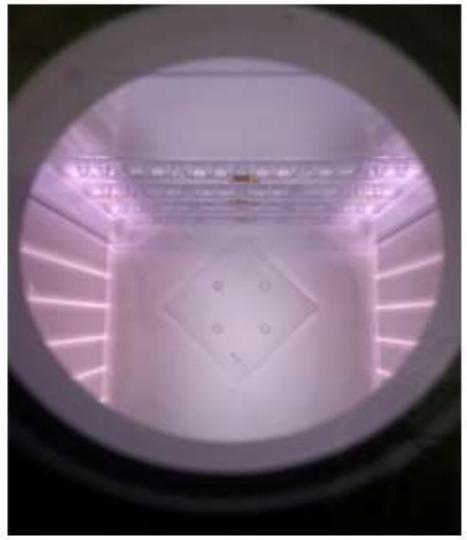


When to use Low Pressure Plasma for PFAS replacement and other coatings

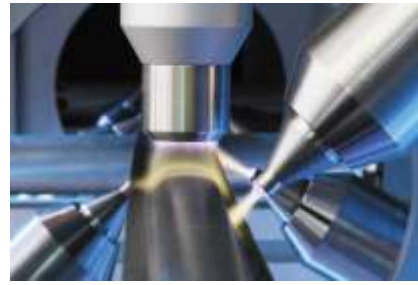
Klaus Kresser – May 12th 2026

plasmatreat

Who we are









We are surface specialists and leading supplier for **atmospheric Plasma technology** as well as experts for **low pressure Plasma processes**

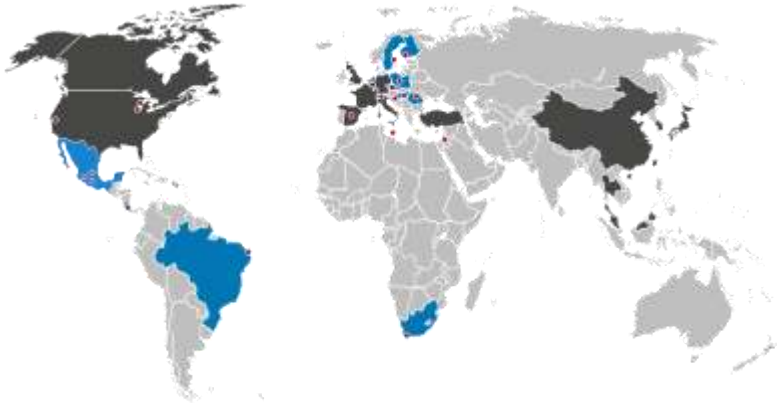
Market leader in Openair-Plasma® Technology

Global Presence

- HQ in Germany
- Production sites in Germany, China & USA
- 24 subsidiaries & Technology Centers in 18 Countries
- 15+ agents in ROW

Family-Owned Business

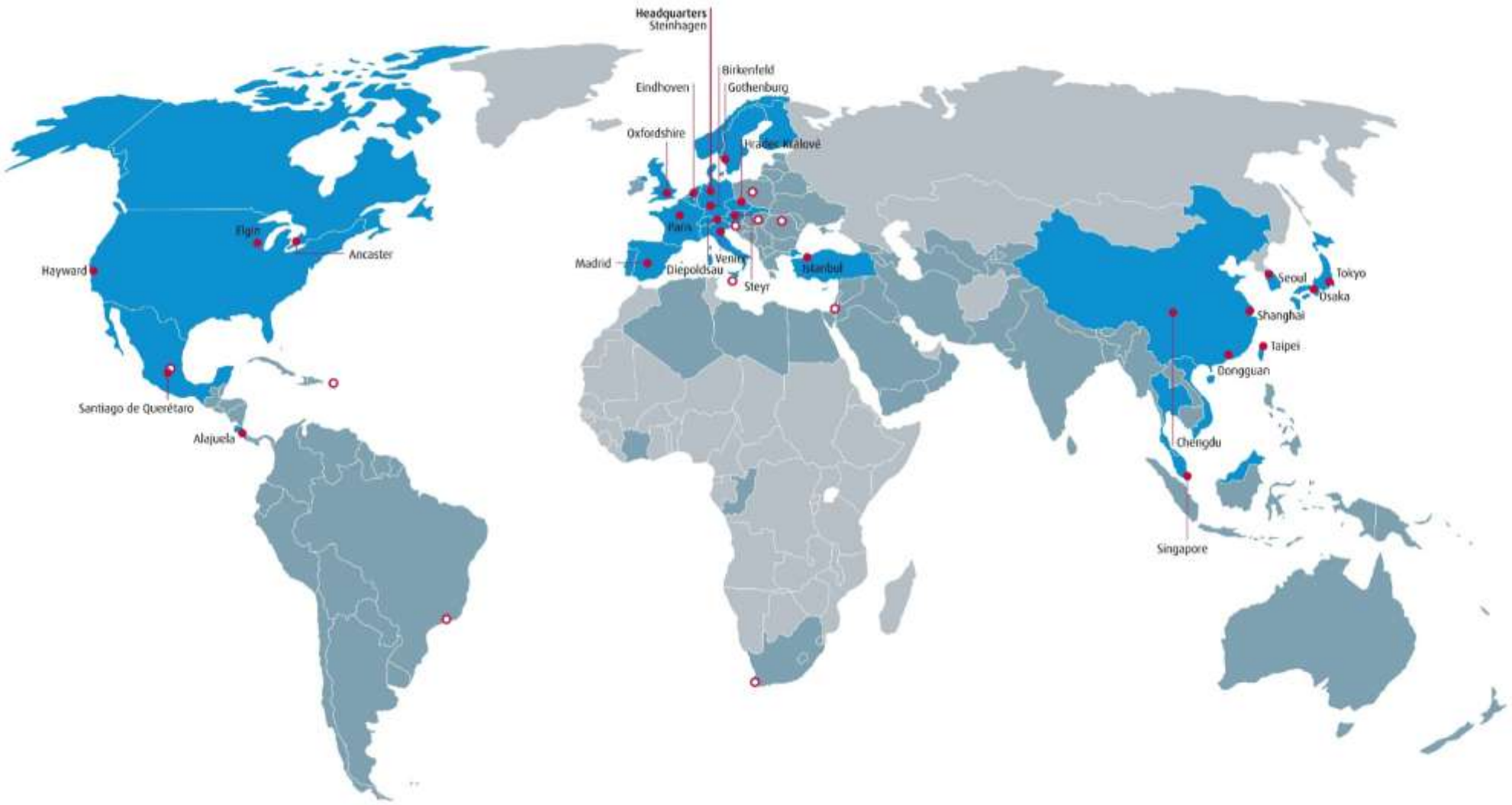
- Founded in 1995
- 300 employees worldwide
- Consolidated turnover: €65 Million



Milestones

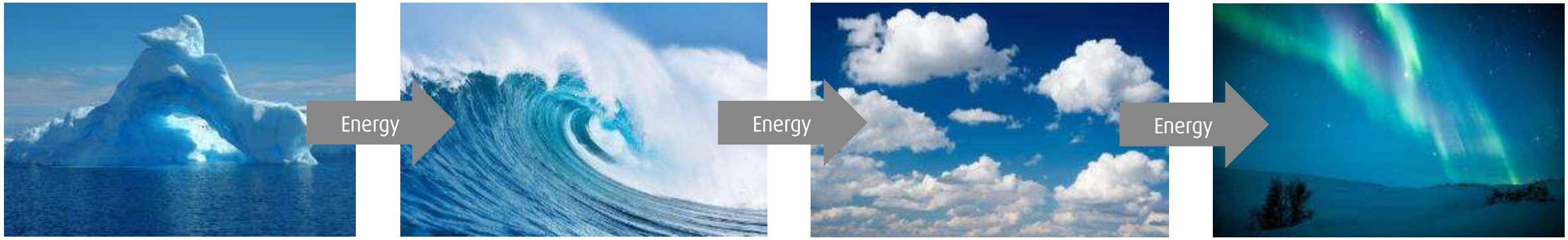
1995: Invention of Openair-Plasma®
2007: PlasmaPlus® coating
2019: Opening of the HQ Technology Center
2020: Plasmatreat Academy
2023: Introduction of REDOX tool
2024: Introduction of HydroPlasma®

Where we are located

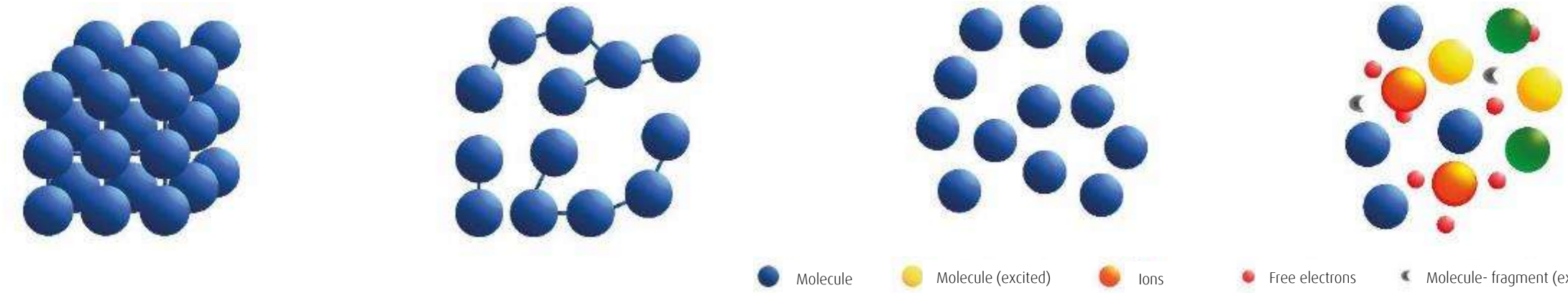


Definition of Plasma

Plasma is formed when additional energy is supplied to a gas by electrical discharge. Plasma is an ionized gas with electrons, radicals and ions that is electrically neutral.



