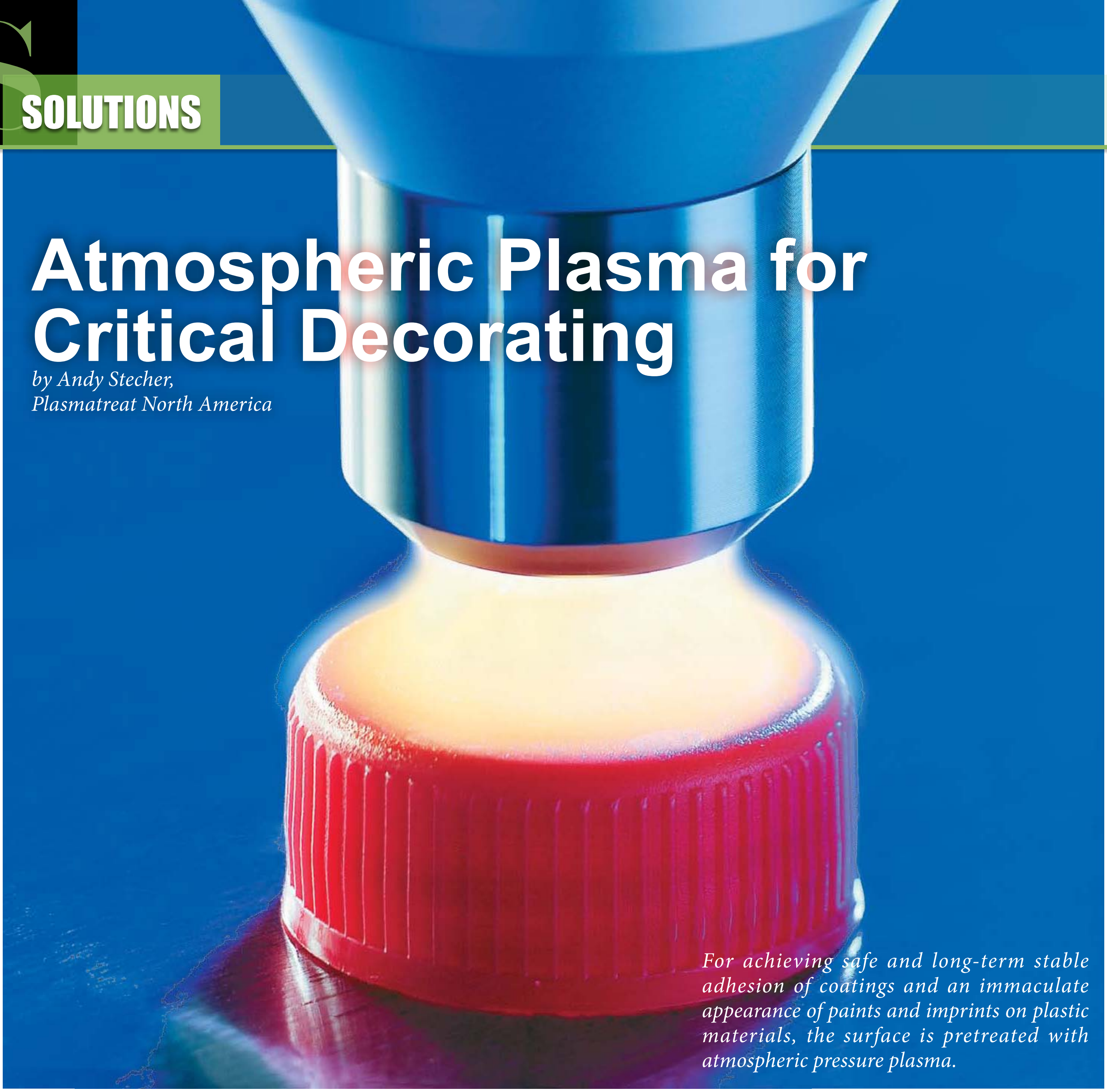

Atmospheric Plasma for Critical Decorating

by Andy Stecher,
Plasmatreat North America

For achieving safe and long-term stable adhesion of coatings and an immaculate appearance of paints and imprints on plastic materials, the surface is pretreated with atmospheric pressure plasma.

Invisible fine dust particles, electrostatic charges and incompatible materials lead over and over again to problems with the adhesive bonding, painting or imprinting of plastic materials. That's where atmospheric pressure plasma technology comes to the rescue.

