What are the uses of technical plasma?

Technical plasma is capable of generating almost any surface characteristics to any materials:

- **Plasma** removes organic residue from all surfaces.
- **Plasma treatment** increases surface energy to improve the bonding of any materials. All surfaces can be etched in plasma, in a way that very fine structures with nanometre-level precision can be created.
- Surfaces of any material can obtain extremely hydrophobic or extremely hydrophilic properties.
- Super thin invisible coatings created in plasma provide protection, are abrasion-resistant, self-lubricating and optically functional.

Plasma: the fourth state of matter

Almost any substance is solid (frozen) when the temperature is low enough. When energy is added (heating), it becomes liquid. When heated further, it becomes gaseous. When even more energy is added to a gas, it causes electrons to separate from molecules and atoms. The result is a plasma.

**Solid - liquid - gas - plasma**

Gas particles become ionised, i.e. positively charged.

It is not only possible to add the necessary energy with an increase in temperature, but also with high-energy radiation or electrical stimulation.

Plasma seems exotic to us. It was only discovered in 1928 by Irving Langmuir, who also named it. And yet, 99% of the universe is made up of plasma, in particular all active stars.

On Earth, natural plasma is only present in lightning and auroras.

From a technical point of view, it is actually relatively easy to produce plasma.

**Diener electronic:**

- Experience with over 6000 low-pressure plasma systems and 2000 atmospheric-pressure plasma systems since 1993
- Applications and experience in all industrial sectors and fields of research
- Technical solutions and systems for all plasma technology applications
- Fully equipped with an analytical laboratory, clean room and pilot plant for process development
- Comprehensive service
- Solutions for every component geometry and size

Drops roll like beads off a surface made hydrophobic by plasma coating.

Positively charged ions and free electrons make the plasma electrically conductive.
This is only possible with plasma technology

- There is no material that cannot be treated with technical plasma. This means that non-polar plastics and even PTFE become suitable for gluing.
- It is usually necessary to use very aggressive chemicals to achieve comparable surface effects by other means. Plasma treatment does not have any negative impact on the environment. The aggressive media are only present within the plasma. Once the plasma is switched off, they are gone.
- Plasma treatment only affects the surface. Thermally sensitive materials and living things can therefore be treated as well (seeds, human body).
- Plasma treatment is efficient. No expenses for the storage and disposal of chemicals, protective measures, the removal of etching agents, or drying.
- Plasma treatment also works in places that cannot be reached by mechanical treatments or liquid chemical compounds, such as in cavities, undercuts and gaps.
- Thanks to plasma’s ability to work with atomic precision, structures with clearances of less than a micrometre can be produced and treated. Likewise, it is possible to produce or remove closed layers in such dimensions.

Technical plasma reacts every time

Almost all of the matter in the sun and stars is ionised, whereas it is always only a small portion in technical plasma. Usually less than 1%. However, many parts work together during a plasma treatment:

- Positively charged ions where a free electron has separated from the atom (molecule)
- Excited atoms where the electrons have not left the atom, but were excited to a higher energy level
- Ionising UV radiation, which is produced when an ion recaptures a free electron and becomes a neutral atom again
- Radicals: Molecular sections that were separated by ionising UV radiation

All of these “active species” are highly reactive. I.e., they react strongly with matter, even if it would otherwise be inert. Plasma thus works on all substances.

Technical plasma is excited electrically. This is done using either high voltage or high-frequency electrical fields.

Plasma exposed to the open atmosphere Atmospheric-pressure plasma

In a strong electrical field, the positive and negative charge concentrations in the atoms are pulled far apart. This can cause electrons to be torn out of the atomic compound. Here is how high-voltage discharge under atmospheric pressure works:

- The active species react very rapidly with other particles at atmospheric pressure. As a result, the throw distance is shorter. At atmospheric pressure, the plasma achieves expansion in

How Plasma Technology Works

The colour of plasma:

Even mundane technical plasma is fascinating due to its mystical luminous colour. This radiation is created by the energy emitted by atoms when they return from an excited state to their ground state. Because the electrons in the atom can only populate certain “discrete” energy levels, the same amount of energy (specific to the gas) is released every time an energy jump occurs. This is why each gas glows in its own typical colour.
Diener electronic covers all your needs

Diener electronic offers solutions to any surface problem. While our competitors specialise in specific aspects of plasma technology, Diener electronic has experience and offers answers for all fields where surfaces are treated.