Solid | Liquid | Gas | Plasma



From Langmuir's lightbulb moment to technical plasmas in vacuum

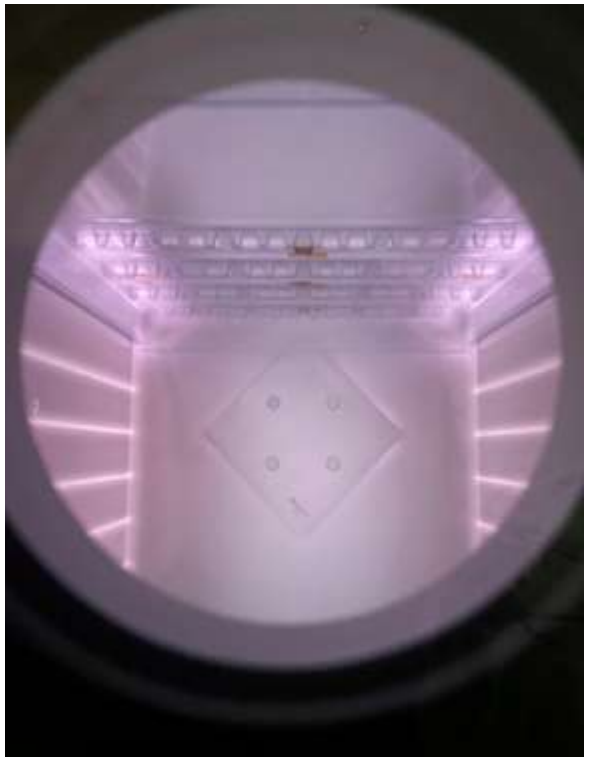
https://quotesgram.com/irving-langmuir-quotes, 20.01.26

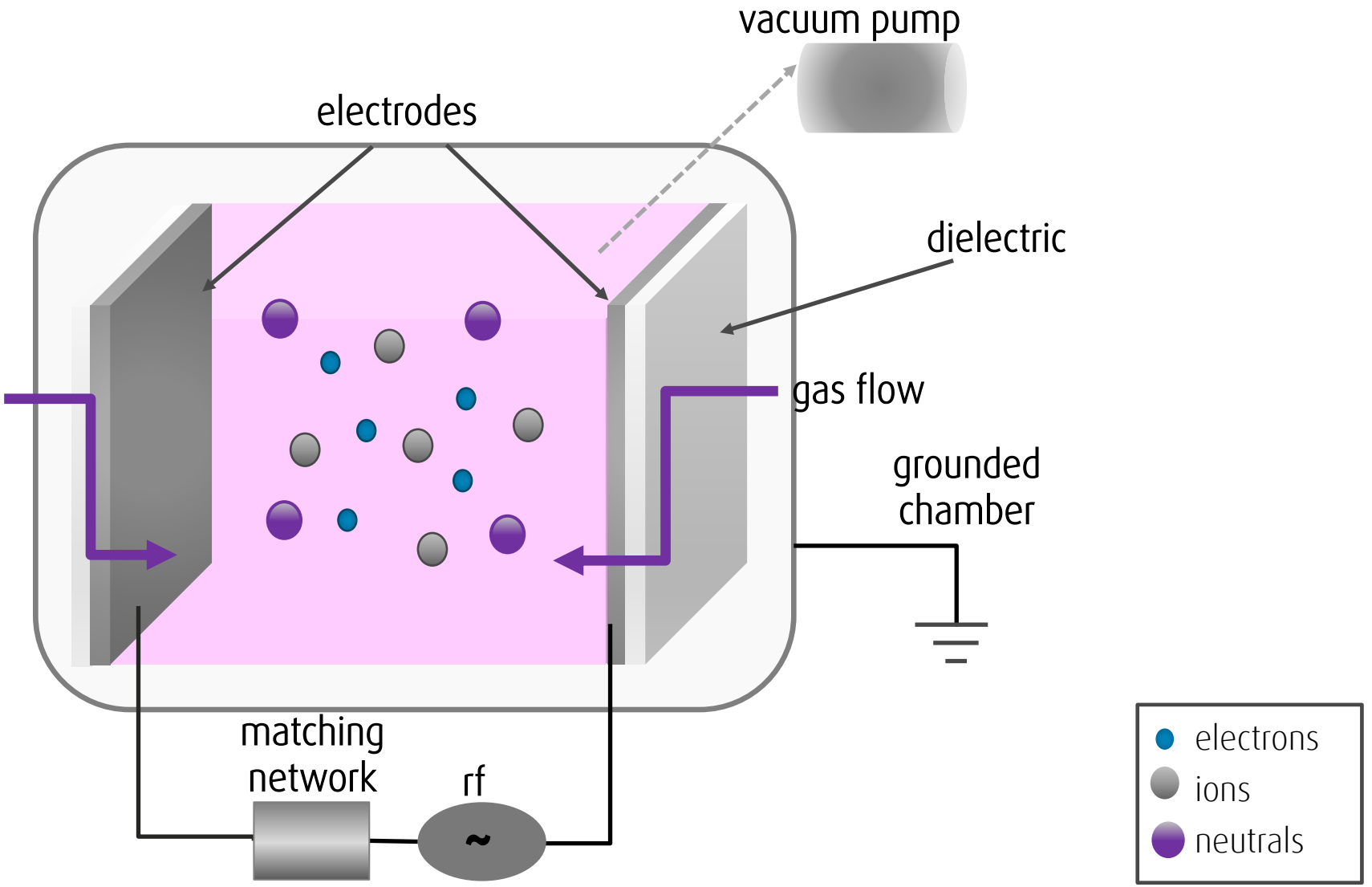
Irving Langmuir

Low pressure Plasma in a vacuum

Under **low pressure** (below 0.001 bar) by selective "heating" and coupling electromagnetic waves.

Configuration of a Low-Pressure Plasma System





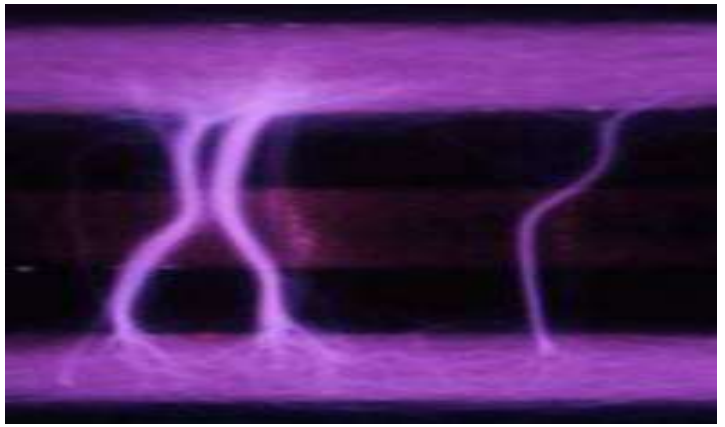
„Cold“ low pressure and atmospheric pressure plasmas

Benefits

- High reactivity due to high electrode temperature WITH low thermal impact into substrate material due to low ion temperature (T_i)
- Very good activation and cleaning effect

Low pressure plasma

- Under **low pressure** (below 0.001 bar) by selective "heating" and coupling electromagnetic waves - mean free path is very large



Dielectric Barrier Discharge (DBD)

- Under atmospheric conditions:
  – generation of "streamers" to the surface by high-frequency alternating voltage

Openair-Plasma®

- Under atmospheric conditions: **pulsed plasma - very high reactivity within short excitation times**
- No formation of streamers at the surface

How is low pressure plasma different from atmospheric plasma?

Low Pressure-Plasma

Atmospheric Pressure-Plasma

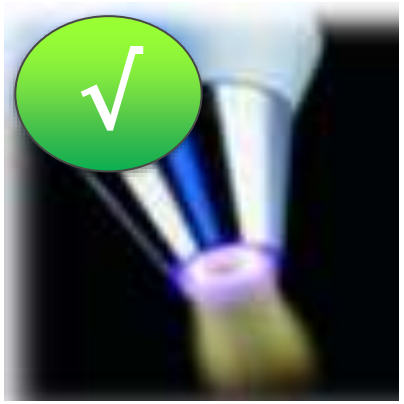
Questions to ask prior to choosing treatment platform:

- Part: Geometry, Size, Quantity, Cycle Time
- Inline vs. Batch Processing
- Is the material vacuum compatible?
- What plasma chemistry is required?
- Fluorocarbon, Teflon, etc.
- CapEx budget

Low Pressure-Plasma	Atmospheric Pressure-Plasma
RF plasma generation	Arc discharge
Vacuum-based	Atmospheric pressure
Batch processing	Continuous/Inline processing
3D geometry capable / everything gets treated	Localized treatment, larger areas require automation
Wide variety of chemical precursors	Limited (but environmentally friendly) precursors

Material compatibility – main question

Question	Equipment Choice
1) Are the materials vacuum compatible?	Atmospheric Pressure-Plasma
Presence of solvents, foam layers or moisture can cause long pump down times	
2) What are the byproducts from the reaction with plasma?	Low Pressure-Plasma
Harmful additives might be released	
3) Is the material a Teflon-like polymer?	Low Pressure-Plasma
No BKM for Openair	



Cycle Time

Aurora Process Flow

1-15 minutes minimum:

- Loading of parts
- Pump down
- Process Run
- Vent and remove treated parts

Openair Process Flow

<1min - 5 minutes:

- Loading of parts
- Process Run
- Allow exhaust and remove treated parts

Plasma chemistry options – gases and precursors

- Ar, He, N2, air
- O2, H2, N2O, CO2, CxFy, SF6, NH3
- PTP 1000, 1100, 2900, 1200,1800, etc

- N2, air, N2/H2, Ar
- PTP 1000, 1100, 2900, 1200, 1300, 1800

Plasma Processing of Materials

Both types of plasma technologies can promote:

❑ Surface treatment

- Surface cleaning and activation
- Etching*
- Increase surface energy
- Enhance surface tribology*

