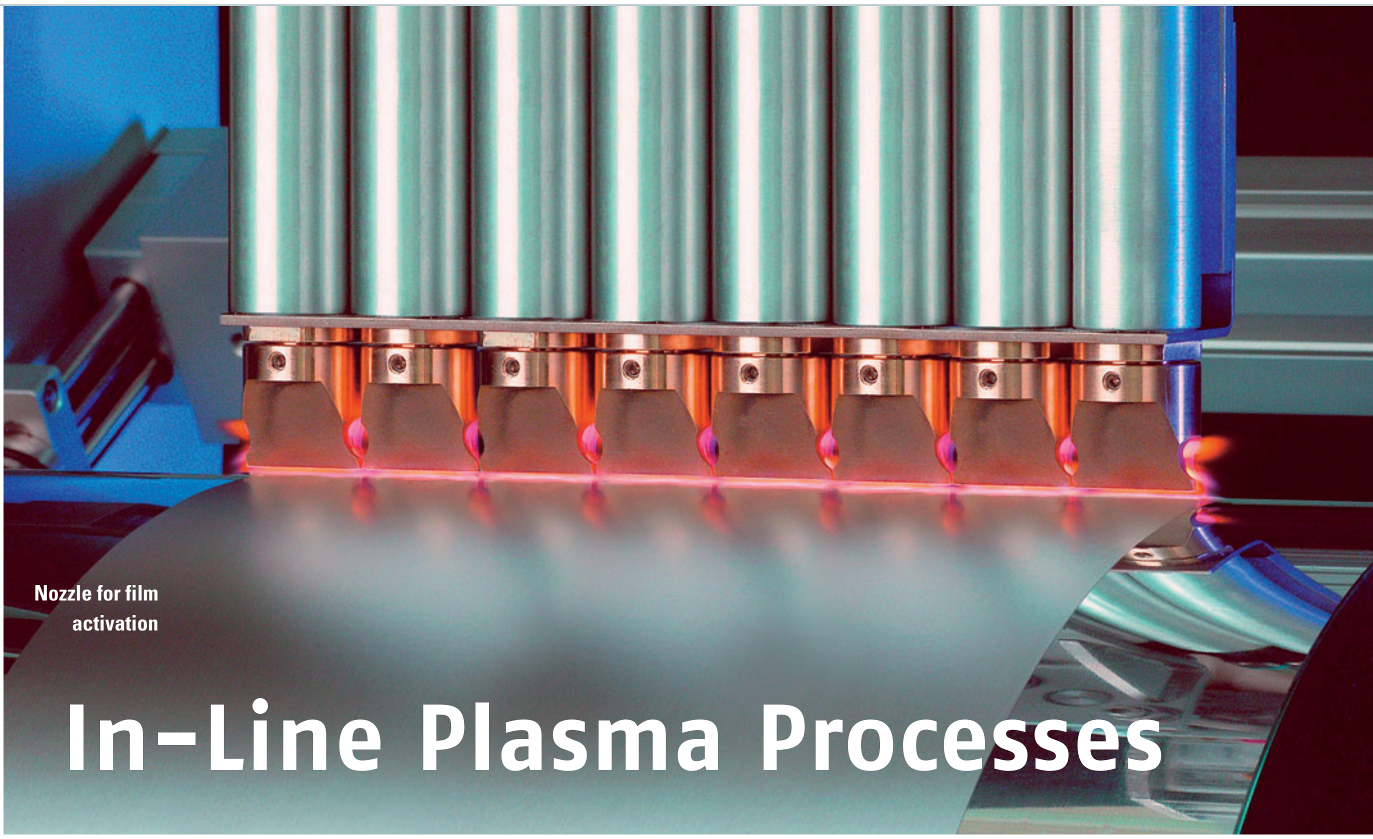

In-Line Plasma Processes

Surface Technology. The Openair plasma process has, for some years now, been creating a variety of new applications, especially for the cleaning, activation and coating of moulded parts and film. Now, a modular system has been developed for the in-line pretreatment of PP film that works with flexible widths and allows a high level of activation.

