Chemical-free pretreatment with plasma

For many material surfaces, an effective pretreatment is essential to ensure reliable and long-time stable adhesion of adhesive bonds and coatings. The use of atmospheric pressure plasma is an environmentally friendly method that not only enables in-line cleaning, activation and nanocoating at the highest level, but is also particularly cost-effective.

Reliable adhesion of adhesives and coatings to materials such as plastics, metals or glass 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. Various pretreatment methods are available to achieve these two conditions, with wet chemical substances still the most widely used. One process that can entirely eliminate the need for chemical pretreatment is a plasma jet technology developed 20 years ago by the Westphalian system engineer Plasmatreat and now used worldwide in virtually all sectors of industry. The Openair plasma process brings about the chemical-free microfine cleaning and simultaneous activation of material surfaces, especially plastics, metals, glass and ceramics, in a single step lasting only a matter of seconds (Fig. 1). The result is high surface wettability and long-time stable adhesion of adhesives, paints, varnishes and foams. Adhesion, printing or coating can be carried out immediately after treatment. The process is suitable for fully automated and continuous production processes. Pretreatment can be performed in-line or outside the production line under normal atmospheric conditions, as required. Since the process uses nothing other than compressed air and electrical energy, VOC (volatile organic compound) emissions during production are avoided from the outset.

Fig. 1: Openair plasma technology brings about the microfine cleaning, high activation and nanocoating of material surfaces in an environmentally friendly way. (Image Plasmatreat)

Cleaning and activation in a single step

Without the high level of activation which a non-polar plastic such as polypropylene receives during the plasma process, wetting problems would arise, making coating impossible. Dr Alexander Knospe, Director of Innovation at Plasmatreat, explains the chemical processes: "During plasma pretreatment the surface energy of the plastic increases substantially as polar groups, such as hydroxyl groups, are created at the surface. The effect of this is two-fold: firstly the paint or adhesive is able to completely wet the surface, and secondly its forms covalent bonds, i.e. very stable atomic bonds, at the surface." The result is a homogeneous paint finish and long-time stable adhesion of adhesives and coatings even under very challenging load conditions. Trials at Plasmatreat have shown that in many cases surface energy values in excess of 72mJ/m² can be obtained when plastics are pretreated with plasma (Fig. 2).

Electrostatic discharging

When the plasma hits a surface, electric charge carriers in the electrostatically charged workpiece are able to flow to ground, in other words the surface is electrostatically discharged. This is a huge advantage, because it prevents the surface from attracting impurities from the ambient air during upstream adhesion or coating processes. The plasma radiation is so intense that processing speeds of several 100m/min can be achieved.

Coating

Some years ago Plasmatreat became the first company in the world to successfully bring a plasma coating process under atmospheric pressure to series-production on an industrial scale. The patented PlasmaPlus technology, developed in close cooperation with the Fraunhofer Institute IFAM in Bremen, for the first time enabled a locally selective, functional coating to be applied to material surfaces under atmospheric pressure. Functional coatings may serve to promote adhesion or give a high degree of corrosion protection, for example. An organosilicon compound is added to the plasma to produce a coating. Due to high-energy excitation within the plasma, this compound is fragmented and deposited on the surface in the form of a vitreous layer. The chemical composition can be varied according to the application to ensure that optimum results are obtained for any given material.

Solvent-free adhesion of plastics

Target technologies for Openair plasma treatment in the plastics industry include

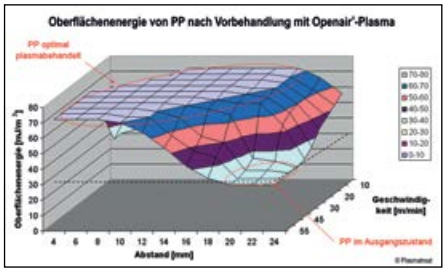

Fig. 2: The figure shows a non-polar plastic surface that was pretreated as a function of distance and speed with plasma. Treatment renders the surface polar and the surface energy rises to >72 dyne with a large process window. (Image Plasmatreat)

2-component injection molding as well as up- and downstream processes such as painting, bonding, printing, foaming and coating plastic surfaces. The plasma's high activation capacity makes it possible to bond substrates previously thought to be incompatible. Furthermore, masking processes – often required for pretreatments using flame technology – can be entirely eliminated since the effect of the plasma nozzle is locally selective, i.e. it can be targeted to activate only the desired areas (Fig. 3). Equally important is the fact that water-based (solvent-free) adhesive and paint systems can now be bonded to very adhesion-resistant (non polar) plastics. Furthermore, the technology offers great potential for fine cleaning and adhesion promotion in multi-component systems for plastic-metal composites.

