

Potential-free surface treatment

AP plasma ensures sustainable adhesive processes for LED lighting

ELECTRONICS MACHINES AND SYSTEMS, ADHESIVE BONDING TECHNOLOGY – Changing from an established industrial process to a completely new one is a huge step. One of the leading lighting manufacturers - Herbert Waldmann GmbH & Co. KG - decided to radically change his pretreatment process prior to bonding. Replacing wet chemical processes with atmospheric pressure plasma (AP plasma) was a very environmentally safe means of increasing the long-term stability of the adhesive bond.

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 LED surface-mounted machine lighting »1. They are used to illuminate the interior of machines, especially those where the lighting housings have to withstand tough conditions: Metal chips fly from machine tools used for turning, drilling, milling and grinding. The lighting housing and covers 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. However, a strong, long-time stable bond invariably requires effective pretreatment of the material surface.

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 here. The future-oriented company 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 a more efficient, environmentally friendly method.

Plasma instead of chemistry

The 180-degree turn that Waldman executed with the pretreatment of their lighting housings started with a study of modern methods of enhancing adhesion and resulted in the switch to Openair-Plasma technology »2. The technology now deployed throughout the world has led to the creation of 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 procedure 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 100 m/min. 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 multiple effect outweighs 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 plas-

ma, 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 (mJ/m^2) of the solid material being higher than the surface tension (mN/m) of the liquid adhesive. Plastics generally have a low surface energy of < 28 to $40 \text{ mJ}/\text{m}^2$. But experience shows that only surface energies above around $42 \text{ mJ}/\text{m}^2$ offer the right conditions for adhesion, which means that the original energy state of the surface must be increased by activation. This is achieved through the chemical and physical interaction between the plasma and the substrate. When the atmospheric 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

Apart from the clean and environmentally friendly nature of the process, those in charge were particularly impressed by its apparent high process reliability, accurate reproducibility and on-screen monitoring facility. Just one thing gave cause for concern. Since the electronics are pre-installed in the housing of some of the lights, any pretreatment process that conducts electrical potential could cause short-circuits, leading to the destruction of electronic components. But Openair-Plasma technology has a special feature to allay these fears: In recent years the company has developed special nozzles which discharge the electrical potential

»1 **Surface-mounted machine lighting must withstand tough conditions and the requirements for seal tightness are extremely high**

(Photo: Waldmann GmbH & Co. KG)

»2 **Environmentally friendly, adhesion-enhancing and harmless to electronics: Instead of wet chemicals, the machine lighting housing is now pretreated with Openair-Plasma before bonding**

(Photo: Plasmamatreat GmbH)



to such an extent that the plasma impinging on the material surface is virtually potential-free. So it is now possible to pretreat even highly sensitive SMD assemblies and other delicate electronic components.

Extensive test phase

Since these lights have very strict requirements for seal tightness and the change in pretreatment process was also accompanied by the introduction of a new adhesive, the pretreatment and bonding process were to be tested on not just one, but three different materials. The housing of the surface-mounted machine lights, which are up to 1.20 m 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 (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.

The microfine cleaning and activation power of the plasma was demonstrated during the 18-months test phase: Test ink measurements carried out before plasma treatment revealed surface tensions of < 44 mN/m for aluminum, < 36 mN/m for glass and 40 mN/m for plastic. After plasma activation, tension values ranging from > 56 mN/m to 72 mN/m were measured on all three substrates, which corresponds to

the modified energy values (mJ/m²) 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-h storage of several adhesive samples at 30°C in different cooling lubricants and oils. But the critical adhesive test to confirm the long-term stability and safety of use of the adhesive bond 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.

Summary: Lean processes, high efficiency

After the test phase, the 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 now operates continuously for eight to twelve hours a day and treats 1000 lighting housings per week. The LED electronics in all the lights work perfectly and the high level of process reliability has been proven too. So 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.

Facts for purchasers

- Reduction in the number of operations and smooth integration into the production process ensures a high level of efficiency

Facts for quality assurance managers

- Openair-Plasma technology facilitates the potential-free pretreatment of many surfaces – a key requirement in electronics manufacturing

Further information

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