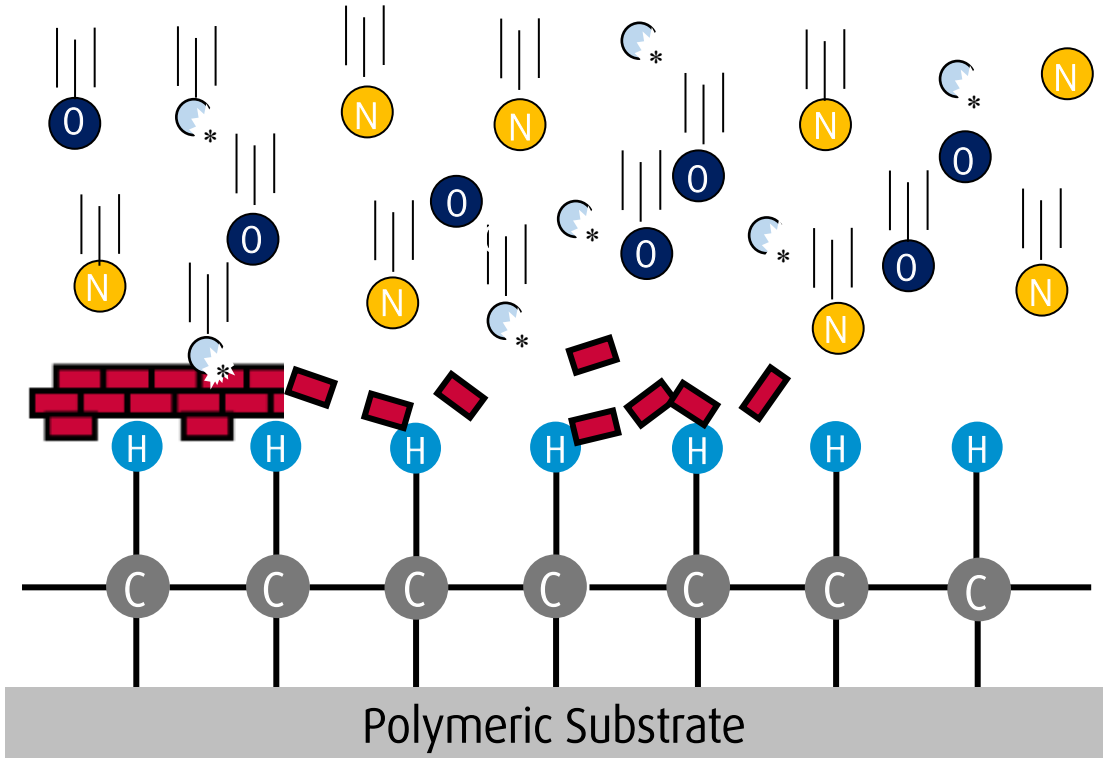
❑ Deposition of Functional Coatings

- Adhesion promotion
- Hydrophilic
- Hydrophobic *
- Oleophobic *
- Biocompatible *
- Electrical insulation
- Barrier- moisture and oxygen
- Anti-corrosion

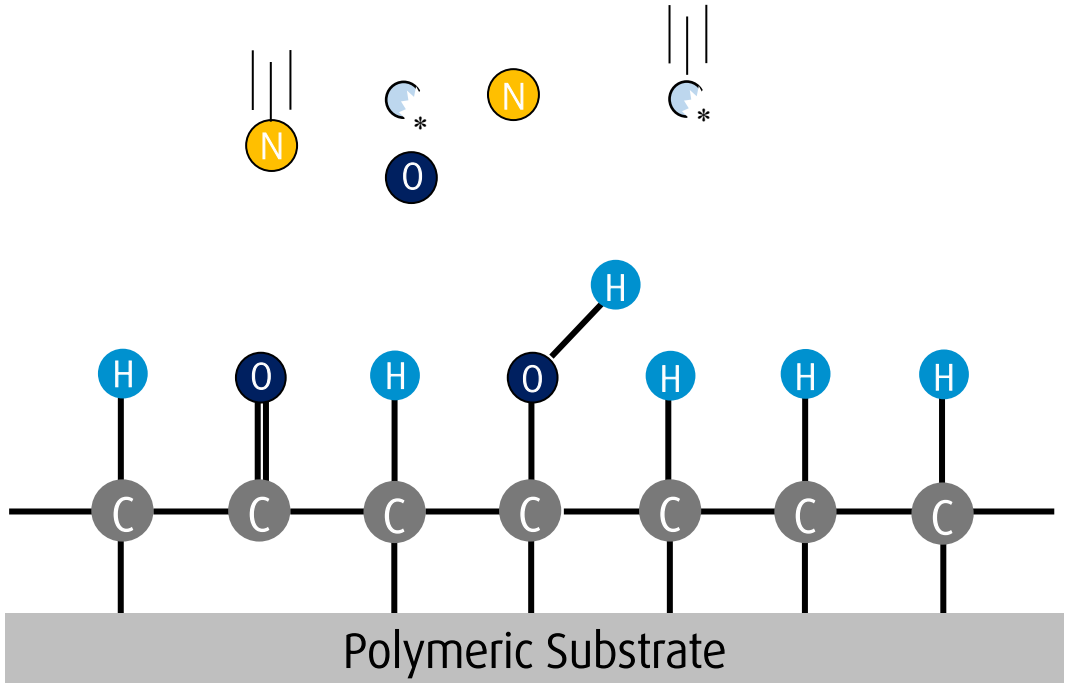
* Better results with low pressure plasma