...or we invent a solution for you

- Diener electronic was the first manufacturer to mass produce low-pressure systems with low-frequency (LF) excitation, which dominate in many areas of technology today.
- If there is no standard-system to meet your expectations, we will develop it. More than any of our competitors, we have optimised our production in such a way that we can build special systems quickly and efficiently for any application.

Atmospheric or low-pressure plasma?

There is no "better or worse" method, but the "appropriate or non-appropriate one".

- Large parts can be treated in low-pressure plasma as well, but there are limits; otherwise the system costs become enormously high. Atmospheric-pressure plasma can treat components of any dimension.
- Any gaseous substance can be used in low-pressure plasma, but only certain gases can be used in the open atmosphere. Certain processes, especially coatings, are therefore only economically efficient at low pressure.
- Atmospheric-pressure plasma works in a highly precise manner. Surfaces must be scanned. This may take some time and does not usually require complex automation. Low-pressure plasma works on the entire surface. Where this is not desired, the surface must be covered.

Cost-effective method for the activation of plastic and elastomer surfaces.

With air under atmospheric pressure as process gas

A gas discharge is ignited in the inhomogeneous field between two electrodes. The voltage is about 10,000 V.

The air flowing through is ionised in the discharge zone.

The plasma is blown out of the electrode region by the airflow. The substrate can be treated in the escaping corona.

A strip measuring several centimetres in width is treated in the corona. Entire surfaces can be treated with multiple parallel plasma generators.

For the activation of pipes, hoses, profiles, sheets and plates made of materials that bond only poorly in preparation for gluing, lamination, painting and printing. The stream of gas is electrically charged and therefore not suitable for conductive substrates.
A gas discharge is ignited between a central electrode and an insulated ring electrode. A plasma is excited in the stream of gas flowing through. The plasma is blown out through the nozzle. There is no high voltage in the plasma jet. Metallic substrates can also be treated. The temperature is relatively high. Thermally sensitive substrates can only be treated very briefly in a continuous manner.

The effective treatment spot has a diameter of approx. 10-12 millimetre, but treatment speed is high. The plasma can therefore generally be guided over the substrate quickly. Handling and robotics systems make it possible to rapidly treat curved surfaces of any dimensions.

Homogeneous plasma throughout the chamber

All chamber sizes of 0.1 L to (currently) 12,600 L are filled with a homogeneous plasma, allowing the entire surface of the component to be treated simultaneously.

Varying effects depending on the excitation frequency

The alternating electric field allows the plasma to be excited under low pressure starting at 40 volts. The choice of excitation frequency makes it possible to control not only the speed, but also whether the treatment effects are dominated by ions, excited atoms, or UV radiation.

Large variety of plasma gases, large number of effects

Any substance which is gaseous in a vacuum can be used as a process gas.

Generalists and specialists

Efficient production plants are usually optimised for one treatment method, such as PlasmaCleaner, PlasmaAsher, etc. Laboratory and test facilities in particular can also be used universally for cleaning, activation, etching and coating.

To illustrate the basic principle: Low-pressure plasma system with a high-frequency generator.

Compressed air 5-7 bar

Gas and electricity supply in a flexible tube

Dry and oil-free compressed air 5-8 bar, up to approx. 2000 L/h

Atmospheric-pressure plasma system

Plasma jet without dangerous high voltage potential

Process gas supply

External grounded electrode

Gas channel

High-voltage generator

Electric arc gas flow

Insulator

Central electrode

For precision cleaning and activating substrates of components of any dimension, even endless substrates or individual parts, on a conveyor belt (in-line)
## Applications and properties