CHRISTIAN BUSKE
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Plasma – the "fourth state of matter" – describes a material that has a high instable energy level. Energy is constantly introduced as heat via the three aggregate states: solid, liquid and gas (Fig. 1). The plasma technology does not stop at the gaseous state: If energy is additionally introduced into the material by means of electrical discharge, the electrons acquire a higher kinetic energy and break free from the electron shell. The result is free electrons, ions and molecule fragments. Under normal pressure, however, this state is virtually unusable because of its instability. It is only with the Openair atmospheric pressure plasma process, conceived and patented by Plasmatreat of Steinhagen/Germany, that new possibilities have been created. Through the development and deployment of plasma nozzles, it has now become possible to al-

Translated from Kunststoffe 11/2005, pp. 82–86

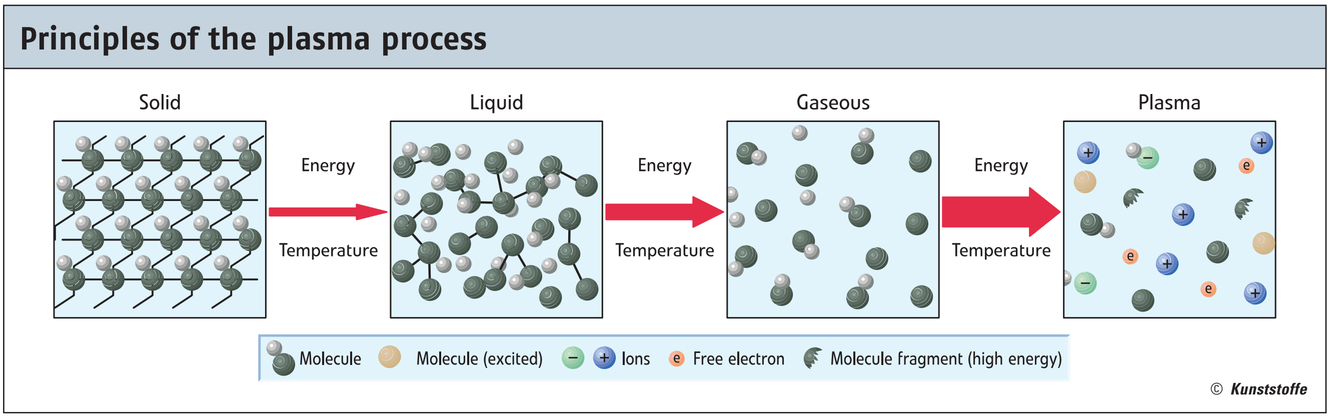

Fig. 1. Plasma as the fourth state of matter

so utilize this aggregate state (which has, until now, seldom been used in industrial applications) in production processes.

Electrically Neutral Plasma Jet

The nozzles are operated with air or with some other process gas in combination with a high voltage (Fig. 2). The emerging jet of plasma can, depending on the nozzle geometry, reach a treatment width of up to 25 mm; the source of plasma is moved at a distance of 40 mm from the surface being treated. The emerging plasma is electrically neutral, which significantly extends and simplifies application. Depending on the introduced energy and the structure of the plasma source, the temperature of the emerging plasma is between 300 and 1500 °C. This allows very high processing speeds with optimum effect. The typical heating-up of the plastic surfaces during treatment is $\Delta T < 20\,°C$.

Because the plasma modifies the surfaces of plastics, it is used for

- the cleaning of surfaces, e.g. the removal of release agents and additives,
- activation, i.e. to generate functional groups, allowing the adhesion of adhesives and coatings,
- improving the properties of the composite through a plasma-polymer coating.

Non-polar materials such as plastics bondings cannot generally be bonded without pretreatment. After activation with Openair plasma, the tensile shear force increases around 50-fold (Fig. 3). This is still the case eight weeks later, which means that the treatment remains stable over the long term.

Numerous Application Possibilities

There are no limits to the possible applications of this efficient plasma technology. It is used for cleaning and de-coating, for improving adhesion properties and for coating applications generally.

Through the use of Openair plasma, processes like the removal of mould release agents from moulded polyurethane parts – for example, furniture profiles, airbag covers (Fig. 4) and bicycles saddles – can be considerably streamlined compared with conventional processes. The layer-by-layer removal of organic coatings, the stripping or partial removal of paint or metal before bonding, the production of car headlamps and the treatment of reflectors are just some examples of the successful inline application of the

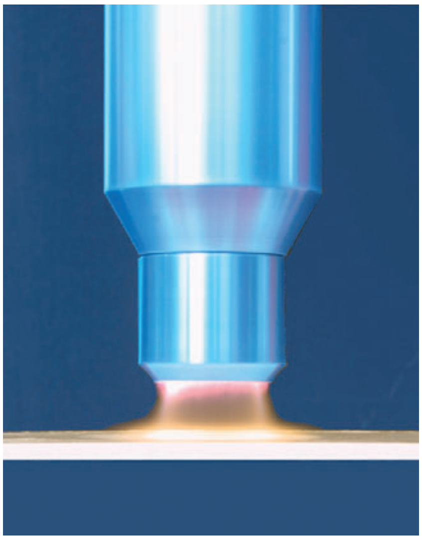

Fig. 2. Depending on the nozzle geometry, the emerging plasma is available in a treatment range of up to 25 mm; the distance from the surface is approx. 40 mm

Openair plasma system in cleaning and coating processes.

