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# Pretreating With Plasma

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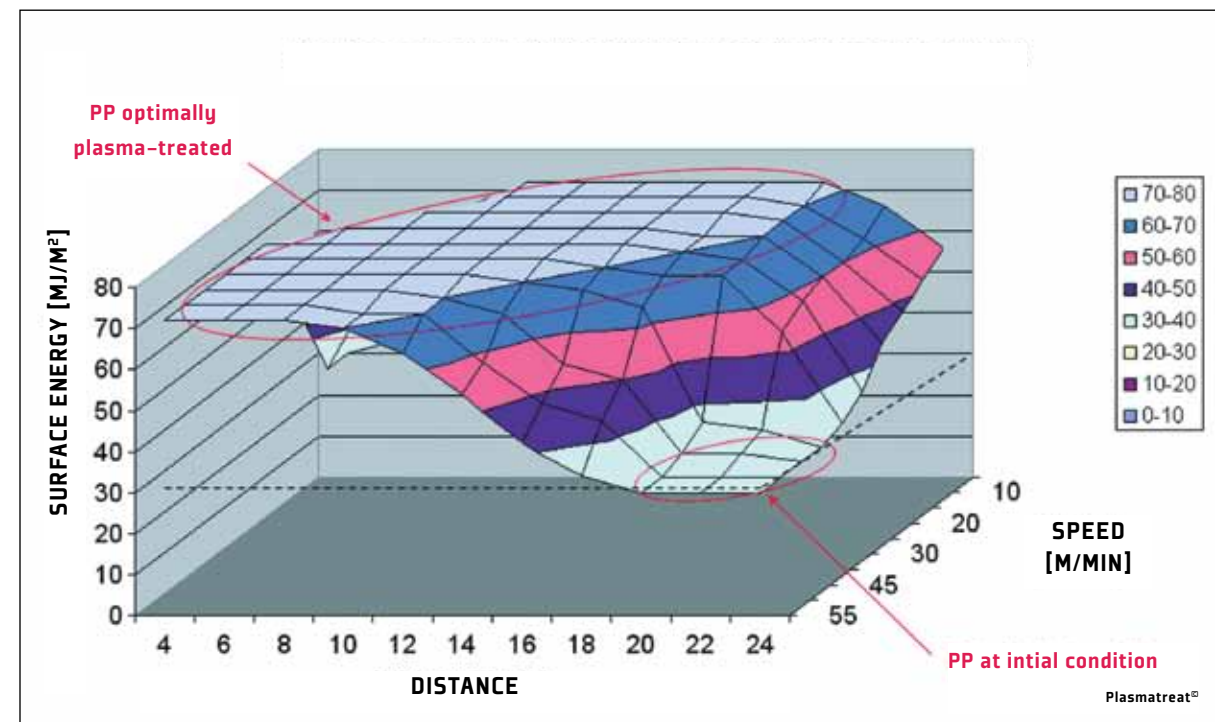
All photos provided courtesy of Plasmatreat.

# A Question of Surface Energy

Atmospheric-pressure plasma presents a solution for challenging industrial applications.

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**Figure 1** The plasma nozzles are solely operated with air and high voltage. In a matter of seconds the process brings about microfine cleaning, strong activation, and functional nanocoating of a material's surface.



Substrate pretreatment often is used to achieve safe, stable, long-term adhesion of inks, coatings, adhesives, and finishes. Methods for substrate-surface preparation include ionization, flame impingement, power washing, primer application, mechanical cleaning, plasma, and more. While each has its place, this discussion focuses on plasma pretreatment as a solution for optimizing surface energy for printing and other manufacturing processes.

#### THE FOURTH 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 gas. If further energy is added to a gas, it becomes ionized. 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 is also known as the fourth state of matter.

Previously, this state could hardly be used in industrial production at normal atmospheric pressure because of its instability. The development of specialized jetting nozzles remedied the challenges of using plasma at atmospheric pressures and enabled the use of plasma inline for large-scale, industrial use (**Figure 1**).

Atmospheric plasma jet operates on air and high voltage. The process is engineered for microfine cleaning, activation, and—by adding a precursor—functional nanocoating.