The more technologies conform to one another, the more important visual appearance becomes in the purchase decision. Attractive design elements, high-quality imprints and immaculate surfaces are distinguishing features which are assuming an increasing importance to the consumer. Whether it's a light switch or a mobile phone housing, a cosmetic tube or a plastic folding box – the plastics industry has squared up to the requirements and is spending exponentially rising sums on advancing its decorating processes.

In recognition of the growing demands for high quality, design innovation, reduced weight and environmental protection, the plastics industry constantly increases its efforts to improve adhesive bonding, painting and imprinting. The decisive factor during these operations is the pretreatment of the material surface before it undergoes further processing. Treatment methods range from ionization, flame impingement, power washing or primer application through to mechanical cleaning with ostrich feathers. In spite of all efforts, the production wastage rate caused by dust particles exceeds 10 percent in many cases. Electrostatic charges of the surface, tiny but intolerable remainders of fine dust particles in deeper lying areas and environmental pollution are among the most common concerns.

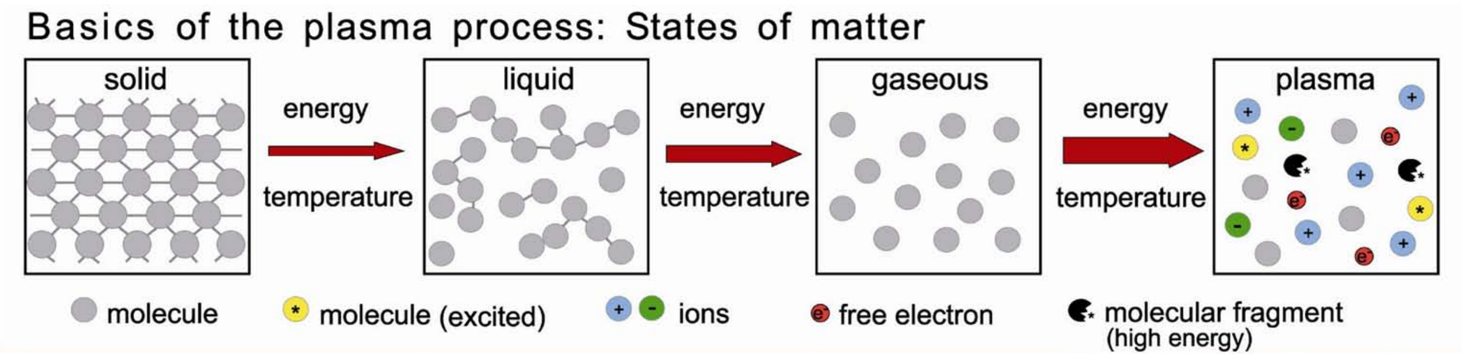

Figure 1. Plasma technology does not stop the gaseous state of matter. If, by means of electronic discharge, additional energy can be fed into the material, then the electrons gain more kinetic energy and leave their atomic shells.

For achieving safe and long-term stable adhesion of bondings and coatings and an immaculate appearance of paints and imprints on plastic materials, atmospheric plasma-jet technology is used in almost all industries. It not only completely eliminates the above concerns, but also replaces environmentally detrimental or cost-intensive cleaning processes. The technology is equally suited for cleaning surfaces to a microfine level or for improving adhesion.

The plasma state of matter

Plasma is based on a simple physical principle. By supplying energy, the states of matter change: from solid to liquid and from liquid to gaseous. If further energy is added to a gas, it becomes ionized (i.e., the electrons gain more kinetic energy and leave their atomic shells). Free electrons, ions and molecular fragments are formed, and the gas turns into a plasma state, which also is known as the "4th state of matter" (Figure 1). This state, however, was rarely used in industrial production at normal pressure because of its instability.

Usage increased when an atmospheric pressure plasma-jet technology by the name of Openair-Plasma was developed by the German plasma system manufacturer Plasmatreat. By inventing and using special plasma nozzles, it became possible for the first time to integrate in-line what was an almost never used state of matter for industrial production processes. Consequently, plasma was made usable for large-scale pretreatment of material surfaces in a normal atmosphere.

Atmospheric jet-plasma is eco-friendly and, unlike gas-flame treatment, there is no risk of explosion or overheating substrates due to complex component geometries. The nozzles are solely operated with air and high voltage. The green technology also is cost efficient. The process brings about the following effects on the material's surface:

Figure 2. Electrostatic effects are the principal cause for the adhesion of dust. Atmospheric plasma-jet treatment allows extremely efficient cleaning before decorating.

