Low-Pressure Plasma Technology

Plants and systems for surface-treatment
Plasmaanlage

Lagerplatz für Paletten

Paletten
Perfecting the production of high-grade spectacle glasses: the unworked plastic is cleaned and activated in a single plasma cycle for improved coating properties.
PINK GmbH Plasma-finish is the youngest company of the PINK Group and emerged mid-2007 through a majority stake acquired in Plasma-finish GmbH in Schwedt. As a result, the Wertheim-based company has, in addition to its vacuum and drying and processing technology activities, now committed itself to the future-oriented market of surface technology.

Since 1995, Plasma-finish has been developing and producing systems of high quality for surface activation, cleaning and coating in the sector of low-pressure plasma technology.

Our capabilities

• Consulting, design and engineering
• Process development
• Plant construction to standards or customer specifications
• Automation
• Worldwide sales and service

For PINK as a systems supplier, it is all part of routine business to engineer and build tailor-made plants and systems to customer specifications.

PINK regards customer requirements as a challenge that it analyzes in close detail to develop optimum products superior to run-of-the-mill standard solutions. In doing so, PINK attaches the utmost value to the reliability and productivity of the equipment and its components.

Not only does PINK manufacture a wide variety of low-pressure plasma systems in a variety of configurations (standalone, reel-to-reel) the Company also engineers and supplies complete inline systems for automated surface-treatment technology.

PINK’s capabilities reach from consulting, engineering and project planning via design and production to supply, installation and dependable on-site service.

The structure of a low-pressure plasma unit

The reaction chamber of a low-pressure plasma unit during a cleaning process.
Low-pressure plasma
The innovative surface-treatment technology

When matter is continually fed with energy, its temperature increases and it passes from a liquid to a gaseous state. If more energy is now supplied, the atomic shell disintegrates and produces radicals, negatively charged electrons, and positively charged ions. This mixture is referred to plasma and is often called the “fourth state of matter.”

Plasma occurs in nature as, for instance, the Northern Lights, lightning flashes or sun. In our day-to-day lives we also encounter plasma in the form of low-energy or fluorescent lamps.

At atmospheric pressure, plasma is very hot – as in flames and arc discharge. However, if plasma is ignited at low pressure (e.g., at 100 Pa), we have so-called cold plasma or, more precisely, nonthermal plasma. Here, too, highly reactive gas particles form, yet the equilibrium temperature stays low. For the treatment of plastic, this is a favorable situation since very little heat is developed. Despite this, these electrons possess energies of several thousand K.

Low-pressure plasma can be created artificially and in concentrated form by exposing gases or gaseous mixtures to high-frequency electromagnetic fields in a vacuum chamber and causing them to discharge. The gas is ionized; radicals and UV radiation are produced. The outcome: highly active process gas that, by correct selection of the process gas composition, the excitation frequencies and the power decoupling mode, can be applied for surface-treatment effects.

The principles of plasma production

Depending on excitation frequency (kilohertz, megahertz – radio frequencies or gigahertz – microwave) and the gas employed, a variety of treatment processes can be applied to achieve various treatment effects.

Such low-pressure plasma technology processes are not only highly effective; they are also ecological and economical since they do not give rise to any polluting solvents or additional waste disposal costs.

Proven low-pressure plasma applications
- Activation/modification
- Cleaning
- Coating
- Etching

The principle of low-pressure plasma

Dissociation
Ionization
High-energy products
Excitation

O₂
Electromagnetic energy

O₂⁻, O⁻
O₃
O₂⁺, e⁻
O + O

PLASMA
Superior polymer adhesion

The surfaces of countless industrial plastics such as polyolefins (PE, PP, EPDM or PTFE) are so very nonpolar that they cannot be adequately wetted by paints, printing inks or adhesives. Bioorganic materials or metals are also often very difficult to coat or only with the aid of costly, specialized polymer products.

With the aid of low-pressure plasma technology, it is now possible simply and efficiently to obtain an activation or chemical modification of polymer surfaces. In numerous industrial applications, this process has already proven itself in terms of improved polymer processing properties (bonding, printing, painting, etc.).

Applications

- Automotive and automotive component industry
- Medical technology
- Electronic industry
- Electrical engineering
- Chip card production
- Plastics processing
- R&D

Plasma surface activation in the auto industry

Hydrophobe polymer surface before a plasma treatment.

After plasma treatment the same surface has a hydrophile character.

In medical technology, numerous plastic components are plasma treated in order to achieve improved hydrophilic properties on surfaces of microtiter plates, syringe hubs, etc.

