# MATERIALS WEEK EUROPE

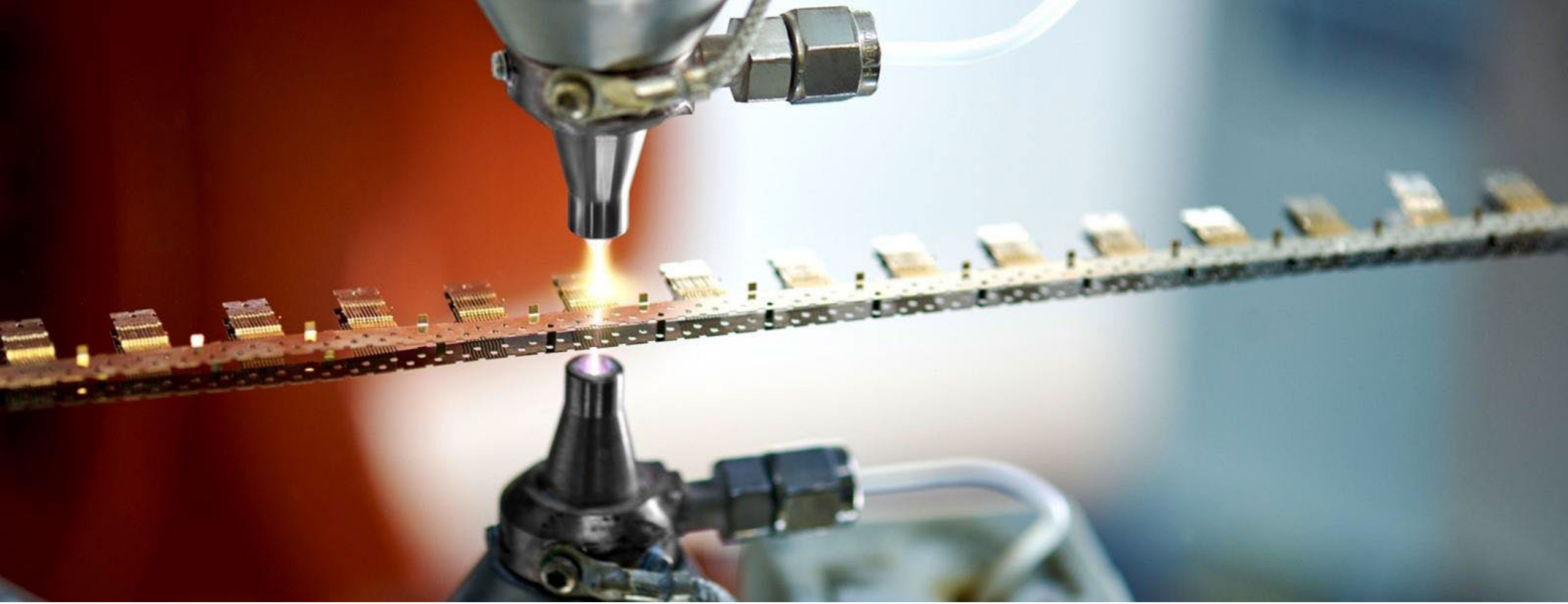
## The next speaker is...

**Job Van Galen**
Managing Director
**Plasmatreat**

plasmatreat

*Plasma Treatment of Surfaces for Bonding and Interface Engineering*

Scan below for Conference Agenda



# Materials Week Europe - Plasma Treatment of Surfaces for Bonding and Interface Engineering


Job van Galen

+31 6 48 42 37 25

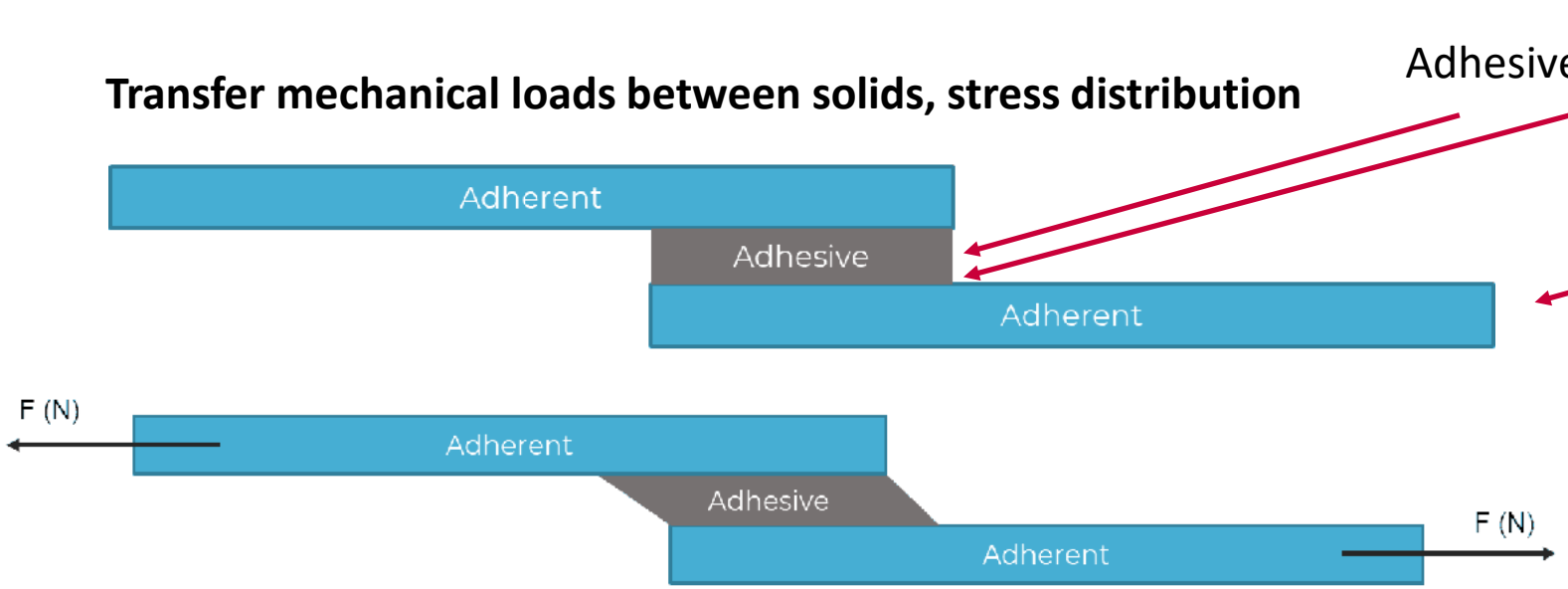
Job.van-galen@plasmatreat.com

www.plasmatreat.com


plasmatreat

# (Adhesive) bonding

**Transfer mechanical loads between solids, stress distribution**




Interphase

Adhesive

Substrate material

**Deformation compensation -** Joining materials with dissimilar expansion rates

# Adhesive

Organic adhesives
Silicones
Inorganic adhesives

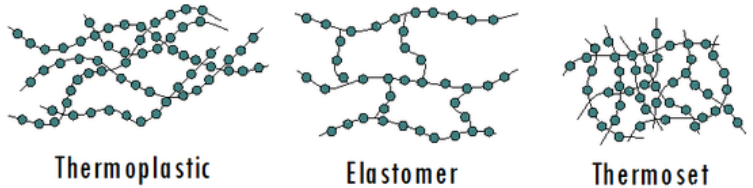
- Chemically reactive curing → Epoxy, Polyurethane, Silicones, ….
- Physically setting → Hotmelt, Solvent based adhesives, ….
- Non-curing → Pressure sensitive adhesives


- Monomers
- Prepolymers
- Additives and fillers
- Initiators/radicals/reactive diluents /cross linking agents, etc…



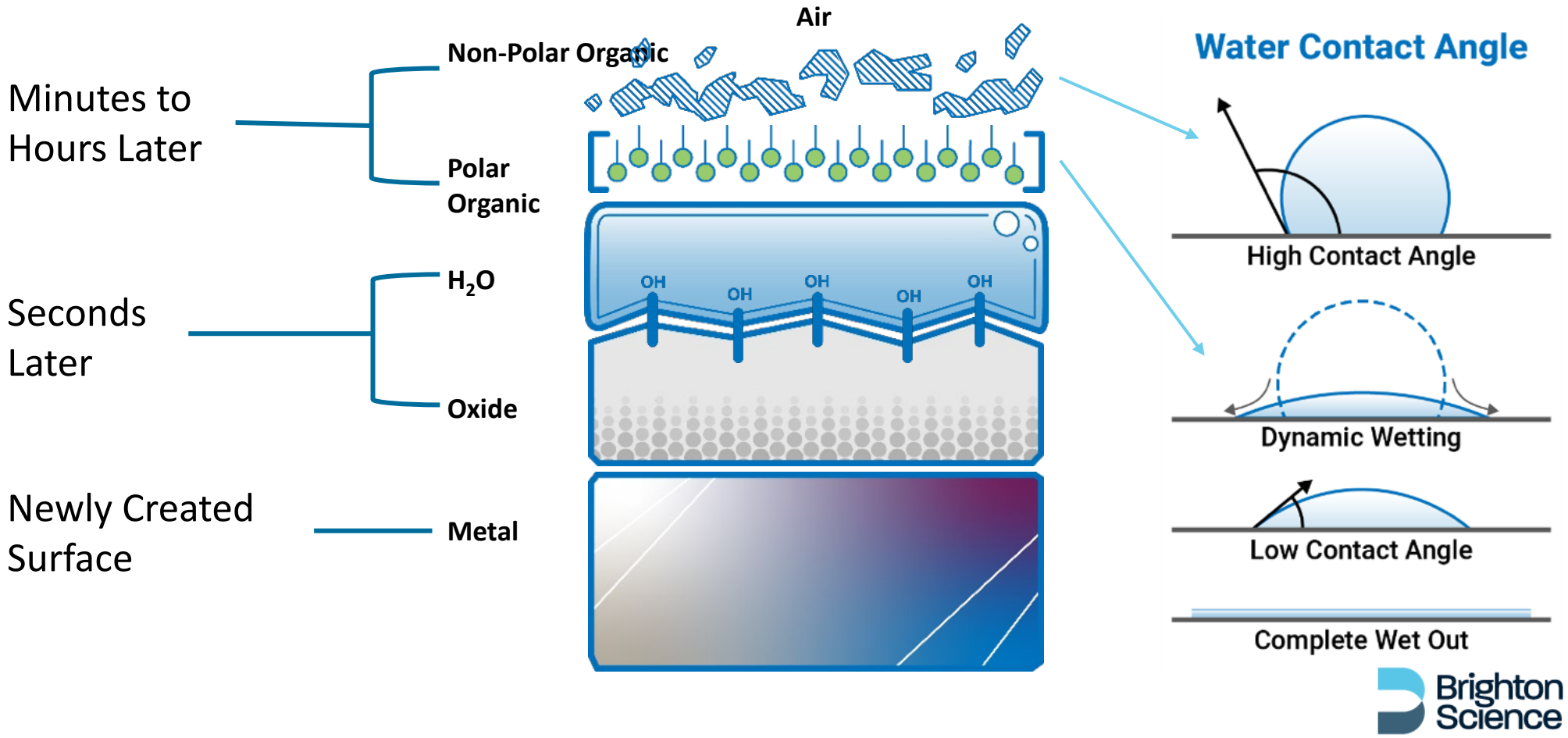
(Mixing) dispensing & Curing

Chemically reactive:
**Exothermic** curing reaction

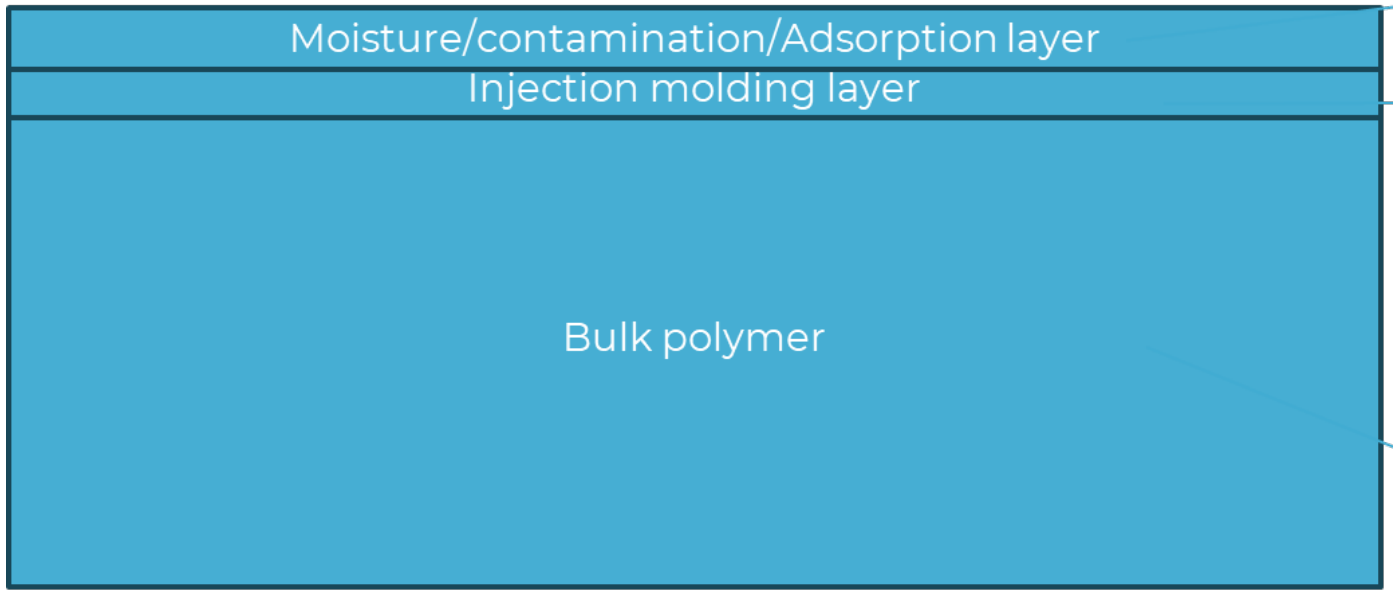



"Final" cured polymer

# Substrate material - Metal



# Subtrate material - Plastic




Layer forming naturally depending on the environment and storage conditions

"Skin" layer formed during injection molding processes which has different properties than the bulk due to shear forces and temperatures during injection molding and additive migration

Expected bulk properties, plastic as designed

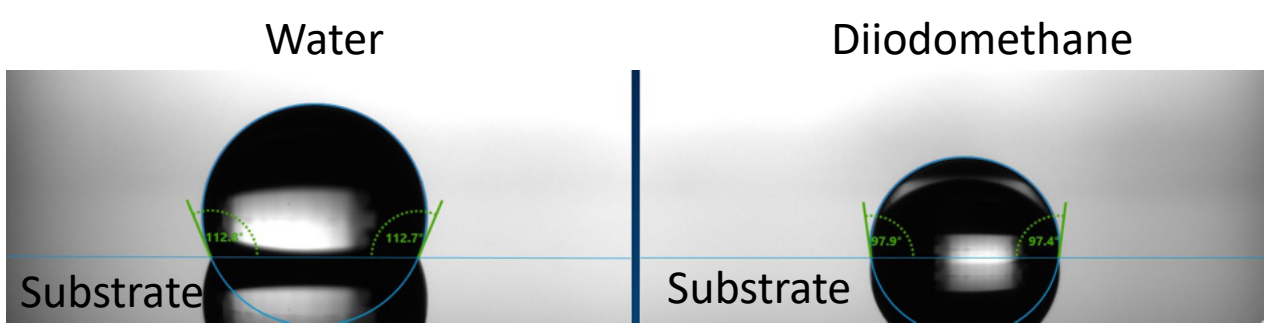
# Adhesion?

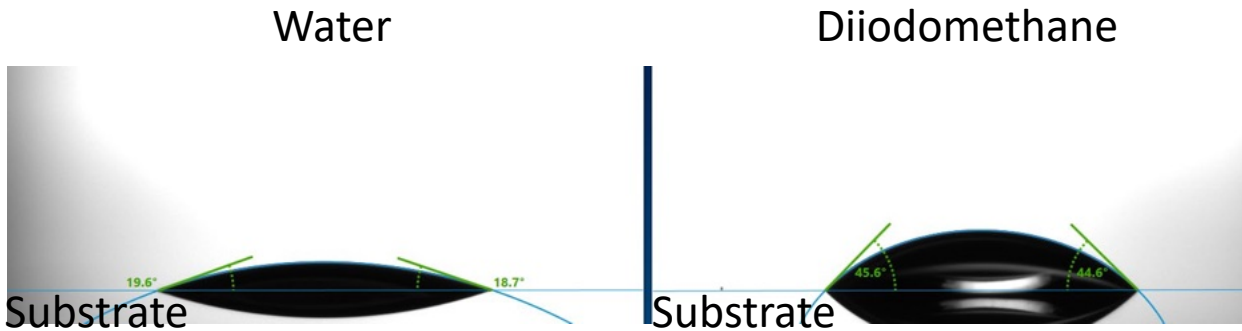
# Wettability

- surfaces are in a **higher energy state than the bulk** due to missing intermolecular interactions.
- Surface energy (σ) is the **excess free energy per unit area.**

Rule of thumb for good **<u>Wettability;</u>** How well does a liquid spread across and make intimate contact with a surface:

$$\sigma_{substrate} > \sigma_{liquid}$$



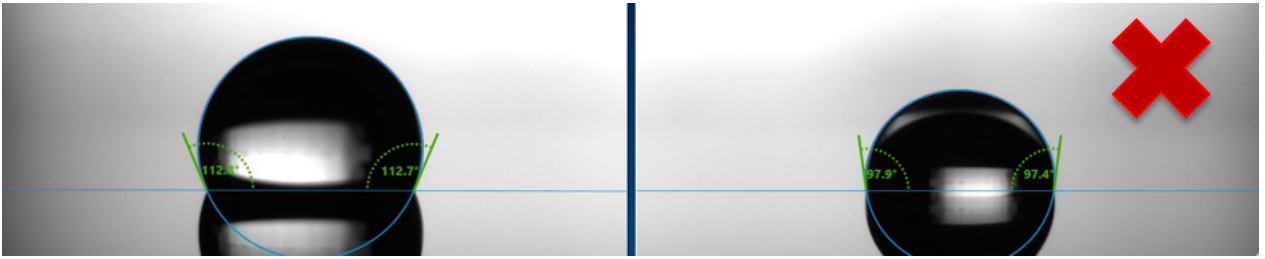
# Wettability – Sheep example

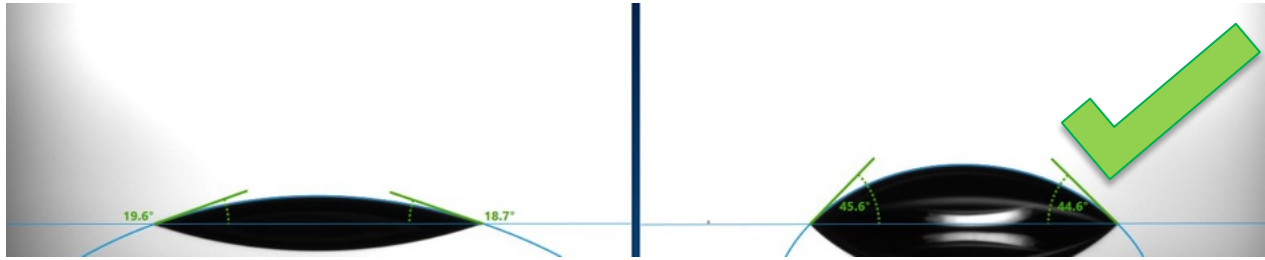
Substrate

Adhesive

Poor wettability – I have low surface energy

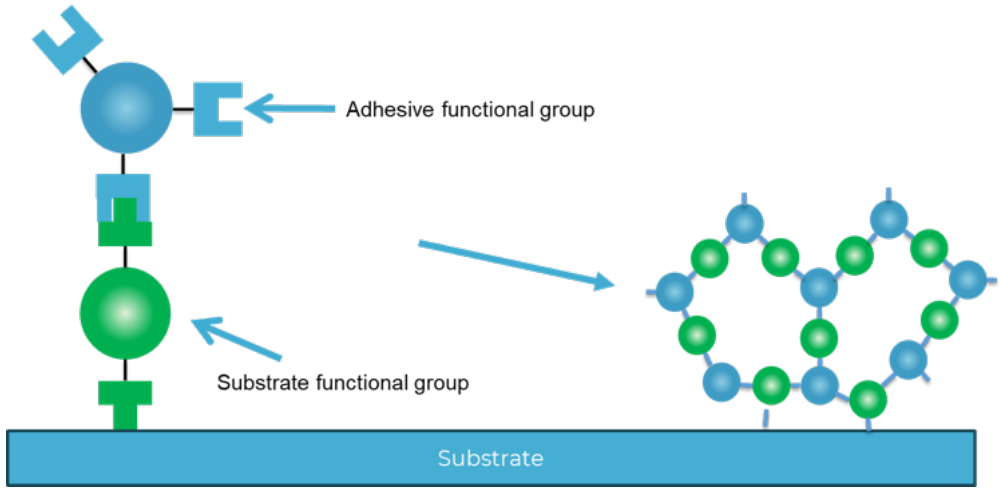
Plasma treated – I have high surface energy good wettability



