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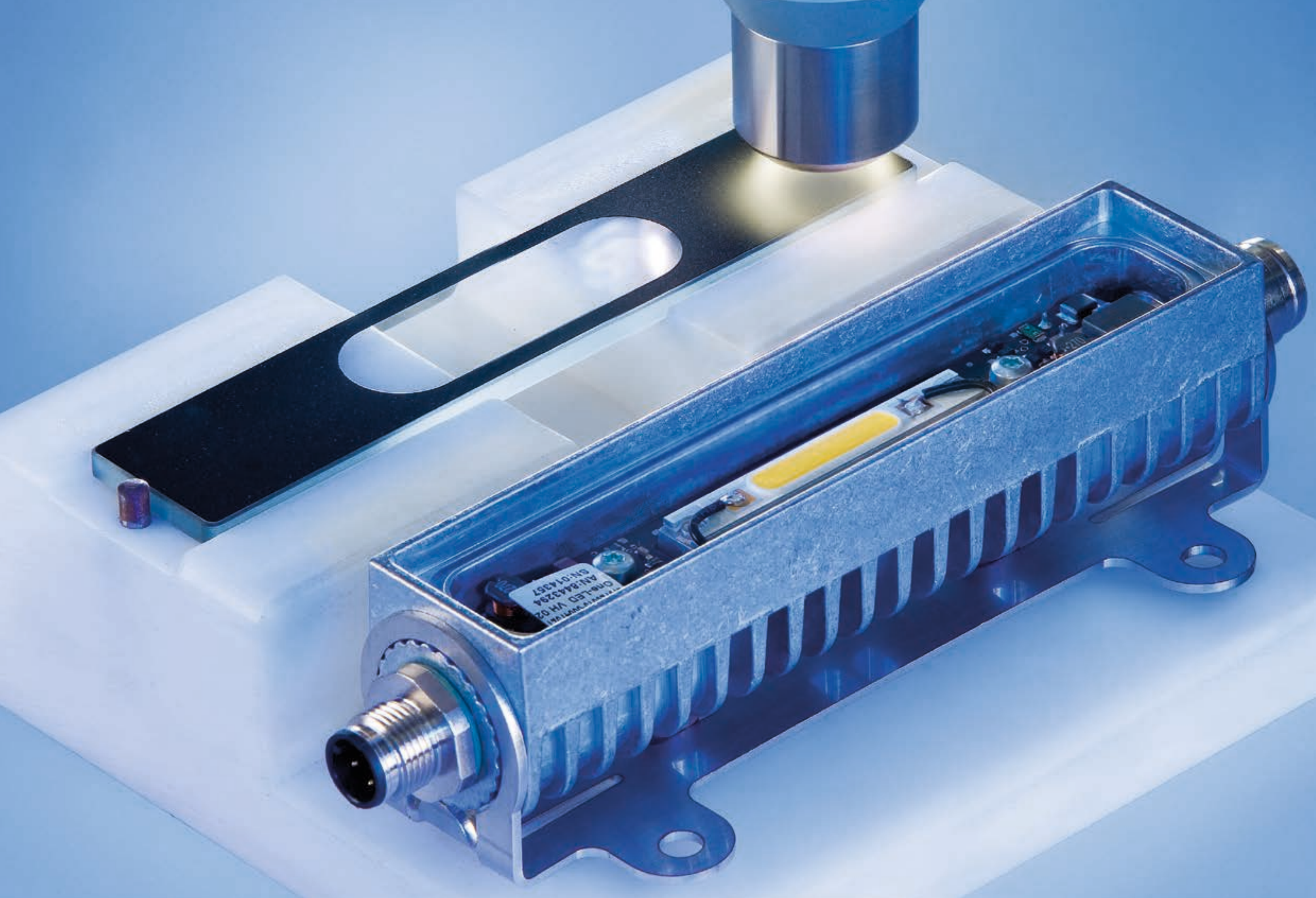
Quality Assurance
Cleanliness is extremely important and must be well controlled

Vacuum Insulation Panels
The protection of VIP panels was performed by various adhesives

