“Certainly not superficial”

Out of the multiplicity of pre-treatment methods in industrial processes, the use of plasma at normal pressure is continually gaining in importance in automotive engineering. The following examples of applications demonstrate that the plasma process is equally suitable for rendering surfaces ultra clean as well as for improving adhesion.

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The key factor in achieving bonding between plastics of long-term stability and capable of bearing loads is in most applications the creation of the right preconditions on the surfaces of the materials. To create these, use of what is known as the Openair Plasma pre-treatment process is recommended. In automotive engineering this process is already employed in some 30 different applications. From the pre-treatment of windscreens prior to bonding via use in engine control housings, from the structural bonding of truck cooling system fittings through to the bonding of body parts this plasma technology is used to ensure simple, reliable and solvent-free pre-treatment.

Plasma, the fourth state of matter

Plasma is the name given to matter at a high, unstable energy level. Energy is input via the solid, liquid and gaseous states of matter, always in the form of heat. Plasma technology does not stop at the gaseous state of matter: if by means of electric discharge additional energy can be fed into the material, the electrons gain more kinetic energy and leave their atomic shells. Free electrons, ions and molecular fragments are produced (see Figure 1). This state, however, can scarcely be used at normal pressure because of its instability. Only the patented atmospheric pressure "Openair" plasma process opened up new possibilities: by employing plasma jets this state of matter, scarcely used hitherto in industry, was successfully used for the first time in production processes, some of them "in-line"

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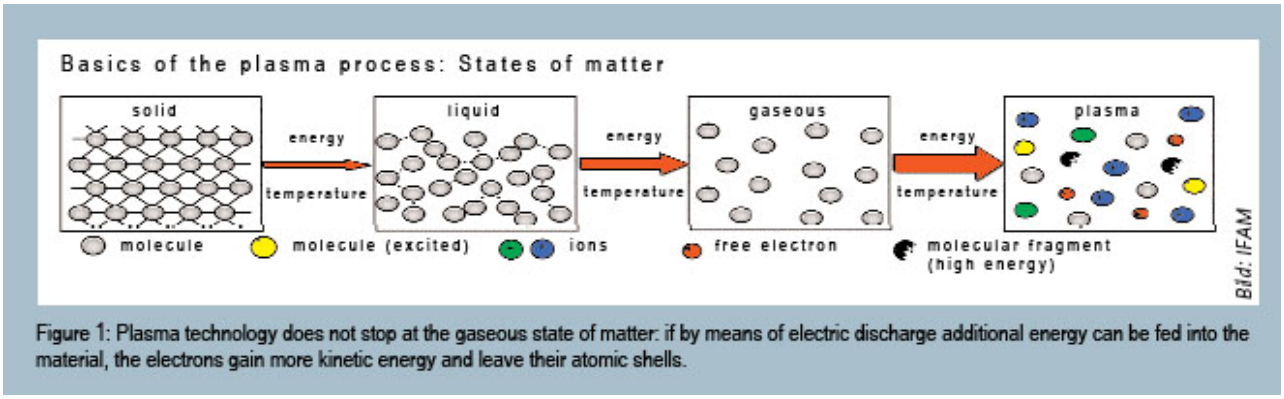

Figure 1: Plasma technology does not stop at the gaseous state of matter: if by means of electric discharge additional energy can be fed into the material, the electrons gain more kinetic energy and leave their atomic shells.

Electrically neutral plasma beam

The jets are operated solely by air, if need be with a desired process gas, as well as by high voltage. Depending on the jet geometry the emergent plasma is effectively available over an operating domain up to 25 mm wide or at a treatment distance of 40 mm (see Figure 2).

Photo Plasmatreat

Figure 2: Depending on the jet geometry the emergent plasma is effectively available over an operating domain up to 25 mm wide or at a treatment distance of 40 mm-

A particular characteristic of the emergent beam of plasma is that it is electrically neutral, which greatly extends and simplifies opportunities for use. The temperature of the plasma emitted depends on the power supplied and the configuration of the plasma source and can range from 300 to 1500 °C. This allows very high operating speeds with optimum effects. Heating up of the plastic surfaces during treatment in this case is typically $\Delta T < 20$ °C.

Structural bonding of cooling system fittings

A particular field of application of the zero-potential atmospheric pressure plasma is found in the trailer company Schmitz Cargobull. Here, as early as the 1990s in association with the development of a new generation of vehicles, bonding was introduced as the

Photo Schmitz Cargobull

Figure 3: At the trailer company Schmitz Cargobull for the last two years surface pre-treatment has been done completely by Openair Plasma.

sole method of assembly of cooling system fittings (see Figure 3). For this purpose experience and know-how relating in particular to:

- structural design in keeping with bonding,
- special surface pre-treatment and cleaning
- automatic application of adhesives, and
- process monitoring

were put into practice. With this generation of vehicles the move to integral structural bonding was completed. Here for the last two years surface pre-treatment has been done completely by Openair Plasma. The latest rotary plasma systems are integrated into the process flow and allow extremely effective and thoroughly efficient pre-treatment of surfaces to be bonded.

Pre-treatment of plastic subassemblies

In bodywork on grounds of weight saving individual subassemblies are now no longer manufactured from sheet steel or aluminium, but rather from high-performance plastics (see Figure 4).

Photo Plasmatreat

Figure 4: In bodywork individual subassemblies are now no longer manufactured from sheet steel or aluminium, but rather from high-performance plastics. Secure adhesion of a two-pack polyurethane adhesive to SMC or PPO (e.g. Noryl) is achieved by pre-treatment with plasma.