Plasma: Activation of polymer surfaces

Cleaning and activation of the surface

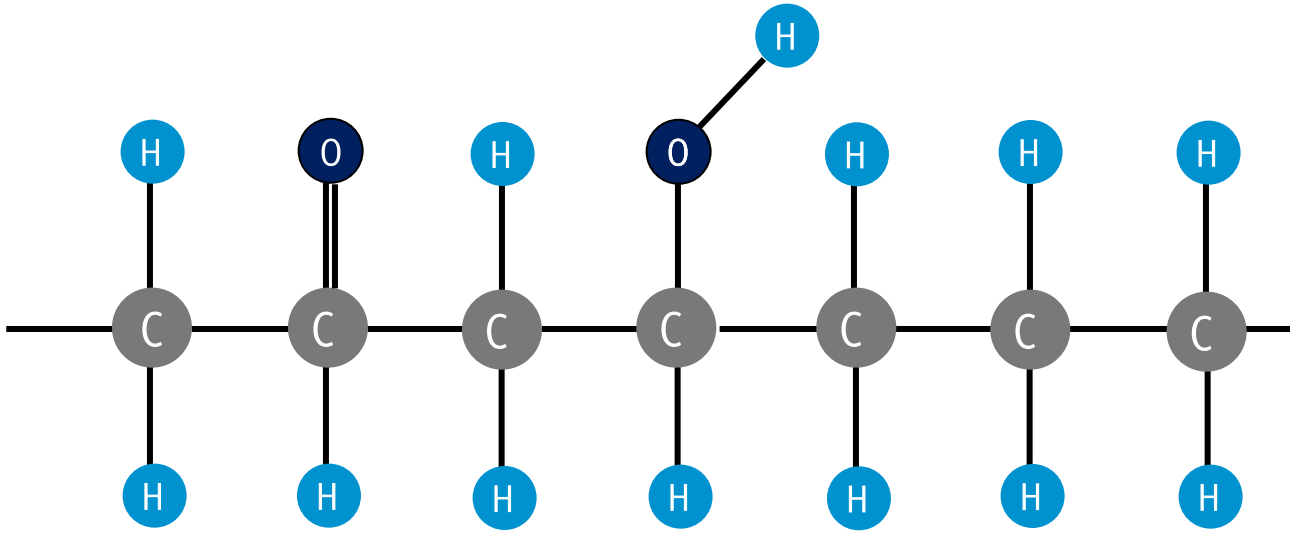


Activation = formation of functional groups

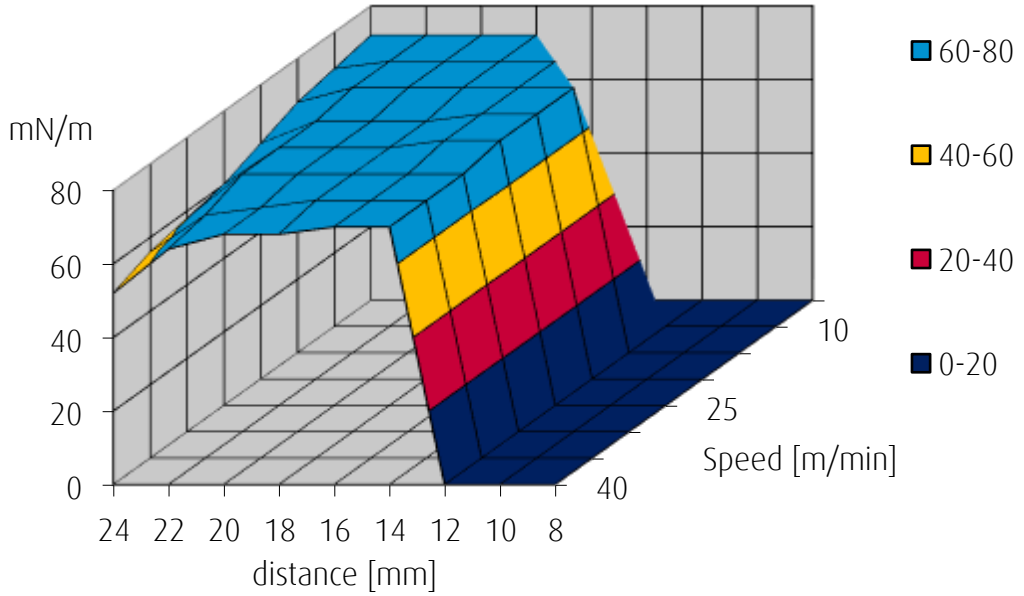


Activation and functionalization of polymer surfaces

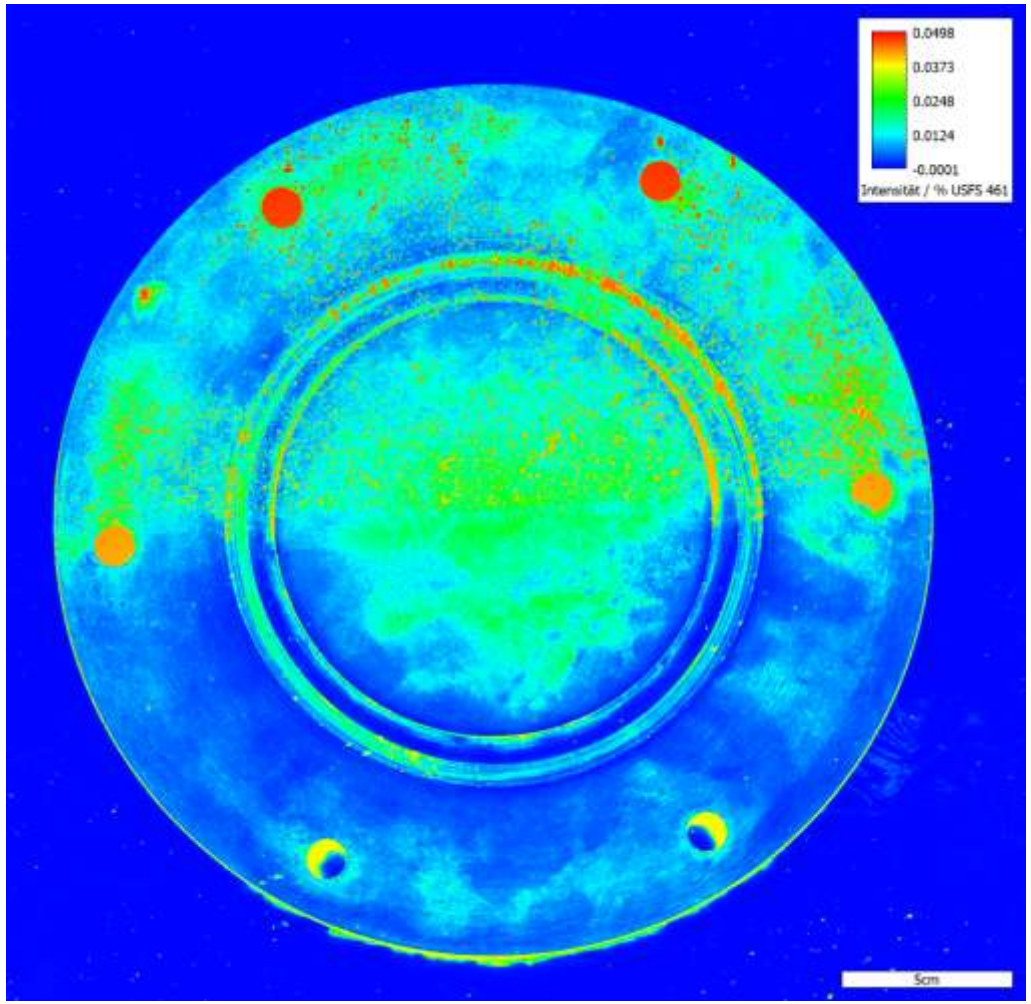
With the fine cleaning, the surface is always activated
Standard value for activation 50-60 mN/m.



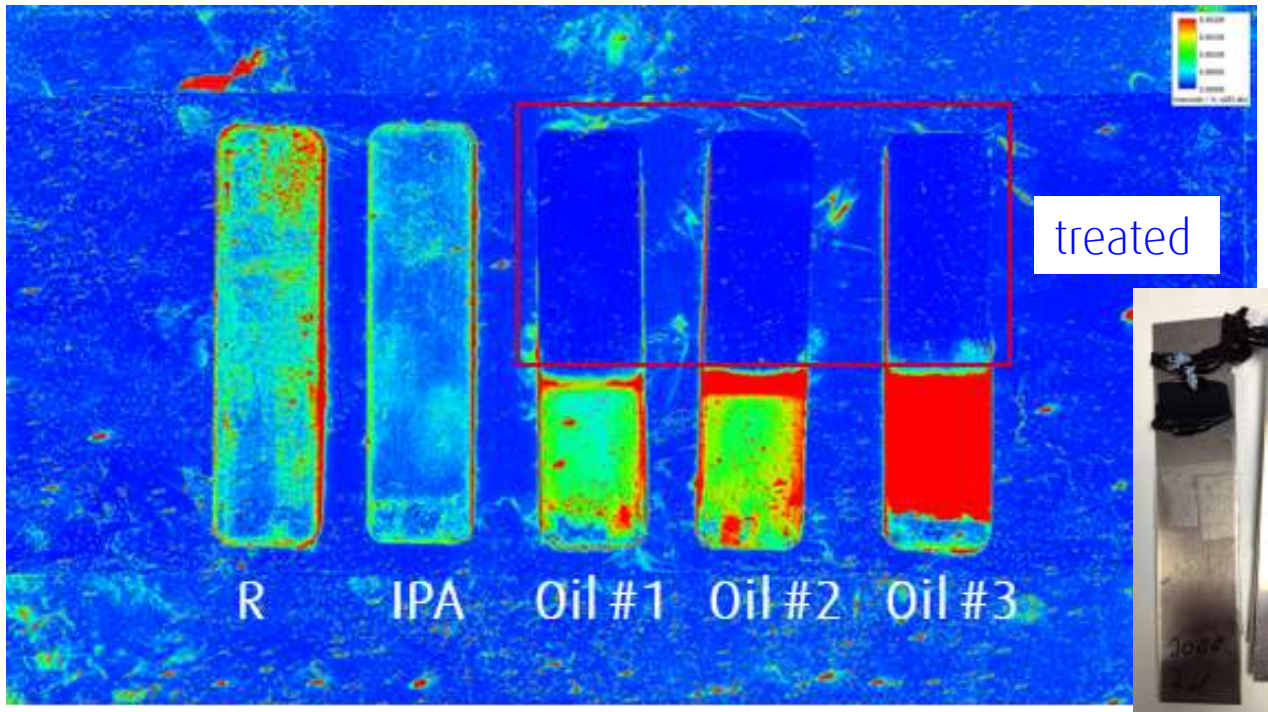
Surface free energy from PE



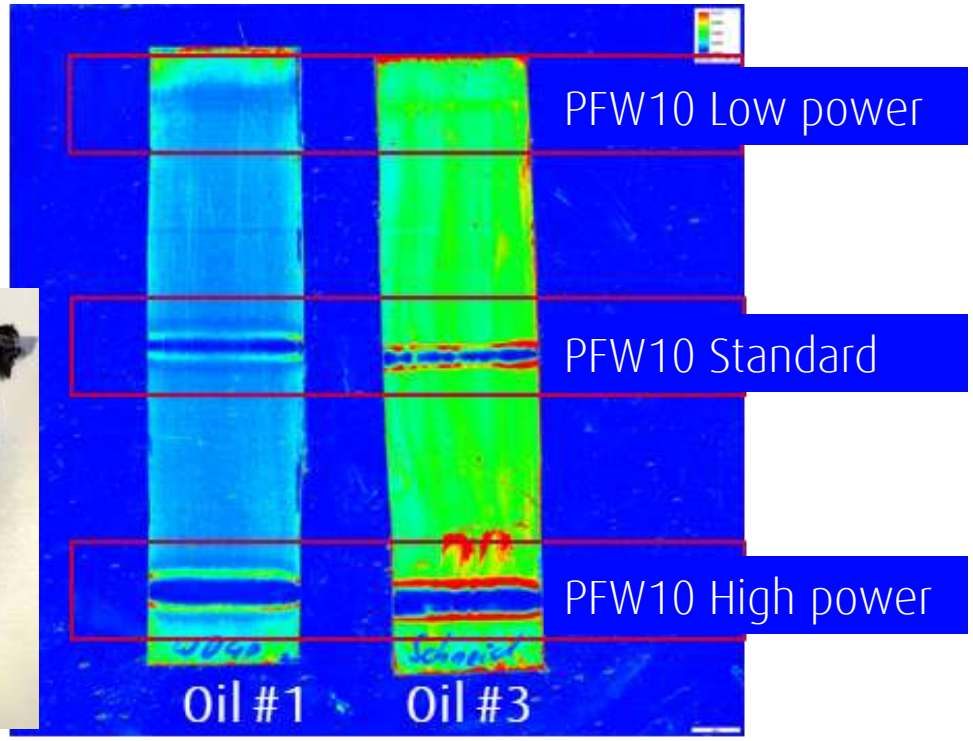
Surface Cleaning - Laser fluorescence measurement



Surface Cleaning – Laser fluorescence analysis on metals



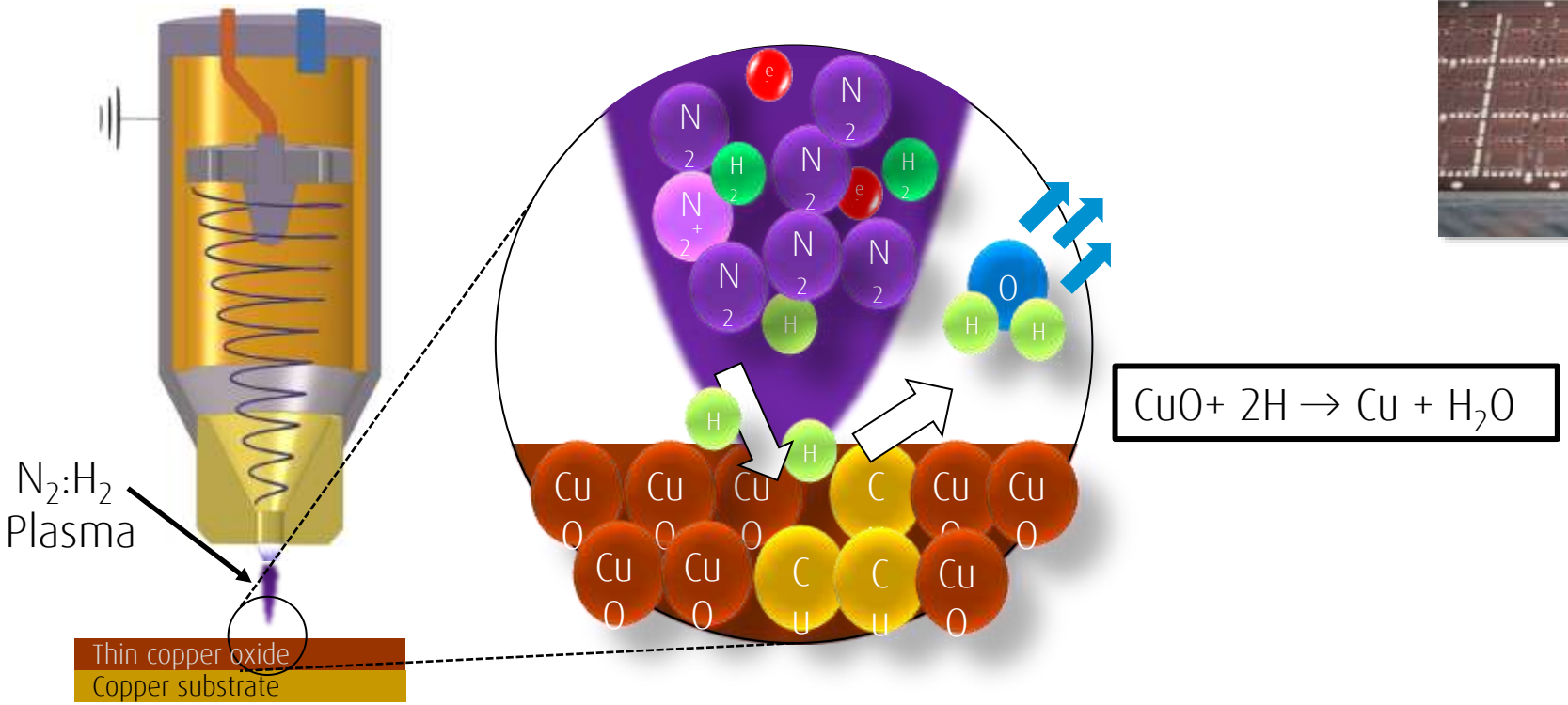
Openair-Plasma® Cleaning of Steel 1.4301

