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Klaus Kärcher, Otto Bihler Maschinenfabrik: *»Bihler wird auf dem Weg zu Industrie 4.0 an der Spitze marschieren und Maßstäbe setzen.«* **80**

Michael Wohlmuth, Simufact Engineering: *»Der Verknüpfung von Produkt- und Fertigungswelt gehört die Zukunft.«* **86**

bbr FUTURE

INDUSTRIE 4.0, LEICHTBAU, SIMULATION

Vorbehandlung und Beschichtung

ATMOSPHÄRENDRUCKPLASMA *hat als Methode zur Oberflächenbehandlung eine große Zukunft.*

16 SEITEN
AKTUELLES ÜBER INDUSTRIE 4.0, LEICHTBAU, PLASMA UND SIMULATION

»WE LOVE LIGHTWEIGHT CONSTRUCTION«

PLASMA – *that's the strange flickering purple light that we remember from physics lessons, science museums and uncoated gas discharge lamps. Or from cutting and welding arcs, which we shouldn't look at without eye protection. But plasma can also be entirely harmless – and extremely useful.*

If you went to school fifty years ago, you would have learned that there are three states of matter: solid, liquid and gas. Although it was known about in the 19th century, »plasma« was not widely used as a physical term – and this fourth state of matter still mystifies many contemporaries even today. Anyone who works with metal will know that plasma is a fairly blunt tool for cutting and welding. But it can also be used for very gentle surface treatment, even of sensitive plastics.

Let's concentrate on defining it first: The molecules in gases move around freely and yet remain intact, but in plasma the electrons have disassociated themselves partially or completely from the atomic shell and can move around in space independently of the ions in the nuclei. This is what makes plasma electrically conductive. To produce plasma you need a lot of energy – energy which it can also release again. According to our current understanding, 99 percent of visible matter in the universe consists of plasma.

In earthly engineering we recognize there are four fundamentally different methods of plasma technology: Corona, high, low and atmospheric pressure plasma.

Low-pressure plasma technology requires a vacuum chamber (10-3 to 10-9 bar), whereas atmospheric pressure plasma treatment, which is the subject of this article, does not require complex equipment and is readily adaptable to user requirements. Atmospheric pressure plasma can be used to clean (to microfine level), activate and coat surfaces.

One in five employed in R & D

Founded in 1995, Plasmatreat GmbH from Steinhagen, Germany, is the pioneer and (according to the relevant encyclopedia) official world market leader in the field of atmospheric pressure plasma surface treatment. Twenty years ago, when ›Openair plasma‹ jet technology was invented, the company consisted of three people. Today it employs over 170 people at 13 sites around the world, 90 of whom work in Steinhagen. As early as 1995, the company supplied the first industrial plant to Hella for the series production of polypropylene headlight housings. Others soon followed, including for world market leader Krones. Four years later it was discovered that plasma coating, which previously could only be carried out under vacuum, could also be performed on surfaces under normal atmospheric pressure. In 2000 Plasmatreat supplied Volkswagen with 14 plasma systems. Other prominent customers such as Bosch and TRW soon followed. Nowadays, the process is used in industries all around the world.

Plasmatreat CEO Christian Buske, keen to expand further, has taken steps to ensure that his company retains its market position: »More than one in five employees in Steinhagen is involved in research and development. We invest twelve percent of our annual turnover in this sector.«. The reward for intensive research is not merely of a commercial nature, it also has a non-material basis: Plasmatreat regularly receives national and international recognition for its innovative spirit, this year winning the ›Würth Future Champion Award 2015‹.