<table>
<thead>
<tr>
<th>Applications and properties</th>
<th>Advantages of low-pressure plasma</th>
<th>Disadvantages of low-pressure plasma</th>
<th>Advantages of atmospheric-pressure plasma (PlasmaJet (plasma nozzle method))</th>
<th>Disadvantages of atmospheric-pressure plasma PlasmaJet (plasma nozzle method)</th>
<th>Advantages of atmospheric-pressure corona</th>
<th>Disadvantages of atmospheric-pressure corona</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plasma generation in general</strong></td>
<td>Plasma is evenly distributed inside a plasma chamber. Chamber volume varies from 0.1 to 12,600 litre (other sizes can be ordered)</td>
<td>Complex vacuum technology. In-line plasma treatment applications are limited.</td>
<td>Plasma treatment can be realized directly at the conveyor belt. Suitable for in-line. No vacuum technology required.</td>
<td>The plasma treatment track is limited due to the plasma excitation principle (approx. 8-12 mm). More nozzles must be used or the nozzle must be moved for the treatment of larger objects.</td>
<td>Plasma treatment can be realized directly at the conveyor belt. Suitable for in-line. No vacuum technology required.</td>
<td>Only suitable for non-conductive substrates. Relatively low treatment rate compared with atmospheric-pressure plasma (plasma nozzle method).</td>
</tr>
<tr>
<td><strong>Treatment of metals</strong></td>
<td>Oxidation-sensitive objects can be cleaned with plasma. (e.g. H₂ as process gas)</td>
<td>The energy can be coupled to the objects by microwave excitation. This causes overheating of the object. With kHz plasma no overheating is observed.</td>
<td>In plasma treatment of aluminium, very thin oxide layers (passivation) can be generated.</td>
<td>In plasma treatment of copper, thin oxide layers can be generated.</td>
<td>No applications</td>
<td>Not possible</td>
</tr>
<tr>
<td><strong>Treatment of polymers/elastomers</strong></td>
<td>Plasma activation of PTFE is possible (etching process). Good plasma processes for elastomer and PTFE seals have been developed and are in use.</td>
<td>Some materials (e.g. elastomers) require larger pumps to achieve the required process pressure.</td>
<td>Pretreatment of &quot;endless&quot; objects is possible (e.g. hoses, cables, etc.). Very short process time.</td>
<td>Plasma jet has a temperature of approx. 200-300 °C. Process parameters must be well adapted to the surface to avoid melting (thin materials).</td>
<td>Pretreatment of &quot;endless&quot; and wide objects (up to 60 mm) is possible.</td>
<td>Relatively low treatment rate compared with atmospheric-pressure plasma. The treatment uniformity and the surface energy are somewhat lower in comparison with atmospheric and low-pressure plasma.</td>
</tr>
<tr>
<td><strong>3-D objects</strong></td>
<td>All objects in the plasma chamber are treated equally. Even cavities can be treated from the inside (e.g. ignition coils, water tanks, etc.)</td>
<td>Not known</td>
<td>Local surface treatment is possible (e.g. adhesive grooves).</td>
<td>Elaborate articulated robot technology is required. Gap penetration properties of atmospheric-pressure plasma are limited.</td>
<td>Only conditionally suitable. Very poor gap penetration properties.</td>
<td>Elaborate articulated robot technology is required. Gap penetration properties of the corona plasma is very limited.</td>
</tr>
<tr>
<td><strong>Bulk material items and powder</strong></td>
<td>Rotary drum method allows uniform plasma treatment of bulk material items. The number and volume of parts may be variable.</td>
<td>Only approximately 1/3 of the rotary drum volume is used (recommended).</td>
<td>E.g. the powder can already be activated “as it passes by”.</td>
<td>Strong airflow blows the small parts away.</td>
<td>The treatment of bulk material items in conjunction with a rotary drum is possible. The parts can be treated directly on a conveyor belt.</td>
<td>Reduced treatment intensity compared with low-pressure plasma. Strong airflow blows the small parts away.</td>
</tr>
<tr>
<td><strong>Electronic/semiconductor technology</strong></td>
<td>Plasma treatment of electronic components, circuit boards and semiconductor parts by means of low-pressure plasma is state of the art.</td>
<td>Not known</td>
<td>Plasma pretreatment of metal or ITO contacts must be implemented immediately before the bonding process (e.g. LCD, TFT and chip production)</td>
<td>The assembled PCB surface can only be reached to a limited depth.</td>
<td>Not possible due to direct high-voltage discharge.</td>
<td>Not suitable due to high voltage potential</td>
</tr>
<tr>
<td><strong>Coating processes</strong></td>
<td>Production of uniform coatings. Many PECVD and PVD processes have been developed and are applied. There are many applications used in industry.</td>
<td>Plasma chamber can be contaminated by the polymer layer.</td>
<td>In-line coating possible.</td>
<td>Requires a great deal of maintenance. Dust and nano particles formation.</td>
<td>Not possible</td>
<td>Not possible</td>
</tr>
</tbody>
</table>

### Low-Pressure Plasma Technology or Atmospheric Plasma Technology?

- **Low-Pressure Plasma Technology**
  - Plasma is evenly distributed inside a plasma chamber.
  - Chamber volume varies from 0.1 to 12,600 litre (other sizes can be ordered).
  - Complex vacuum technology.