Whether it is a question of high-tech bonding, simple wet-labelling or the sticking together of folding cartons, the precise pretreatment of the bond surface by the highly developed plasma nozzles enables the use either of modern solvent-free UV adhesives or of natural, water-borne systems. For example, after pretreatment with Openair plasma, the polycarbonate display windows can be bonded into the half-shells of mobile phone housings with solvent-free UV adhesives (Fig. 5). On the other hand, casein adhesives can be used equally well for the labelling of plastic drums.

Plasma coating is a process, which, until now, could only be carried out in a vacuum. If the Openair technology is combined with a newly developed feeding-in of precursor material, coating under atmospheric pressure is also possible. The precursor is an evaporating reactive material that is left behind after the treatment in the form of a coating on the plastic. The advantage of this technology can now also be used for coating plastics. For example, water vapour barriers are already being applied in this way to CD blanks. This is a newly developed process from Plasmatreat, which is being widely used on an industrial scale for such coating applications.

In addition to the technical benefits, the process also saves considerable material costs because, for example, polycarbonates can be used instead of expensive cycloolefins.

Kufoplas Research Project

Thanks to a number of specific developments over the last three years as part of the Kufoplas research project (sponsored by the BMBF – the German Federal Ministry of Education and Research), Openair plasma is now also available for applications with large treatment widths. For the first time, these processes can be applied to the treatment of plastic film.

Kufoplas – the shortened form of the German for "plastic film plasma treatment" – is a research and development project within the framework concept "Research for the production of tomorrow". There are three partners in the project: Plasmatreat GmbH in Steinhagen,

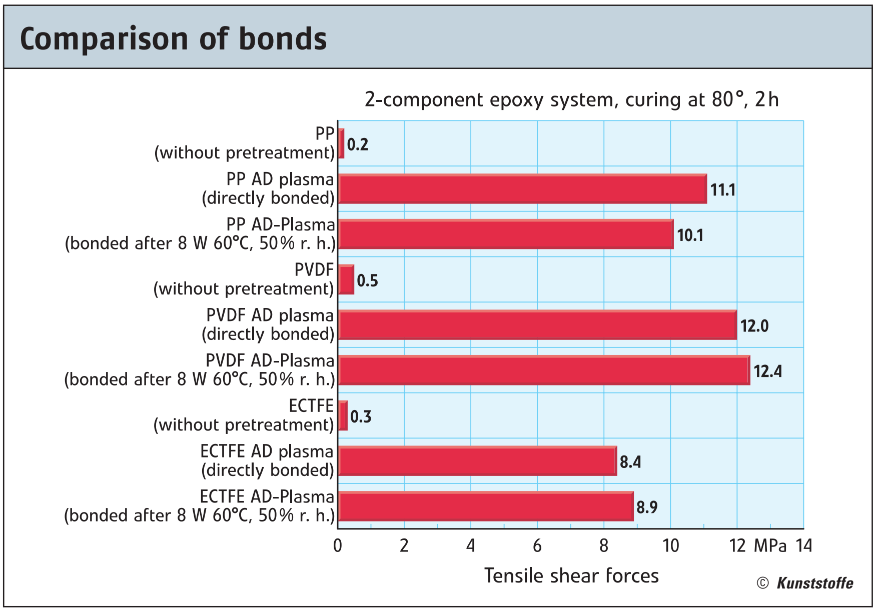

Fig. 3. Tensile shear forces of plastics bonds with and without pretreatment

which is responsible for developing the plant engineering, Treofan Germany GmbH & Co. KG in Neunkirchen, which is responsible for selecting various film substrates and integrating the pretreatment into the process for manufacturing the film, and the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research (IFAM) in Bremen, which is working on the research of the scientific principles as the basis for all the processing engineering developments of relevance to this subject.