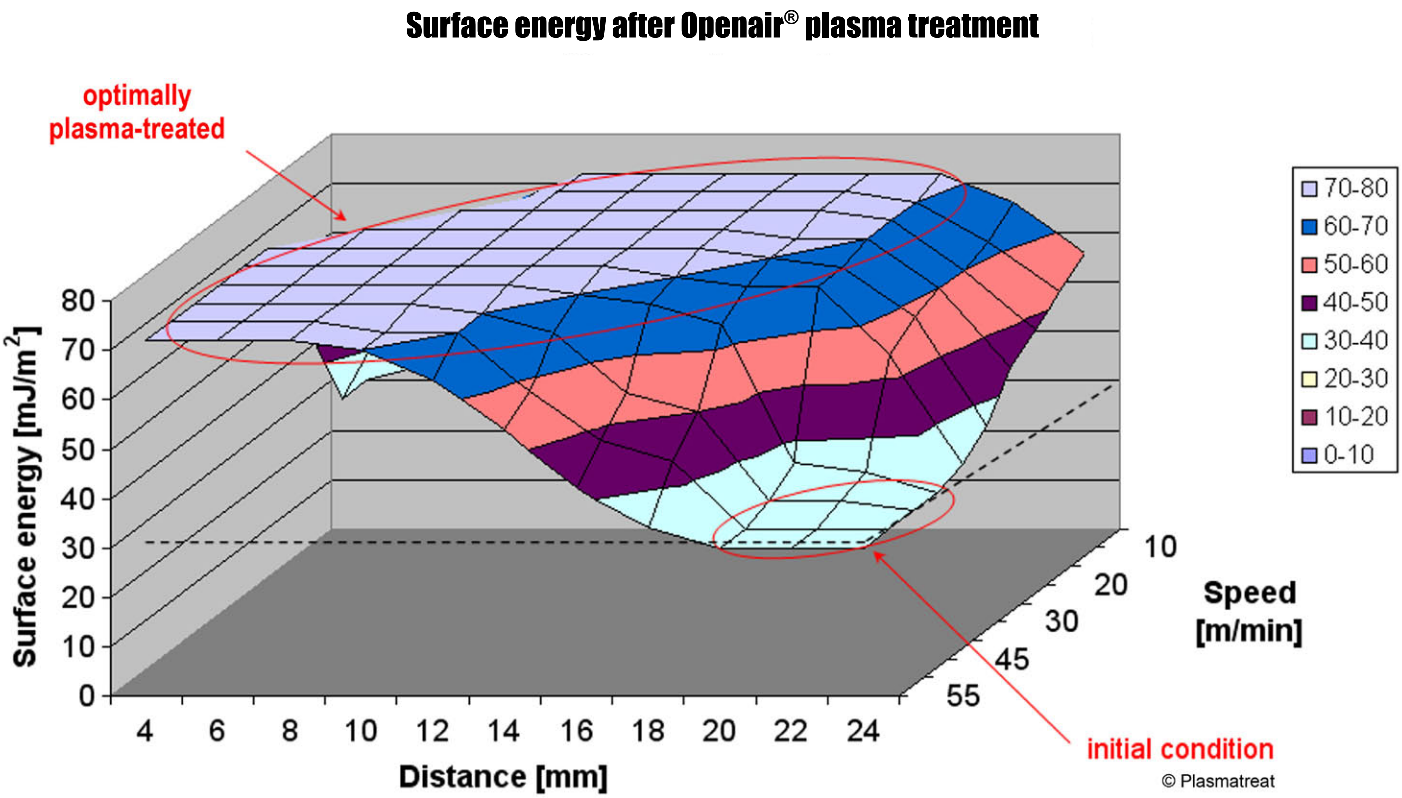

Figure 3. The figure shows a non-polar plastic surface that was pretreated as a function of distance and speed with plasma. Treatment renders the surface polar, and the surface energy rises to >72 dyne with a large process window.

Cleaning: Contrary to flame treatment, the plasma flowing with almost ultrasonic speed onto the surface brings about microfine cleaning (Figure 2). The cleaning effects exceed those of conventional systems by far. This effect is additionally promoted by the extremely high emission speed as a result of which loosely adhering particles are effectively removed from the surface. Chemical or manual precleaning processes can be entirely omitted.