- **Atmospheric Pressure Plasma**
  - Plasma treatment can be realized directly at the conveyor belt. Suitable for in-line. No vacuum technology required.
  - Plasma jet has a temperature of approx. 200-300 °C. Process parameters must be well adapted to the surface to avoid melting (thin materials).

**Advantages**

- Plasma treatment can be realized directly at the conveyor belt. Suitable for in-line. No vacuum technology required.
- Plasma treatment can be realized directly at the conveyor belt. Suitable for in-line. No vacuum technology required.
- Plasma jet has a temperature of approx. 200-300 °C. Process parameters must be well adapted to the surface to avoid melting (thin materials).

**Disadvantages**

- Plasma treatment can be realized directly at the conveyor belt. Suitable for in-line. No vacuum technology required.
- Plasma jet has a temperature of approx. 200-300 °C. Process parameters must be well adapted to the surface to avoid melting (thin materials).
- Only suitable for non-conductive substrates. Relatively low treatment rate compared with atmospheric-pressure plasma (plasma nozzle method).
Precision cleaning of organic residue with oxygen plasma is a precondition for any further treatment in all industries.

In the field of optics, scratch-proof and optically active coatings (polarising, anti-reflective, etc.) are applied using plasma coating.

In precision technology, gear parts are given a wear-resistant coating and bearings become epilamized.

There are numerous applications in the electronics industry:
- Etching, structuring, ion implanting of semiconductors
- Etching of masks used in photolithography for applying conductor tracks, photoresist ashing
- Deoxidation of conductor contacts.
- Hydrophobic protective coating on circuits or entire devices

In automobile industry:
- Activation of plastic components before painting and gluing and of interior parts before flocking and much more

Elastomer technology
Precision technology
Semiconductor technology
Electronics
Laboratory equipment
Optics
Sealing technology

Textiles
Plastics
Medical technology
Automobile industry
Biotechnology
Research

Jewellery, design:
- Hydrophobic, self-cleaning surfaces (anti-fingerprint)

Medicine:
- Activation and etching of implants for bio-integration, anti-adhesive coating for enhancing flow in cannulas and tubing

Space travel
- Laboratory equipment:
  - Micrometre-scale etching of micro-fluidic components, LOC, hydrophilic coating of microtiter plates
  - Plastics:
    - Activation and etching of non-polar plastics before printing, gluing and coating
  - Textiles:
    - Waterproof hydrophobic functional textiles, water-permeable hydrophilic filtration textiles, composite optimisation of reinforcing fibres

Diener electronic has produced all of these applications and many more.

www.plasma.com
Where is plasma technology applied?

Wherever surfaces are to be modified in a targeted and effective manner.

Organic residue can be found on even the cleanest surfaces. Release agent residue is present on components that have just rolled off the production line, and even short-term exposure to the surrounding air leads to deposits from the atmosphere. Wet chemical cleaning will not remove these deposits from cavities and narrow gaps. Moreover, it pollutes the environment and often damages the substrate itself.

Plasma cleaning removes all organic residue from any material.

Applications
- For all surfaces that need coatings, adhesive bonds, paint finishes or ink patterns to adhere

Components
- Low-pressure plasma does not harm the substrate chemically or thermally. As a result, practically any solid materials can be cleaned in plasma.

Inorganic residue
- Micro-sandblasting can remove any inorganic residues that is hard to remove by other means. Bombardment with high-energy argon ions can be used on any coating (non-selective).

Oxide layers
- Perfect adhesion and perfect electrical contact require clean metal surfaces. Plasma treatment removes oxide layers.

Users
- All those who require high-quality connections, adhesive bonds, coatings, ink patterns or paint finishes

PWIS = Paint-Wetting Impairment
Substances prevent sufficient paint adhesion. The cross-cut test brings this to light.

