Activated Surfaces

Plasma Technology in Lightweight Panel Production

Recycled plastics and wood/plastic composites have largely difficult-to-bond surfaces which made them almost impossible to use for industrial processes in the past. The inline plasma system of the type described here is deemed a breakthrough for future cost effective production of composite panels. A new rotary nozzle method allows, for the first time, to pretreat large and lightweight composite panels with potential-free atmospheric pressure plasma at high speeds in a continuous process.

When producing modern plastic panels, bionics has served as a model since their initial development: honeycombs served as a model from biology, fig. 1, plastic technology contributed with the material polypropylene. Honeycomb panels are finding increasing use as the core layer for lightweight composite panels since they are water-resistant and offer high resistibility and rigidity, fig. 2. The most important property, however, is without doubt their light weight.

Plasma technology also makes use of another natural phenomenon in the form of technical plasmas generated in imitation of natural discharges in the atmosphere.

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, fig..3. 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 is also known as the "4th state of matter". This state, however, could previously hardly be used at normal pressure because of its instability.

"Plasma technology makes use of a natural phenomenon by generating technical plasmas in imitation of natural discharges in the atmosphere."

Inès A. Melamies is a freelance journalist in Bad Honnef

FIG. 1. The natural and masterful structure of a honeycomb serves industry as a model for the core layer in composite panels

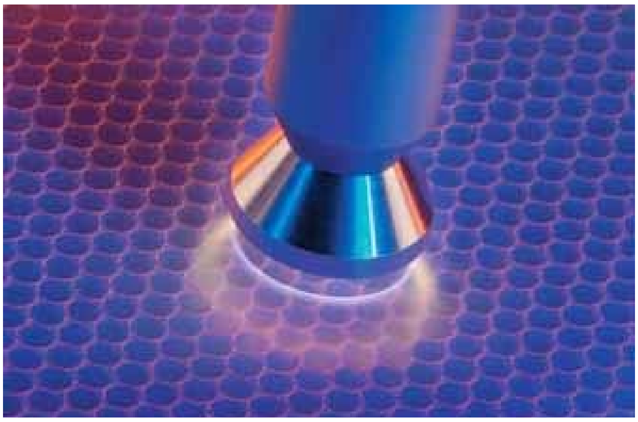


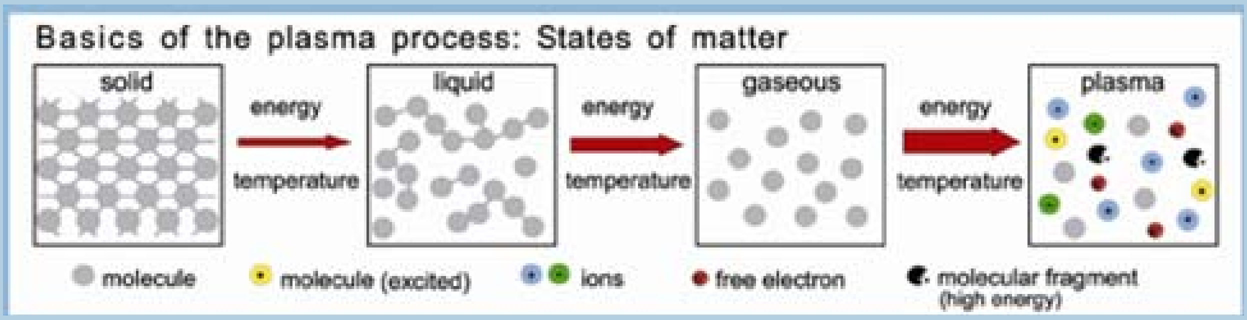
FIG. 2. Plasma treatment of the fine ribs in the PP honeycomb ensures long-time stable adhesive bonding of the plastic facings

The invention of the patented Openair atmospheric pressure plasma technology by Plasmatreat, Steinhagen, in 1995 opened up new possibilities: By developing and using plasma nozzles it became possible for the first time to integrate inline what was an almost never used state of matter for industrial production processes, and hence make plasma usable for large-scale pretreatment of material surfaces in a normal atmosphere. In this way a technique was realized, the use of which only requires air as the process gas and electrical energy.
This technology, which is used worldwide today in industrial applications, is characterized by three features: the plasma jet activates surfaces through controlled oxidation processes, discharges them at the same time and provides a microfine cleaning effect on metallic, plastic, ceramic and glass surfaces.