In Buske's view, the potential for growth for this groundbreaking process in general and Plasmatreat in particular is enormous: »Virtually any surface process can be improved with atmospheric pressure plasma. Yet even though this type of pretreatment has been used for years throughout the world, many potential users are still unaware of its existence.«

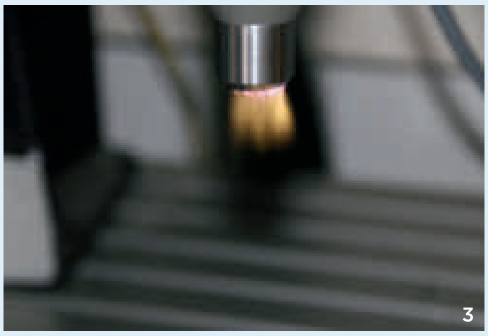
1 Functional coatings from the plasma nozzle: PlasmaPlus gives aluminum a high degree of corrosion protection.

2 One of the principal applications for the Openair process is the pretreatment (cleaning and activation) of adhesives surfaces.

3 Patented rotary nozzle for pretreating large areas

4 Plasma activation of a painted aluminum strip

5 Wetting is far better after plasma activation (center) than after wet-chemical treatment.

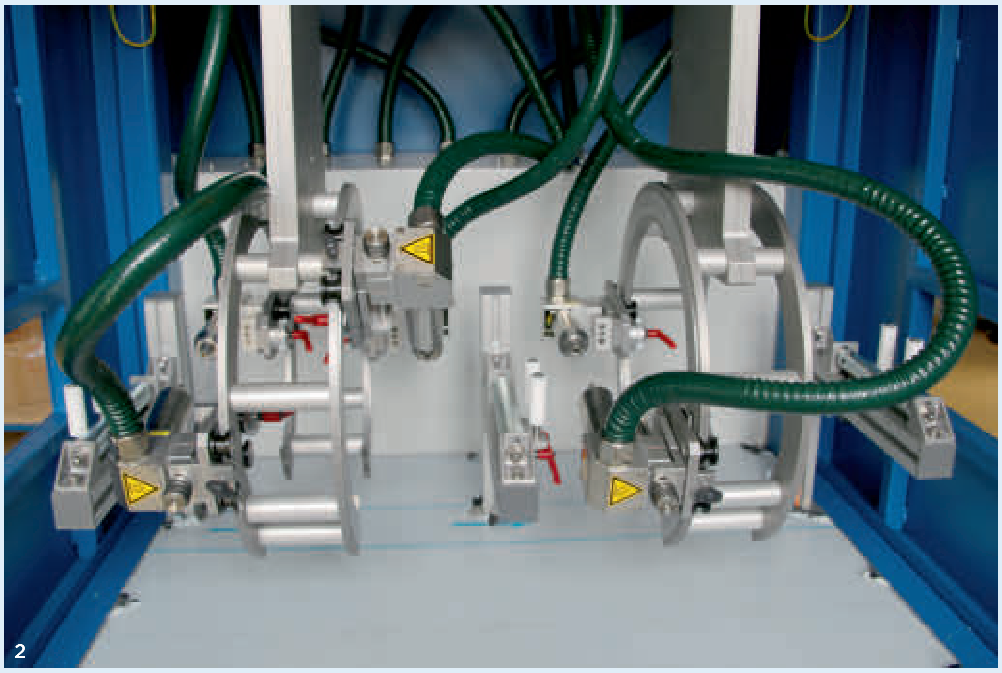


Microfine cleaning, activation and coating under atmospheric pressure

Plasmatreat differentiates between three different processes: Microfine cleaning with Openair plasma removes dust, grease, release agents and additives from surfaces very quickly, gently and thoroughly, whilst plasma activation modifies surfaces in a targeted way and enables long-time stable adhesion of adhesives and coatings. Furthermore, ›PlasmaPlus‹ nanocoating (plasma polymerization) can be used to create functionalized surface characteristics designed to meet specific product requirements.