Applications
- Multi-component plastic parts
- Rubber/plastic connections
- Film lamination
- Plastics bonded to other materials
- Flocking

“difficult to bond” materials
- Plasma activation makes it possible to bond any material, even PTFE.
Plasma technology makes anisotropic and isotropic etching possible: Isotropic etching by means of chemical multi directional etching, anisotropic etching by means of physical etching (ion etching approach the surface approx. from one direction), as well as (RIE = Reactive Ion Etching).

Isotropic etching is made possible by polymeric degradation and chemical reaction on organic materials. Anisotropic etching by ion bombardment is generally effective on any substrate.

Applications for isotropic etching
- Nanostructuring of surfaces for surface enlargement and improved adhesion
- Etching of PTFE
- For perfect paint and glue adhesion when dealing with difficult connection problems
- Good bio-integration of implants
- Photoresist ashing
- Removal of oxide layers
- Filter ashing for asbestos analysis

Applications for an isotropic etching + RIE
- Etching masks for printed circuit boards
- Micro-fluidic structures
- Photolithographic production of PDMS chips and bonding (LOC = Lab On-Chip)
- Micro-mechanical components

Users
- All areas of plastics technology
- Semiconductor industry, electronics
- Laboratory equipment
- Research institutes

Plasma coating methods:
- CVD (Chemical Vapour Deposition)
- DLC (Diamond Like Carbon)
- Plasma sputtering
- Plasma polymerisation

The method of plasma polymerisation is of particular importance. Monomer gases, which are used as process gases, react to polymers in the plasma and are then deposited on the substrate as a solid layer. With this method firmly adhering PTFE-like coatings can be produced.

Applications
- Depositing hydrophobic layers
- Depositing hydrophilic layers
- Depositing protective or insulating layers
- May be used as a diffusion barrier, for example

Components
- High-precision gearboxes
- Chemically polluted components (washers)
- Medical devices
- Optical components (headlamp reflectors)
- Etc.

Users
- Biochip manufacturers
- Precision mechanics
- Appliance manufacturers
- Medical technology
- Sensor manufacturers
- Textile manufacturers and finishers
- Watch manufacturers
- Etc.

Plastics and semi-conductors

All technical materials, metals, glass, ceramics and textiles
High level of competence in plasma systems

- Diener electronic produces all systems entirely in-house in Germany.
- Diener electronic produces a complete range of atmospheric and low-pressure systems in all sizes and for all areas of technology.
- Our products do not come “off-the-shelf”. Instead, our production process is designed to ensure a tailor-made solution for every client and every application.
- Our systems are used in every industry and for all applications where plasma technology is required.
- Diener electronic is the market leader in the field of low-pressure plasma systems.
- Diener electronic introduced low-pressure Plasma systems with kHz generators to the industrial market. Thanks to their unproblematic and versatile applications in all industries, these systems dominate the market today.
- Diener electronic manufactures an almost infinite range of equipment options and accessories.

Therefore we will never sell you a solution simply because we have it. Instead we will find the best available option for you and your application.

At the beginning of our cooperation, our support team will look into all the options together with you to guide your project to success, our support team offers:

- Comprehensive consultation
- Process development
- Plasma treatment of sample parts
- Technical training
- Surface treatment (also in the certified clean room)
- Rental systems
- On-site commissioning
- Maintenance, customer service and spare parts service

Process development

A member of our project development team will oversee your application from project launch all the way to series production. During that process, our entire range of facilities, including all equipment options, are available to you.

Your project development support person will work with you to determine the appropriate system design and size and the appropriate process parameters.

In order to test the results, we have a fully equipped laboratory with highly modern equipment for chemical and physical analysis.

Our strengths lie in the competent advice and individual care of our customers.
Surface Treatment Services

- Do you only rarely have parts which need to be treated with plasma?
- Is the shape of your parts so complicated that it is difficult to find a system that would fit your budget?
- Do you lack a clean room for treating your parts?
- Would you like to leave the plasma treatment of your parts to the experts?
- You are not yet ready to invest in your own plasma technology?
- Your own capacity for plasma treatment is not sufficient?

For all of these cases we offer in-house surface treatment. Experienced and trained staff are available to ensure optimum surface quality of your parts and components.

