roofs, trunk lids and hoods to be 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 plasma cleaning, on the other hand, any residual release agents are completely broken down and eliminated in seconds before bonding.

Bonding vehicle headlamps

Hella, a leading automotive component supplier for lighting technology and electronic products, has been using plasma technology from Westphalia for more than 20 years for their headlights. 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

Figure 6 > Hella has used Openair-Plasma for over 20 years as a pretreatment in the process of bonding polycarbonate lenses to polypropylene housings.

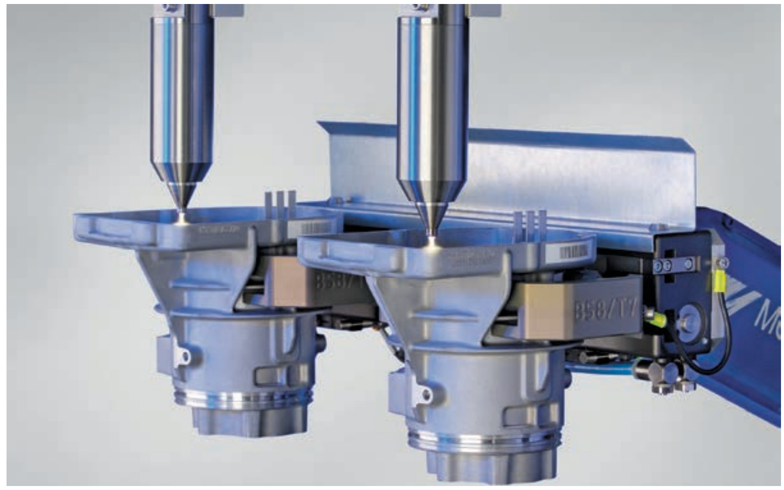

Figure 7 > At TRW Automotive, motor pump housings for steering units are cleaned with Openair-Plasma before a functional PlasmaPlus coating is applied.

penetration leading to impairment of the lens, which in turn would adversely affect the beam angle of the light. Hella 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 (*Figure 6*). As a result, the surface energy of the PP increases from 35 dyne to over 72 dyne. This has the effect of improving the adhesive characteristics of the subsequent bond to ensure seal tightness.

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 bubble-free and have good adhesive characteristics. This calls for a very clean surface with extremely high surface energy. Bavarian automotive component supplier Preh from Bad Neustadt an der Saale 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.

Dual functionality: Adhesion promotion and corrosion protection

Die-cast aluminum housings are often used in the automotive industry to protect electronic components such as engine control systems or electric motors from corrosive attack. Since the housings usually consist of two halves, the weak point is the adhesive joint. Depending on environmental influences, corrosive media can migrate beneath the adhesive bond and thus cause the housing to leak. This would result in failure of the electronics.

At TRW Automotive, world market leader in vehicle safety systems, motor pump housings for steering units are first cleaned with Openair-Plasma plasma (*Figure 7*) before a functional PlasmaPlus coating is applied. The coating complies with the requirements of DIN EN ISO 9227 and has both adhesion-promoting and anti-corrosion properties. It forms a covalent bond with the metal to ensure optimum protection against moisture ingress. Recently conducted salt-spray tests show that with this coating, components can withstand even 960 hours of exposure before failure, depending on the alloy or seal configuration. At the same time, the plasma-polymer coating provides an excellent adhesive substrate for both liquid seals – such as the Loctite adhesive used by TRW – and solid seals, e.g. EPDM. Coating with atmospheric pressure plasma plays a key role here. The plasma polymer coating achieves greater corrosion protection and a significantly better seal than the process previously used, which involved spraying a fluoropolymer-based corrosion inhibitor manually onto the bonded joint from the outside after gluing.

Conclusions

The case studies described here illustrate the virtually unlimited scope of environmentally friendly pretreatment methods. Apart from their effectiveness, other factors which have persuaded users to switch to the Plasmatreat technologies described here include high process speed, high process reliability, robot compatibility and accurate process reproducibility. The technology offers easy integration into process operations and signal chaining to higher and lower-ranking control units, as well as being more cost-effective than other conventional methods. //

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