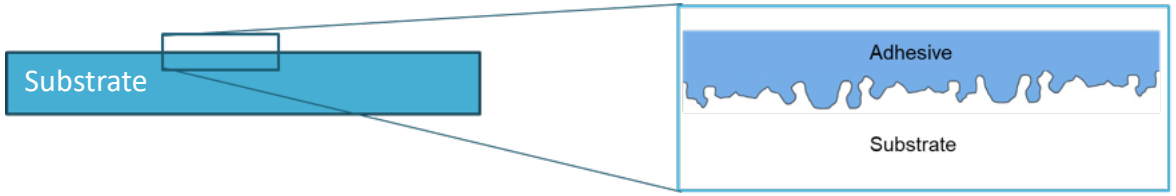



# (some) Adhesion Mechanisms

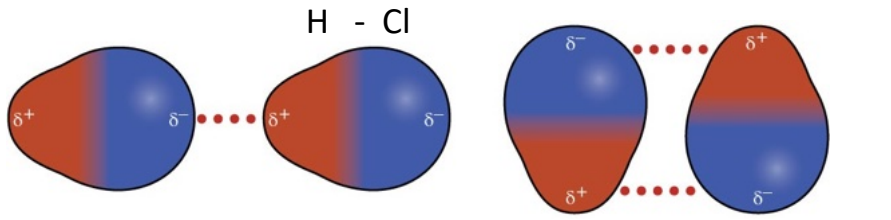
## Chemical adhesion




## Mechanical interlocking

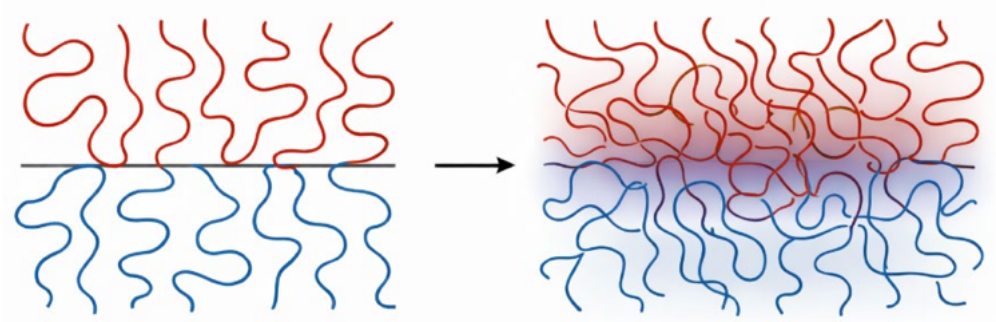



## Physical interactions




https://chem-textbook.ucalgary.ca/version2/chapter-5-main/intermolecular-forces/dipole-dipole-attraction/

## Interdiffusion

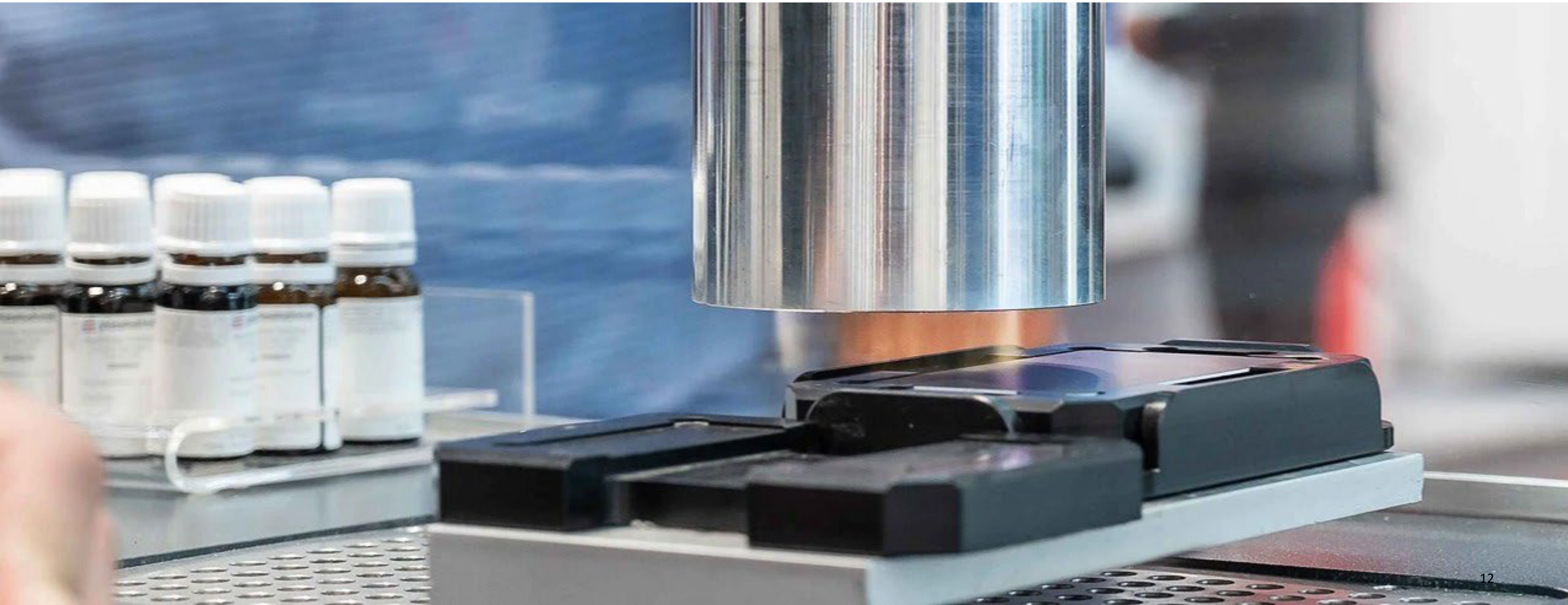


# Adhesion – Sheep example

Adhesion failure (AF)

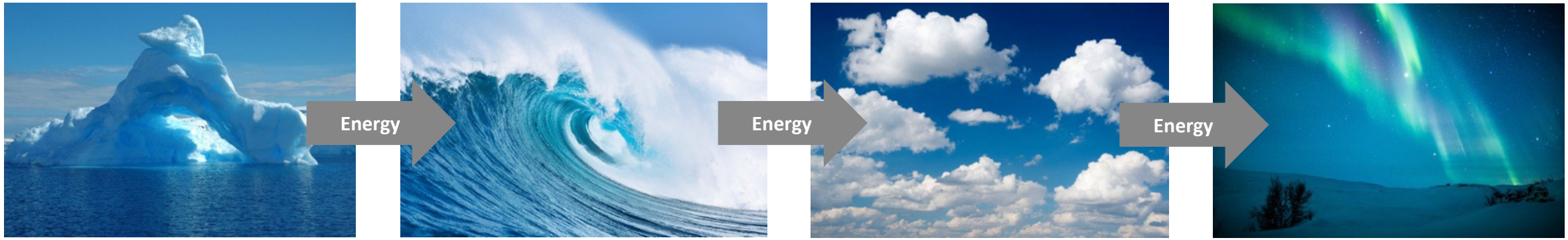
Cohesion failure (CF)

# Altering surface properties

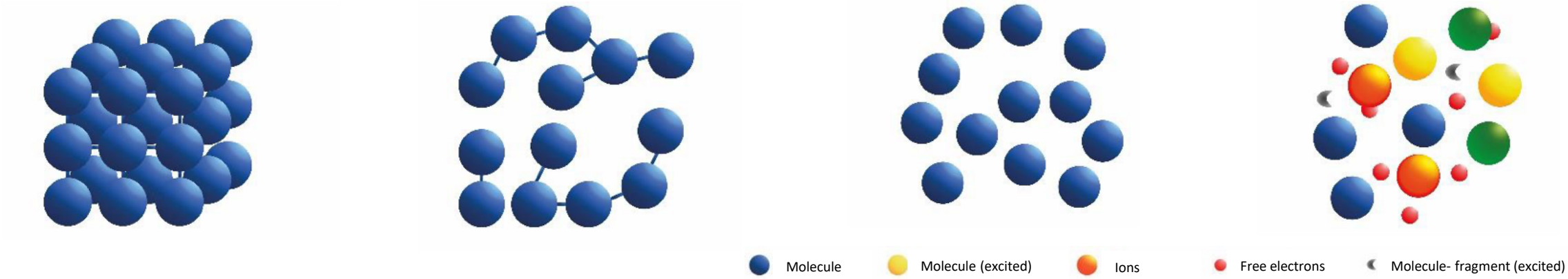


# Definition of Plasma

Plasma is formed when additional energy is supplied to the gas by electrical discharge. Plasma is an ionized gas with electrical conductivity that is electrically neutral.