Plasma flows at almost ultrasonic speed onto the surface to achieve microfine cleaning. High emission speed removes loosely adhering particles effectively and eliminates the need for chemical or manual precleaning processes.

Secure adhesion of a coating is conditional on the surface energy of the solid material being greater than the surface tension of the liquid printing ink or coating. In general, plastics have a low surface energy, usually between 28-40 dyne. Experience has shown that good prerequisites for adhesion are first achieved with surface energies greater than 38-42 dyne. Trials have demonstrated that energy

**Figure 2** This diagram shows the surface energy of a non-polar PP plastic surface that was pretreated with atmospheric plasma as a function of distance and speed. Treatment renders the surface polar, and the surface energy rises to more than 72 dyne with a large process window.

values of more than 72 dynes on many plastic substrates are achievable with atmospheric plasma (**Figure 2**).

Without a high degree of activation, a non-polar plastic such as polypropylene will suffer from wetting problems, making coating impossible. Polar groups, such as hydroxyl functions, are formed on the surface. Thus, not only complete surface wetting with a given ink or adhesive is strongly improved, but also the creation of a covalent bond, which is a very stable atomic bond, is made possible on the surface.

The intensity of the plasma atmospheric jetting is so high that treatment speeds of hundreds of meters per minute can be achieved when using static nozzles. Nozzle heads allow millimeter-precise, locally selective treatment. Typical rises in temperature of a plastic surface during don't exceed 30°C.

In technical terms, a plasma state is described as an electrically conductive gas. In atmospheric jetting, the emergent plasma beam is generally low in potential. As a result, applications are greatly extended and simplified. This counts especially for electronics applications, where the treatment space above the substrate surface remains electrically neutral so that sensitive electronic components can be activated without risk of damage (**Figure 3**). When the plasma beam hits the surface, the electric-charge carriers on the electrostatically charged work piece can dissipate to earth. This way, the surface is also electrostatically discharged, which is extremely important with dust-adhering plastic components.

#### PLASMA IN THE PRINTING PROCESS

Atmospheric-plasma technology can be used as part of common

printing processes—pad printing, flexography, screen printing, offset, and more. It helps ensure full wettability of inks and the durable adhesion of the imprint on surfaces such as polypropylene, polyethylene, polyamide, polycarbonate, glass, and metals. It's engineered to deliver very high surface-energy dyne levels while providing ultrafine cleaning—all without ozone emissions. Here are a couple of application examples.

**Pad printing on glass** A perfume-bottle manufacturer from Germany produces millions of flacons annually with exclusive imprints through a fully automated production process. Among its numerous glass-finishing techniques, the company also uses pad printing for lettering and logo imprinting. For several years now, this glass manufacturer has used atmospheric plasma for the cleaning and activation of these delicate glass bottles. Initial experiments with flame treatment did not create the desired result, nor could the process meet the company's strict safety requirements in its production environment. Today, atmospheric plasma is fully integrated in the production process. The robot-controlled pretreatment takes place immediately before the imprinting process.

#### Screen printing on circuit boards

Secure adhesion of conductive inks printed on circuit-board materials is critical to reliability and functionality. A global manufacturer of potentiometric and non-contacting position transducers and rotary sensors previously relied on low-pressure plasma in a vacuum chamber to pretreat circuit boards. The company found the process to be suited perfectly for batch processes; however, it was much less effective for pretreatment of large quantities. Process times were too long, and the technology couldn't be integrated easily into existing screen-printing lines. In addition, the low-pressure solution was very labor-intensive. One person had to equip and another one had to empty the low-pressure chamber. Atmospheric plasma enabled the company to pretreat quickly and with reduced labor, essentially enabling the company to triple throughput.


The company manufactures sensors built with printed circuit boards. These sensors are used in a variety of industries. A typical field of application is motor management, where they measure, for example, the throttle-valve position or pedal position. The

PCBs of these sensors are manufactured with a specifically developed conductive ink that's applied by screen printing. The boards are made of glass-fiber-reinforced epoxy material that is processed in a cleanroom environment.