Pretreatment of LED lights

Turn to the Future



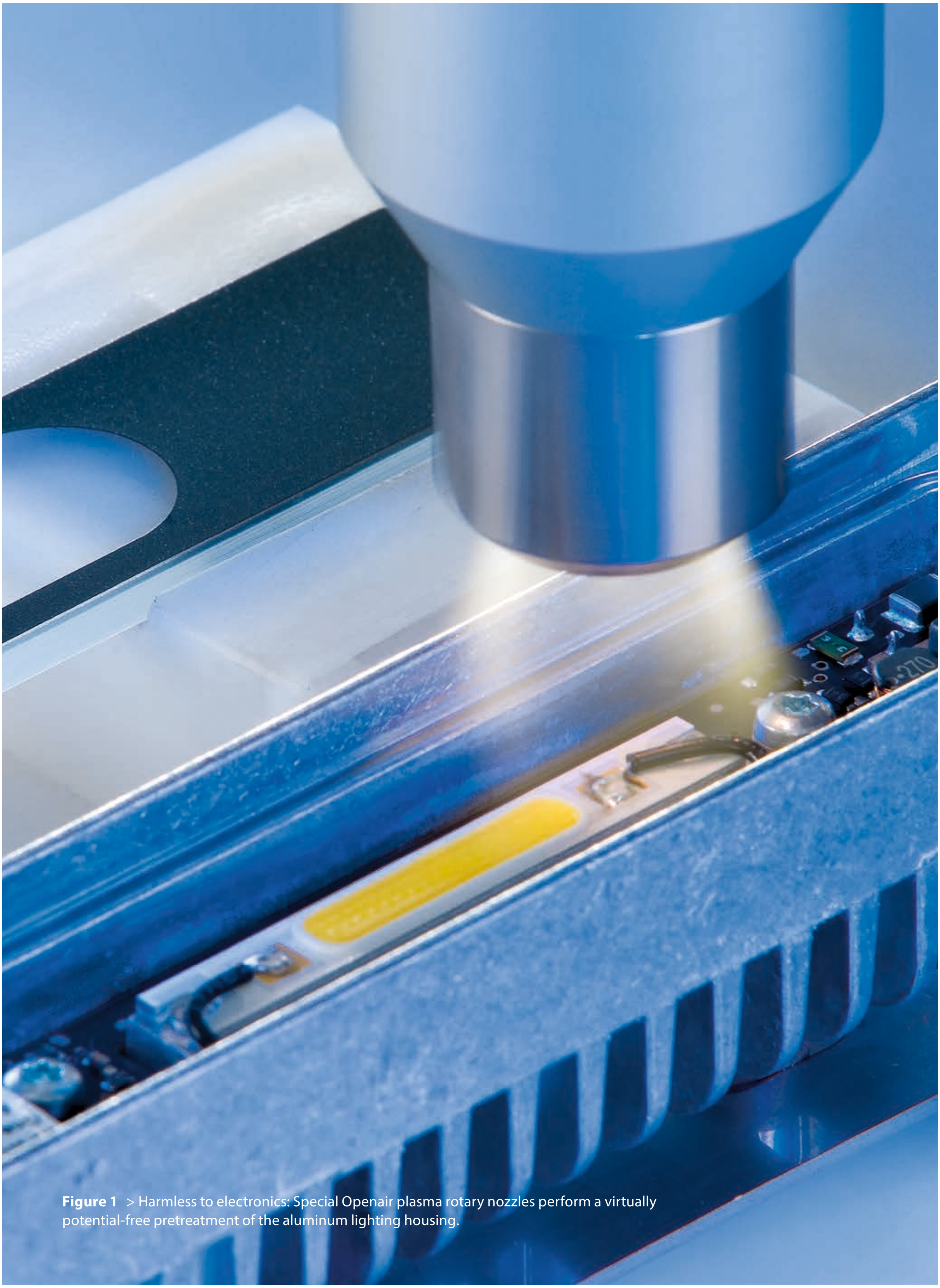


Figure 1 > Harmless to electronics: Special Openair plasma rotary nozzles perform a virtually potential-free pretreatment of the aluminum lighting housing.

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Turn to the future

Inès A. Melamies

After using wet chemicals for years, a leading south German lighting manufacturer decided to radically change his pretreatment process. Instead of using solvents and primers, the surface-mounted LED machine lights are now pretreated in an environmentally friendly way with atmospheric pressure plasma in preparation for bonding.