Door handle (PP) activation for improved paint adhesion.

Modifying the surface of ignition coil housings for improved insulating compound adhesion properties.
Plasma activation – for outstanding bonding properties

Polyolefins, perfluoride polymers, siloxanes and aromatic polyesters possess low surface energies whereas, in contrast, metals, glass or polymers with polar functional groups (alcohols, acids, amines, cyanurates, etc.), feature high surface energies and, simultaneously, chemically reactive functional groups.

In order to achieve adhesion between these two categories of substances, polar groups must be created on the low-energy surfaces. This leads to an approximation of the interfacial energies and to a rise in thermodynamic-related affinity.

If, in addition, this leads to the formation of unipolar chemical bonds between the substrate and the adhesive or coating, the outcome is especially high adhesion properties. Under such circumstances, the bond deteriorates only under high mechanical loads and not at the interface but within the bonding components.

With the aid of low-pressure plasma technology, polar functional groups can be integrated into the surface of plastics.

Depending on the gas applied, these may include oxygen groups such as -OH or nitrogen groups such as -NH₂. This effect is limited to the surfaces themselves (1-10 µm). The polymer substrate is unaffected.

ESCA analysis of a polypropylene surface

Composition of a plastic surface (PP) before and after oxygen plasma treatment.
Clean, reliable

Surface cleaning in industry is important for improving coating adhesion.

Conventional cleaning methods very quickly reach the limits of their capability and, following wet-chemical cleaning, detergent traces are still found on the surface and even after thorough rinsing and drying are not completely removed.

Low-pressure plasma cleaning results in surfaces with zero contamination. Treatment cycles of only a few minutes produce outstanding results with no surface residues.

Low-pressure plasma possesses excellent crack penetration. Even intricately shaped parts are perfectly cleaned since the gas readily penetrates minute gaps inaccessible to liquids.

The decisive factor in the plasma cleaning process is the formation of gaseous and hence volatile products. The plasma constituents react with the organic contaminants and disintegrate into water and carbon dioxide even at room temperature:

\[ (-\text{CH}_2\text{-CH}_2)^n + 3n \text{ O}_2 \rightarrow 2n \text{ CO}_2 + 2n \text{ H}_2\text{O} \]

The reaction products are gaseous and hence easily removable from the reaction chamber.

Printed circuits cleaned in low-pressure plasma for improved contact properties.
Advantages of plasma cleaning

- Very thorough cleaning (ultrapure)
- Low treatment temperature
- Extremely good crack penetration
- No downstream drying necessary
- No residues
- Zero or only slight waste disposal costs
- Low operating costs
- Eco-friendly process

The plasma process is barely suitable for inorganic contaminants. In combination with wet-chemical precleaning, it is however possible to clean workpieces containing both inorganic and organic contaminants.

Production integration options

Intelligent automation engineering allows plasma units to be integrated into production lines.

Selecting suitable pump systems allows evacuation times to be reduced to such a degree that cycle frequencies can be matched to application requirements.

Applications

- Optical industry
- Microelectronics
- Chip card production
- Electrical engineering
- Glassware industry
- Metalworking industry
- Clock & watch manufacture

Low-pressure plasma technology opens up new possibilities in production: within a single work cycle, chip card modules are both cleaned and activated.

Plasma surface cleaning in the lighting industry: before coating, the bulbs are cleaned in plasma for improved adhesion properties.

Plasma-cleaned capacitor components: low reject rates and high reliability.
Low-pressure plasma

High-precision surface etching

Flexible application-optimized processes

Virtually all sorts of organic material can be plasma etched. The etching effect is based on the same chemical reactions as the cleaning effect. Only the parameters such as time and intensity must be adjusted to the requirements.

In addition to oxygen other gases can be used which increase the etching rate significantly. In most cases fluorinated gases as CF₄ are employed. The fluorinated radicals created in these processes are much more reactive than the oxygen plasma. Their reaction products must, however, be controlled with the aid of suitable filters.

Advantages of plasma etching

• Good crack penetration, hence also suitable for micro holes
• Virtually all dielectrics etchable
• No toxic chemicals necessary
• Simultaneous treatment of all holes
• Low operating costs

Ecological and economical

Compared with conventional bath methods, plasma treatment uses very little chemicals and these are harmless (e.g., oxygen, nitrogen, or CF₄), easily available and inexpensive.

There are no significant expenses for occupational safety or waste disposal. Energy consumption is relatively low and since the process is dry, there is no need to subsequently dry the parts.