Treatment with plasma ensures proper wetting in the screen-printing process, as well as good ink adhesion. Atmospheric plasma removes particles that cling to PCB surfaces and neutralizes at the same time the electrostatic charge of the circuit boards generated by unpacking. Atmospheric plasma cleans and activates the surface of the circuit boards in less than 1 sec (**Figure 4**). The PCBs are automatically transported to the screen-printing plant immediately after the plasma treatment and then printed with conductive ink.

#### CONCLUSION

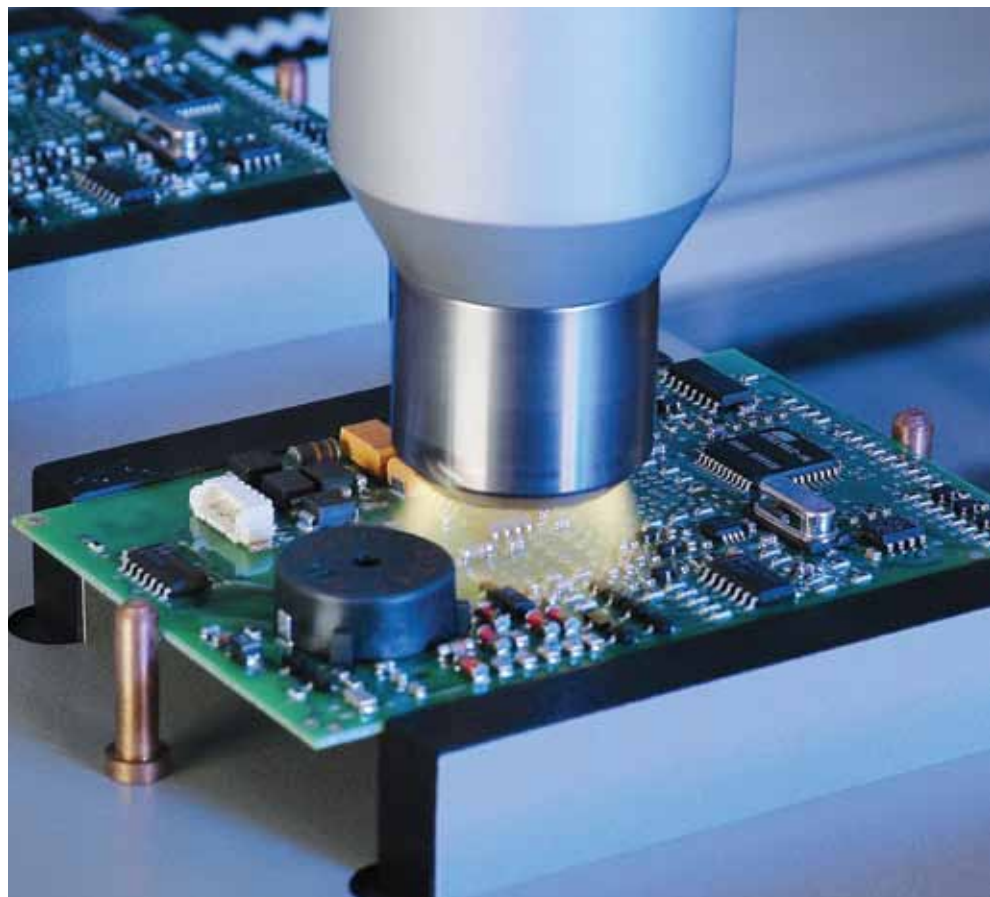
Atmospheric-plasma technology is finding a place in demanding applications where quality, productivity, environmental

compatibility, precision, and flexibility are critical. Practically all substrate materials can be treated by atmospheric plasma, and the systems can be integrated into new and existing production lines. The systems are designed to treat surfaces uniformly and perform ultrafine-cleaning and surface-energy modification in one step. Because of these attributes, atmospheric-plasma technology is one of the key technologies with which innovative, long-term solutions can be developed in almost all areas. 



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**Figure 3** Atmospheric plasma is practically potential-free, which means the space above the substrate surface remains electrically neutral. Circuit boards are activated with atmospheric plasma in less than 1 second directly prior to printing.