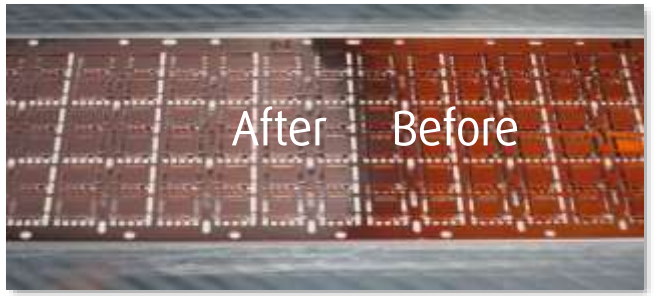


Openair-Plasma® Cleaning of Aluminum

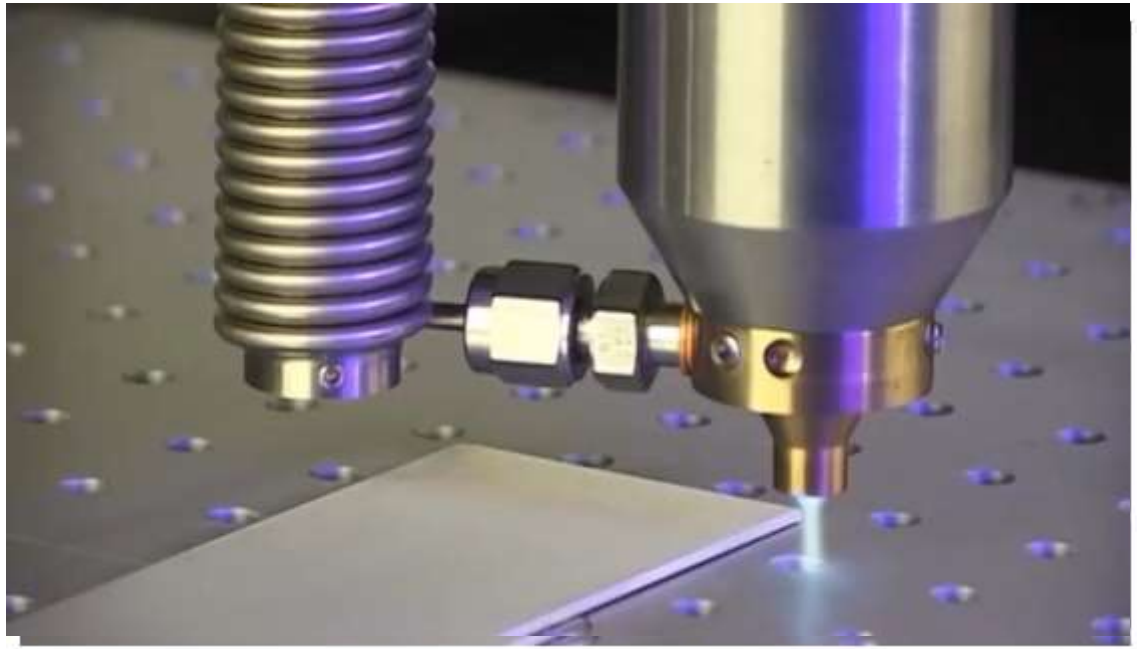
Forming Gas (N_2:H_2) Plasma - The Reducer

- Forming gas: N_2 with H_2, forming **atomic H•** radicals
- Highly effective in **reducing surface oxides** (i.e., on Cu, Sn, Ag, ..) and removing molecular contaminants
- Prepares metals for soldering, bonding, or coating with minimal delay





PlasmaPlus® - Atmospheric thin film deposition on substrates



Openair-Plasma®-Coating

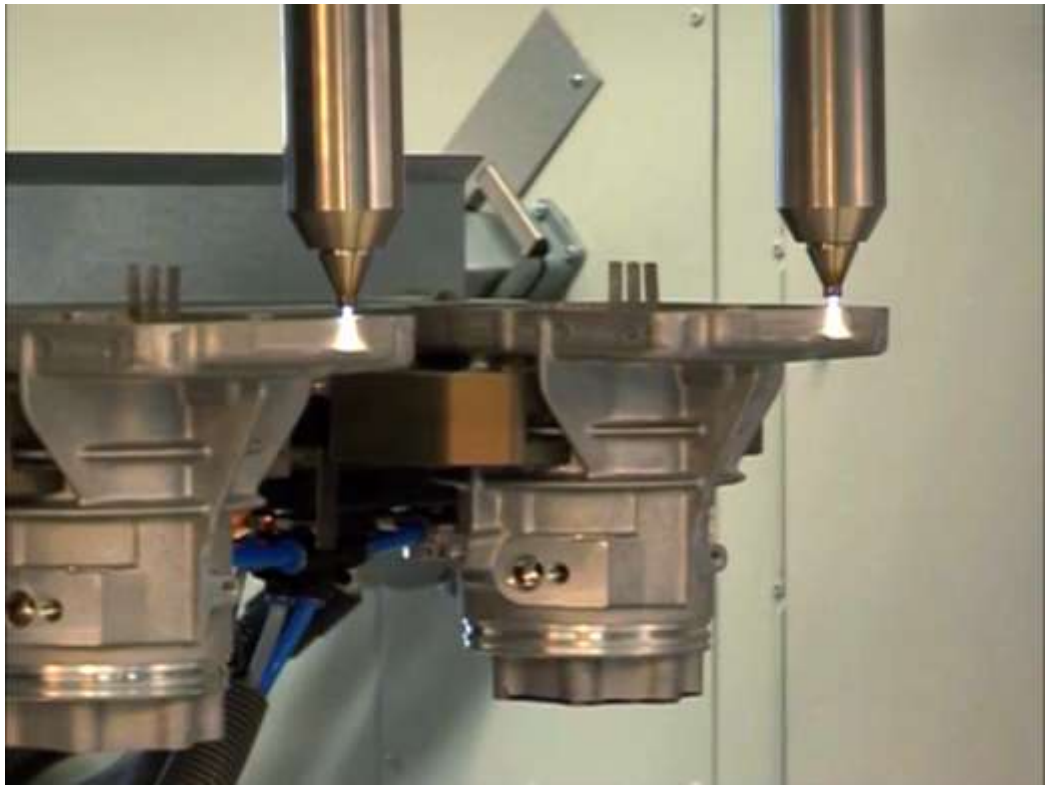
Coating deposited on aluminum with varying thickness between 15 und approx. 700 nm

Possible functionalities:

Hydrophilic, hydrophobic, chemical functionalities

Substrates:

- Metal, polymer, glass



PlasmaPlus® - Atmospheric thin film deposition on substrates

Plasma polymer coating:

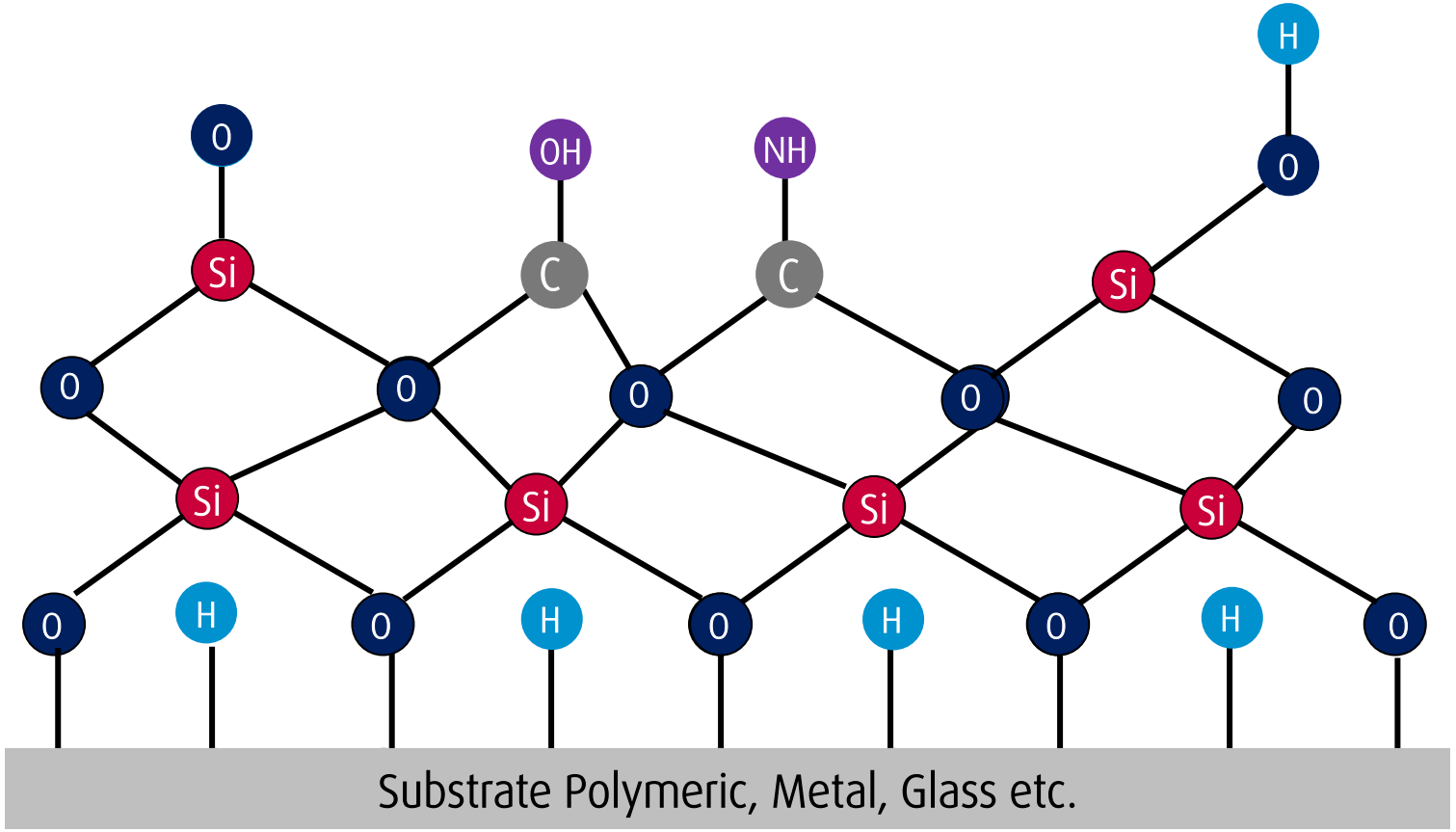
- Bi-functional layer 5-15 nm
- Long stability bond connections
- Dry inline process