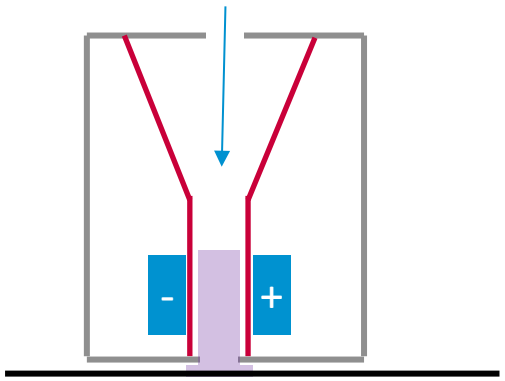



Solid | Liquid | Gas | Plasma

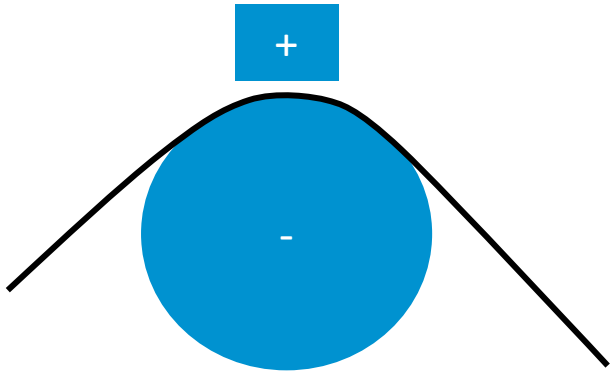


# How is plasma generated

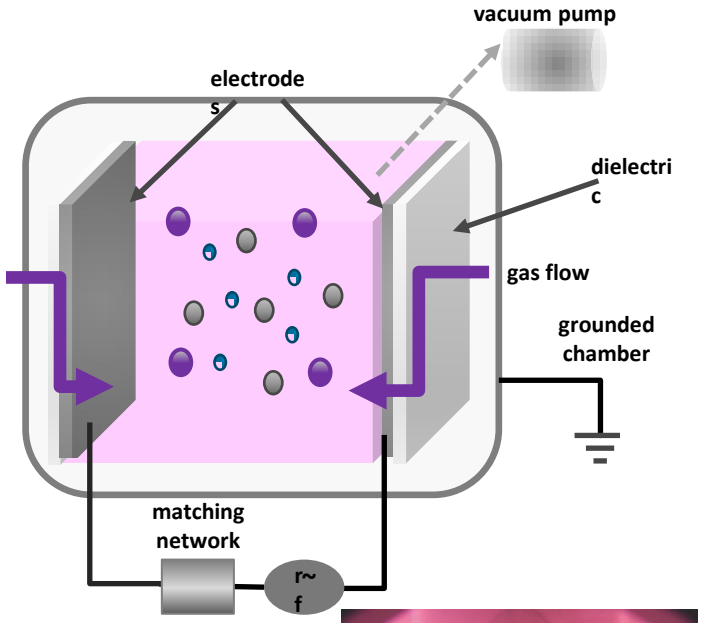
## DBD plasma



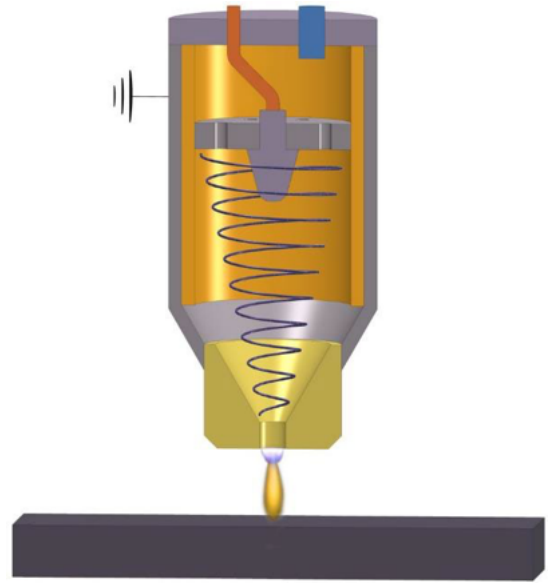

## Corona Plasma



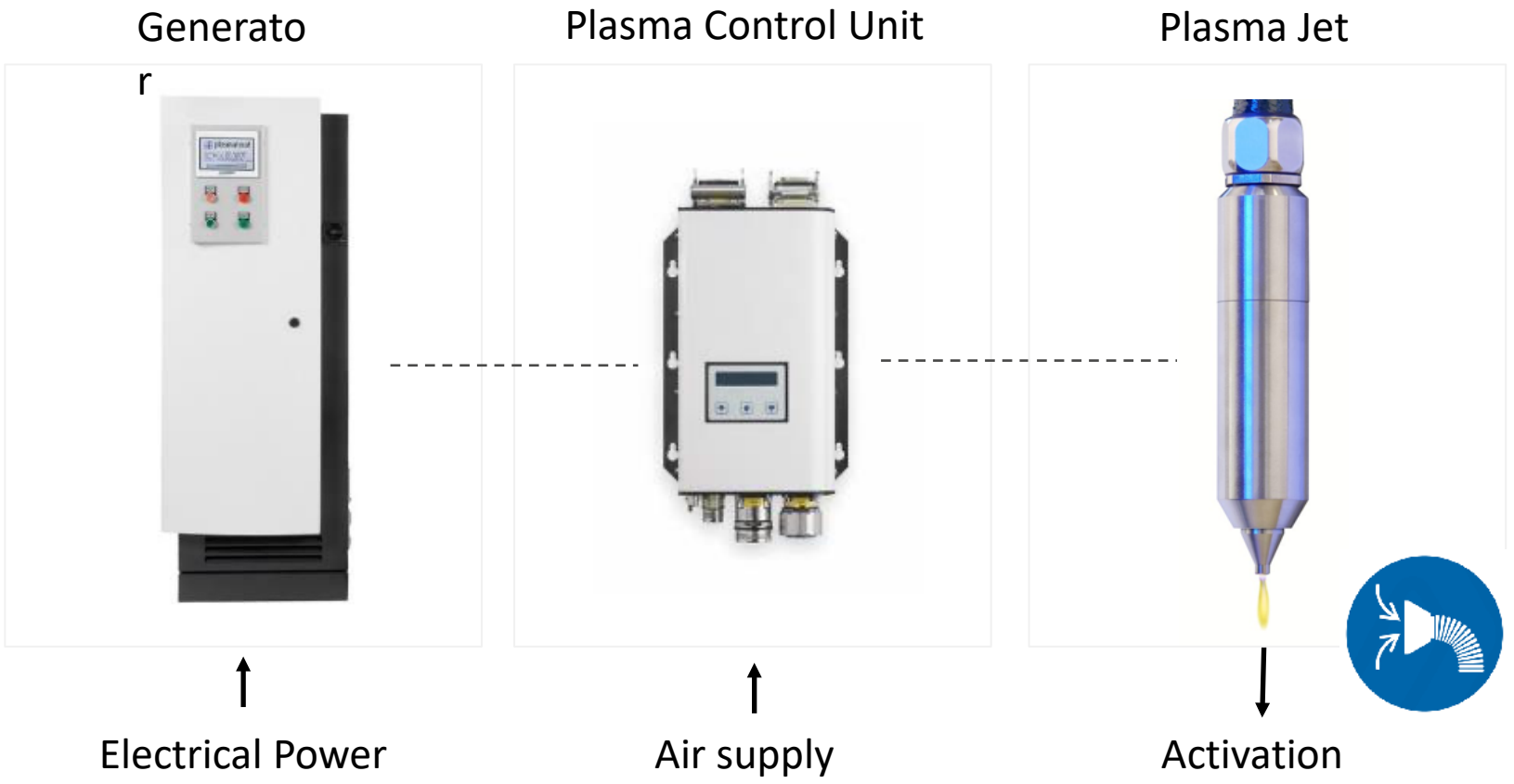

## Arc discharge plasma



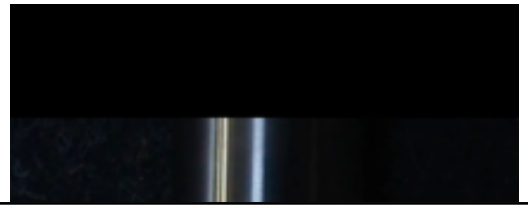

## Arc discharge plasma

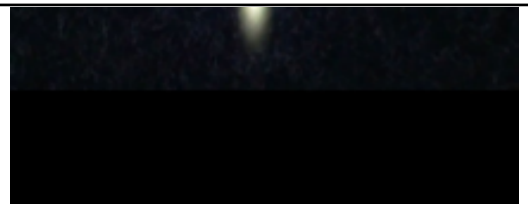


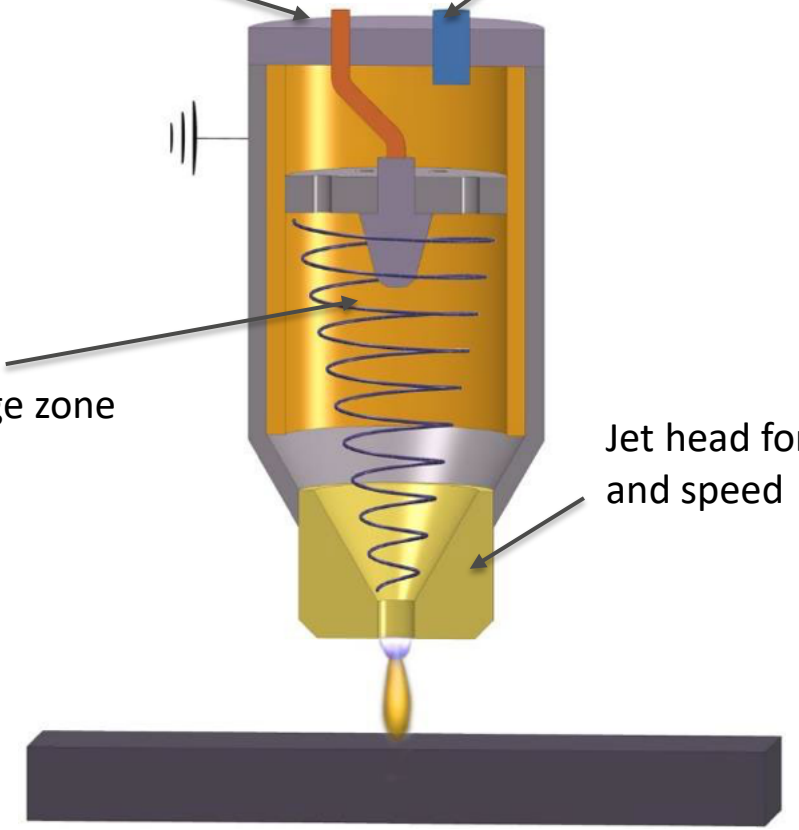
# How is plasma generated



# Openair-Plasma® treatment



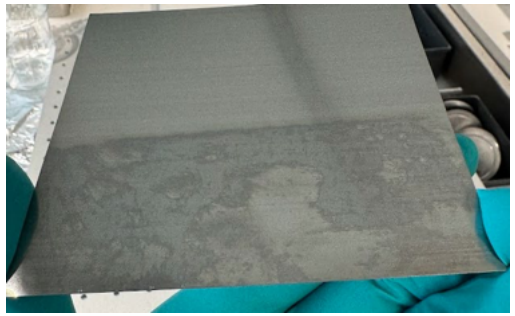


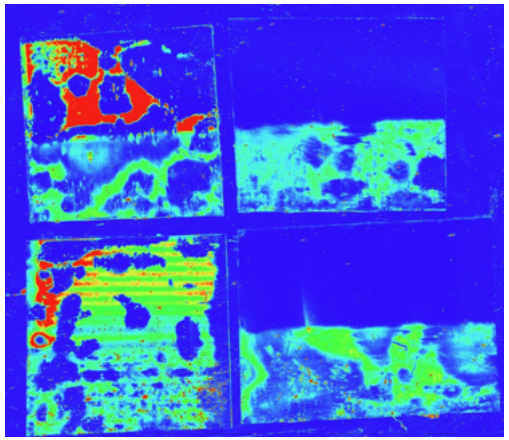


# Openair-Plasma®

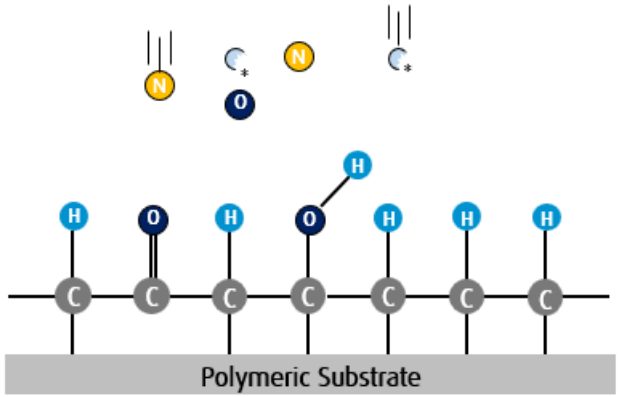
plasmatreat

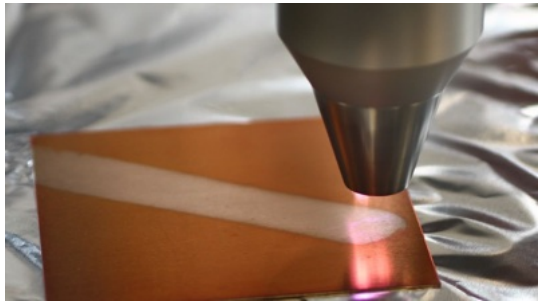
## Cleaning



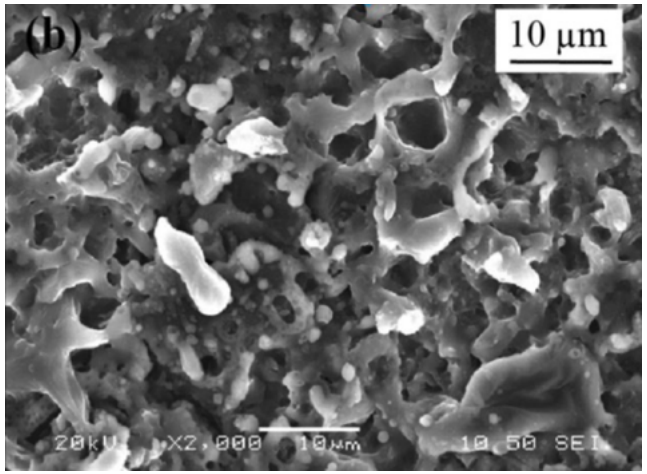


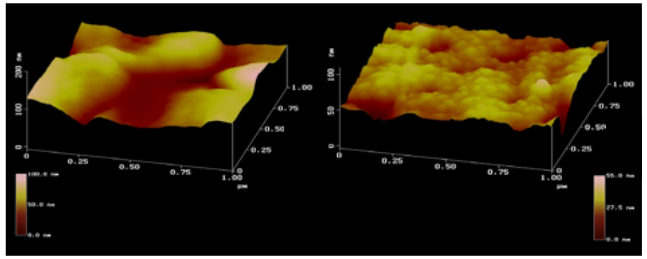
## Chemical Modification



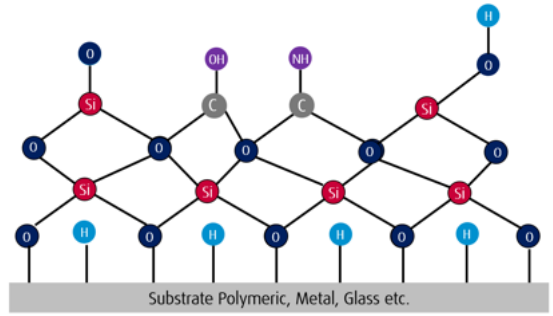



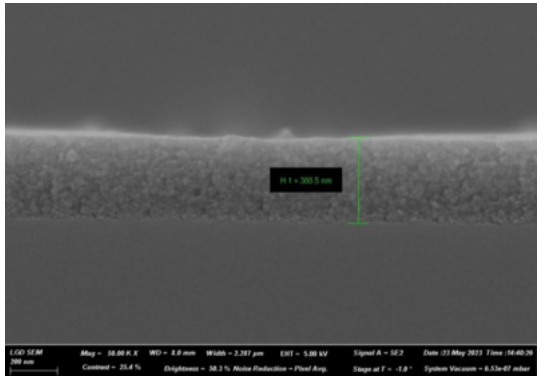
## Mechanical Modification



## Nanocoating

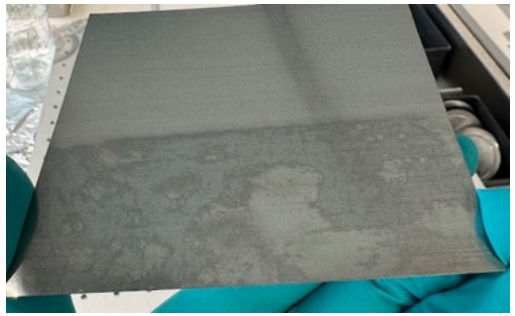


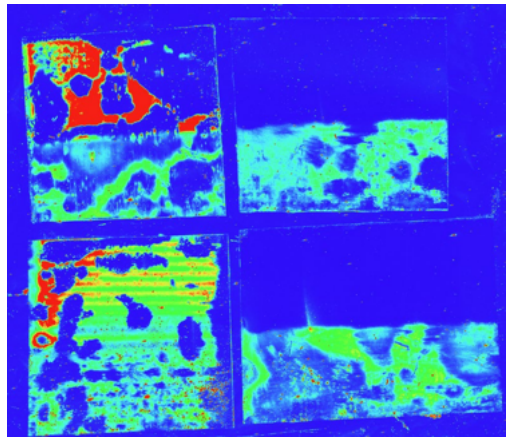



