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WOMAG

 Kompetenz in Werkstoff und funktionaler Oberfläche

180 degree turn in the pretreatment process

Plasma replaces wet chemicals for aluminum lights

Changing from an established industrial process to a completely new one is a huge step. Lighting manufacturer Waldmann decided to radically change their pretreatment method prior to bonding. Instead of wet-chemical processes, the company now uses environmentally friendly atmospheric pressure plasma to achieve a long-time stable adhesive bond and simultaneously increase surface quality.

Energy-saving safety lighting designed to safeguard workers in production areas and a successful Far Eastern production philosophy are the hallmarks of South German lighting manufacturer Herbert Waldmann GmbH & Co. KG from the Swabian town of Villingen-Schwenningen. 2001 heralded a new era in production for Waldmann employees with the introduction of the Japanese concept Kaizen, which translates as change for the better. Inspired by this philosophy, company boss Gerhard Waldmann converted the entire business to the just-in-time production system developed by Toyota in the late 1940s which is now regarded as standard in the automotive and aerospace industry. The continuous improvement process now extends to all levels of the company and affects every step of production, from development to component production and finally to the end product.

High seal-tightness standards

One of the company's specialist areas is the production of industrial lighting, especially LED surface-mounted machine lighting. Since these lights are designed to illuminate machine interiors, their housings and covers are frequently exposed to high mechanical loads, as e. g. flying chips, and in particular, to chemical substances such as cooling lubricants and oil (Fig. 1). None of these contaminants should compromise the impermeable seal of these lights, which is why the requirements for the bonded joints in the housing are extremely high. However, a strong, long-time stable bond invariably requires good pretreatment of the material surface.

In search of an alternative

The use of wet-chemical substances that are harmful to the environment for the pretreatment of material surfaces is still one of the most widely used application methods. It was no different at Waldmann. For years, an employee working in a separate pretreat-



Fig. 1: Surface-mounted machine lighting must withstand tough conditions, which is why the requirements for seal tightness are extremely high (Photo: Waldmann GmbH & Co. KG)

ment booth cleaned the adhesive surfaces by hand using a cotton cloth soaked in solvents. He then inserted the parts in an automatic priming station, where they were treated first with an activator and then again with a chemical adhesion promoter using a felt applicator. The fourth step was to remove the parts and air-dry them, then finally transport them by trolley a distance of ten meters to the bonding station.

Waldmann had been looking for an alternative to this outdated method for a very long time. Not only was it harmful to the environment, the use of chemically reactive substances was associated with substantial additional costs for cleaning, materials and disposal. Other factors such as open times, shelf life and storage stability of the primer, as well as cleanliness of the rise cables in the station also had to be continuously monitored. The activator, adhesion promoter, spare parts, service and maintenance of the

primer station alone incurred annual costs running into five figures. It was clear that the entire wet-chemical process should give way to a more efficient, environmentally friendly method. The only question was – which process was capable of replacing it and at the same time satisfying the stringent bonding requirements?

180 degree turn

Waldmann's re-examination of the pretreatment process for their lighting housings began when technology engineer Denis Stehle, head of Waldmann's automation and manufacturing equipment production department, attended a seminar organized by adhesive manufacturer Rampf. There he learnt at first hand from adhesive experts about a method for optimizing adhesion which he had previously only read about: the environmentally friendly pretreatment of material surfaces with atmospheric pressure plasma (AP plasma); or more precisely, Openair-Plasma® technology from Plasmatrete (Fig. 2).

The process is based on the use of plasma nozzles. Over twenty years ago, the developer and systems engineer from Steinhagen in North Rhine Westphalia succeeded in integrating a state of matter up till then scarcely used in industry into continuous production processes, thereby making the use of plasma under normal pressure feasible on an industrial scale for the first time. The plasma technology now deployed throughout the world led to the creation of a pretreatment process requiring nothing other than compressed air as the process gas and electrical energy. This avoids VOC emissions (volatile organic compounds) during production from the outset. When combined with fixed individual nozzles, this technology enables substrates to be transported through the plasma jet at speeds of several hundred meters per minute. The highly effective procedure is used mainly on materials such as plastics, metals, glass and ceramics.