Herbert Waldmann GmbH & Co. KG from the Swabian town of Villingen-Schwenningen in Southern Germany can be considered one of the pioneers of high quality, energy-saving health and safety lighting designed to illuminate production areas and has developed one of the most successful manufacturing concepts in the industry. The medium-sized family business founded in 1928 is one of the leading developers and manufacturers of lighting, electrical and medical technology.

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 process of continuous improvement extends to all levels of the company and effects every step of production from development to component production and finally to the end product.

High requirements

Having the right lighting in the right place is a key factor in increasing productivity and worker motivation in industrial production. One of the company's specialist areas is the production of industrial lighting, especially surface-mounted machine lighting such as the Mach LED Plus forty and One LED. They are used to illuminate the interior of machines, particularly those where lighting housings are required to withstand challenging conditions: Metal chips fly from machine tools used for turning, drilling, milling and grinding *(Figure 2)*. But more importantly, lighting housings and panels in these machines, as well as forming machine tools, pressure and woodworking machines and packaging machines, are also exposed to chemical substances such as cooling lubricants and oils. None of these contaminants should compromise the bonded joints in these lights, which is why the sealing requirements are extremely high.

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Figure 2 > Surface-mounted machine lights must withstand extreme loads. The housings are pretreated with atmospheric pressure plasma to ensure seal tightness.

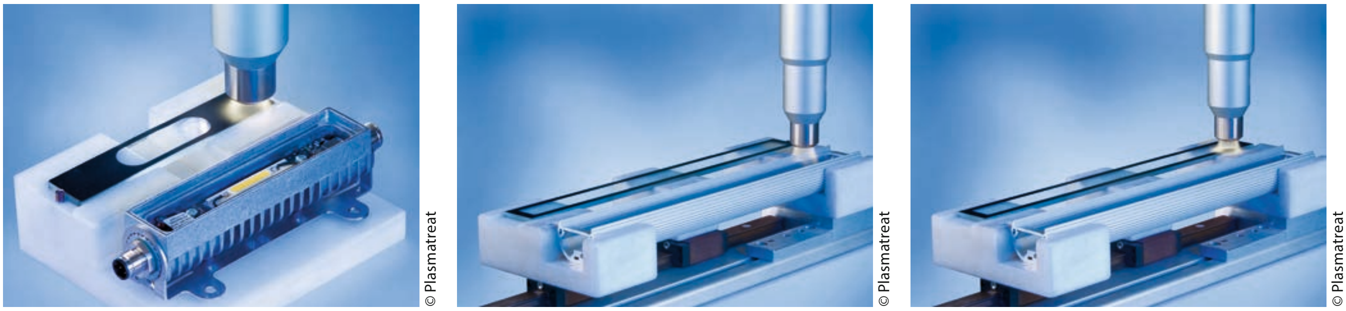

Figure 4 > Three different materials have to be pretreated at the same time: the PMMA plastic panel of the industrial light (left), the aluminum surface of the housing (center) and the single pane safety glass panel (right).

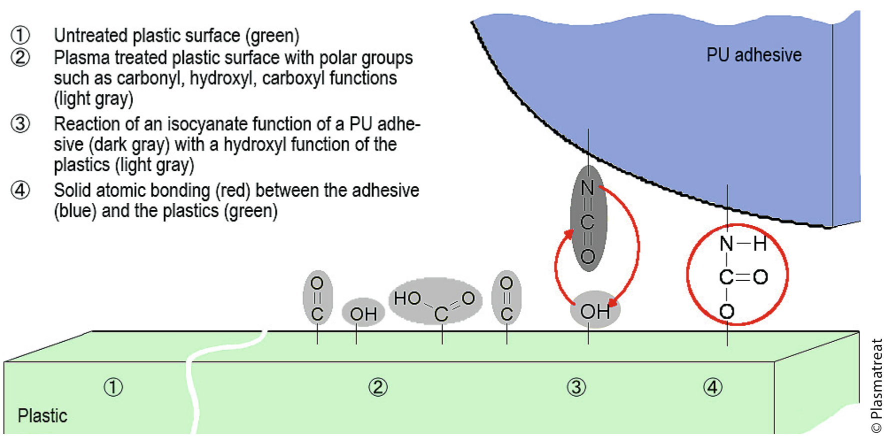

Figure 3 > When the plasma hits a plastic surface, groups containing oxygen and nitrogen are incorporated into the mainly non-polar polymer matrix. This makes the non-polar substrate polar at this place, thereby increasing its surface energy.