# Openair-Plasma® - Cleaning

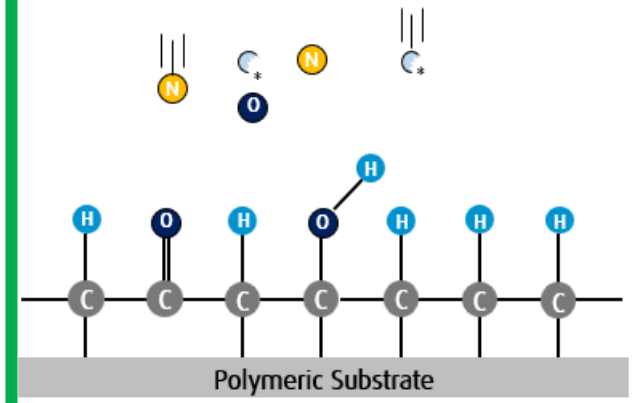
plasmatreat

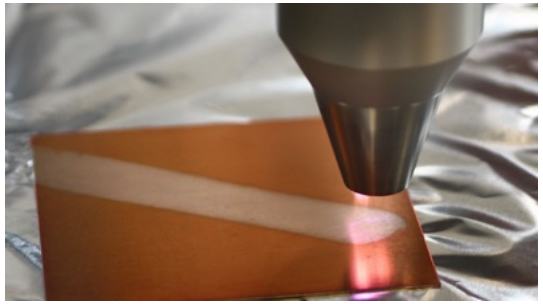
## Cleaning



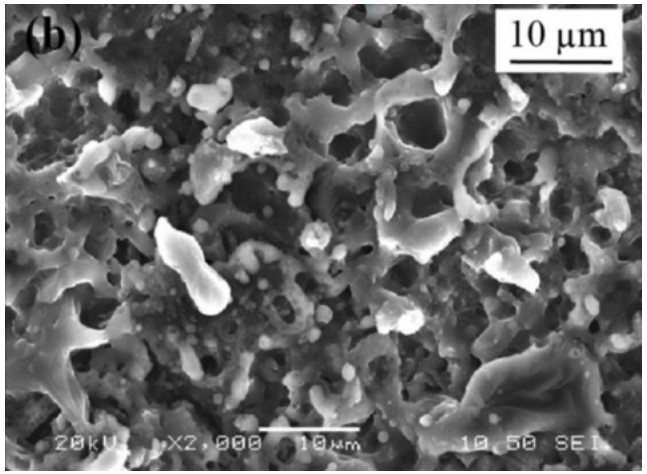


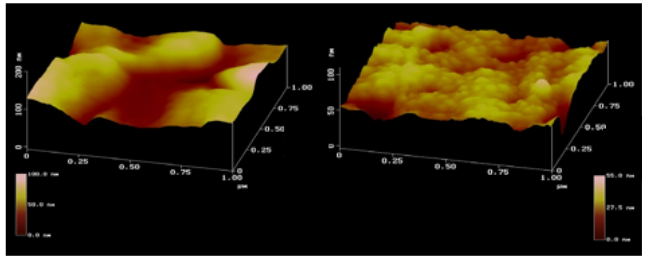
## Chemical Modification



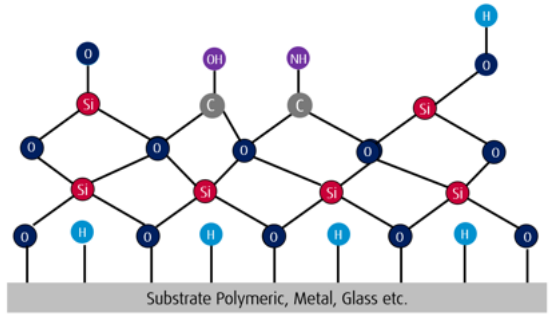



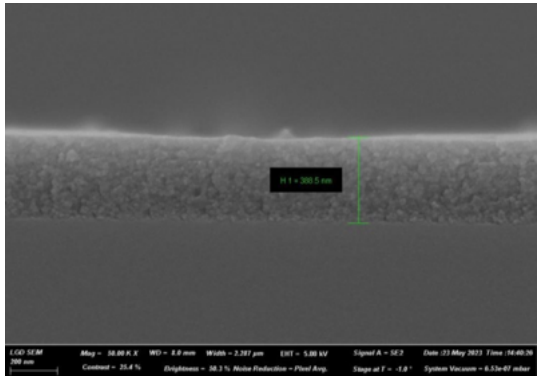
## Mechanical Modification



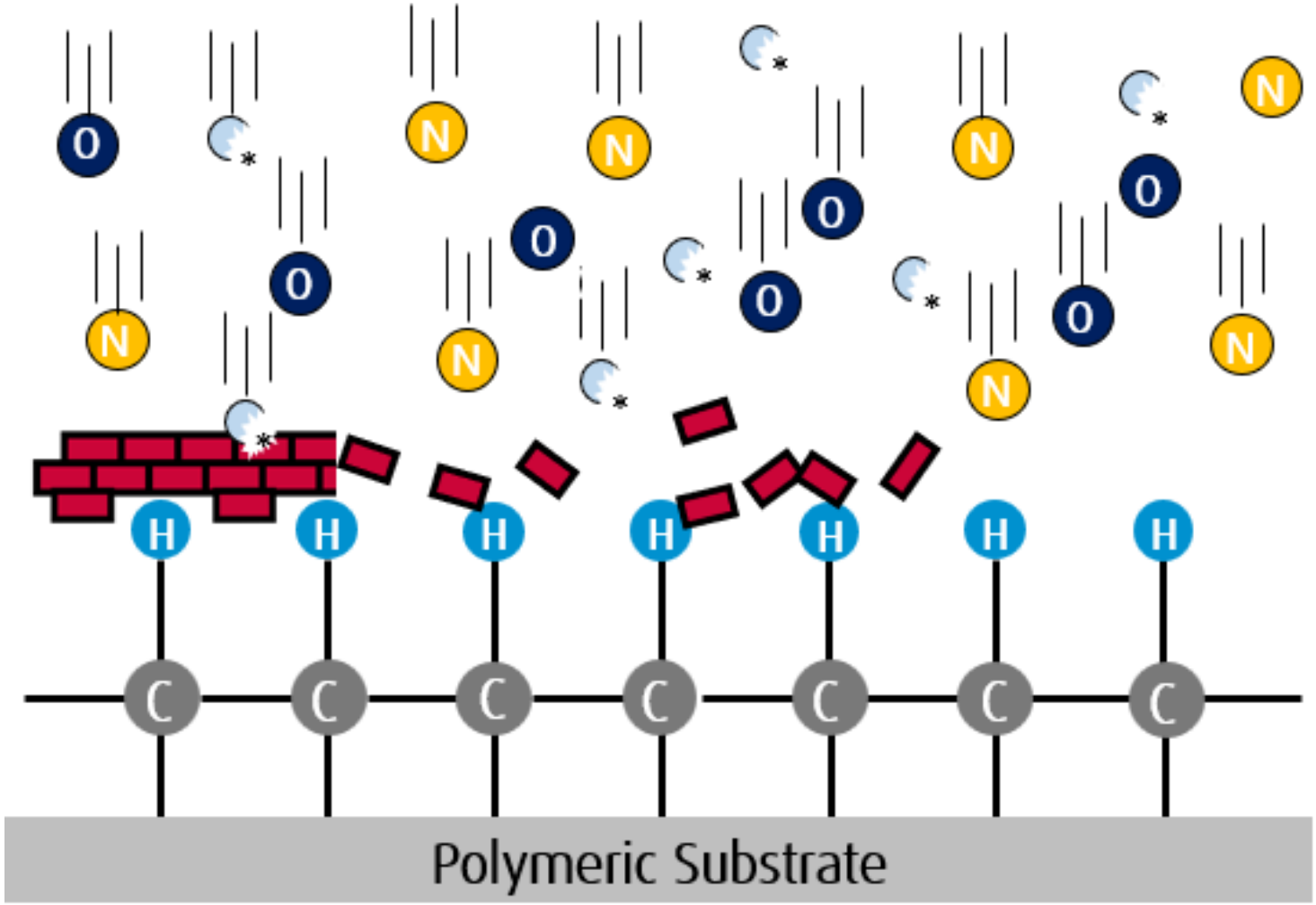



## Nanocoating

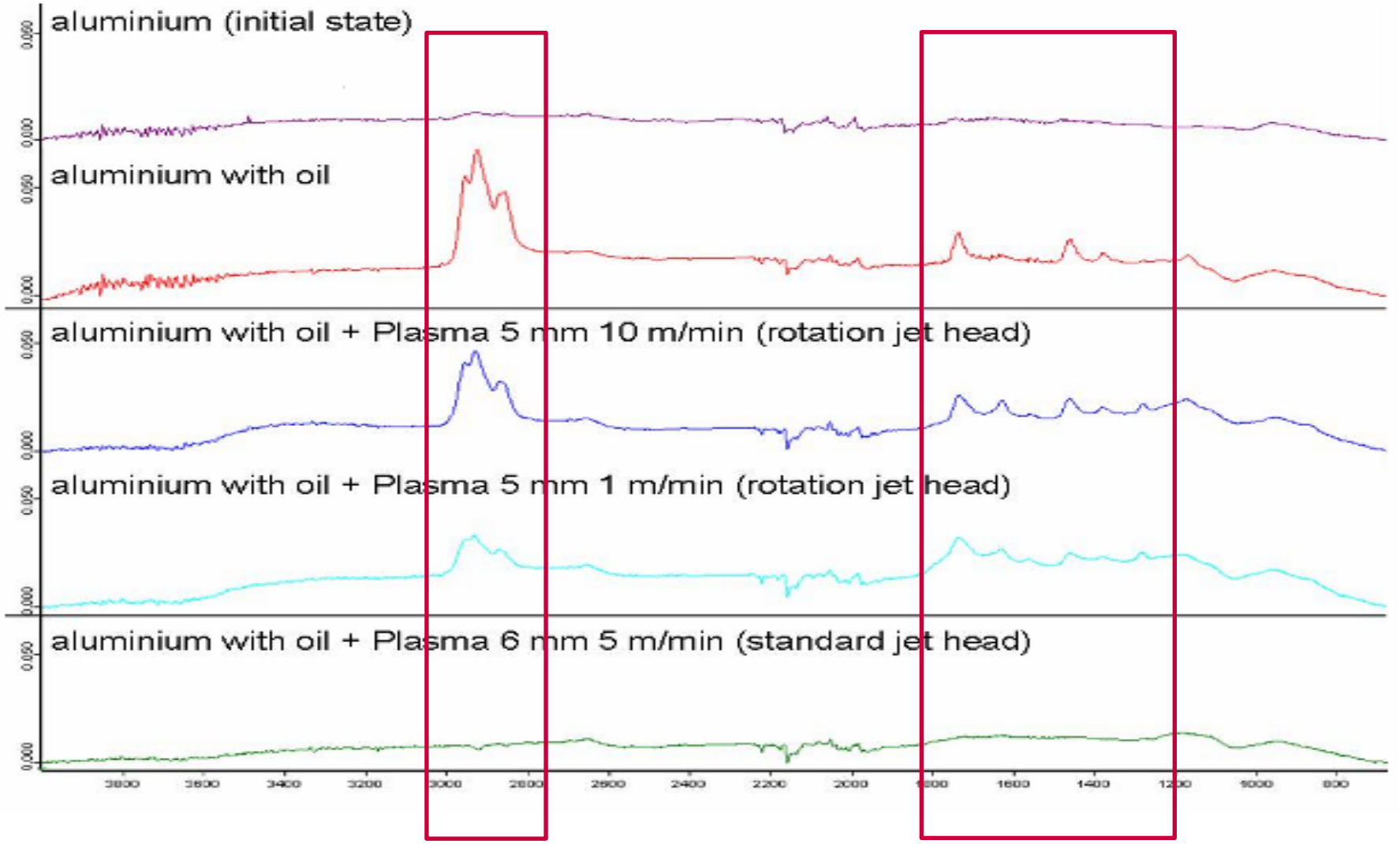


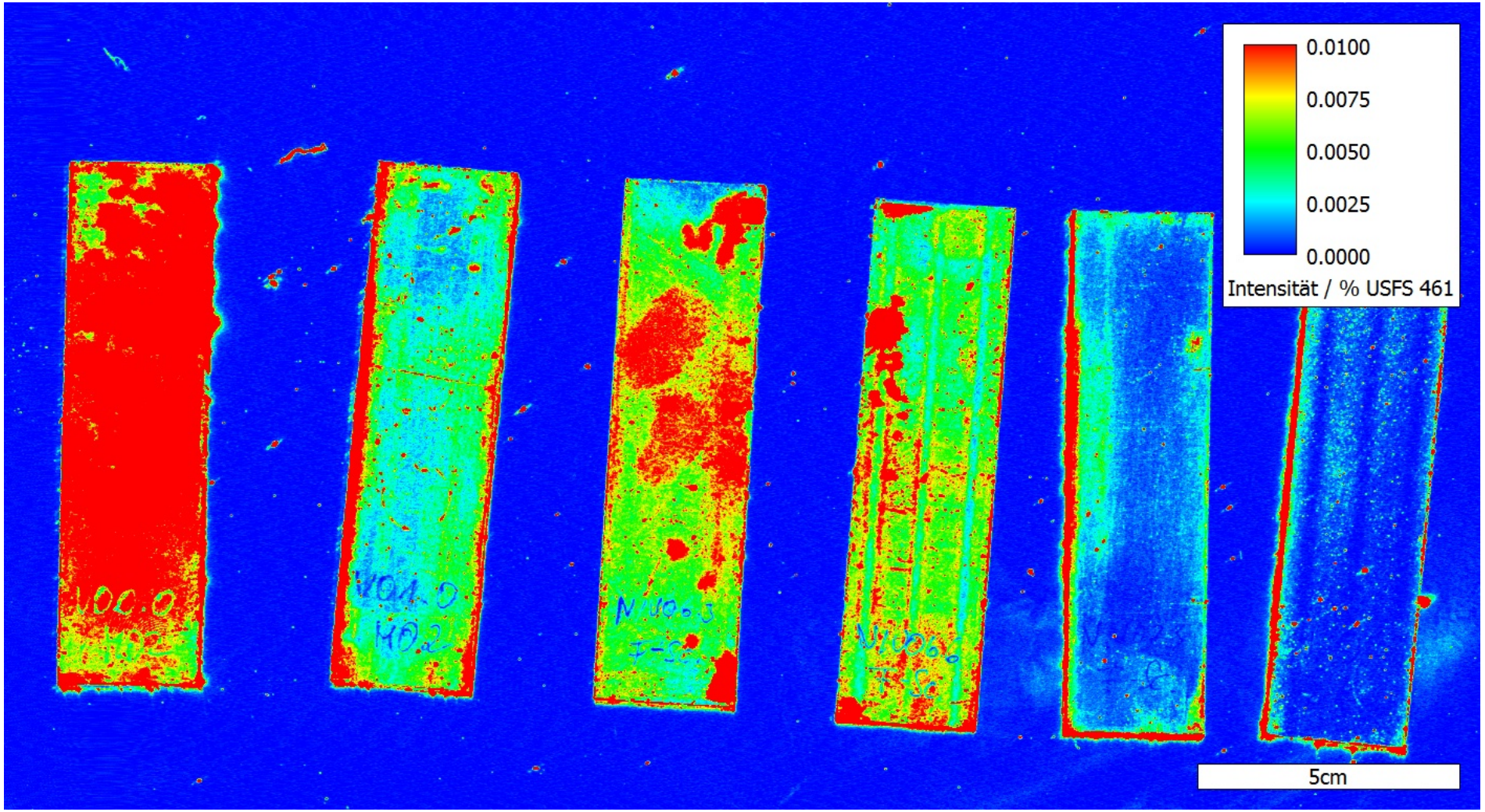
# Openair-Plasma®: Cleaning of polymer/metal surfaces

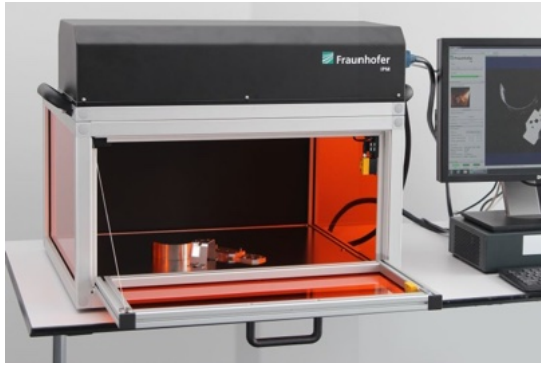


# Openair-Plasma® – Cleaning - FTIR measurement



# Openair-Plasma® – Cleaning

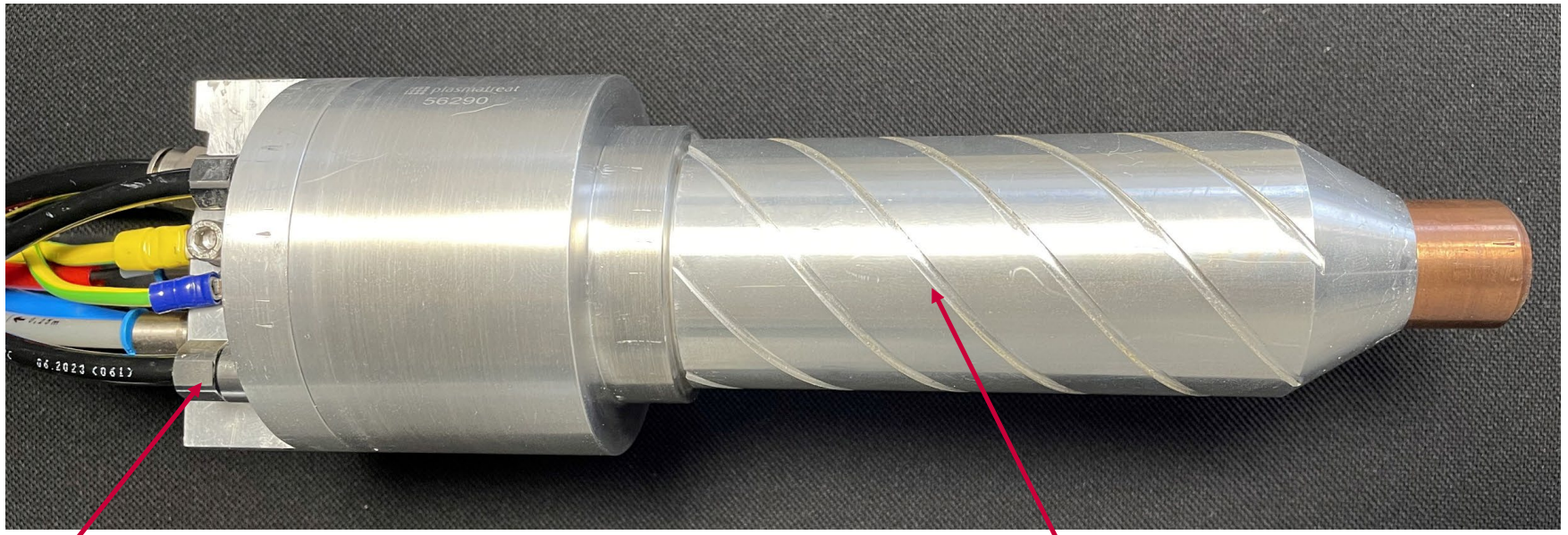



| Reference | IPA | Air | Forming gas | IPA + Air | IPA +Forming gas |
|---|---|---|---|---|---|

# Openair-Plasma® – Cleaning

Totally redesigned air chamber and inner electrode with the introduction of a water-cooled jet!

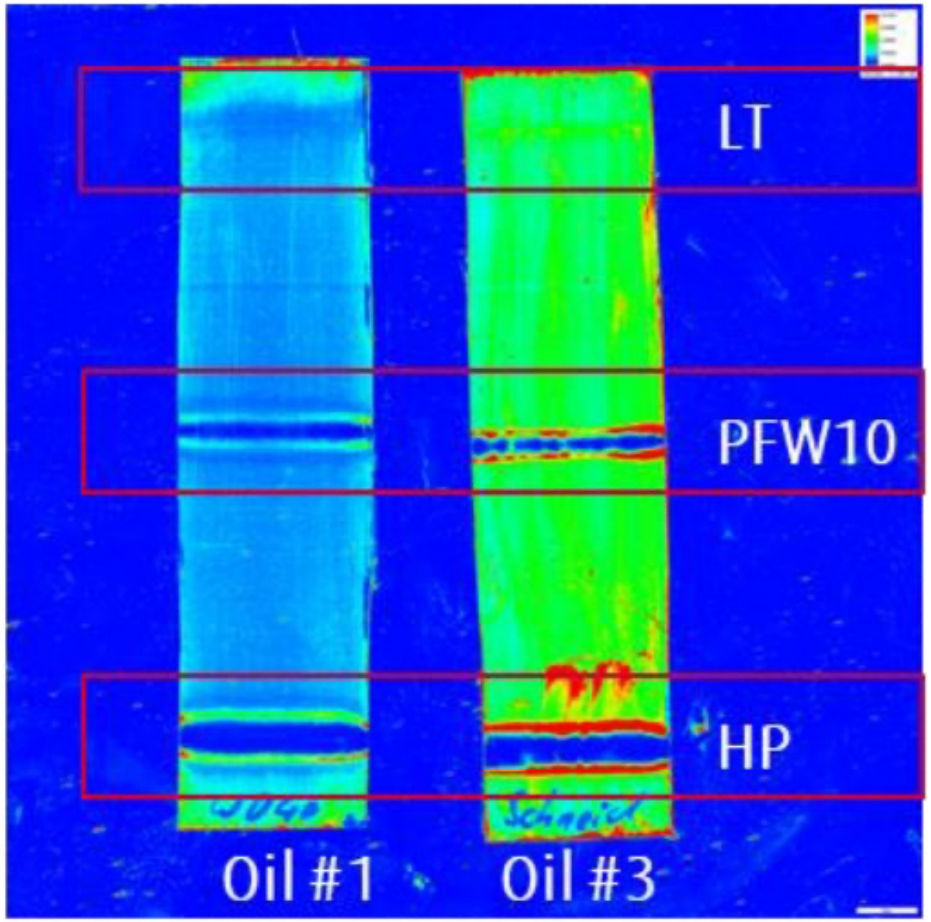



Water cooled

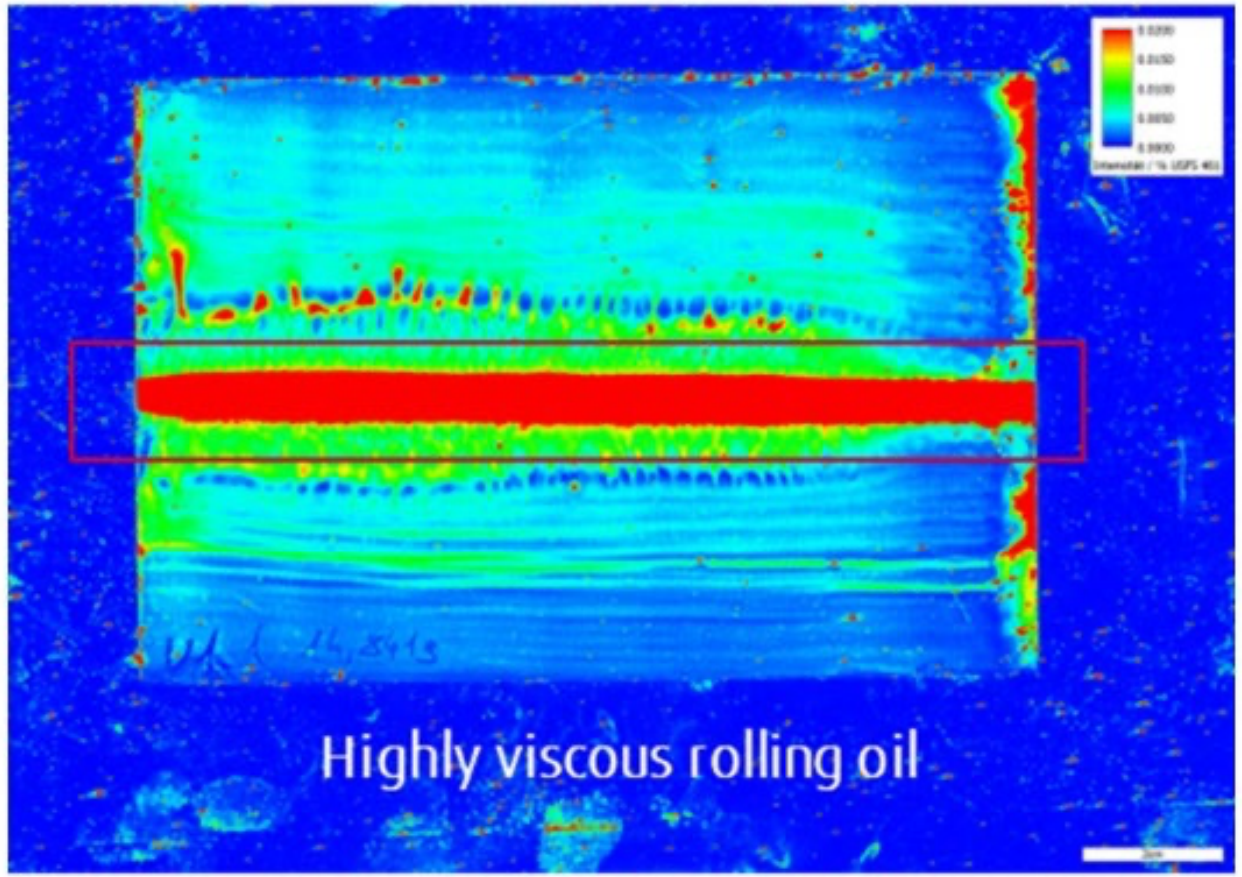
Helical machining for convection cooling

Four times more powerful than our standard jet!