ACTIVATION OF THE SURFACES

When the atmospheric pressure plasma jet strikes a plastic surface, oxygen- and nitrogen-containing functional groups are attached to the mostly nonpolar polymer matrix so that the surface is modified. This effect becomes possible by the energy-rich radicals, ions, atoms and molecular fragments existing in the plasma and releasing their energy to the surface of the material being treated - thus initiating chemical reactions. The produced functional hydroxyl, carbonyl, carboxyl and ether groups (but also the oxygen compounds of nitrogen) enter into partly very solid chemical bonds with adhesives and paints and thus help improve adhesion, figure 4. The typical temperature increase when treating plastic surfaces is less than 30 °C. Thanks to the specific nozzle design, the treatment space above the substrate surface remains almost electrically neutral so that, in addition to plastics and metals, also more sensitive electronic components can be activated.

FIG. 3 Fundamentals of Plasma Process: States of Matter



SURFACE ENERGY

Surface energy (mJ/m²) is the amount of energy required for breaking up chemical bonds when producing new material surfaces. It is the most important measure for assessing the probable adhesion of an adhesive layer or a surface coating. In general, plastics have a low surface energy, usually between < 28 mJ/m² and 40 mJ/m². Experience has shown that good prerequisites for adhesion are first achieved with surface energies greater than 38 ... 42 mJ/m².

With a plasma treatment, however, the surface energy can be increased significantly due to the formation of polar groups, such as hydroxyl functions, on the surface.

During this process, not only the wettability 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.

For liquids, the surface energy is equal to the surface tension, and each liquid, each paint, each adhesive has its own inherent tension. Secure adhesion of a coating is conditional on the surface energy of the solid material being greater than the surface tension (mN/m) of the liquid adhesive. Trials at Plasmatreat have demonstrated that energy values of over 72 mJ/m² are achievable with Openair plasma pretreatment, figure 5. The consequence: it is not only possible to bond previously incompatible substrates but also adhesion of water-based adhesive or paint systems on very adhesive-unfriendly surfaces such as nonpolar resins, becomes possible in the majority of cases.

FIG. 4. Bonding process of a plasma activated plastic surface with PU adhesive

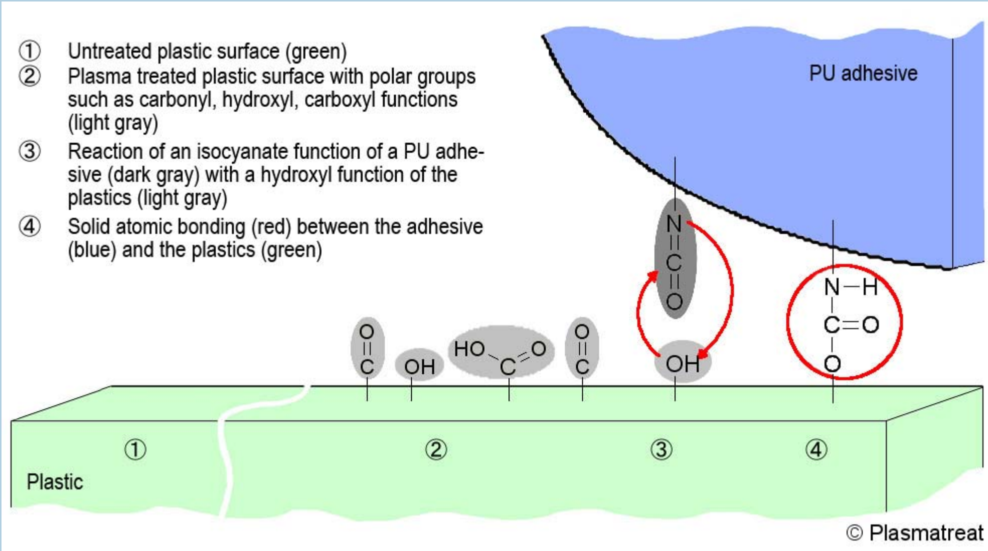
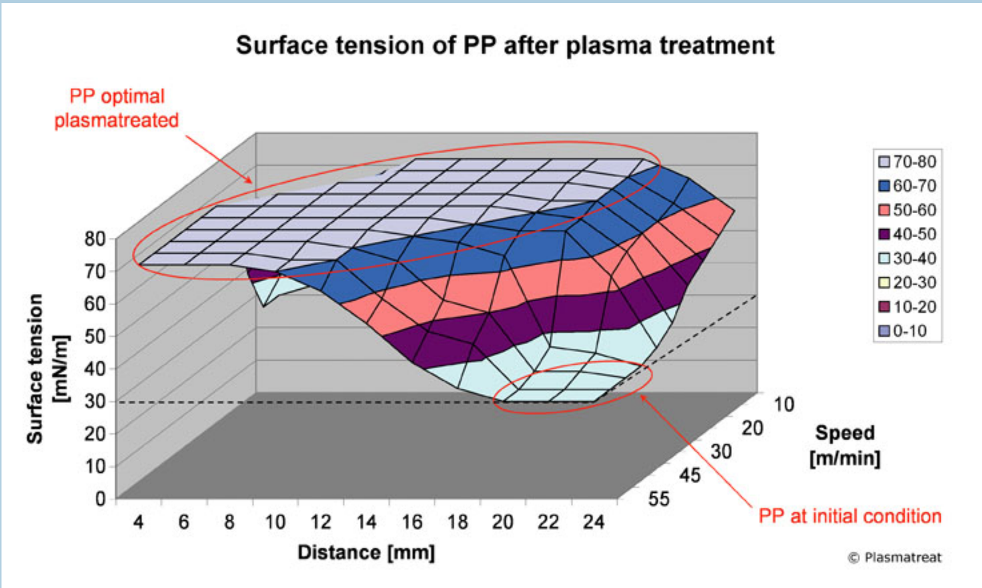