Organic group:

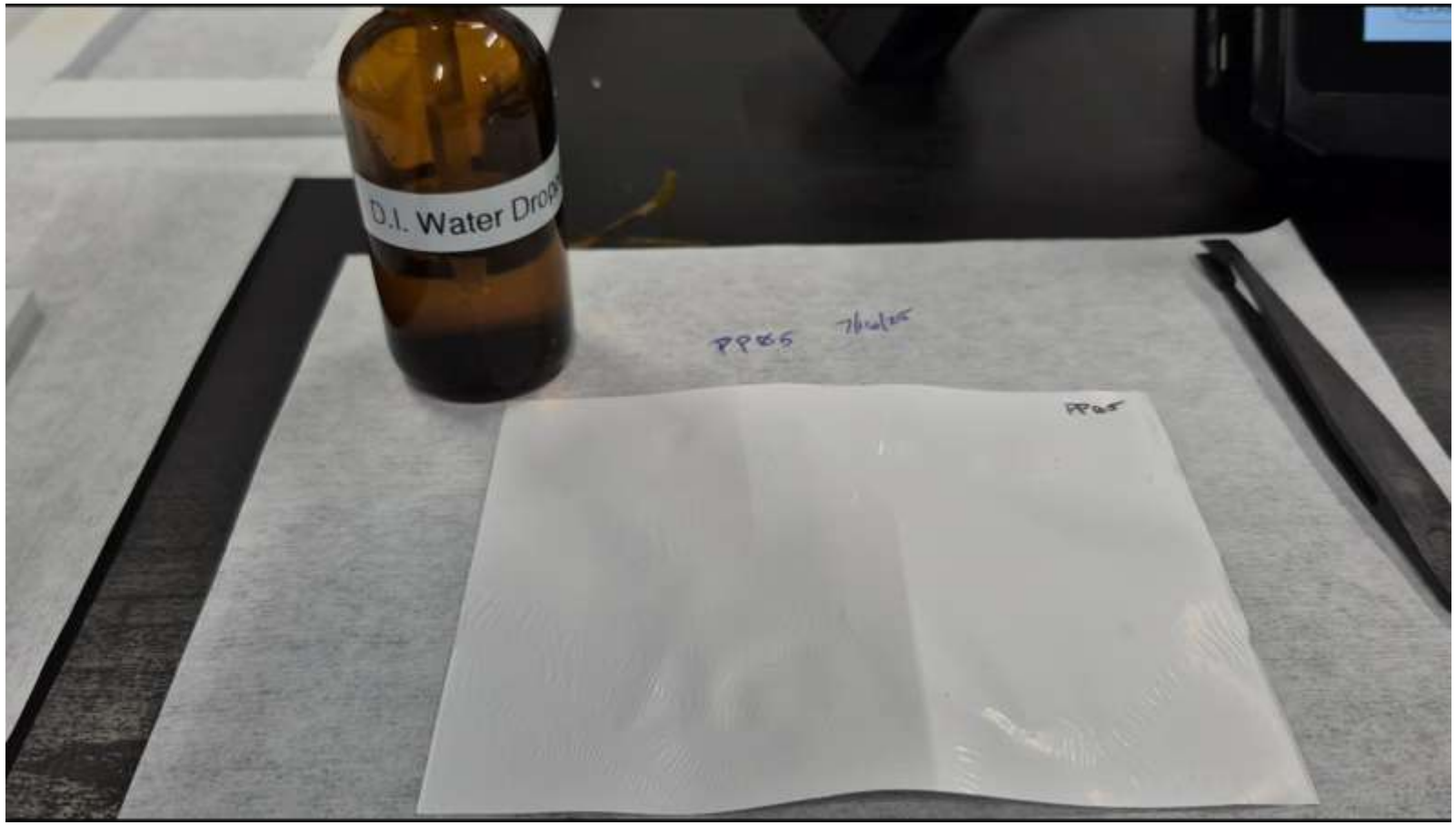
- Amine, Epoxy, Methyl, Acrylate,...

Inorganic backbone:

- -Si-O-



Superhydrophobic Coatings on atmospheric pressure Plasma-Treated Membranes



Substrate: porous membrane

Plasma jet: PFW10-PAD
Plasma-sample distance: 40mm
Plasma jet speed: 300 mm/s
Precursor flow: 25 g/hr

Coating thickness: 160nm
WCA: > 140°

PlasmaPlus® hardware configuration - Atmospheric pressure

Generator

Electrical Power

Plasma Control Unit

Air supply

Plasma Atmospheric Deposition (PAD)