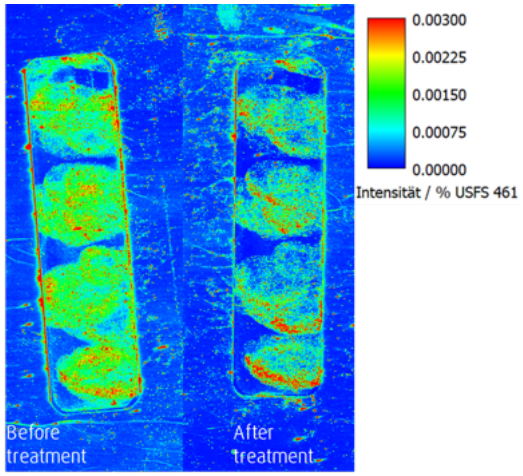
# Openair-Plasma® – Cleaning



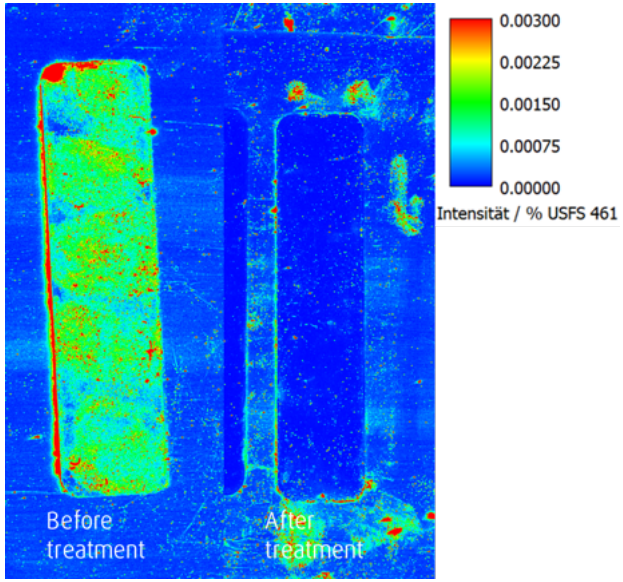

## Limitations: Resinification & Destruction



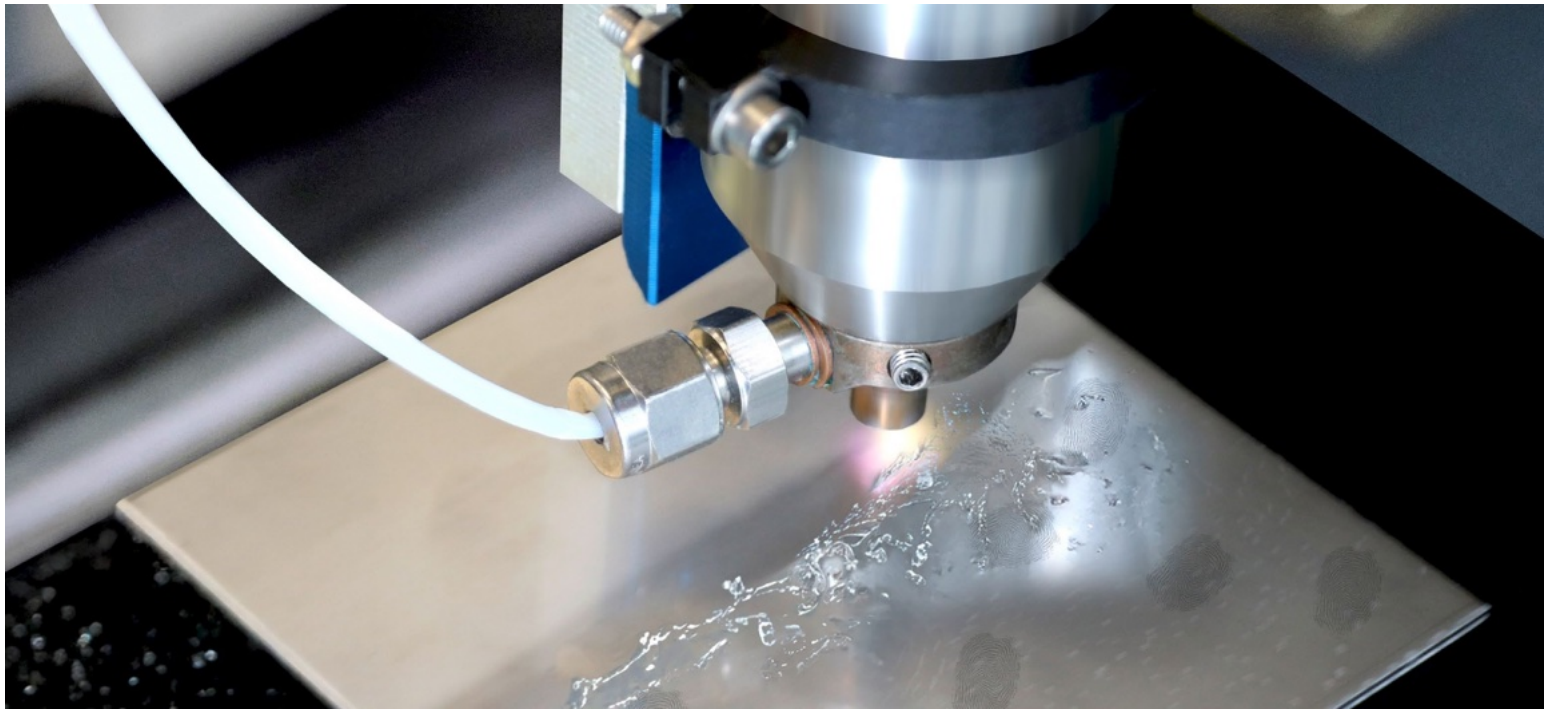
# Openair-Plasma® Hydroplasma– Cleaning



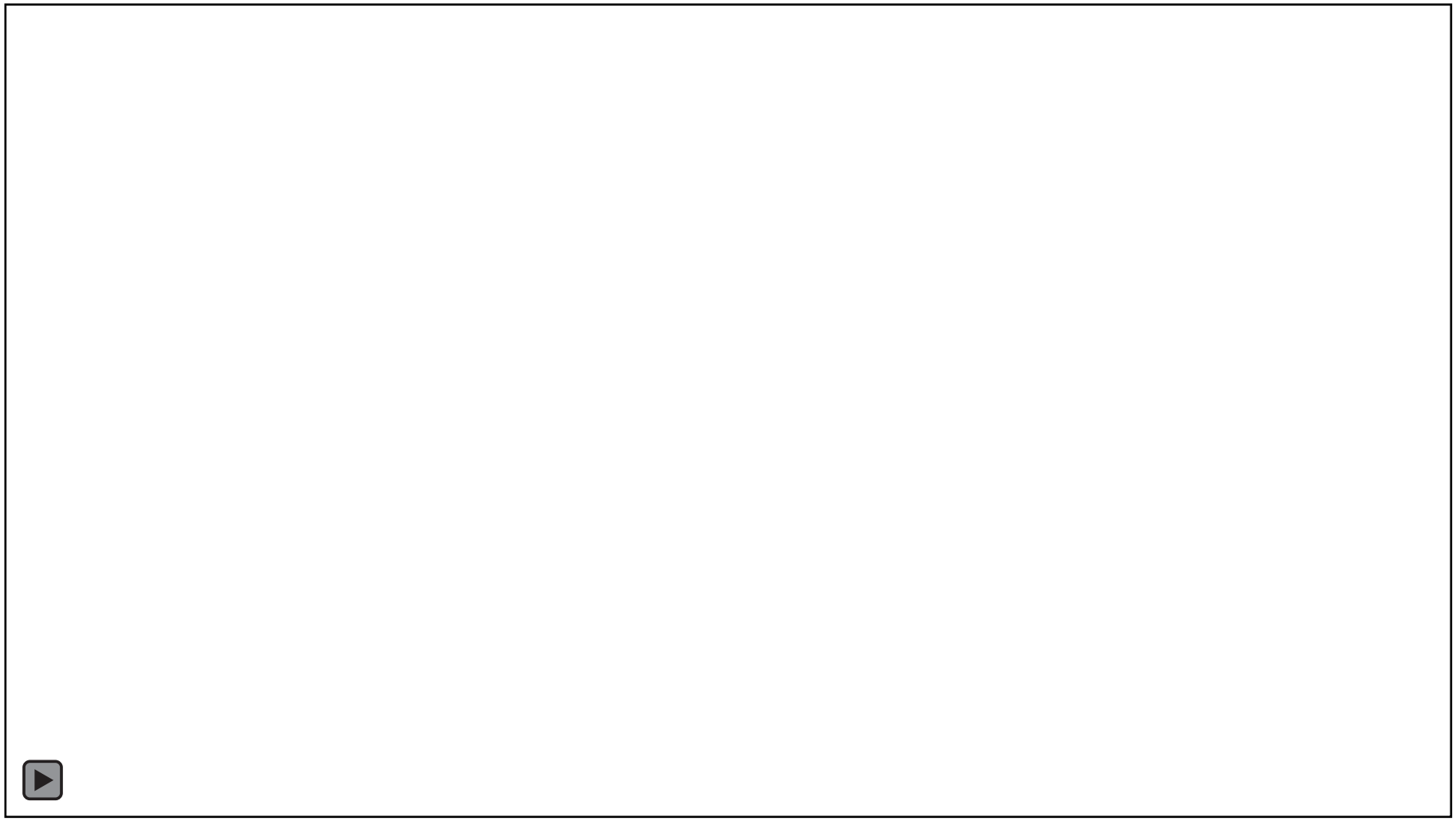

OpenAir-Plasma




Hydroplasma cleaning



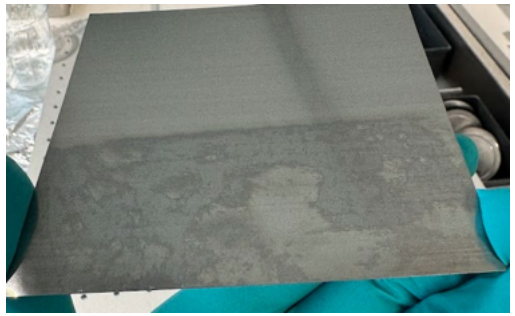
# Openair-Plasma® Hydroplasma– Cleaning

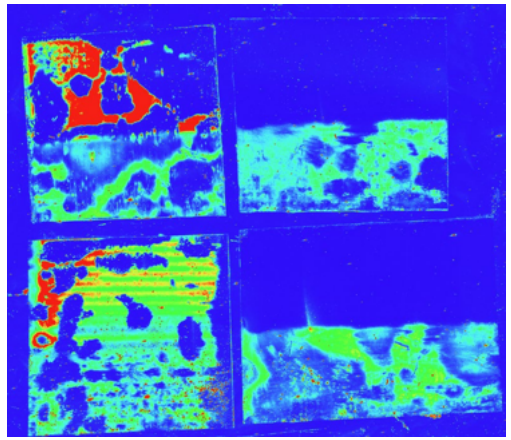


# Openair-Plasma® – Treatment of metal

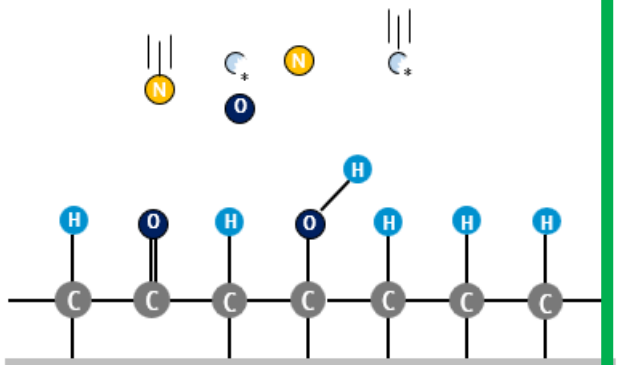
plasmatreat

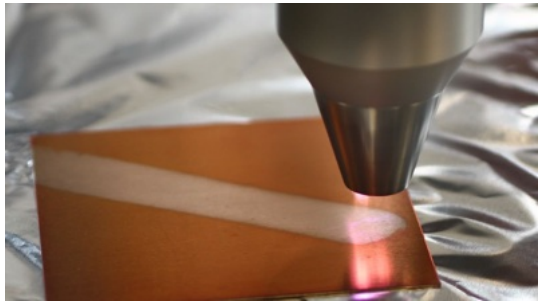
## Cleaning



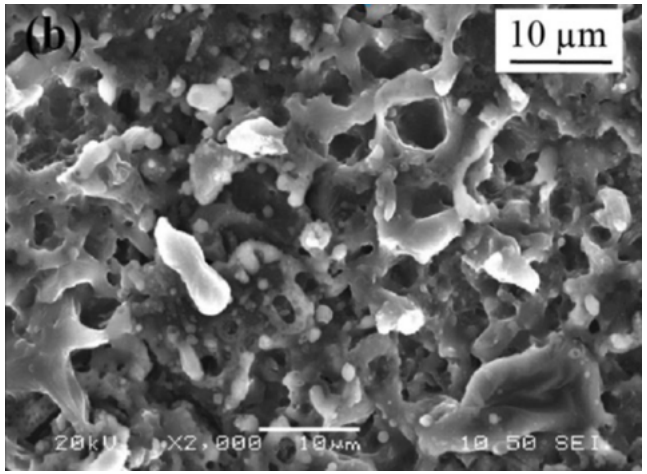


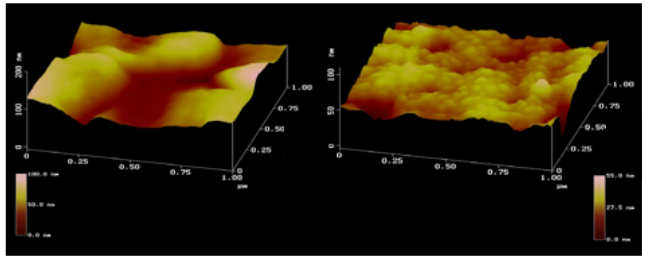
## Chemical Modification



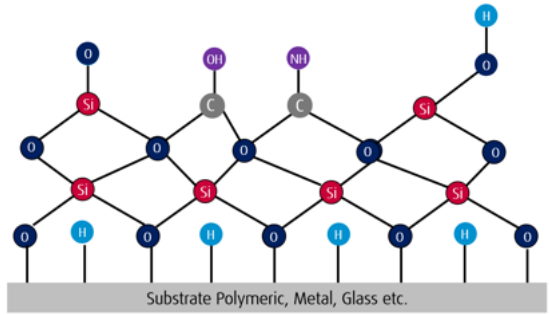



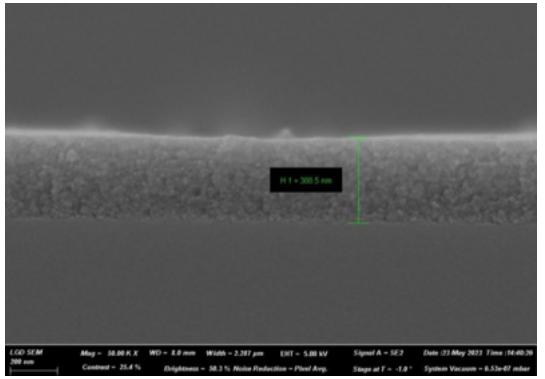
## Mechanical Modification



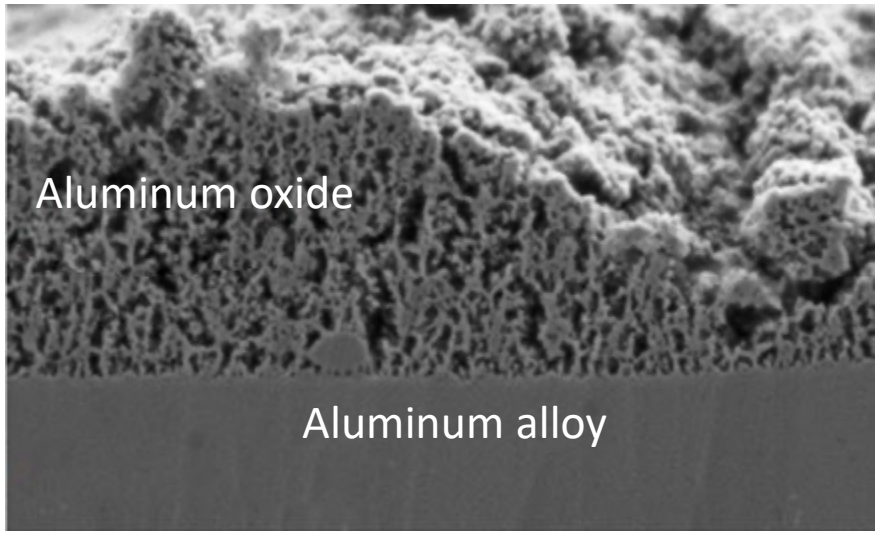
## Nanocoating



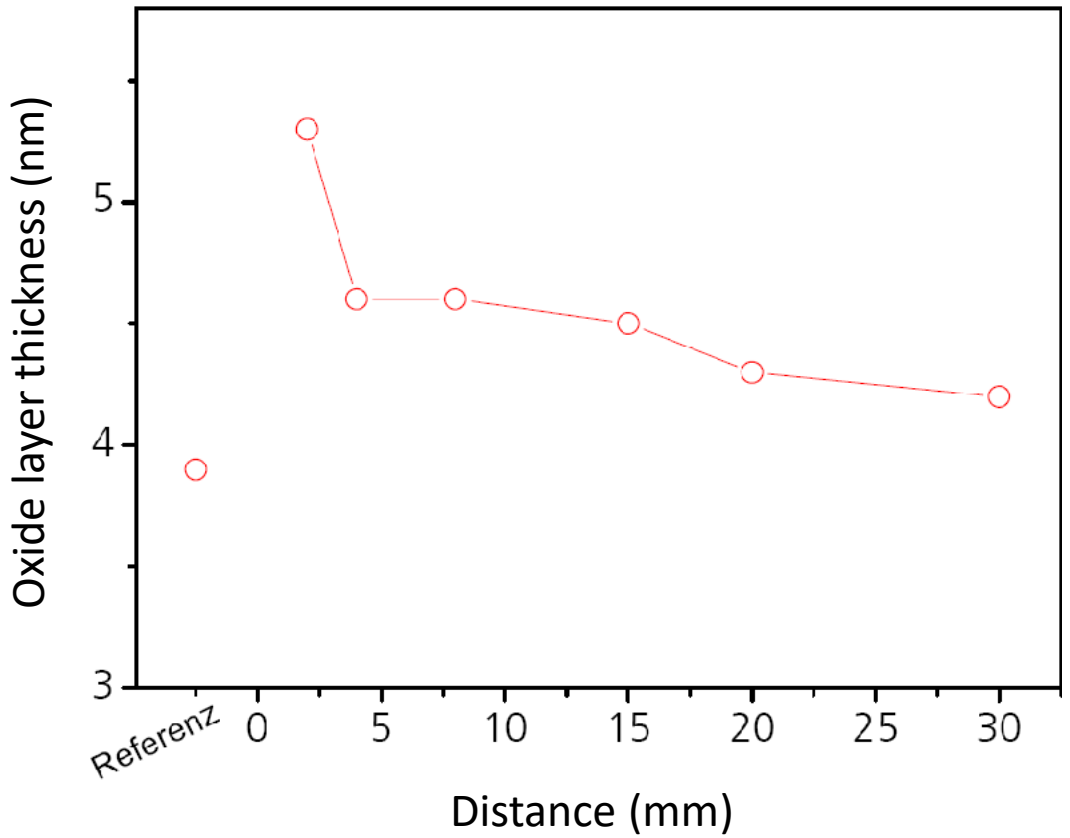



# Openair-Plasma® – Chemical modification

Layer thickness of aluminum oxide in
dependence of jet distance (measured by XPS)

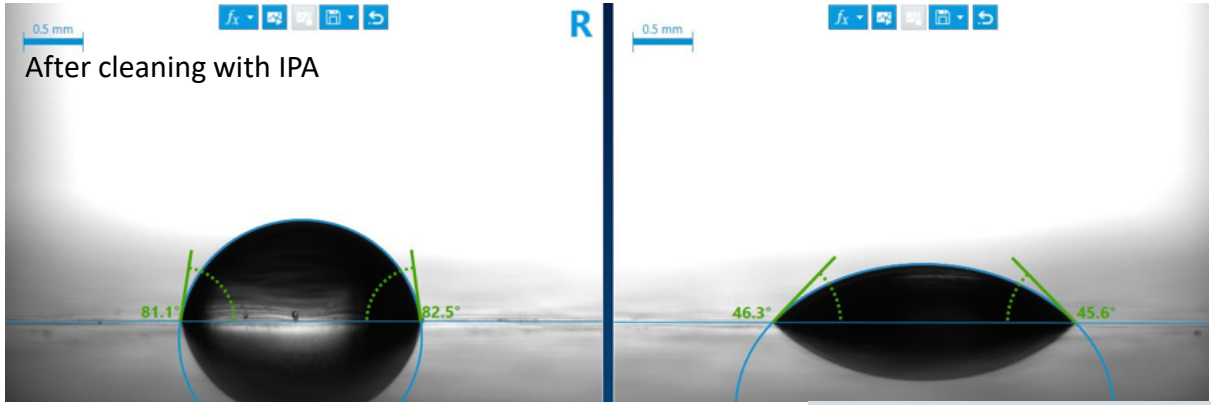



$O_2$-Plasma, 20 m/min
(alloy AA2024)

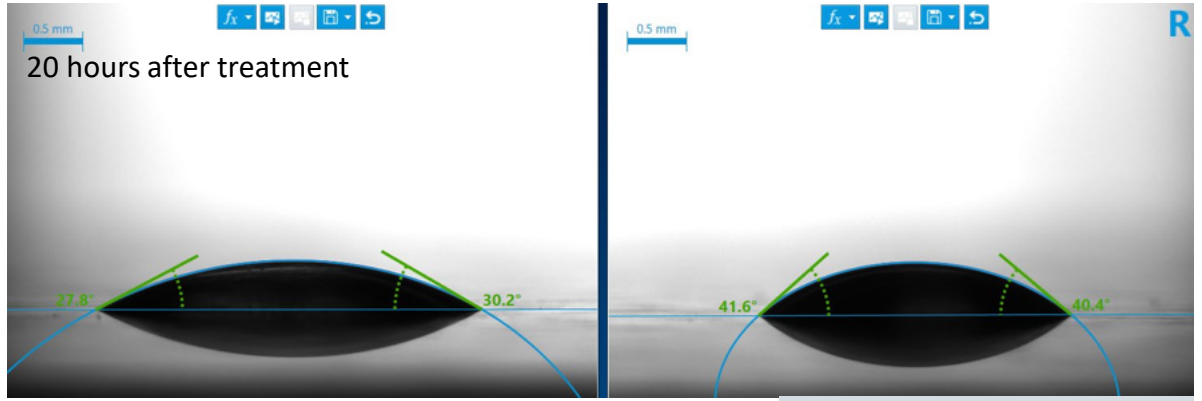


# Openair-Plasma® – Chemical modification

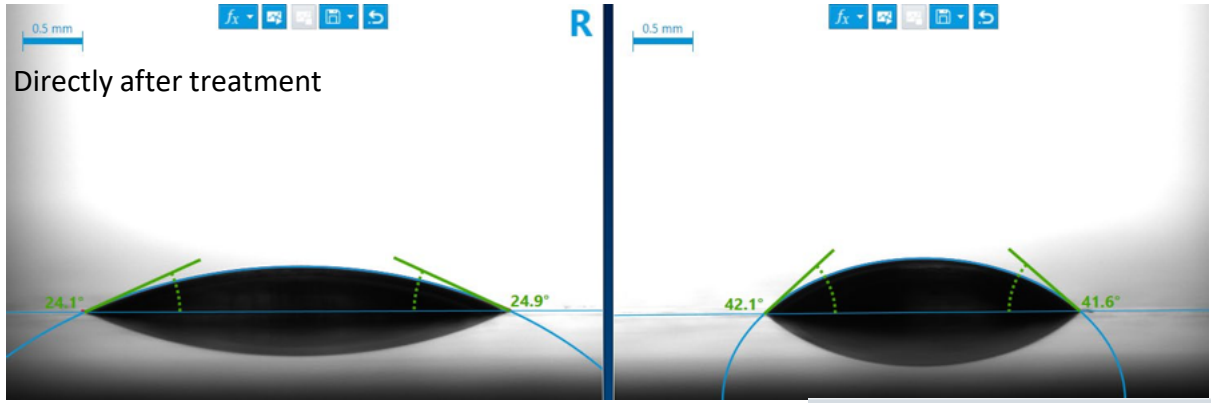
Al alloy 6082 (AlMgSi1)