In doing this, within the process for assembling a subassembly, such as an inner mud guard, for example, single parts are bonded to one another in the course of an automatic joining process. As is well known the ability of a plastic to bond well depends essentially on its surface tension which should be greater than that of the adhesive. This is frequently not the case, however, so that a suitable surface pre-treatment becomes necessary. Secure adhesion of a two-pack polyurethane adhesive to SMC or PPO (e.g. Noryl) is achieved by pre-treatment with plasma which cleans the surface to the limit of detectability and additionally activates it. Conventional methods of preparing SMC surfaces - such as sanding down or cleaning with acetone - are not only replaced by plasma treatment, conventional bonding results are also surpassed. After assembly the high-performance thermoplastic and thermoset parts fulfil all requirements with regard to lightweight construction, passive safety, mechanical properties and a first class surface finish.

Table 1: Surface energy of SMC after Openair Plasma treatment

	Distance [mm]								
Speed [m/min]	18	16	14	12	10	8	6	4	2
60	68	70	72	72	72	72 TL	72 TL	72 TL	72 TL
55	70	70	72	72	72	72 TL	72 TL	72 TL	72 TL
50	70	72	72	72	72	72 TL	72 TL	72 TL	72 TL
45	70	72	72	72	72	72 TL	72 TL	72 TL	72 TL
40	72	72	72	72	72 TL	72 TL	72 TL	72 TL	Z
35	72	72	72	72	72 TL	72 TL	72 TL	72 TL	Z
30	72	72	72	72	72 TL	72 TL	72 TL	72 TL	Z
25	72	72	72	72	72 TL	72	72 TL	72 TL	Z
20	72	72	72	72 TL	72 TL	72 TL	72 TL	72 TL	Z

72 TL - 72 mN/m =adversely affected by heat, Z = damaged by heat

Here, Openair technology can be used as a pre-treatment process both for the bonding as well as for the surface coating of these subassemblies, as is the case, for example, in vehicles made by BMW and Rolls Royce.

In-line plasma technology in two-component injection moulding

The production of functional and visually attractive plastic structural parts feeling good to the touch for motor car interiors requires costly assembly processes.

The base support manufactured from a rigid component (such as PP, PA or ABS) is covered with a flexible material (such as leather, synthetic leather, PU or TPO slash skin). In this case the feel of the material is provided, on the one hand, by the material and, on the other hand, by a foam backing containing a flexible component.

The extremely tedious production process is associated with very high assembly costs which makes it inefficient and relatively unreliable.

Photo Krauss-Maffei

Figure 5: In the two-component injection moulding machine the base support for the car interior is injection moulded and following treatment with Openair Plasma this is immediately over moulded with a flexible component

A much less costly and more reliable method consists in producing a component directly ready for dispatch in a two-component injection moulding machine (see Figure 5). In the machine the base support is injection moulded and following treatment with Openair Plasma this is immediately overmoulded with a flexible component. In this way manual handling of the individual parts is unnecessary as after each cycle the component drops "ready" out of the machine.
The requirements for function, visual appearance and feel or handle are always met by the choice of the second "flexible" component. For this purpose both PU materials, such as "SkinForm" from the injection moulding machine manufacturer Krauss-Maffei, and TPU materials can be employed.
The use of the plasma process as a tool for adhesion creates the preconditions for attaining compatibility between the rigid and flexible components.

Bonding door seals during production

As a concluding example of applications in the automotive sector, the bonding of door seals is briefly mentioned. In various VW models extra sound insulation is provided by an additional door seal in the upper region of the front doors. This increases driver comfort by cutting out road noise.

For the base material of the seal VW selected a thermoplastic elastomer (TPE) which as a nonpolar material exhibits very low surface energy.

Source: Plasmatreat with authorization of VW

Figure 6: In the meantime almost all door production lines at Volkswagen have been equipped with the Openair Plasma pre-treatment system.

For pre-treatment prior to applying the MS polymer adhesive a solvent-free system was definitely to be used. After comparing different corona and plasma systems, special importance being attached to a wide process window, VW decided in favour of rotating Openair Plasma jets. Table 2 clarifies the effects of Openair Plasma treatment. Since then nearly all of the door production lines at Volkswagen have been equipped with this system (see Fig 6).

Table 2: Surface energy [mN/m] of TPE after Openair Plasma treatment

	Distance [mm]				
Speed [m/min]	12	10	8	6	4
30	62	68	70	**72**	**72**
25	64	68	**72**	**72**	**72**
20	66	70	**72**	**72**	**72 TL**
15	66	70	**72**	**72 TL**	**72 TL**
10	66	**72 TL**	**72 TL**	**72 TL**	**72 TL**
5	70	**72 TL**	**72 TL**	**72 TL**	**Z**

72 TL - activation to 72 mN/m = adversely affected by heat, Z = damaged by heat

Conclusion

The applications described should make it clear that there are scarcely any limits to the diversity of uses of the Openair Plasma pre-treatment method. The most important advantages of the method include the reliability and quality it provides in the production process. Accordingly, the requirements of motor car manufacturers, which are known to be high, can be met. Furthermore, other desirable features such as simple integration into process flows and compatibility of the treated surfaces with cathodic electrodeposition painting can be provided in addition to higher economic efficiency by comparison with conventional methods and all of this is done with absolutely no adverse effects on the environment.

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