Highly effective and yet gentle (because it is potential-free) plasma can be integrated directly into production processes under normal atmospheric conditions by using Openair nozzle technology. In most cases pretreatment with atmospheric pressure plasma can completely replace wet chemical or mechanical treatment methods. Perhaps the greatest advantage of atmospheric plasma – alongside its process reliability and reproducibility – is its in-line capability. Buske: »Our process is ideal for translationally moved surfaces such as sheets and profiles. Our systems can very easily be adjusted to the profile geometry either manually or automatically.«

And they are fast: With static nozzles, you can process several hundred meters per minute continuously, although the nozzle then leaves a track just a few millimeters wide. Working widths of 100 mm can be processed with rotary nozzles (patented), but the band speed must then be reduced to 20 to 30 m/min. For large lightweight panels such as plastic/metal composite boards, Plasmatreat has developed systems in which staggered rotary nozzles arranged in series pretreat panels up to 3 meters wide inline. →



1 Mysterious: At this stage one can only imagine the numerous potential applications for plasma
2 The working chamber of an Openair plasma system for pipes and profiles

Easy to integrate and very environmentally friendly

Plasma cleaning is also very environmentally friendly. Christian Buske cites the integration of a coil coating plant as an example: »In Switzerland we were able to replace a wet cleaning line over 60 meters in length, which used very problematic detergents and required extensive safety, extraction and treatment equipment, with an Openair plasma system comprising 48 nozzles which is just two meters long. This step saves 20 tons of hazardous waste in the form of filter cake each year.« Even more satisfying is the fact that the plasma treatment entirely eliminates the need for chemicals such as flammable and potentially carcinogenic chromic acid ($H_2SO_4 + CrO_3$).

The Plasmatreat boss also sees advantages over mechanical cleaning systems: »We don't leave any grinding marks in the workpiece, neither is there any abrasion caused for instance by corundum. Nor do we produce any dust.«

For Christian Buske the ›Holy Grail‹ in plasma part cleaning is the simultaneous activation of the surface, whereby the release agent from a previous process is modified by bombardment with plasma in such a way that it becomes the adhesive substrate. In some cases this is already happening.

And so we have established an elegant link to the second major area of application, surface activation: Bombarding the surface with ions causes the molecules to reorientate themselves in an environmentally friendly and permanent way. Anyone who has ever tried to bond polyolefins (PE, PP) or ABS will know that smooth surfaces can form a bond with these polymers only after chemical pretreatment, and then only to some extent. What might reasonably be achieved in your shed with a small tin of primer and a paintbrush can become critical on an industrial scale, both on financial and environmental grounds. It is easier, and indeed more effective, to selectively increase the surface energy, i.e. its reactivity, using plasma. This noticeably improves the hydrophilic properties: After plasma treatment the contact angle of aluminum strips lies between 18° and 28° as opposed to 48° and 52° after wet-chemical treatment.

Stronger, more uniform, more reliable adhesion

In practice this not only results in better adhesion, it can also eliminate entire operations, as Christian Buske explains: »To obtain a reliable adhesion, the surface energy of the solid body must be higher than the surface tension of the coating. Previously, to remove paint defects such as nibs the topcoat had to be sanded to provide a key for the newly applied base coat. Vehicle bodywork with defective paintwork would have to be sidelined, manually sanded and then repainted. Now the surface can be activated and repainted in an in-line process using plasma.« So it's not just the paint that can be applied robotically, as is customary, but the plasma treatment as well. And what's more, a plasma head has now been successfully integrated into a machining center as the final tool. Energy is transferred to the spindle by induction.

How about some more examples of plasma surface treatment? Here we go: It is generally known that heating pipes nowadays receive several layers of thermal barrier coating. The frequent temperature change combined with different expansion coefficients of metal and plastic foam (PE) place the adhesive surfaces under enormous stress. By preparing the metal pipes with plasma, a uniform and reliable bond can be achieved.

Preparation is also important in electrical engineering to reliably bond metal to plastic – and can be problematic if the joints are exposed to constantly fluctuating environmental conditions. Water finds its way into the smallest of gaps. Gaps which only appear over time because the tensile and shear stresses at the boundary surfaces are too high due to thermal or mechanical loading. Christian Buske mentions outdoor LED lights as an example – vehicle or aircraft headlamps or streetlights: »There are quite a number of metal-to-plastic bonds in these lights. Water ingress changes the color of the LEDs, and that is something that the manufacturers cannot allow. Thus in the past, unreliable bonds have led to very high scrapping rates and correspondingly high costs. Pretreatment with plasma creates a durable, uniform and reliable bond between metal and plastic in this application as well. Plasma microfine cleaning and activation can thus significantly increase the quality of electrical and electronic assemblies.