FIG. 5. Illustration of a plastic surface that was pretreated with plasma, as a function of distance and speed. Treatment renders the surface polar, and the surface energy rises to >72 mJ/m² with a large process window



DISCHARGE

In technical terms a plasma state is described as an electrically conductive gas. When the potential-free plasma jet strikes the surface, the electrical charge carriers of the statically charged workpiece can dissipate to earth or, in other words, the electrostatically charged material surfaces can be neutralized completely.

MICROFINE CLEANING

Compared to conventional methods Plasmatreat, by employing the atmospheric plasma technique, has managed to decisively rationalize processes such as the removal of dusts adhering to the surface and the removal of mold release agents or additives from polymer materials. Even metals, when subjected to plasma treatment, are cleaned to a microfine level. During this process organic contaminants such as greases and oils are vaporized, fragmented, and partially oxidized into carbon dioxide and water.

FLAT LAMINATION

The term "flat lamination" is commonly used to describe adhesive bonding of several material layers over a large area. In general, adhesive bonding of wood-based materials or PUR foam panels presents no problem. However, things look completely different when it comes to bonding plastic-based panels which are coming more and more into use and which are usually made from PP or PVC. On the one hand, they are supposed to offer significant benefits, such as high stability and high strength together with low weight and water resistance. On the other hand, these plastics often come with disadvantages in terms of processing. As nonpolar resins, PP and PVC have an extremely low surface energy which makes adhesive bonding practically impossible without additional activation of the surface. In the case of PVC, the plasticizers remain on the surface and must absolutely be removed before bonding.

ADHESION IN HONEYCOMB COMPOSITES

For the production of large polypropylene composite panels, Plasmatreat has developed and put into industrial use the world's first system allowing plasma pretreatment of PP panels for subsequent adhesive bonding or coating processes in a continuous, inline production line. With the new Openair large panel system, also the honeycomb core layer of a composite panel – or, more precisely, the narrow ribs of the plastic honeycomb – can now be activated on a large area scale with no need for any primer. For the facings bonded to the top and bottom of the honeycomb, long-time stable adhesion to the fine ribs of the honeycomb structure is of utmost importance. After plasma treatment, a solid composite of the honeycomb PP core layer with facings made from materials such as steel is also possible.