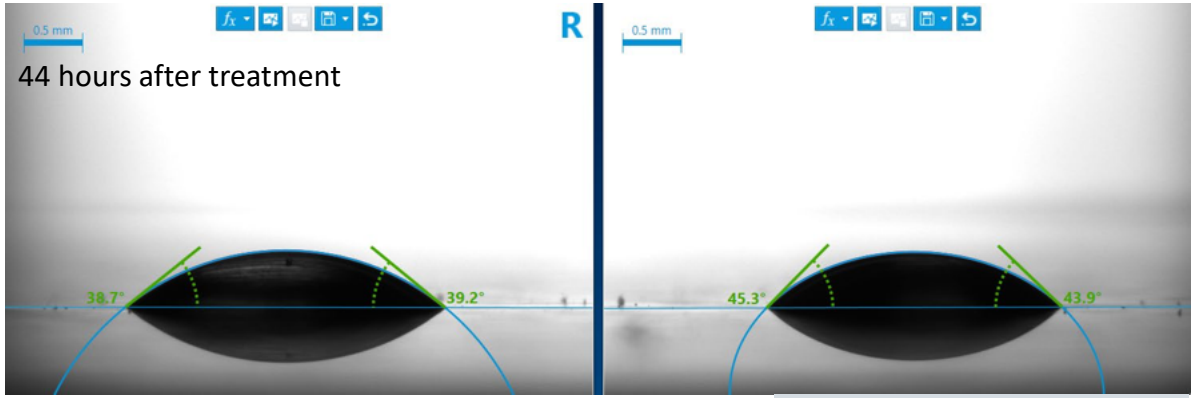

| | |
|---|---|
| SFE total | 38.96 ±3.55 mN/m |
| SFE disperse | 35.49 ±2.37 mN/m |
| SFE polar | 3.47 ±1.18 mN/m |




| | |
|---|---|
| SFE total | 68.68 ±0.99 mN/m |
| SFE disperse | 38.95 ±0.30 mN/m |
| SFE polar | 29.73 ±0.69 mN/m |

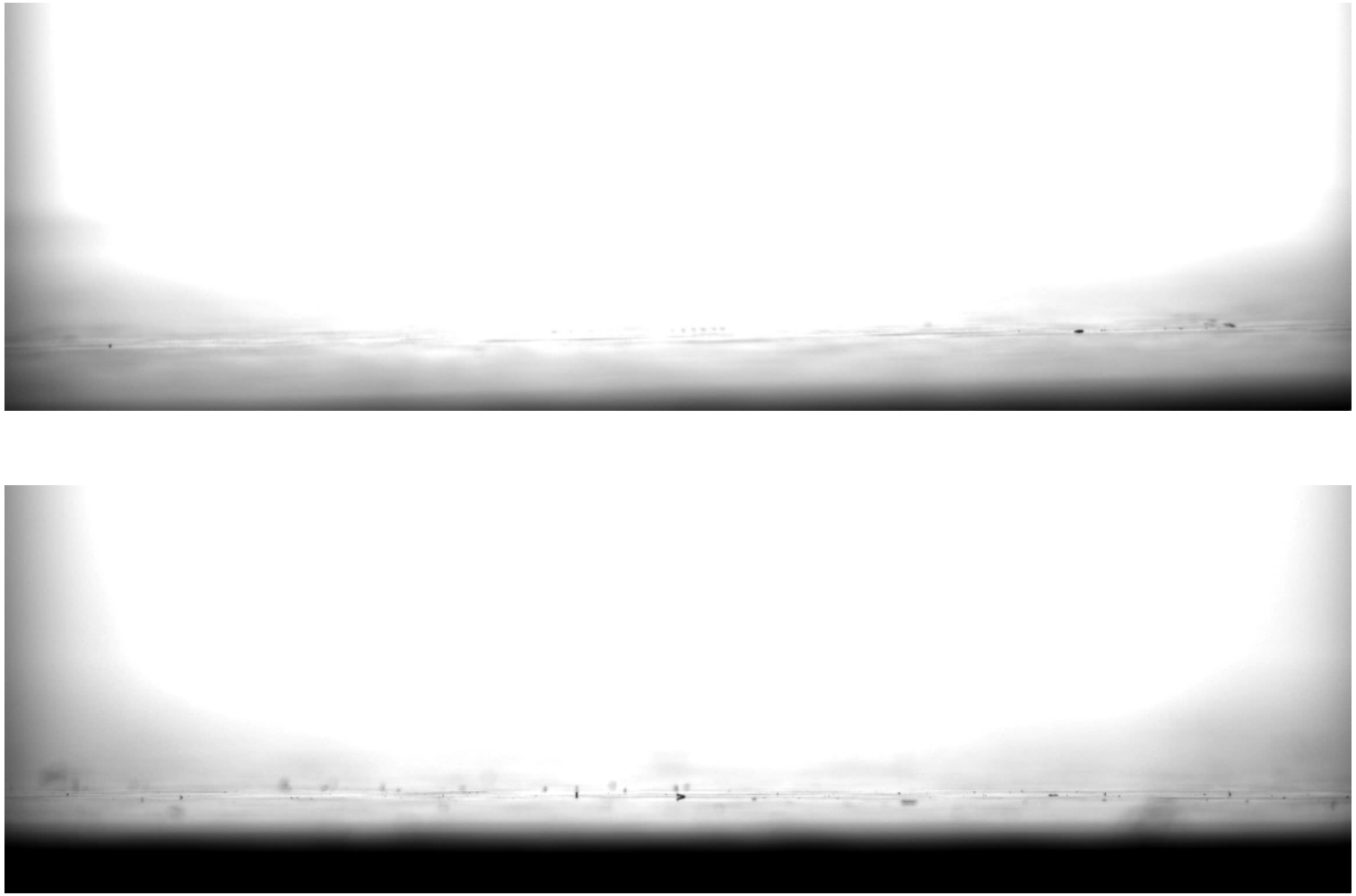



| | |
|---|---|
| SFE total | 70.00 ±1.55 mN/m |
| SFE disperse | 38.84 ±0.29 mN/m |
| SFE polar | 31.16 ±1.25 mN/m |



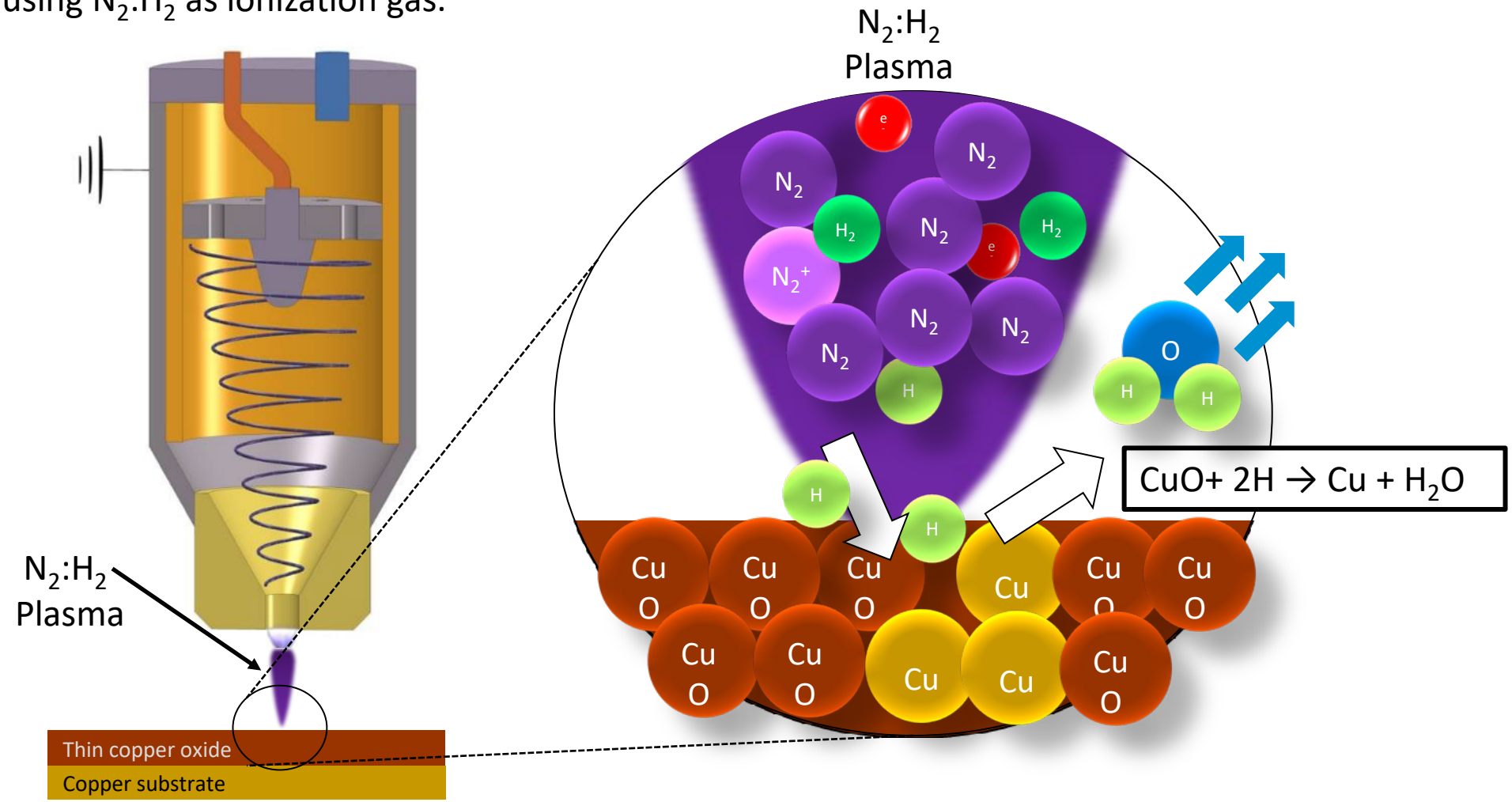

| | |
|---|---|
| SFE total | 63.01 ±1.27 mN/m |
| SFE disperse | 37.45 ±0.28 mN/m |
| SFE polar | 25.56 ±0.99 mN/m |

# Openair-Plasma® – Chemical modification



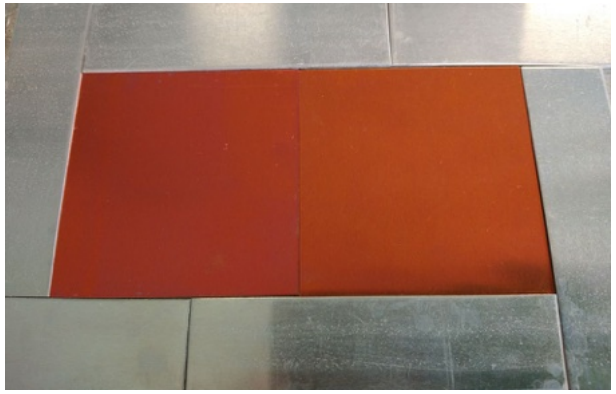
# Openair-Plasma® - Chemical modification - Reduction

Surface reduction using $N_2$:$H_2$ as ionization gas.

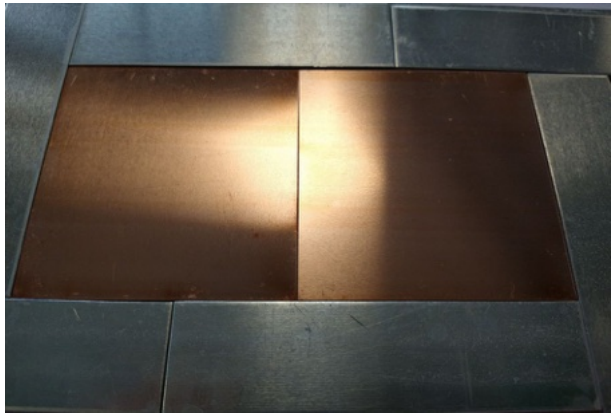


# Openair-Plasma® - Chemical modification - Reduction

Before:

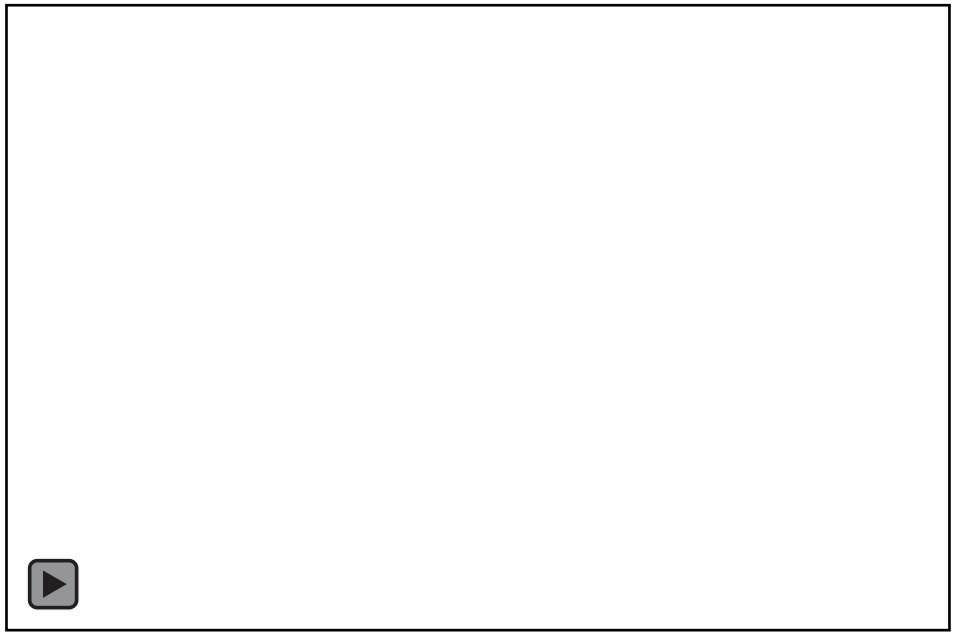


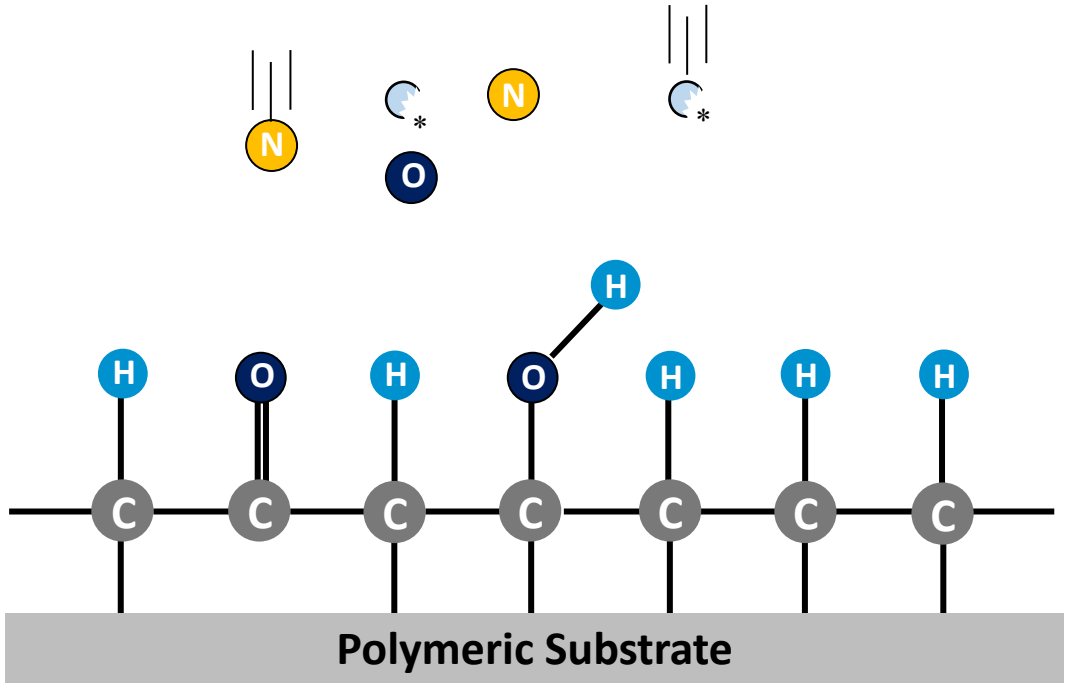
After:



# Openair-Plasma®: Activation of polymer surfaces

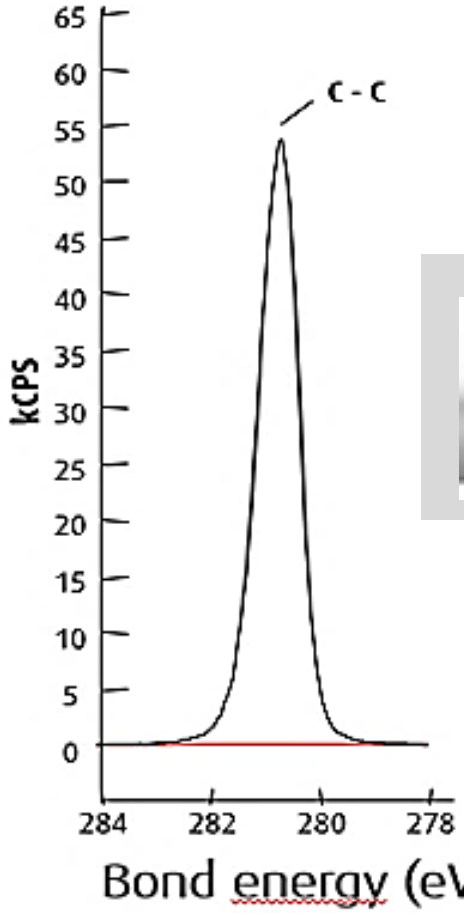
Activation = formation of functional groups

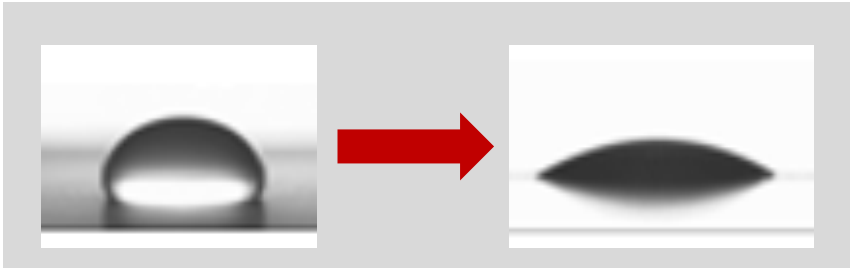




# Surface activation – XPS analysis on plastics

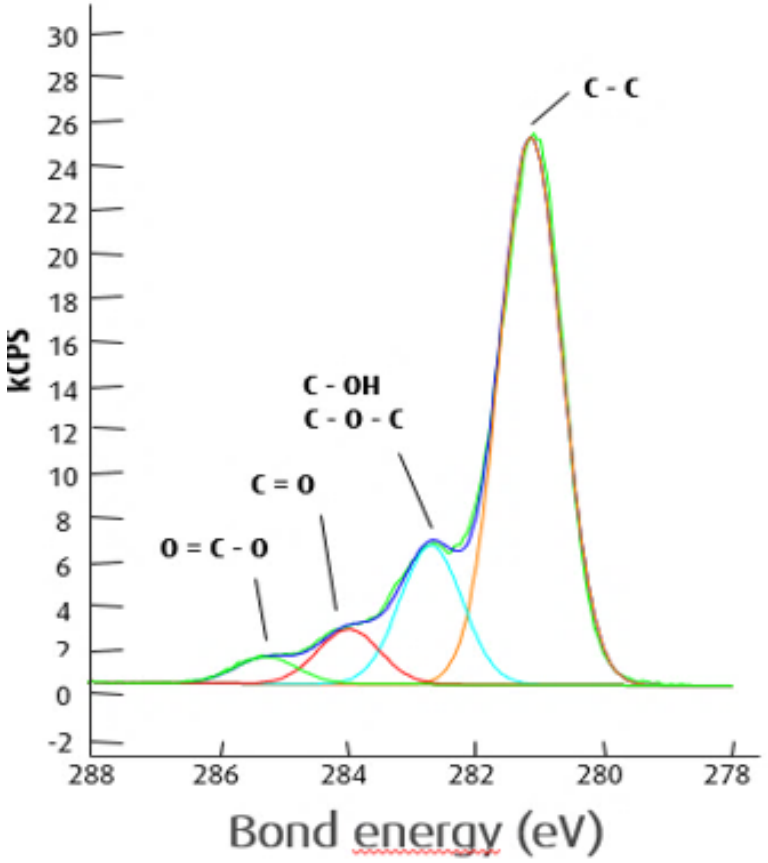
**Polypropylene (PP): untreated**
> Surface energy: **27 mN/m**



