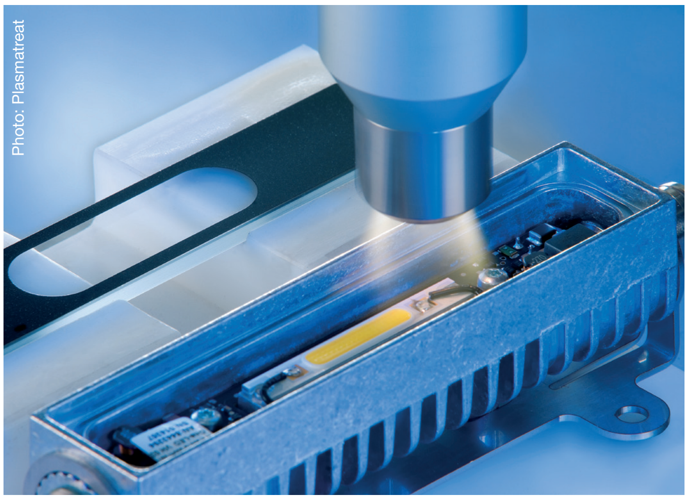
GIVING THE GREEN LIGHT

After using wet chemicals for years, a lighting manufacturer has decided to radically change his pretreatment process. Instead of using solvents and primers, the surface-mounted LED machine lights are now pretreated with non-polluting atmospheric pressure plasma before bonding.

Lighting designed to safeguard workers in production areas, environmentally friendly energy-saving manufacturing 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 extends to all levels of the company and affects every step of production, from development to component production and finally to the end product.



Housings with exacting standards

One of the company's specialist areas is the production of industrial lighting, especially surface-mounted machine lighting. Since these lights are designed to illuminate machine interiors, their housings and covers are frequently exposed to high mechanical loads (e.g. flying chips) and in particular, to chemical substances such as cooling lubricants and oil. 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. 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 pretreatment 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 with a chemical adhesion promoter using a felt applicator. A 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 solution for a long time. Not only was the process harmful to the environment, the use of chemically reactive substances was associated with substantial additional costs for cleaning,

◄ **Environmentally friendly and non-hazardous even for pre-mounted electronics. Special Openair plasma rotary nozzles perform a potential-free pretreatment of the lighting housing.**

► When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix. This renders the non-polar substrate polar at this place, thereby increasing its surface energy.

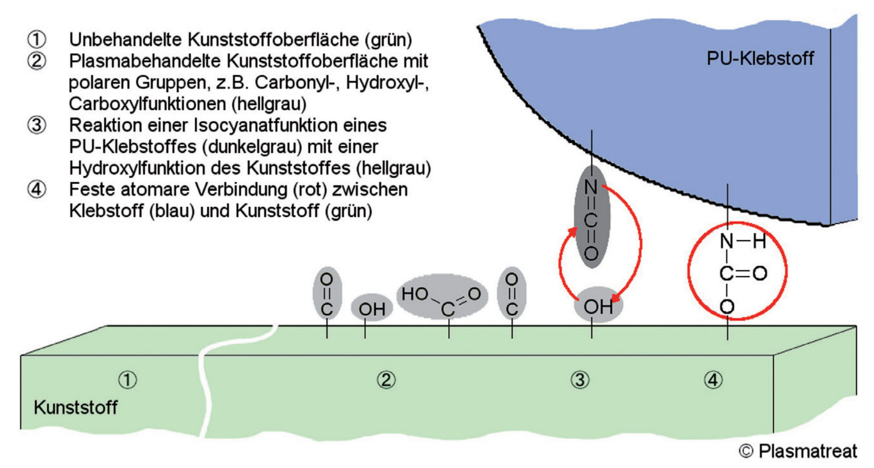


Photo: Plasmatreat

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 question was – which process was capable of replacing it and at the same time satisfying the stringent bonding requirements?

Plasma instead of chemicals

The 180 degree turn that Waldmann performed with the pretreatment of his 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 pretreatment of material surfaces with atmospheric pressure plasma (AP plasma). Or more precisely, Openair plasma technology from Plasmatreat.

Through the development of a plasma nozzle technique about 20 years ago the Westphalian plasma systems engineer created an industrial 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. The plasma process is used mainly on plastic, metal, glass and ceramic surfaces.

The plasma system performs three operations in a single step lasting only a matter of seconds: Dry microfine cleaning, electrostatic discharging and 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.

The area-selective plasma radiation activates the surface, i.e. modifies it at molecular level in a precisely defined area. This activation leads to an increase in surface energy. 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.

Many plastics have a low surface energy of < 28 to 40 dyne. But experience shows that only surface energies above around 42 dyne offer the right conditions for adhesion, which means that the original energy state of the surface must be increased by activation.

To increase the surface energy, the surface is activated by the chemical and physical interaction of the plasma with the substrate. When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix. The area-selective plasma treatment renders the non-polar substrate polar at this place, thereby increasing its surface energy. Aluminum and glass have naturally polar surfaces, but this surface energy which gives them their adhesive characteristics can be compromised by layers of dust deposits, grease and oils or other contaminants. This is where the microfine cleaning action of the plasma comes into play, revealing once again the high level of surface energy already present in the substrate. Materials can be further processed immediately after cleaning and activation with AP plasma

Potential-free plasma

Stehle was excited about the plasma process. Apart from the efficient and environmentally friendly performance of the process, he was particularly impressed by its supposedly high process reliability, accurate reproducibility and on-screen monitoring facility. Just one thing gave him cause for concern. ""The electronics are pre-installed in some of our lighting housings", he explained. "It was obvious to me that any pretreatment process that conducts electrical potential could cause short-circuits, leading to the destruction of electronic components. For me, the ultimate question was: Would the electrical potential in the plasma beam damage the sensitive LED components?"