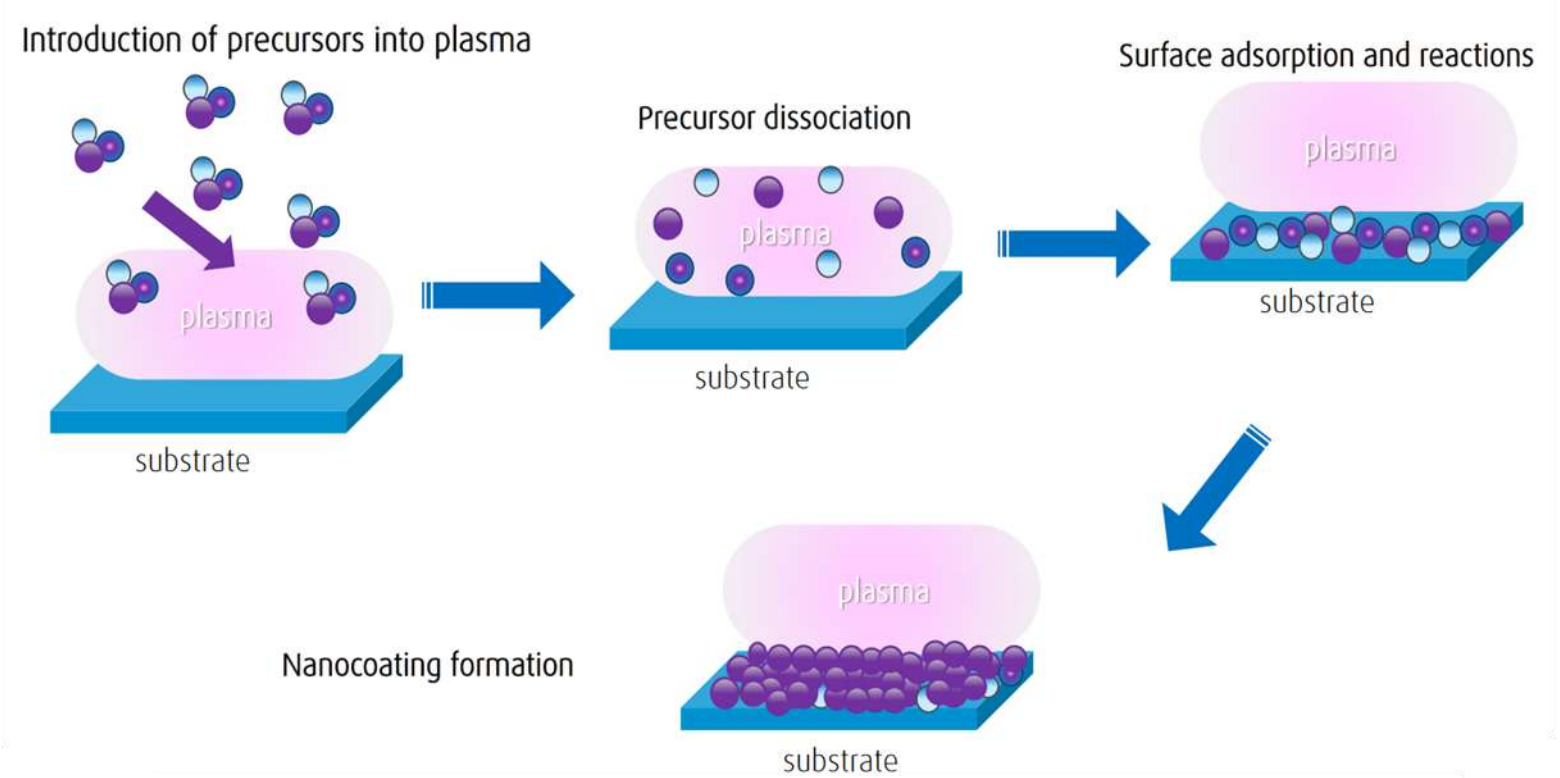
Precursor supply

Plasma Jet

Deposition

Aurora - Low pressure Vacuum Plasma – PFAS alternative

Aurora – Low pressure chamber used for thin film deposition



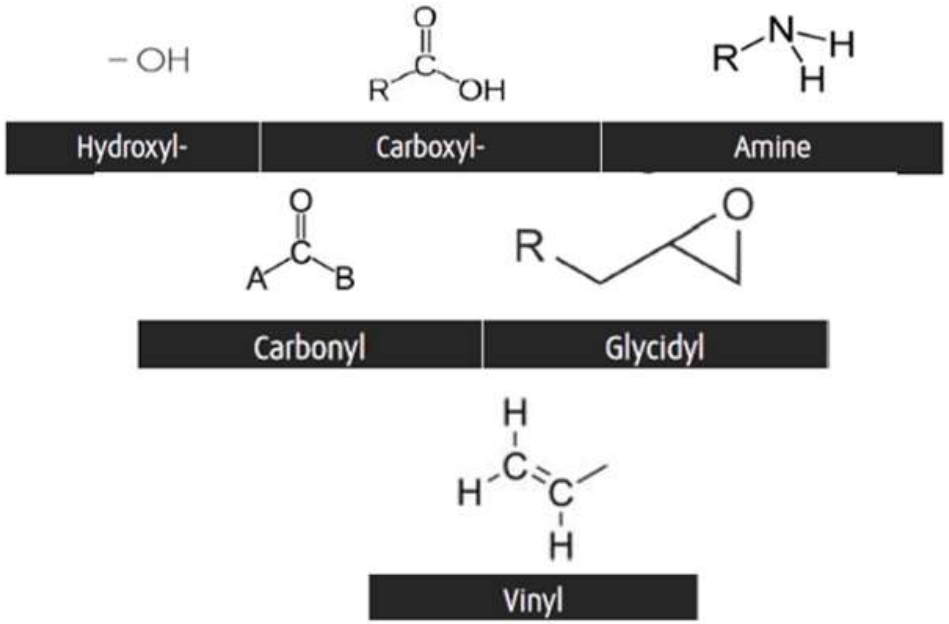
The film chemistry will be influenced by the plasma deposition parameters (power, ionization gas, precursor flow…) and the precursor used

Aurora - Low pressure thin film deposition on substrates

- Dry deposition method
- Applicable on a variety of substrate materials
- Low cost
- 3D geometry
- Ambient temperature

Deposition processes typically require 2 min to 20 min.

Coating thickness ranges from 25 nm to 300 nm.



Aurora hardware configuration - Low pressure

Aluminium chamber

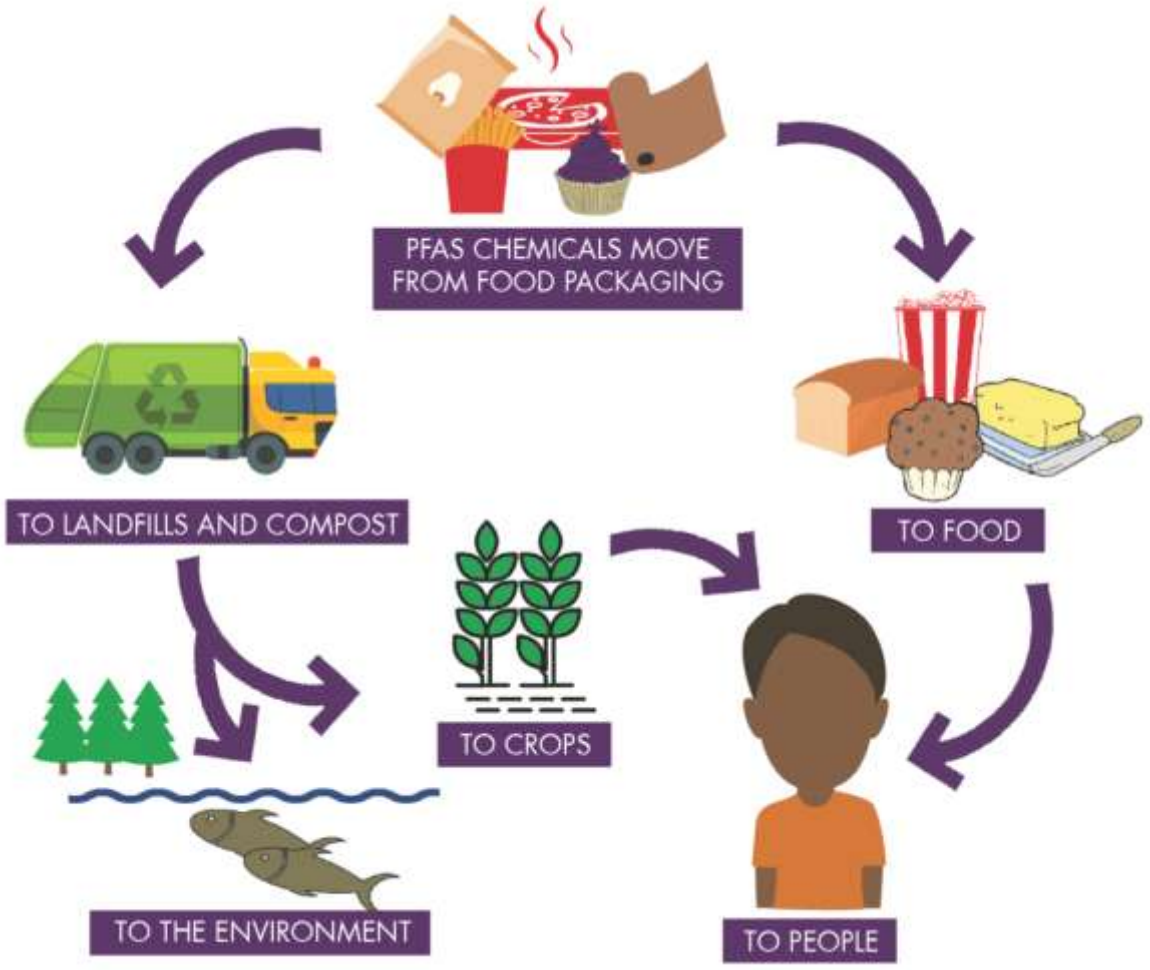
What are PFAS and where they can be found ?

Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic chemicals that contain carbon-fluorine bonds.

- C-F bond Energy : 485 kJ/mol
- **Chemically Inert** that provide long term performance under harsh environmental conditions, such as extreme temperatures, corrosive solvents, and aggressive reagents.

PFAS are found everywhere as polymer material (PTFE, Teflon, ECTFE,...) and also as fluorinated coating.

What are PFAS alternatives ?



Possible health issue

- Alternative using different polymers :

  POM, PEEK, PA, PET, PPSU…

  These polymeres can be used and recycled

- Deposit plasma coating with different chemistry to propose a reliable alternative and provide:

  - Hydrophobicity
  - Friction reduction
  - Superhydrophobicity
  - Long time stability