PRIMER OUT - PLASMA IN

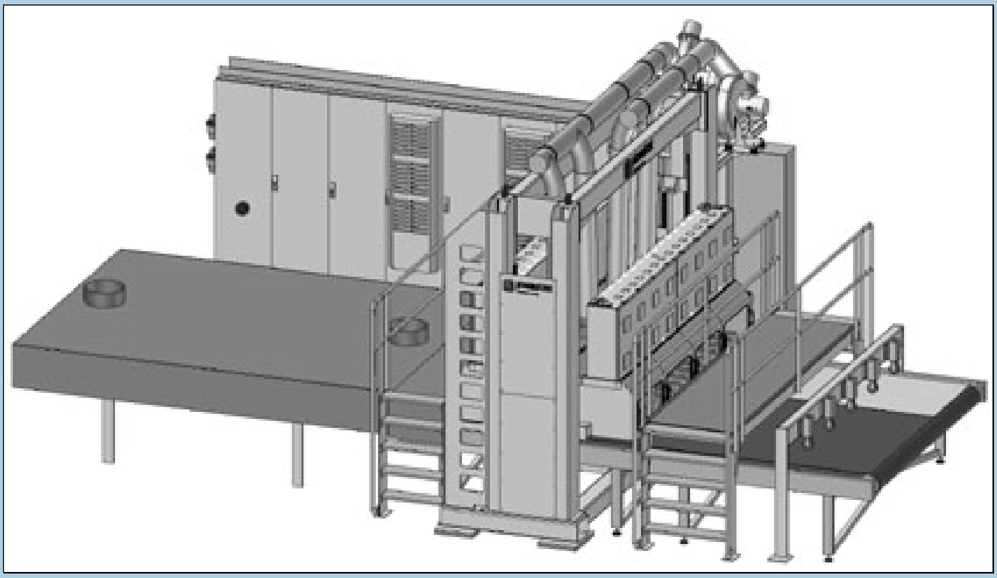
New panel technology can be used to its full potential, however, only when components can be manufactured at low cost, used effectively and in an environmentally friendly manner in equal measure.

Until now, pretreatment of the PP or PVC composite panels was based largely on wet chemical techniques employing solvent-containing primers which pose significant problems for humans and the environment alike because of their high VOC content. These are usually applied to the core layer manually. Even though they are sprayed or rolled on, these methods always lead to certain irregularities during application which is never really uniform. Adding to this is the problem that, when using primers, the temperature of the material being treated must be given due attention.

FIG. 6. The new inline plasma panel system is designed for large treatment widths and high throughputs

FIG. 7. 28 rotary nozzles, each designed for a treatment width of 100 mm, are arranged in two rows and offset from one another. In this way, up to 3 m wide panels can be activated and cleaned to a microfine level (all figures: Plasmatreat).

FIG. 8. The three major components of the new system are the generators (on the left), the plasma pretreatment system (at the center) and a vertically adjustable maintenance platform (on the right).



A change to solvent-free primers would in principle be possible but would require much more energy for these water-based adhesive primers during processing. After application of the primer, the water contained therein migrates to the surface and must then be removed from large areas. This is accomplished with the aid of radiant heaters or hot air, both of which require a great deal of expensive energy. In addition, this limits the feed rate in the production line, and the systems must be operated more slowly.

None of the above problems occur with this plasma method. With this reproducible and environmentally benign process, the surface energy is not only increased severalfold by plasma treatment but can also be defined exactly. The cleaning or activation of the surface is always uniform, regardless of the temperature of the material, and since the surface energy remains constant, faster production is possible. During this process, the operating states of the plasma are monitored by a multitude of sensors (process control function) which are integrated in the technical equipment of the system. And not to be forgotten: the operating personnel on the production line are no longer exposed to any health risk.

HIGH-TECH SOLUTION

With the newly developed rotary nozzle technology, it is possible for the first time to carry out inline plasma pretreatment over a width of up to approx. 3 m at very high processing speeds of 25 m/min during continuous production. The system is equipped with 28 adjacent plasma nozzles of type RD 1010 which are offset in two rows and designed in a way that permits pretreatment of panels with a width of up to 3 m. The entire system can be first adjusted to the height at which the panels are to be pretreated. The panels are transported through the pretreatment system on a conveyor belt with the ability to adjust precisely for height differences of 1 mm in the plasma system. The system detects the width of the panels to be pretreated automatically and enables only the appropriate plasma nozzles for the current application. The entire system has been designed to be service-friendly by allowing the plasma nozzles to be adjusted to the desired height for maintenance, and can be accessed via two bridges.

CONCLUSION

The world's first inline plasma system of the type and size described here simultaneously represents a breakthrough for future cost effective production of PP composite panels. And more: In addition to the high throughput, it will now also be possible in the future, because of plasma treatment of large areas, to exchange the core material in panels for far lower-cost materials such as recycled plastics. Recycled plastics and wood/plastic composites (WPC) have largely difficult-to-bond surfaces which made them almost impossible to use for high-speed industrial processes in the past. ●

The Authoress:

INÈS A. MELAMIES is a freelance journalist in Bad Honnef