However, a strong, long-time stable bond invariably requires good pretreatment of the material surface.

Outmoded and obsolete

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 room cleaned the adhesive surfaces by hand using a cotton cloth soaked in solvent-based isopropanol and a plastic cleaner. 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.

The forward-looking Swabians had long had a sense of unease about this treatment process. 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 an environmentally friendly and more efficient method. The only 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 executed with the pretreatment of his lighting housing began when junior engineer Denis Stehle attended a seminar organized by adhesive manufacturer Rampf. Here 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 – or AP plasma for short.

As is well known the process is based on the use of plasma nozzles. Twenty years ago, systems engineer Plasmatreat from Steinhagen in North Rhine Westphalia succeeded in integrating a state of matter up till then scarcely used in industry into inline production processes and so making the use of plasma under normal pressure

Figure 5 > Application of adhesive to the plasma-treated groove in the aluminum housing

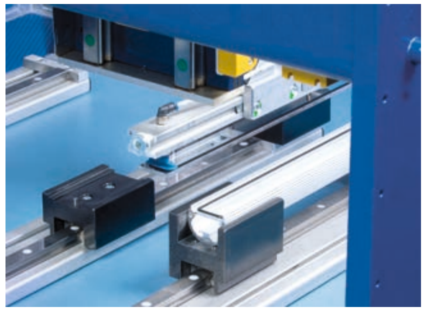

Figure 6 > Suction cups transport the plasma-treated glass panel to the adhesive bead

Figure 7 > The finished bonded housing

feasible on an industrial scale for the first time. Openair plasma technology, which is now used throughout the world, was used to create a pretreatment process requiring nothing other than compressed air as the process gas and electrical energy. This prevents the emission of VOCs (volatile organic compounds) during production from the outset. The highly effective process is used mainly on materials such as plastics, metals, glass and ceramics.

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 plasma system performs three operations in a single step lasting only a matter of seconds: It simultaneously brings about the microfine cleaning, electrostatic discharging and activation of a 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 triple action far outweighs the effectiveness of conventional pretreatment systems. During cleaning the high energy level of the 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 dust in the air 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.

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. Plastics generally 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 *(Figure 3)*. 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 apparent high process reliability, accurate reproducibility and on-screen monitoring facility. Just one thing gave him cause for concern. "The electronics are pre-installed in the housing we use for the One LED light", 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 whether the electrical potential in the plasma beam would 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 nozzles 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 de-

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Figure 8 > Plasmatreat project manager Peter Langhof, Waldmann team leader Bruno Marano and engineer Denis Stehle (left to right) standing between the Openair plasma pretreatment station (back right) and the bonding station opposite.

cided to implement it immediately and ordered a plasma rental-system. The tests could begin.

The test phase

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 is the case at Waldmann – 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. The housing of the surface-mounted machine lights, which are up to 1.2 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 screen-printed PMMA (polymethyl methacrylate) plastic, more commonly known as acrylic glass *(Figure 4)*. 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 micro-fine 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.” However, the accelerated ageing test simulated in the laboratory failed to achieve this objective. The plasma adhesive bond withstood even this.

Kaizen and plasma

At the end of one-and-a-year-long test phase, the old primer station was dismantled, the space reconfigured and a plasma system controlled by a CNC-3-(xyz) axes portal and adjacent bonding station were installed.
In autumn 2015 the environmentally friendly process was integrated into series production *(Figure 5 to 7)*. 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 now operates for eight to twelve hours a day in a continuous process and treats 1000 lighting housings per week *(Figure 8)*. 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.
The use of Openair plasma technology and the associated rationalization and high optimization of the pretreatment process represents another milestone in the lighting manufacturer's process of continuous improvement. “Kaizen never ends”, explains Ralf Storz, plant organizer at Waldmann. “The plasma and bonding stations were positioned in relation to the material flow to prevent any retrograde steps, in other words they are fully integrated in the value stream. The climatic chamber where the bonded parts and adhesive are placed to cure is only three meters away. After a drying time of twelve hours, the lights are transported directly to the assembly station without any detours according to the flow principle.” Change for the better – it has paid off. //

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More information on this topic: Plasmatreat GmbH, www.plasmatreat.de, Herbert Waldmann GmbH & Co.KG, www.waldmann.com