Polypropylene film is used in all kinds of different applications in industry and the home, for example for the packaging of food and cigarettes, as labels, and as technical film in the electrical industry. To guarantee good printing properties and bonding of such films, the surface energy and thus the proportion of polar groups on the film surface must be increased.

Fig. 4. Through the use of Openair plasma, processes such as the removal of mould release agents from polyurethane mouldings (e.g. airbag covers) are speeded up considerably

Fig. 5. Following pretreatment with Openair plasma, display windows made of polycarbonate can be bonded into the half-shells of mobile phone housings with solvent-free UV adhesives

For this purpose, the industry has, for many years now, been using flame treatment and the corona technology, allowing large film widths to be pretreated at medium to high speeds. However, particularly when using the corona technique, there is a risk of both sides becoming treated, which can result in a blocking of the film on the roll. Furthermore, this method of pretreatment produces only moderate to poor activation and, because the resultant effects are not very stable, the effect declines quickly during storage.

Openair plasma has been used for several years in the activation of all kinds of different plastics and is also noted for its long-lasting surface effect. As potential-free atmospheric pressure plasma, it guarantees single-side pretreatment with consistently high surface effects. Surface energies are created, which, in contrast to surfaces treated with corona, even allow the printing of plastics with water-borne coating systems.

Project Targets

The goal of the project, which reached its conclusion this year, was to implement an atmospheric plasma system for the activation of PP-BO (also called BOPP) films in an industrial manufacturing facility for

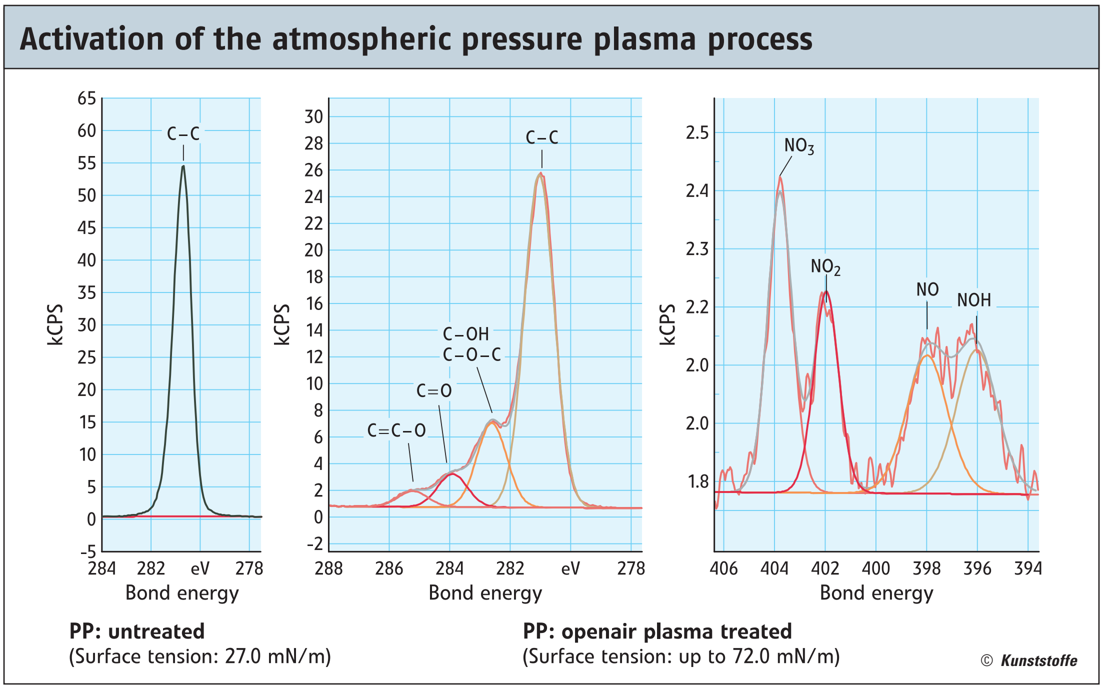

Fig. 6. XPS analysis shows that pretreatment with Openair plasma causes the introduction of carbonyl, carboxyl, ether and hydroxy functions plus nitrogen-oxygen compounds into the surface
(source: Fraunhofer Institute for Manufacturing Technology and Applied Materials Research)

polypropylene film as an in-line process, based on laboratory and pilot plant trials. The objectives were:

- to obtain heat-sealing properties,
- speeds of above 200 m/min,
- film widths up to 10 m,
- single-sided pretreatment (already guaranteed by the plasma),
- surface tension after pretreatment of above 50 mN/m,
- long storage life of the film (at least 36 mN/m after six months).