SURFACES

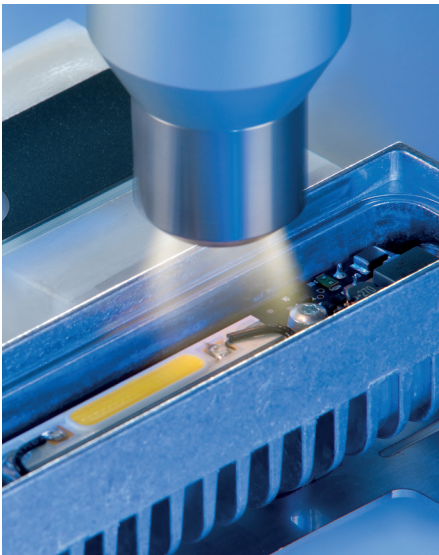


Fig. 2: Environmentally friendly and harmless to electronics: Instead of wet chemicals, Waldmann's machine lighting housings are now pretreated with potential-free Openair-Plasma® before bonding (Photo Plasmatreat)

Three functions in a single step

The plasma nozzles perform three operations in a single step lasting only a matter of seconds: Dry microfne cleaning, electrostatic discharging and simultaneous activation of the surface. The result is homogeneous wettability of the material surface and long-time stable adhesion of the adhesive bond or coating, even under challenging load conditions. This multiple action far outweighs conventional pretreatment systems.

During cleaning, the high energy level of the AP plasma fragments the structure of organic substances on the surface of the material and removes unwanted contamination even from sensitive surfaces. The high electrostatic discharge action of the free plasma beam

has an added benefit for the user: Fine particles of airborne dust are no longer attracted to the surface. This effect is further reinforced by the very high outflow rate of the plasma, which ensures that even particles loosely adhering to the surface are removed.

Surface activation means modifying a surface at molecular level in order to optimize adhesive characteristics for downstream processes such as bonding or coating, for example. Unlike low-pressure plasma (vacuum chamber), activation with plasma jet systems is area-selective; in other words, AP-jet-plasma is applied with pinpoint precision only where it is needed. Long-time stable adhesion is conditional on the material surface being ultra-clean and the surface energy of the solid material being higher than the surface tension of the liquid adhesive. The aim of activation is to increase the surface energy sufficiently to ensure homogenous wettability.

Increase of surface energy is achieved through the chemical and physical interaction between the plasma and the substrate. When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix (Fig. 3). The plasma renders the non-polar substrate polar at this place, thereby increasing its surface energy significantly. Aluminum and glass have naturally high surface energy but their adhesive charac-

teristics can often be compromised by layers by layers of dust deposits, grease and oils or other contaminants. This is where the effective microfne cleaning action of the plasma comes into play, revealing once again the surface energy already present in the substrate (Fig. 4). The entire pretreatment process takes only seconds and the materials can be further processed immediately after cleaning and activation.

Safe for electronic components

Stehle was excited about the technology. Apart from the efficiency and speed of the plasma pretreatment process, he was particularly impressed by its apparent high process reliability, accurate reproducibility and of course the fact that it is environmentally friendly. Just one thing gave him cause for concern: Since the electronics are pre-installed in some of Waldmann's lighting housings, he feared that the electrical potential present in the plasma could cause short-circuits, leading to the destruction of electronic components. For him, the ultimate question was: Would the electrical potential in the plasma beam damage the sensitive LED components?