A new large-panel plasma system enables the large-scale activation of polypropylene honeycomb cores for sandwich composite panels without the need for any primers. This means that long-time stable adhesion can be achieved even with surface layers made from steel. The process is regarded as a breakthrough for the future low-cost production of composite panels, which can now have core materials made from far more favorable materials such as recycled plastics.

Plasma coating of aluminum

Conventional automated chromate coating processes treat the entire component. Areas which do not require coating must be masked, or alternatively the coating, once applied, must then be removed from these areas in a subsequent step. Since in most cases only a small area of the overall component comes into contact with any adhesive, an automated pretreatment that is locally selective would be of particular interest to manufacturers. Very often, the surfaces

Fig. 3: The robot-controlled, locally selective plasma nozzles eliminate the need for masking when pretreating plastics. (Image Plasmatreat)

Fig. 4: The anti-corrosive, adhesion-promoting layer deposited with the aid of PlasmaPlus technology not only confers a high level of corrosion protection, it also provides an excellent substrate for many adhesives. (Image Plasmatreat)

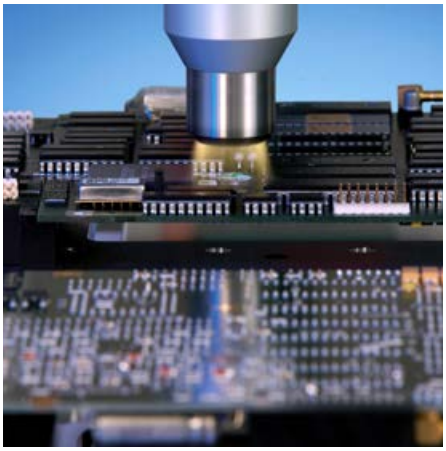

Fig. 5: The potential-free plasma activates the plastic-coated SMD assemblies prior to conformal coating without damaging the highly sensitive electronics. (Image Plasmatreat)

to be bonded are pretreated by manually applying solvent-based detergents, pickling fluids or adhesion promoters. This method is not only costly and unstable; it also poses a potential health risk to the operator.

The PlasmaPlus process offers an environmentally friendly and highly effective alternative which is already used in vehicle manufacturing and the solar industry. The anti-corrosive, adhesion-promoting layer deposited on the surface not only confers a high level of corrosion protection, it also provides an excellent substrate for many adhesives (Fig. 4). The corrosion protection is particularly effective with aluminum alloys: The coating is capable of protecting aluminum from direct salt spray (DIN 50021) for several days without impairing the visual appearance of the metal. TRW Automotive, world market leader in vehicle safety systems, has been using PlasmaPlus technology for years on die-cast aluminum motor-driven pump units. These form part of the power steering system and are subject to high reliability requirements. To prevent corrosion, adhesive joints in the housing are plasma-coated during the fully automated production process.

Potential-free plasma beam for electronics

A particular feature of the Openair process is that the plasma beam is virtually electrically neutral – a characteristic that greatly enhances and simplifies its applicability. In the electronics industry the technology now ranks as one of the new methods of treating components and circuit boards during production and/or assembly. High standards of cleanliness can be achieved as well as a potential-free treatment, i.e. during plasma treatment the circuit boards do not come into contact with electrical voltage. For electronic components, manufacturers use patented rotary nozzles with a particularly gentle rotary action which distribute the pretreatment action evenly across the surface of the component. These repeatedly scan the surface with a short, pulse-like action, providing an extremely effective means of cleaning and activation with a low thermal input. The fact that the plasma is potential-free is of utmost importance to avionics specialist Rohde & Schwarz. The plastic-coated components of assembled circuit boards for airborne communication systems used on long-haul flights are pretreated with this Westphalian plasma technology to enhance the adhesion of the conformal coating. The highly sensitive electronics are not damaged in the slightest during this procedure (Fig. 5).

Well-known suppliers in the automotive industry use this method to protect their sensors and control elements. These perform vital functions, e.g. engine or climate management and control of braking, suspension and lighting systems. According to the IEC standard and the IP protection classes, these electronic components must be protected from moisture and dirt ingress. This places correspondingly high demands on the impermeability of their plastic or aluminum protective housings. Plasma treatment ensures total tightness during the adhesion process.

Summary

The plasma technology described here is an environment friendly and particularly cost-efficient pretreatment process. Not only can it cut down on process steps and reduce operating costs, it also significantly increases throughput and product quality. All the nozzle systems used are fully compatible with robotic applications and can be integrated into new or existing production lines by the user at any time. The technique, which is suitable for fully automated and continuous production processes, is not only highly effective, it also demonstrates a high level of process reliability and reproducibility.

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