Stehle contacted the Electronics Market Manager Peter Langhof at the plasma supplier's subsidiary in southern Germany to voice his concerns. Langhof confirmed that his concerns were justified in principle, but explained that the Openair plasma technology had a special feature: In recent years Plasmatreat has developed special nozzle heads which discharge 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 – successfully: Waldmann decided to implement it immediately.

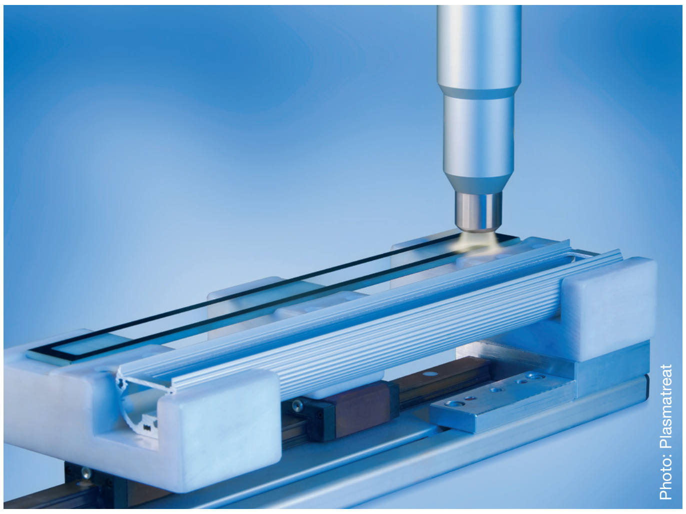
The test phase

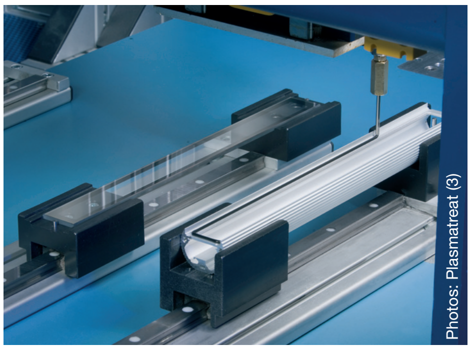
Changing from one industrial process to a completely different one is a huge step which calls for vision, a willingness to take risks and a great deal of patience. Especially when the require-

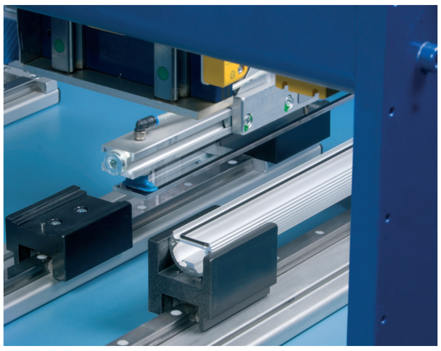
► Adhesive bonding of the housing after plasma treatment: First, the adhesive is applied to the plasma-treated groove in the aluminum housing, then the plasma-treated glass panel is transported to the adhesive bead by suction cup. With this type of lighting, the electronics are inserted in the housing after the bonding process.

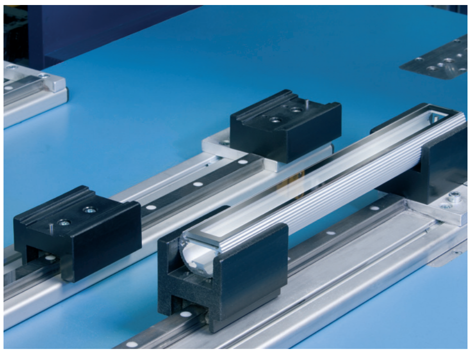
◄ Surface-mounted machine lights must withstand extreme loads. The housings are pretreated with atmospheric pressure plasma to ensure seal tightness.

▼ Pretreating the materials with plasma: Atmospheric plasma treatment of single-pane safety glass panel.









Photos: Plasmatreat (3)

ments for tight bonds are so high and when – as is this case – the switch to the new pretreatment process is also accompanied by the introduction of a new adhesive. Furthermore, the pretreatment and bonding process was to be tested on three different materials. 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) also known as acrylic glass. The overall stability achieved through the combination of AP plasma and the new 1C-PUR adhesive had to be tested on these different surfaces, i.e. 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 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”, says Stehle “was the cataplasma test, the sole purpose of which is to destroy the entire adhesive bond.” The plasma adhesive bond withstood even this test.

Change for the better

„“Kaizen never ends”, explains Ralf Storz, plant organizer at Waldmann. In autumn 2015 the environmentally friendly process was integrated into series production. Its use has eliminated two entire process steps, and also dispensed with the need for drying times and interim storage. The plasma system equipped with a potential-free rotary nozzle and controlled by a CNC-3-(xyz) axes portal 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 immediately after pretreatment in a new bonding station situated immediately opposite to the plasma system.The LED electronics in all the lights work perfectly and the high level of process reliability has long since been proven too. According to Stehle, 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.

Inès A. Melamies