Applications

• Semiconductor industry
• Circuit board industry
• Microelectronics
Electronic industry applications

Plasma etching of circuit boards and electronic components

**Alternative etching:**

**Plasma drilling**

In traditional etching, very small hole diameters and blind holes often lead to complications. In addition, the surge in number of holes per unit area poses problems when drilling. Low-pressure plasma etching is an alternative to conventional techniques.

Engineering dependability, vast flexibility regarding base materials, low production costs and eco-friendly production techniques are the distinguishing features of this process.

**Desmearing/back-etching**

One application for plasma technology is desmearing or back-etching of mechanically drilled circuit boards. This technique can be applied simultaneously to both sides of the board and all holes.

Thanks to the outstanding crack penetration of the plasma process, holes of < 0.3 mm can be back-etched – even on materials such as Teflon.

**Etching/cleaning of laser-drilled holes**

One particular problem in hole cleaning is posed by laser-drilled holes. Because of the thermal effect, the laser deposits carbon in the form of a black layer at the hole edge. This has to be removed.

Since these deposits are very loosely formed carbon layers, a simple oxygen process can be applied, one that does not leave any residues.
Low-pressure plasma

**Functional coating of surfaces**

**Very many coating options on widely differing materials**

Low-pressure plasma technology is a process by which special functional groups can be deposited on surfaces. In this way, a defined coating effect can be achieved on a wide variety of materials.

Such plasma polymerization (PECVD) is a relatively new coating technique and, because of the low thermal impact on the substrate, especially suitable for coating plastics. Moreover, it can also be used on an abundance of other materials such as metals, glass, ceramics, semiconductors, and textiles.

**Coating options**

- Hydrophobic coats
- Hydrophilic coats
- Diffusion-proof coats
- Biocompatible coats
- Primer coats

Plasma coats can, for instance, be used as a primer for downstream processes. In this way, functions such as corrosion protection can be ideally combined.

**Applications**

- Auto and auto component industry
- Medical technology
- Sealing systems
- R&D
- Packaging industry

Especially relevant for industrial coating processes is the wide variety of coat properties obtainable due to the many variable process parameters.

**Resistant – even with extremely thin coats**

In general, plasma polymerized coats are highly cross-linked three dimensionally. Hence, they are thermally, chemically, and mechanically very stable.

Moreover, they lack micropores and can therefore be applied diffusion proof in extremely thin layers of 0.1 µm.

**Advantages of plasma coating**

- Large variety of options regarding coat properties
- Low thermal stress, hence also suitable for temperature-sensitive plastics
- Optionally, high thermal, mechanical and/or chemical stability
- No micropores
PINK stands for high-quality, rugged and durably engineered plants and systems. Our services start with thorough consulting and the development of ideal plasma processes matching customer needs.

In this way, productivity and dependability can be maximized – even in demanding applications.

The systems are engineered in terms of chamber volumes, excitation frequencies and controls individually and closely to customer requirements (type of process, workpiece carriers, etc.).

Our systems are designed to state-of-the-art engineering and the latest occupational safety standards. Likewise closely taken into account are existing guidelines regarding ease of use and environmental compatibility.

PINK’s standalone systems comprise a standard range of compact low-pressure plasma units ideal for small-batch applications as well as R&D tests and experiments.

The V15-G standard unit is engineered for activation and cleaning.

The V620-2GR standalone unit allows bulk materials to be activated and cleaned by plasma processes.

Standalone systems such as the standard V55-GKM are, thanks to their compact dimensions, suitable for industrial small-batch production as well as R&D laboratory use.
Customized automation solutions

**Inline systems, reel-to-reel units**

**Inline plasma treatment**

In order to exploit the advantages of plasma technology in industrial series production, PINK offers customized solutions enabling its systems to be integrated into existing or new production lines. The technical features are individually configured to match customer requirements, enabling the plasma process to be applied fully automatically and with maximum productivity.

**Plastic film plasma treatment: reel-to-reel systems**

Reel-to-reel systems represent a further option enabling plasma treatment to be applied to flexible tape. So that the tape can be guided through the inline plasma chamber, it is rewound from one reel to another. Both reels are surrounded by the process chamber’s vacuum. This setup ensures a consistent treatment and a reproducible result. Reels with interleaf can also be processed.

**PINK plasma plant advantages**

- Custom-tailored integration into existing production processes
- High quality and flexibility of the plant components
- Highly robust process
- Compliance with norms and standards regarding occupational safety, user-friendliness and environmental compatibility
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