Fraunhofer IFAM

**PP: Openair-Plasma® treated**
> Surface energy: up to **72 mN/m**



# State of the art – Polyurethane In-Mold Coating (PUR-IMC)



Consumer

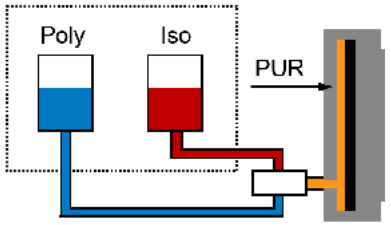
Automotive

PUR-IMC-coated Class-A-surfaces with PC or PC/ABS carrier and optional decorative PC-film

Special effects e.g. sensors or lightning beneath transparent coating

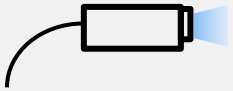
M.Sc. Johanna Hausmann, Research Associate, Neue Materialien Bayreuth GmbH

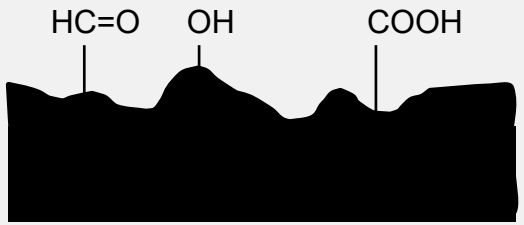
# Plasma adhesion mechanisms

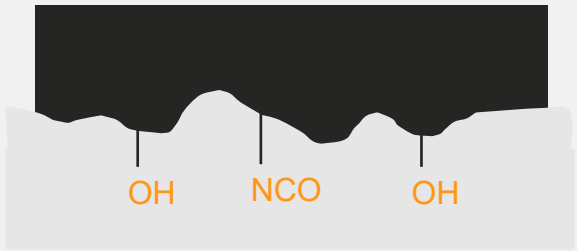



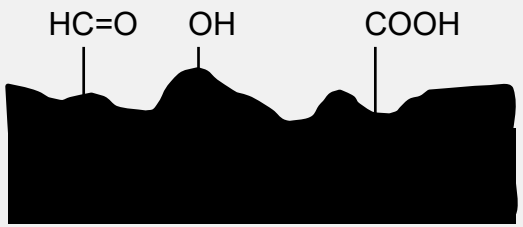


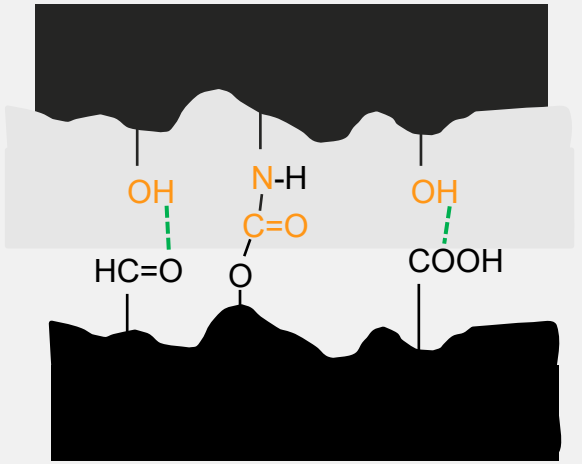
## Plasma treatment






**Change in surface topography & functionality**

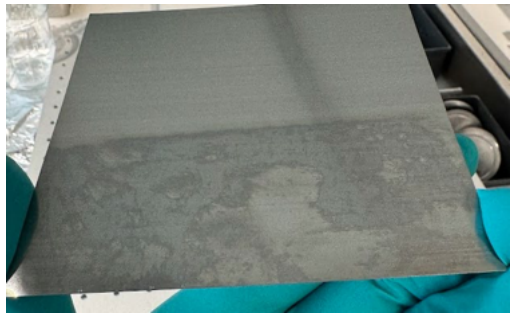
**Chemical interactions due to reactive polyurethane coating system & physical interlocking due to surface roughness**

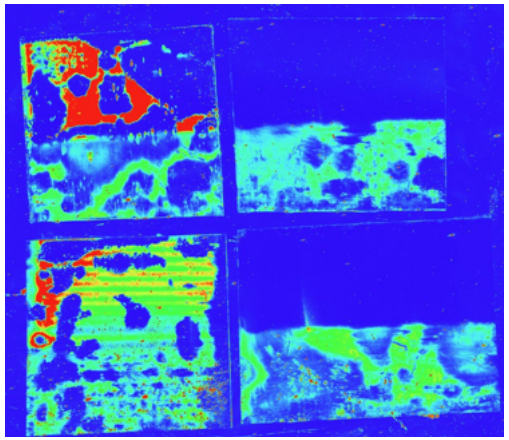
M.Sc. Johanna Hausmann, Research Associate, Neue Materialien Bayreuth GmbH

# Openair-Plasma® – Treatment of metal

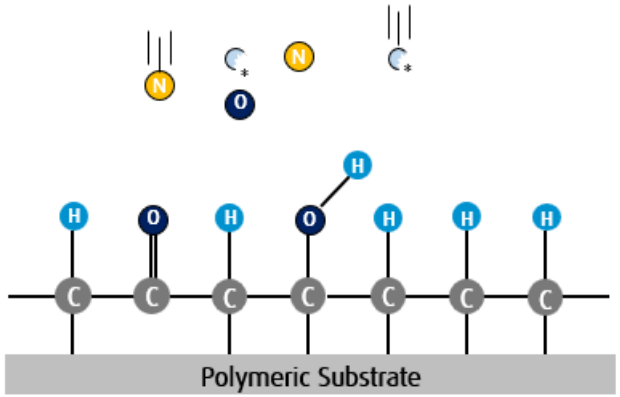
plasmatreat

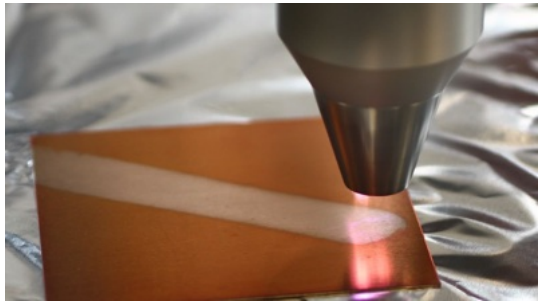
## Cleaning



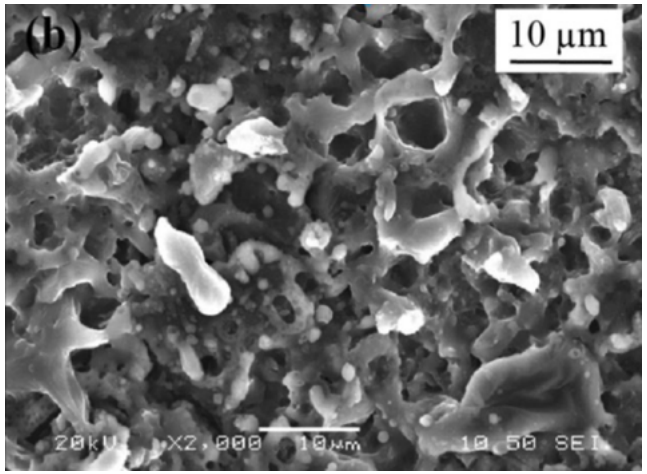


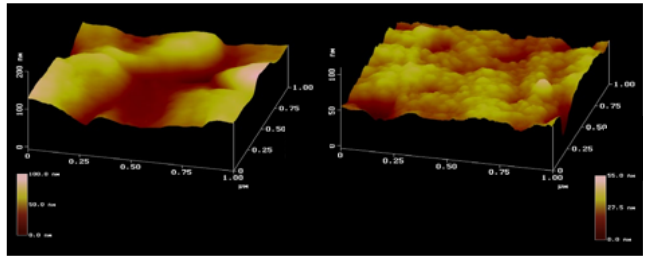
## Chemical Modification



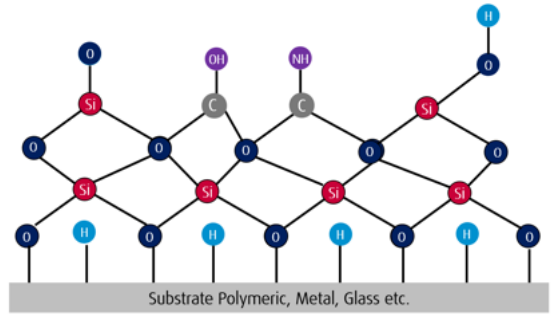



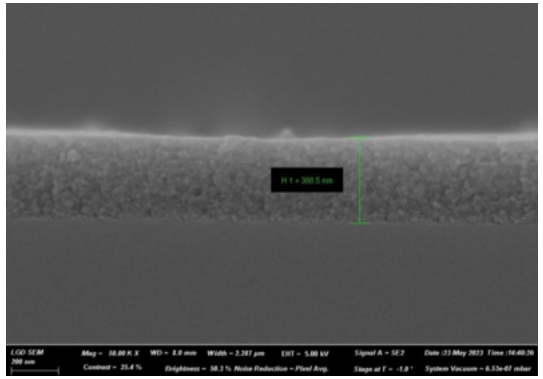
## Mechanical Modification



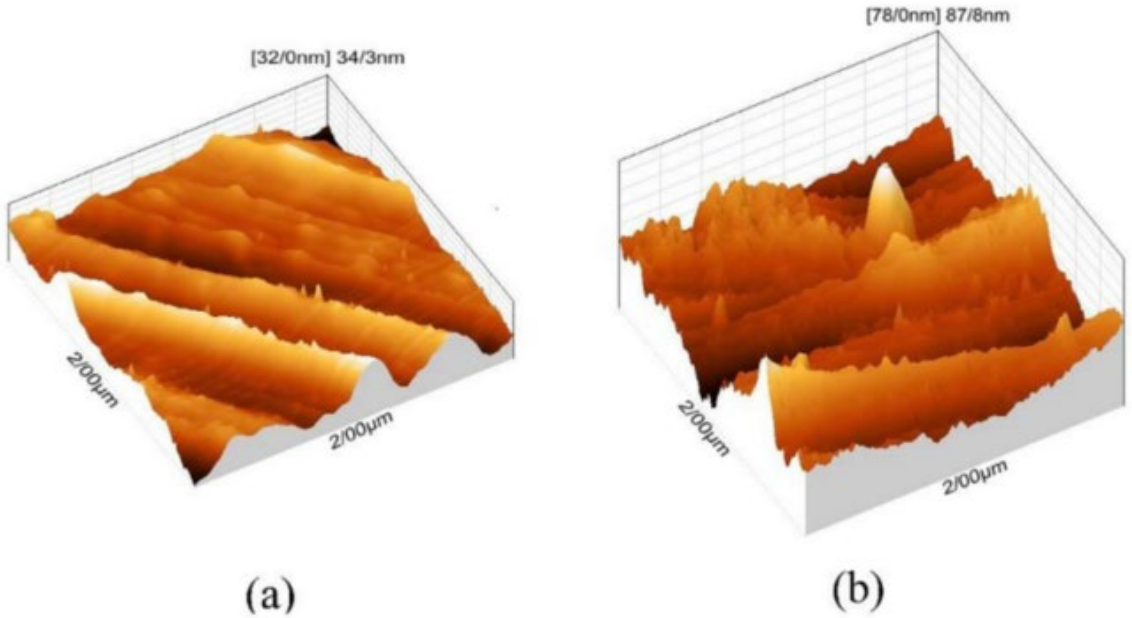
## Nanocoating



# Openair-Plasma® – Mechanical Modification

*A. Maroofi et al.*

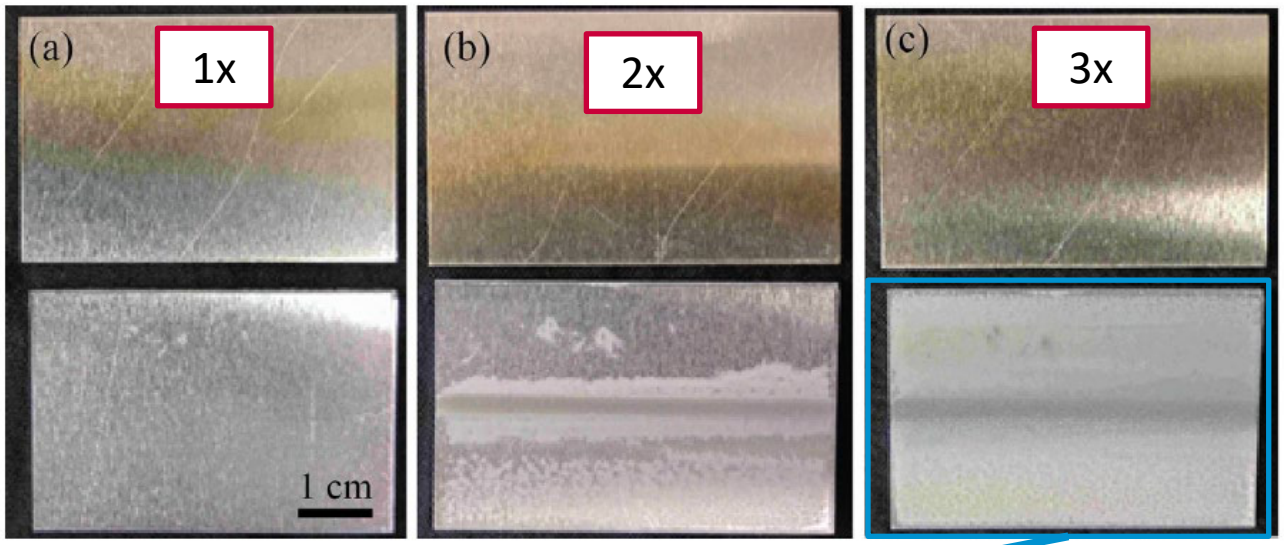



| Parameter | Untreated | Plasma treated |
|---|---|---|
| $R_a$ | 4.2 nm | 8.4 nm |
| $R_q$ | 5.4 nm | 11.0 nm |
| $R_z$ | 30.9 nm | 67.0 nm |

Atmospheric air plasma jet for improvement of paint adhesion to aluminium surface in industrial applications
A. Maroofi, N. Navab Safa *, H. Ghomi

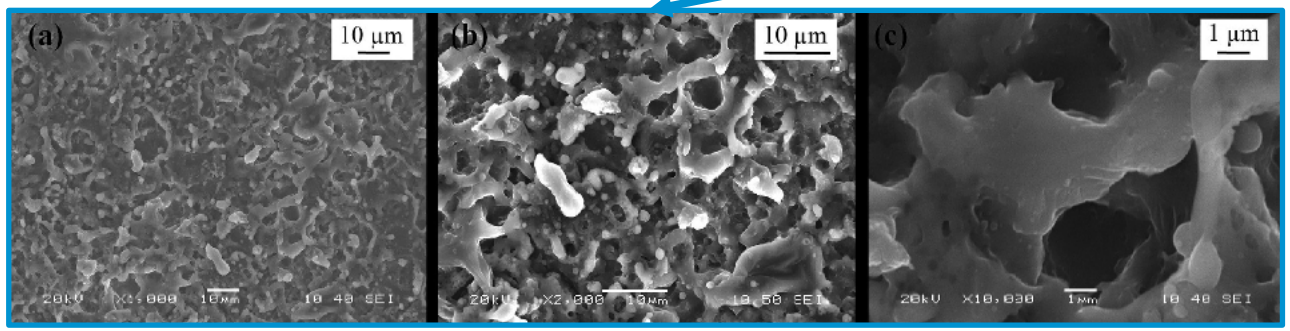
# Openair-Plasma® – Mechanical Modification

AL6061



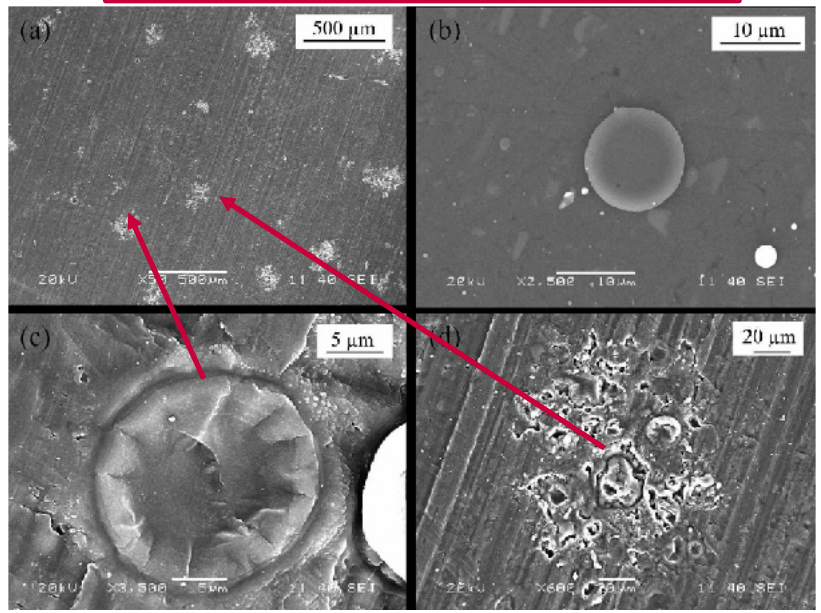

$N_2$

Air




1000x 2000x 10000x

One pass with Plasma

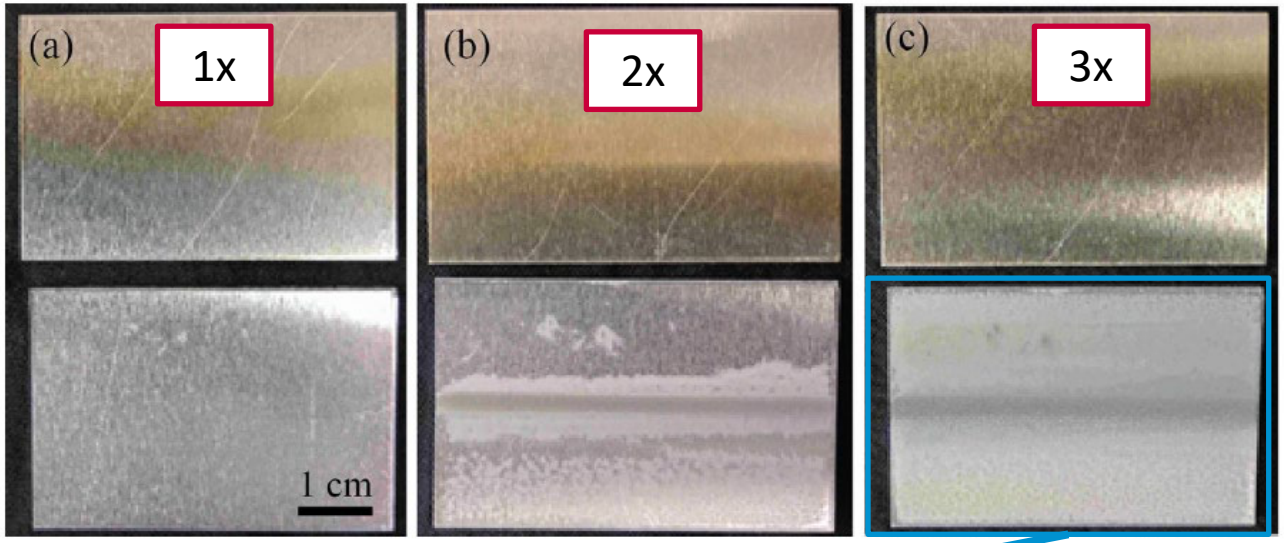



Dominant structure after multiple passes

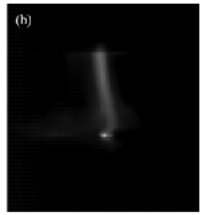
Highly porous micro-roughened structures developed on aluminum surface using the jet of rotating arc discharges at atmospheric pressure
Siavash Asadollahin, Masoud Farzaneh, Luc Stafford (Univeristy of Montreal)