The word ›reliable‹ is very often heard in the context of plasma treatment. It also applies to the pretreatment of glued, soldered or welded metal-to-metal bonds, no matter how large or small they may be. 'Small' in Christian Buske's view relates in particular to contacts in the electronics industry such as the tiny bonds between conductive tracks on silicon chips and lead frames – bonds which are becoming ever more miniscule to match the trend for miniaturization of the chips themselves. The thinner the wire, the tinier the contact surface, the smaller the transmissible force and thus the greater the demands placed on the soldered joint. In this example too, plasma pretreatment brings about significant improvements. The lead frames are cleaned and activated as a strip: in a continuous, reliable, uniform, environmentally friendly and non-contact process. Humans, the disruptive element, are ›excluded‹.

Glued, welded and soldered joints on a larger scale can also be improved by plasma activation. Take cars or even better, airplanes: they are exposed to extreme fluctuations in temperature and humidity, UV radiation, ozone and in particular, high and low frequency variations in mechanical stresses. No bubbles, no shrink holes, no water: That's how soldered and welded joints should be. Plasma activation makes this possible.

In-line coating of almost any substrate

A broad field for Openair plasma. PlasmaPlus, the plasma-assisted precision coating technology developed in collaboration with the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), promises at least the same potential and a tremendous range of different applications. In 1999 a technique was invented for embedding additives in surfaces under atmospheric pressure. Prior to this discovery a vacuum chamber was needed – these not only are expensive and take up a lot of space, they also interrupt production processes, are dependent on batch processing and limit workpiece size. In contrast, PlasmaPlus enables the continuous processing – at least in a longitudinal direction – of ›endless‹ components such as lead frame strips, cables and wires, as well as pipes and profiles. »The ability to manufacture products with selectively functionalized surfaces opens up a completely new dimension in innovation capability, the scope of which we can only begin to imagine at this stage.«

»Plasma treatment offers enormous **potential** for growth.«

Christian Buske, CEO of Plasmatreat

Plasmatreat systems can be integrated into practically any production line. And they don't hold up operations: Deposition rates of 1 µm/s enable processing speeds of between 5 and 30 m/min depending on the desired layer thickness (in the 100-nm range).

The thin layer thickness (< 1 µm) – negligible in geometric and design terms – is a further significant advantage of plasma coating. It enables a surface, even retrospectively, to be electrically insulated and protected from corrosion, moisture and mechanical wear without jeopardizing dimensional tolerances. Director of Innovation at Plasmatreat Dr. Alexander Knospe describes how an anti-corrosion coating can be applied to aluminum, for example: »We add an organosilicon compound to the plasma which is fragmented by the plasma and deposited on the workpiece surface as a vitreous layer.« The exact chemical composition of the additive depends on the substrate and subsequent intended use. Hydrophilic or hydrophobic surfaces can be created using this technique.

Steel: a broad field

Almost any material can be coated in this way. Applications involving steel are still unusual, but Christian Buske unsurprisingly envisages a number of opportunities for what is still by far our most important material and divulges two of them: »You could for instance insulate electrical sheet steel with PlasmaPlus or pretreat tailored blanks with Openair plasma so that they can be glued instead of welded.« Grinning, he adds: »We love lightweight construction.« Amongst other things because plasma can be used to make bonds between different materials safer, more reliable, more cost-effective, easier and more environmentally friendly. Protecting forming dies from wear is another example. But it's not only steel machining where plasma treatment is still in its early stage; it will be years before we discover all the many opportunities afforded by this technology. Whilst Plasmatreat itself is researching new applications, science and industry are expected to provide further impulse. Buske hopes that plasma treatment can establish itself as an industry standard and become as commonplace as turning, drilling and milling.

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