Activation: Secure adhesion of a coating is conditional on the surface energy of the solid material being greater than the surface tension of the liquid adhesive or paint. Without the high degree of activation received in the plasma process, for instance by a non-polar plastic such as polypropylene, wetting problems would arise and make coating impossible. Dr. Alexander Knospe, head of R&D at the Plasmatreat headquarters in Germany, explains the chemical processes: "Plasma pretreatment strongly increases the surface energy of the plastic material since polar groups, such as hydroxyl functions, are formed on the surface. In this application, not only complete surface wetting with a given paint or adhesive is improved, but also the creation of a covalent bond, which is a very stable atomic bond, is made possible on the surface." In general, plastics have a low surface energy, usually between < 28 and 40 dyne. Experience has shown that good prerequisites for adhesion are first achieved with surface energies greater than 38 to 42 dyne. With plasma treatment, the surface energy can be increased significantly. Trials have demonstrated that energy values of over 72 dynes on many plastic substrates are achievable (Figure 3).

Extended plasma system features

Potential-free plasma: In technical terms, a plasma state is described as an electrically conductive gas. A particular feature with the Openair process is that the emergent plasma beam is potential-free and, as a result, applications are greatly extended and simplified. Due to a patented specific nozzle-head design, the treatment space above the substrate surface remains electrically neutral. When the zero-potential plasma beam bombards the surface, the electrical charge carriers on the electrostatically charged workpiece can dissipate to earth. This way the surface is electrostatically discharged.

Power and Speed: The intensity of the plasma in the above mentioned process is so high that treatment speeds of several 100 m/min can be achieved when using stationary nozzles. Through the use of patented rotary nozzles, an operating width of up to 130mm per nozzle at treatment speeds of up to 40m/min can be achieved. The rotating feature ensures that the bottom of a component and its side walls are activated at the same time.

Besides individual nozzles, complete rotary systems also are available for pretreating large areas. Surfaces up to 3000mm wide can be treated in a single pass in a continuous, in-line production line, which allows for the first time the solvent-free pretreatment of large composite panels made from unpolar resins such as PP and PVC. Typical rises in temperature of a plastic surface during treatment amount to $\Delta T < 30$ °C.

Coating: Until just recently, plasma polymerisation was a process that could only be carried out in vacuum. However, in close cooperation with the respected Fraunhofer Institute IFAM, Plasmatreat developed and patented an atmospheric pressure plasma coating process. The principle of this method is based on the fact that an organosilicon compound is admixed with the atmospheric-pressure plasma to produce a layer. Due to the high-energy excitation in the plasma, this compound is fragmented and deposited as a vitreous layer on the surface to be treated. Brought to large industrial use at TRW Automotive in 2007, the process allows selective nanocoating and individual functionalization of surfaces according to the requirements of the product properties needed later.

AP-jet plasma in the printing process

Atmospheric plasma jet technology can be used as part of all the common printing processes like pad printing or flexography, screen, offset and other printing. It ensures full wettability, even on difficult to wet plastics such as PP, and thus the durable adhesion of the imprint (Figure 4).

Compared to the often-applied corona treatment, AP-jet plasma reaches not only higher activation dyne levels and allows additionally for ultrafine cleaning, but it also emits no ozone at all. Its efficiency makes it possible to significantly increase machine speeds. When tubs or tubes are printed, an increase in processing speeds of up to 30 percent can be achieved. The pretreatment process makes print adhesion of solvent-free inks possible, as well as secures long-term adhesion when printing difficult surfaces like polypropylene (PP), polyethylene (PE), polyamide (PA), polycarbonate (PC), glass and metals.

Conclusion

Atmospheric pressure plasma technology is finding application in all areas that place high demands on quality, productivity, environmental compatibility, precision and flexibility. Practically all substrate materials can be treated by means of this process and the nozzle systems can be easily integrated into a new or already existing production line. Additional pretreatment by means of primers or brushing and rinsing surfaces can be dispensed with completely. Emissions of VOCs are furthermore avoided from the outset. Treatment is extremely uniform. Because of its broad application potential, atmospheric plasma technology is one of the key technologies with which innovative long-term solutions can be developed in almost all areas. ■

Plasmatreat is headquartered in Germany. In close cooperation with international research institutes and universities, the company has advanced and patented a large number of research projects and processes in atmospheric plasma-jet technology. The manufacturer has leading innovation engineering centers located in Germany, the United States, Canada, Japan and China, as well as subsidiaries and sales offices in more than 20 countries. For more information, visit www.plasmatreat.com.

Figure 4. Atmospheric plasma-jet technology can be used as part of all the common printing processes. It ensures full wettability, even on difficult to wet plastics such as PP. The effect is an impeccable image and a durable adhesion of the imprint.