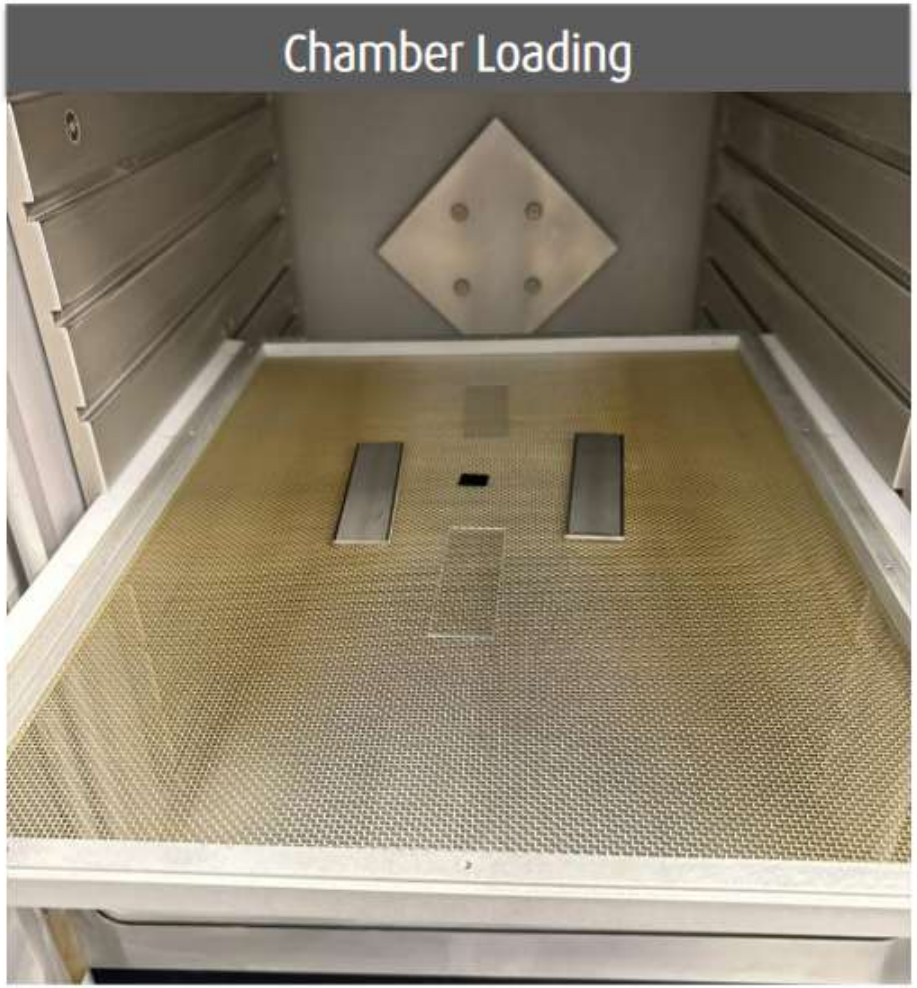
Low pressure Plasma coating

Atmospheric pressure Plasma coating

https://toxicfreefuture.org/blog/seriously-sticky-situation/

Aurora - Low pressure Vacuum Plasma – PFAS alternative

Aurora – Low pressure chamber used for thin film deposition



Aurora - Low pressure Vacuum Plasma – PFAS alternative

Aurora – Low pressure chamber used for thin film deposition

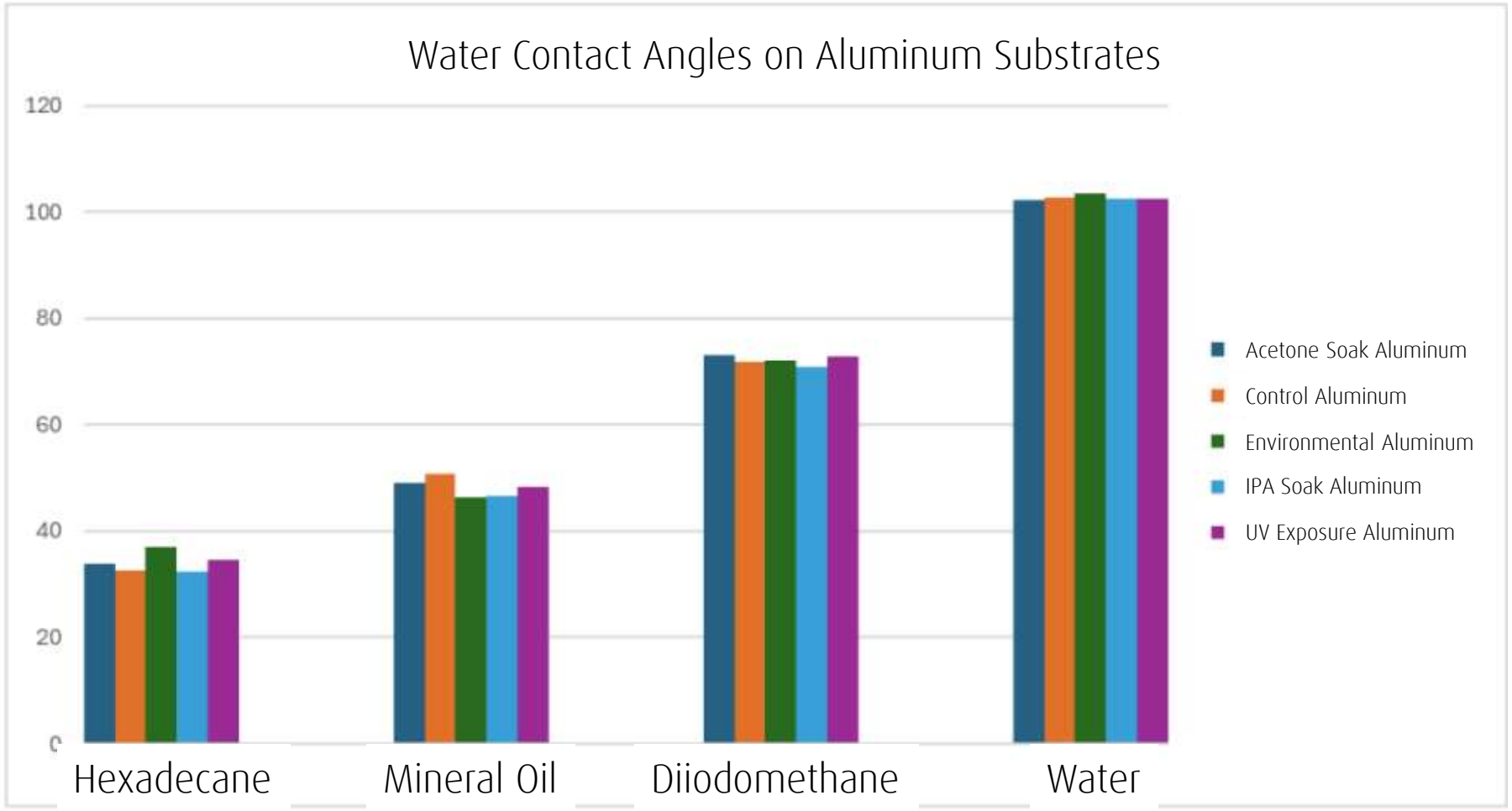
PHB 104 coating on stainless steel

PTFE coupon

Deposition of Hydrophobic coating on stainless and glass with WCA equivalent to PTFE

Aurora – Plasma deposited coating after aging tests

Contact Angle Comparisons on Aluminum Substrate



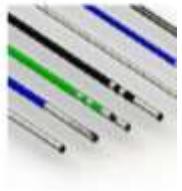
Low-pressure Plasma-Treatments for Blood, Tissue and Water Repellant Coatings

- Non-stick coating
- Biocompatible coating allowing for the release of tissue and to provide non-fouling performance during blood contact
- Water contact angle > 90°
- Applicable to metal medical tools
    - Forceps, graspers, syringe needles

Other Coating Applications

Bonding of dissimilar materials

No Adhesive
Cost Savings
Stronger bond
Universal setup in LP chamber



Waterproofing of wearable devices

Low Friction coating

Easy Release for Mold Tool or Paint

Avoid use of mold release compounds

Easy to clean paint overspray

Corrosion Protection and Barrier

Extend service lifetime and reduce warranty cost

Coating thickness <100 nm

Anti-fouling coating

Activation treatment

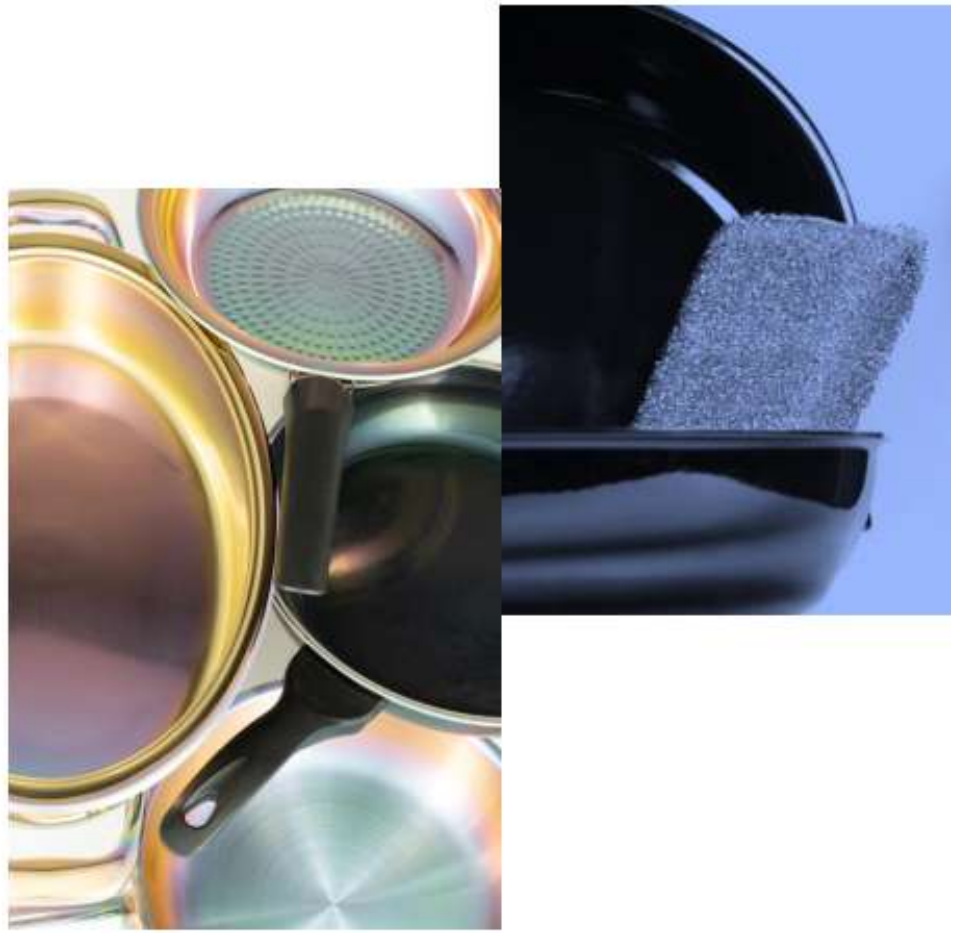
Plasma coatings applications in collaboration with the Fraunhofer IFAM, Bremen/Germany

PLASLON® - hard and resistant

For food and food processing industry

properties:

- Good, durable non-stick and easy-to-clean properties
- Similar hardness to enamel and therefore resistant to cutting and abrasion
- free from fluorine compounds -> siloxane based
- non-porous and tasteless, as it is highly cross-linked
- food-safe
- oleophilic (oil wetting) behavior in relation to edible oils and fats
- perfect reproduction of laser structures or other decorative elements



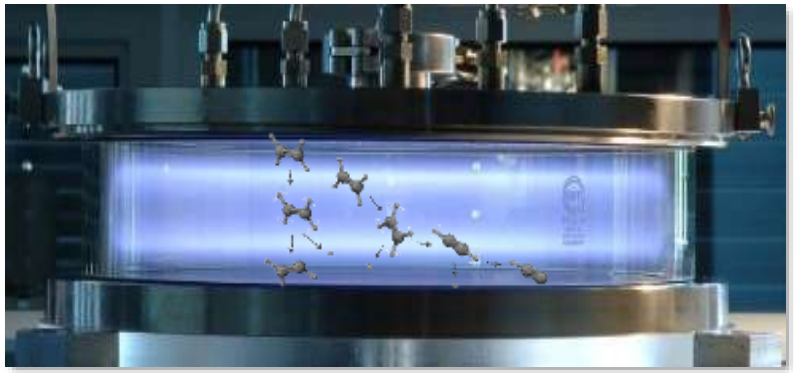
Dr. Jörg Ihde, Fraunhofer IFAM Bremen; joerg.ihde@ifam.fraunhofer.de

Plasma Technology for Textile and Biomed Applications collaboration EMPA, St. Gallen/CH

Empa
Materials Science and Technology

plasmatreat

Surface functionalization



→ Low pressure (1-100 Pa)
→ Plasma deposition/etching at nanoscale

R2R plasma processing (65 cm width)

Industrial applications

Dr. Dirk Hegemann, Empa, St. Gallen; dirk.Hegemann@enpa.ch

Are you interested in our technology?

Our R&D and the Plasmatreat Academy are housed in our HQ technology center with plenty of room for innovative Plasma research and system development.

www.Plasmatreat.de

If you are interested in using Plasma for your application, feel free to contact us or book your free 1×1 online demo!

www.book-a-demo.com

We offer the option to rent our Openair-Plasma® equipment.

Click here for more information

Thank you very much for your attention !

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