Three places were considered for integrating the plasma system into the extrusion and stretching process. Locating it directly after the extrusion has the problem that the film width is low and the substrate suffers high thermal stress due to the low pretreatment velocity. In addition, there are two film-stretching processes to follow. Even if it is located after the longitudinal stretching, the film width is still low and it faces another film stretching process. In any case, a high pretreatment velocity is needed. If the plasma system is not inserted until after the longitudinal and transverse stretching stages, there are no more stretching processes to follow and the pretreatment speed is high. The resultant effect is not subjected to any subsequent stresses.

Results

According to current findings, it is not possible to locate the plasma system directly after extrusion because the activation effect will not be able to withstand two further stretching processes. Also when positioned after the longitudinal stretching, the effect declines because there is still another stretching process to come. During the course of the project, attempts were made to solve this problem by applying a suitable layer of keying agent. If the system is located after the longitudinal and transverse stretching phases, high treatment widths are needed, making it necessary to have a modular, flexible system structure.

XPS analysis shows clearly that pretreatment with Openair plasma leads to the incorporation of carbonyl, carboxyl, ether and hydroxy functions as well as nitrogen-oxygen compounds into the surface (Fig. 6).

Because of the necessary large pretreatment width when positioning the plasma system after both the longitudinal and transverse stretching stages, tests were carried out with positioning it after the longitudinal stretching. The aim was to generate the surface tension with the aid of a suitable coating and to largely maintain this during the last stretching process. For this purpose, a polymerisable precursor gas was added to the plasma via a modified nozzle head. Under the influence of the plasma energy, the gas then formed a low-crosslinked layer on the surface. Based on the initial successes, a tool was developed that allows the transfer of the results to the pilot plant scale (Fig. 7).

Conclusions

A modular system was developed for the in-line pretreatment of PP film. It allows high film activation and can be designed in flexible widths. At process speeds of 250 m/min, the sealing properties of the film are not affected. In addition, further experiments in a pilot plant showed that the coating process can be integrated into the production line. ■

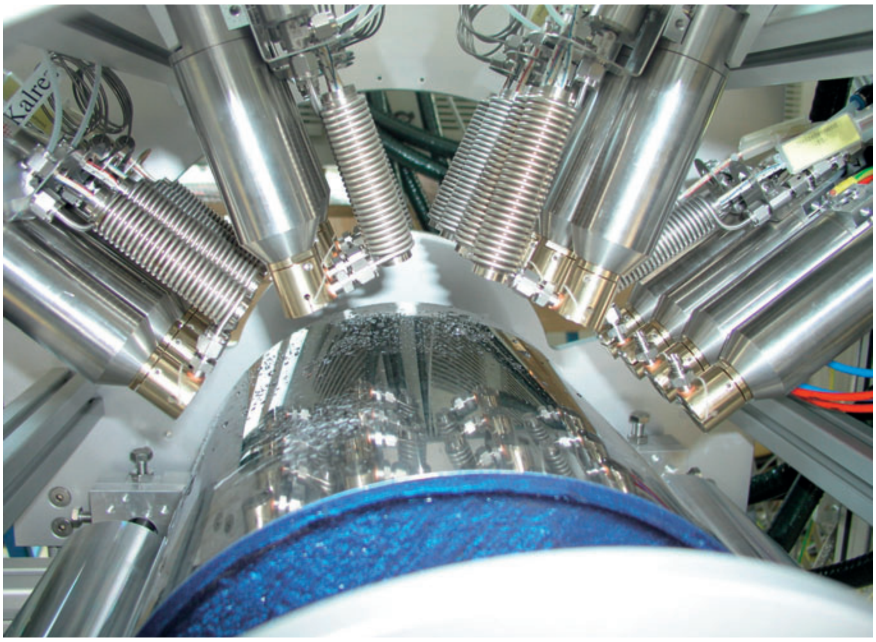

Fig. 7. Flexible nozzle system with specially developed evaporation, in which the gap between the nozzles can be adjusted at will

ACKNOWLEDGEMENT

This research and development project is sponsored with funds from the Federal Ministry of Education and Research (BMBF) within the framework concept "Research for the production of tomorrow". It is looked after by the project executing organisation of the BMBF for Production and Manufacturing Technologies, Karlsruhe/Germany research centre.

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