Plasmatreat confirmed that his concerns were justified in principle, but explained that Openair-Plasma® technology had a special feature: In recent years the company had developed special nozzle heads which dis-

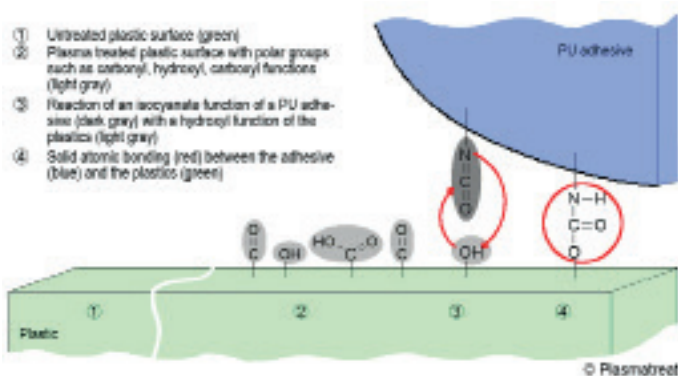


Fig. 3: When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix. This makes the non-polar substrate polar at this place, thereby increasing its surface energy (Photo: Plasmatreat)

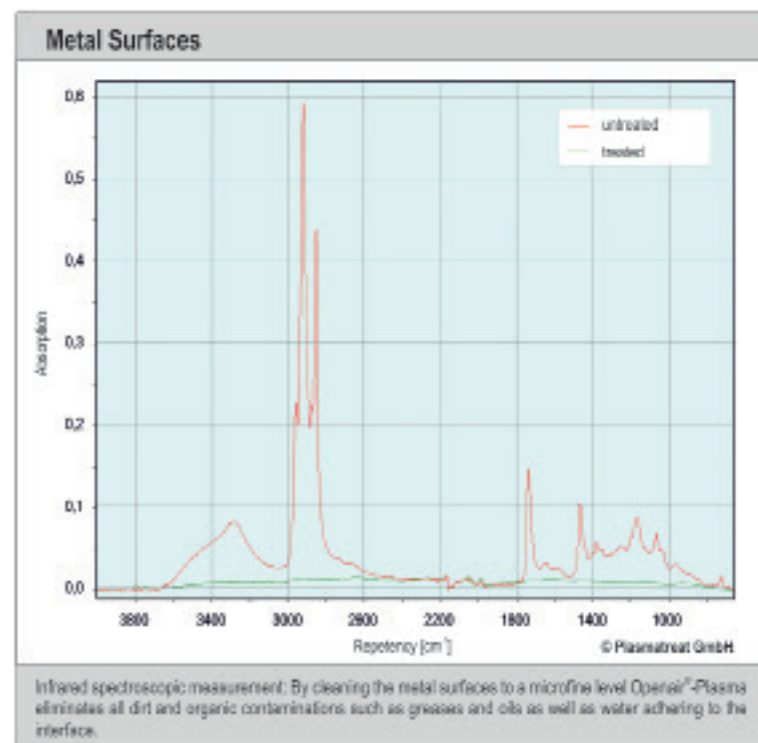


Fig. 4: Infrared spectroscopic measurement

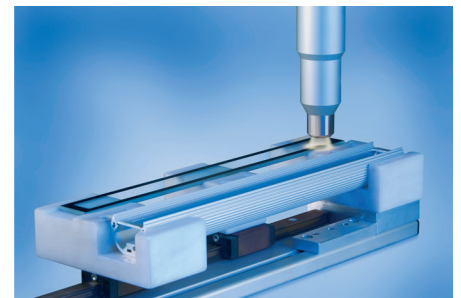
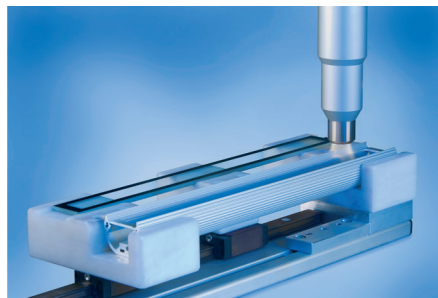
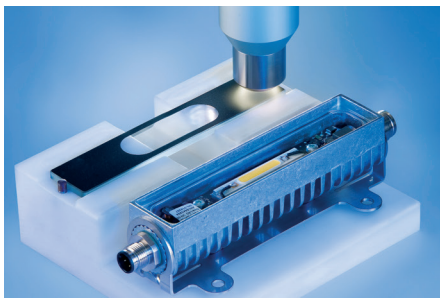