From the time we receive your parts until we ship them out, we keep in close contact with you as our customer to achieve your full satisfaction.

Our product range

- Tetra 100 layered electrode system in the clean room for parts to be placed on top with clean room requirements
- Tetra 30 rotary drum system in the clean room for bulk material items with clean room requirements
- Pico UHP system in the clean room for very small parts with clean room requirements (Ultra High Purity processes)
- Tetra 600 layered electrode system for parts with dimensions up to 760 mm x 480 mm
- Tetra 5600 layered electrode system for parts with dimensions up to 1980 mm x 1370 mm
- Powder treatment system
  (Treatment of several tonnes per month possible)
- Roll-to-roll system for rolls with a treatment width of up to 2 m and a roll diameter of up to 1 m....

Clean Room

Various work processes do not allow contamination by airborne particles. These work processes are carried out in clean rooms.

Work with doped semiconductors and the treatment of medical products and surgical instruments in particular all require a high level of purity.

Distinctive features of clean rooms include equipment, air tight/hermetical partitioning and ventilation with purified air via ventilation systems which ensure special flow conditions and positive air pressure in the room at all times.

For process development and contract treatment of components which are used in semiconductor technology, medicine, chemistry and analytics, Diener electronic has a clean room certified in accordance with DIN ISO 14644-1.

Components that are used in surgery, biology and laboratories are plasma treated in the clean room.

If you exactly know your process, your staff is familiar with the technology of plasma treatment and plasma technology has been introduced at your company:

- You define the required system.
- You place your inquiry.
- You receive our detailed quotation.
- You place an order.
- We deliver and put it into service at your company.

Our laboratory is fully equipped with all facilities and equipment needed for the optimum analysis of surfaces and has suitably qualified scientific personnel.

- All facilities for chemical analysis
- FT-IR by Perkin-Elmer, spectrometer for surface analysis
- Keyence digital microscope (3D)
- Hitachi scanning electron microscope
- Wetting angle measurement device by Data Physics
- Tensile testing machine by Zwick
- TMI coefficient of friction tester
- Coating thickness gauge (profilometer model: Dektak 150)

In all other cases:

- We will discuss your application with you in detail.
- We will treat your sample parts in our pilot plant, check the results and optimise the system and process step by step.
- We will help you define the optimum system equipment and investigate whether a rental system or contract production would be an option for you.
- We will oversee your production until optimum results are achieved.
- Our service team is always on hand to promptly resolve any technical issues.

Our laboratory has already enabled us to invent many new applications. Our development work has resulted in numerous technological and industrial property rights and patents.

Our service team is always on hand to promptly resolve any technical issues.
Advanced solutions for success

Plasma technology is a relatively new field, but it is quickly spreading to almost all areas of industry. Diener electronic has been around since the beginning and is one of the leading companies since 1993. Our products are established across all areas of application for plasma technology, and we have pioneered new developments in many of these fields. At our headquarters in Baden-Württemberg, we employ more than 100 staff members.

Extensive competence from first hand

We require a high level of qualification from our employees because our production is not standardised, but rather we tailor all systems to the customer’s needs. Our large team of engineers, technicians and scientists are also available to help our customers with their concerns.

Outstanding in-house production depth

All main components, as well as the control software, are designed, produced and continuously optimised in-house. This allows for immediate reactions to quality problems. Special requests can be implemented quickly and easily.

With us, you stay ahead.
We stand for competence and innovation in an area of cutting-edge technology.

Rapid customer’s and spare parts service

Customers can count on short response times in the event of maintenance or service work. The essential spare parts are in stock and can be shipped without delay.

Short delivery times

Standard systems can be built at any time within a few weeks. The essential components for all standard system types are always in stock.

Innovative power for new solutions

We operate extremely fast and flexible. New technological developments, changing market requirements and specific customer requirements do not represent a problem, but rather a welcome challenge for us. In this way, we are continuously improving our products, expanding their range of applications and opening up plasma surface technology to completely new fields of applications.
Among our customers are well-known companies in the automotive, electronics, semiconductor and plastics industries as well as institutes and research organisations.
You Can Benefit Too

Please feel free to contact us. Tell us about your surface problems, and we will be happy to inform you about all the possible solutions.

From our staff:
Nicole, Industrial Sales
Katharina, Process Development

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