Fig. 5: One plasma source, three materials: Cleaning and activation of PMMA plastic panel (left), microfine cleaning of aluminum housing (center), pretreatment of single-pane glass panels (right) (Photos: Plasmatreat)

charge the electrical potential to the extent that the plasma impinging on the material surface is virtually potential-free. For this reason, it is now possible to pretreat even highly sensitive SMD assemblies and other delicate electronic components. Suitably reassured, the engineer presented the new pretreatment process to his company and Waldmann decided to implement it immediately.

Trial phase on three materials

Changing from one industrial process to a completely different one is a huge step which calls for a great deal of patience. Especially when the requirements for tight bonds are so high and when – as in the case here – the switch to the new pretreatment process is also accompanied by the introduction of a new adhesive. And if that were not enough, the pretreatment and bonding process was to be tested on not just one, but three different materials (Fig. 5). The housings of the surface-mounted machine lights, which are up to 1.20 meters long, are made from anodized or hard-anodized aluminum. The panels protecting the electronics are made from ceramic-coated single-pane safety glass or silk-screen printed PMMA (polymethyl methacrylate) plastic, also known as acrylic glass. The overall stability achieved through the combination of AP plasma and the new adhesive had to be tested on these different surfaces, in other words the bond between the adhesive and the materials and the strength of the adhesive itself.

During the 18-month test phase, Waldmann explored the uppermost limits of what an adhesive bond subsequently exposed to challenging chemical load conditions would have to endure. The microfine cleaning and activation power of the plasma was easy to demonstrate: Test ink measurements carried out before plasma treatment revealed surface tensions of < 44 dyne for aluminum,

< 36 dyne for glass and 40 dyne for plastic. After plasma activation, values ranging from > 56 dyne to 72 dyne were measured on all three substrates, which corresponds to the modified energy values (mJ/m^2) of the material surfaces.

There then followed a series of tests including single-lap shear and tensile shear strength tests (DIN-EN 1465), constant humidity climate tests (DIN EN ISO 6270-2), climate cycling tests (BMW 308 KWT) and 1000-hour storage of several adhesive samples at 30 °C in different cooling lubricants and oils. But the all-important adhesive test to confirm the long-term stability and safety of use of the adhesive bond was, said Stehle, the cataplasma test, the sole purpose of which is to destroy the adhesive bond. Far from it: The plasma-pretreated adhesive bond withstood even this test.

Integrated into the process chain

Kaizen never ends. Openair-Plasma® was integrated into series production in autumn



Fig. 6: Environmentally friendly and cost-effective: Plasma system (right) and bonding station (left) are immediately opposite one another. The housing is bonded immediately after the Openair-Plasma® pretreatment (Photo: Plasmatreat)

2015. The new pretreatment process has eliminated two entire process steps, and also dispensed with the need for drying times and interim storage. Equipped with a potential-free rotary nozzle and controlled by a CNC-3-(xyz) axes portal, the plasma system now operates for eight to twelve hours a day in a continuous process and treats 1000 lighting housings per week. The lights can now be bonded straight after pretreatment in a new bonding station situated immediately opposite to the plasma system (Fig. 6). The LED electronics in all the lights work perfectly and the high level of process reliability has long since been proven too. According to Waldmann, not only has the plasma treatment created the ideal conditions for bonding, the process demonstrably improves the surface quality and long-term behavior of the adhesive bond as well. Author: Inès A. Melamies

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