# Openair-Plasma® – Mechanical Modification

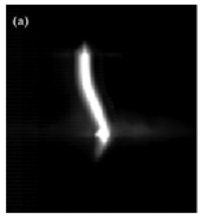
AL6061

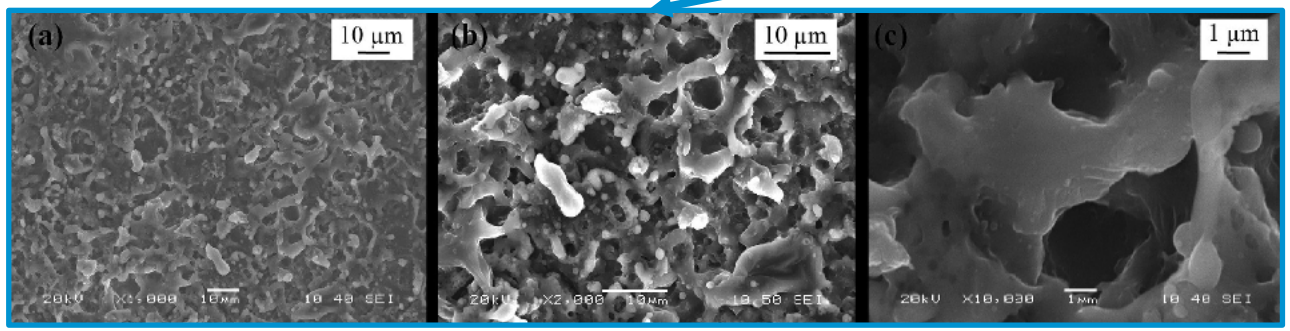



$N_2$

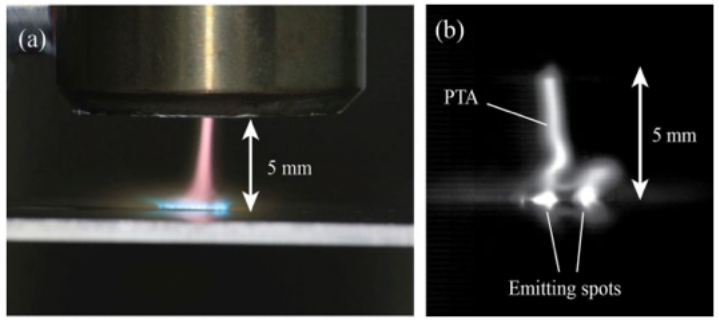


Air






1000x 2000x 10000x




Highly porous micro-roughened structures developed on aluminum surface using the jet of rotating arc discharges at atmospheric pressure
Siavash Asadollahin, Masoud Farzaneh, Luc Stafford (Univeristy of Montreal)

# Openair-Plasma® – Mechanical Modification

# Challenges for metal bonds - Corrosion

A clean and activated surface usually bonds well with the correct selection of adhesive or paint chemistry.

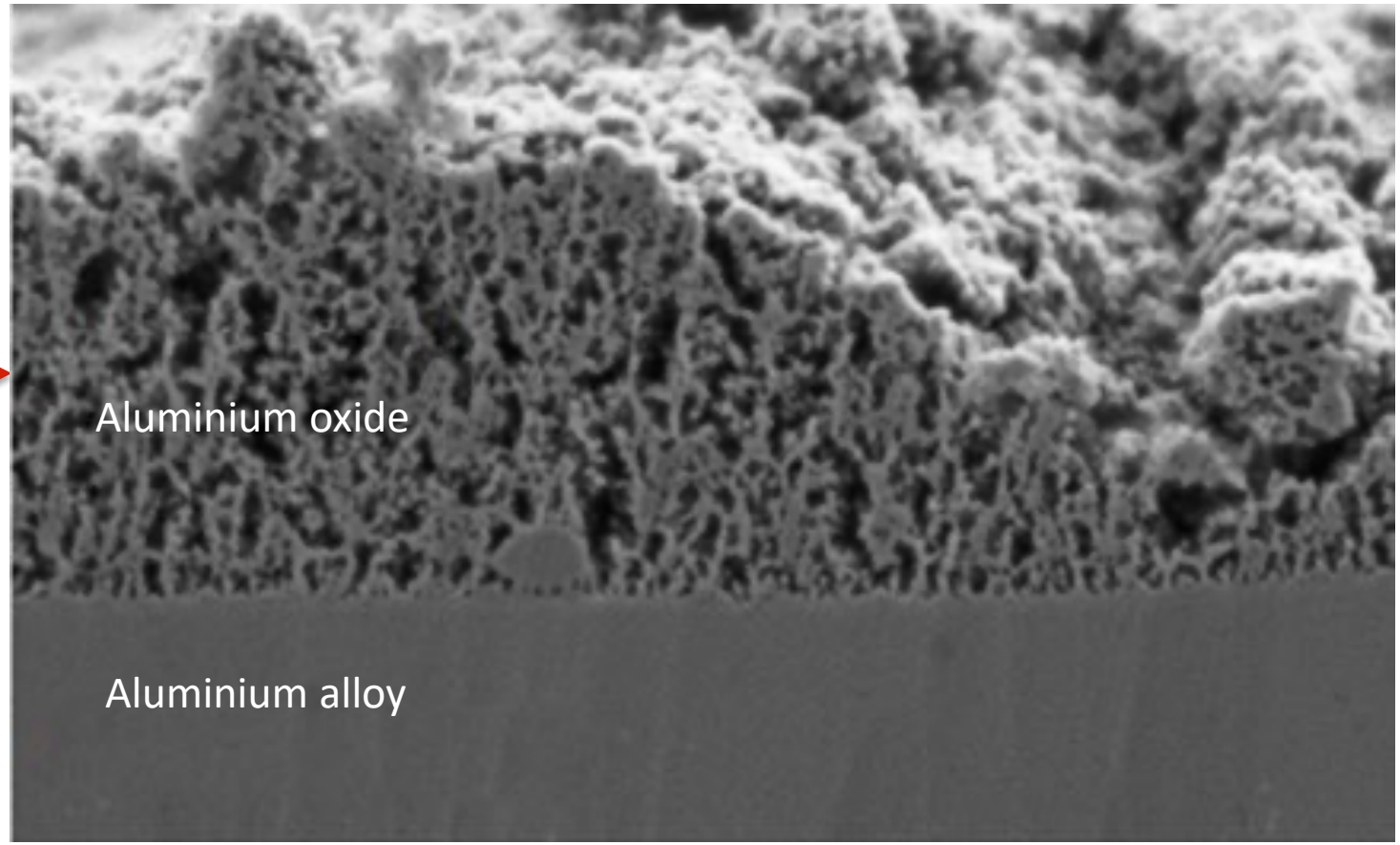
But what about the life of this bond – what can affect this?

**Bond line corrosion.**

# Challenges for metal bonds - Corrosion

Example of
***Environmental Corrosion***

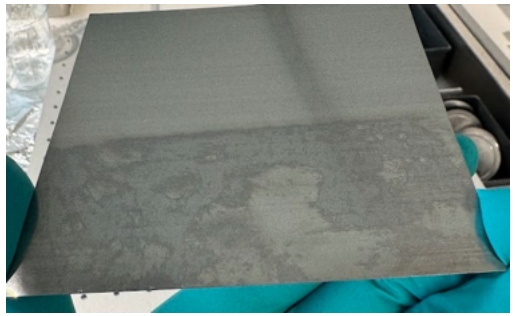
Ingress of saltwater causes oxide layer to corrode

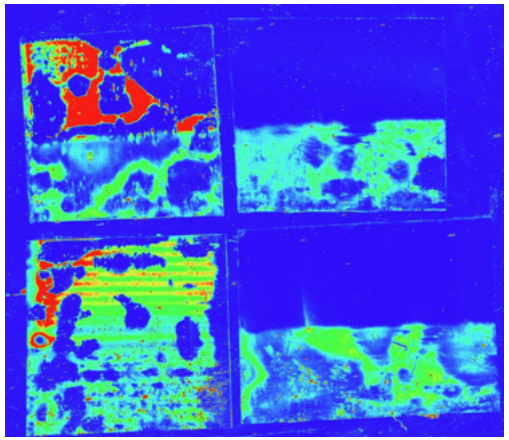


# Openair-Plasma® – Nanocoating

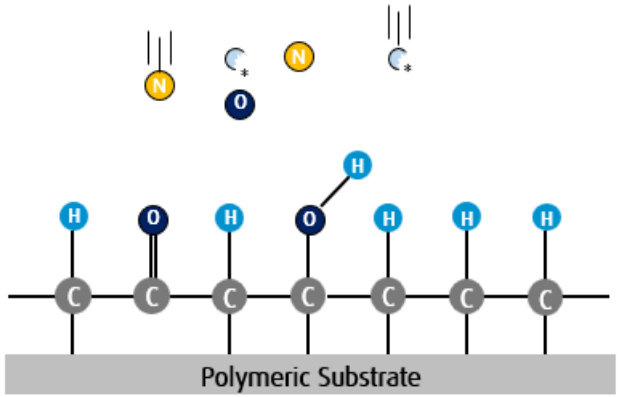
plasmatreat

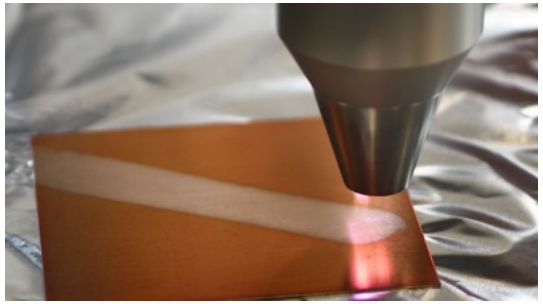
## Cleaning



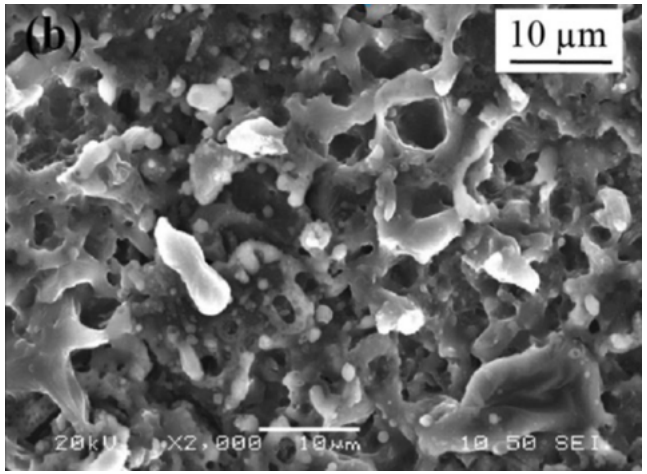


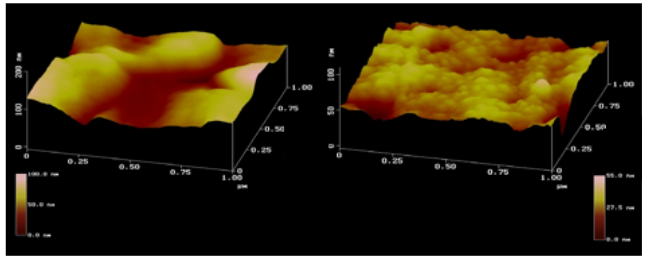
## Chemical Modification



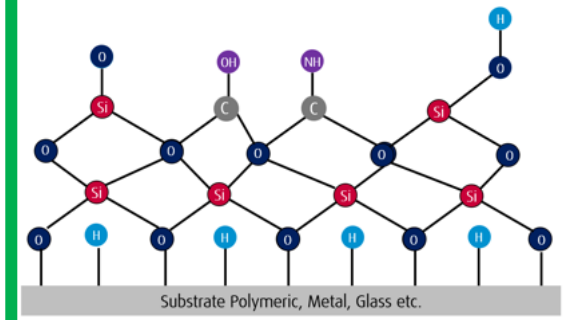



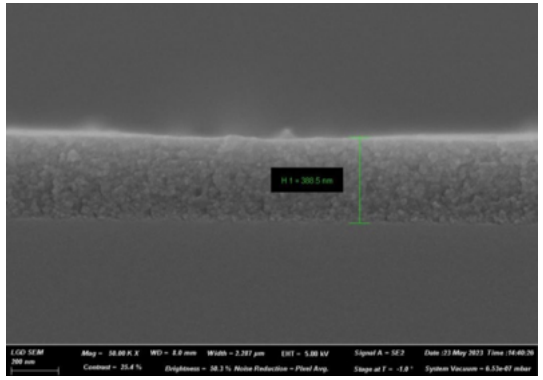
## Mechanical Modification



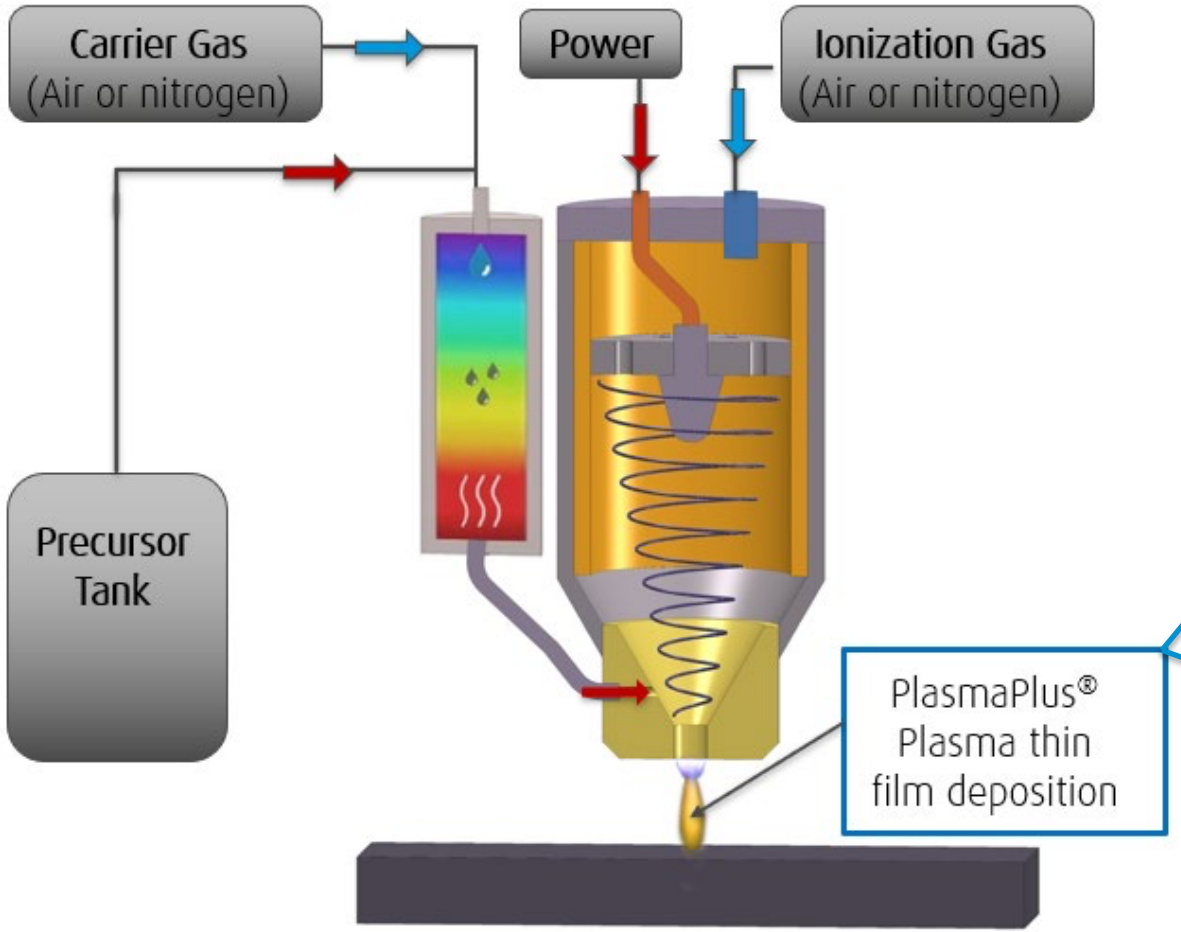



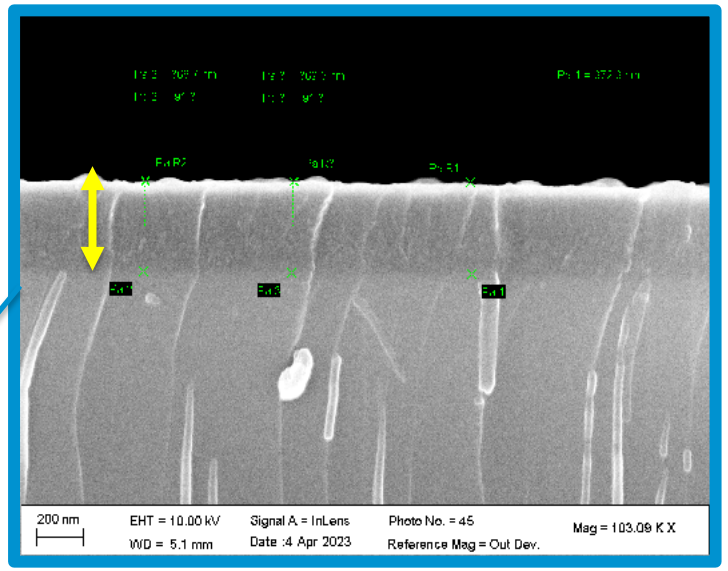
## PlasmaPlus® Nanocoating

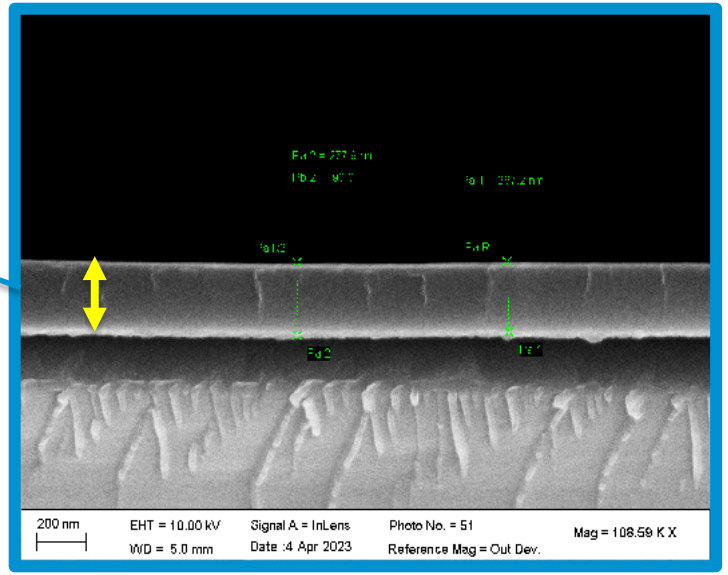


# PlasmaPlus® Process

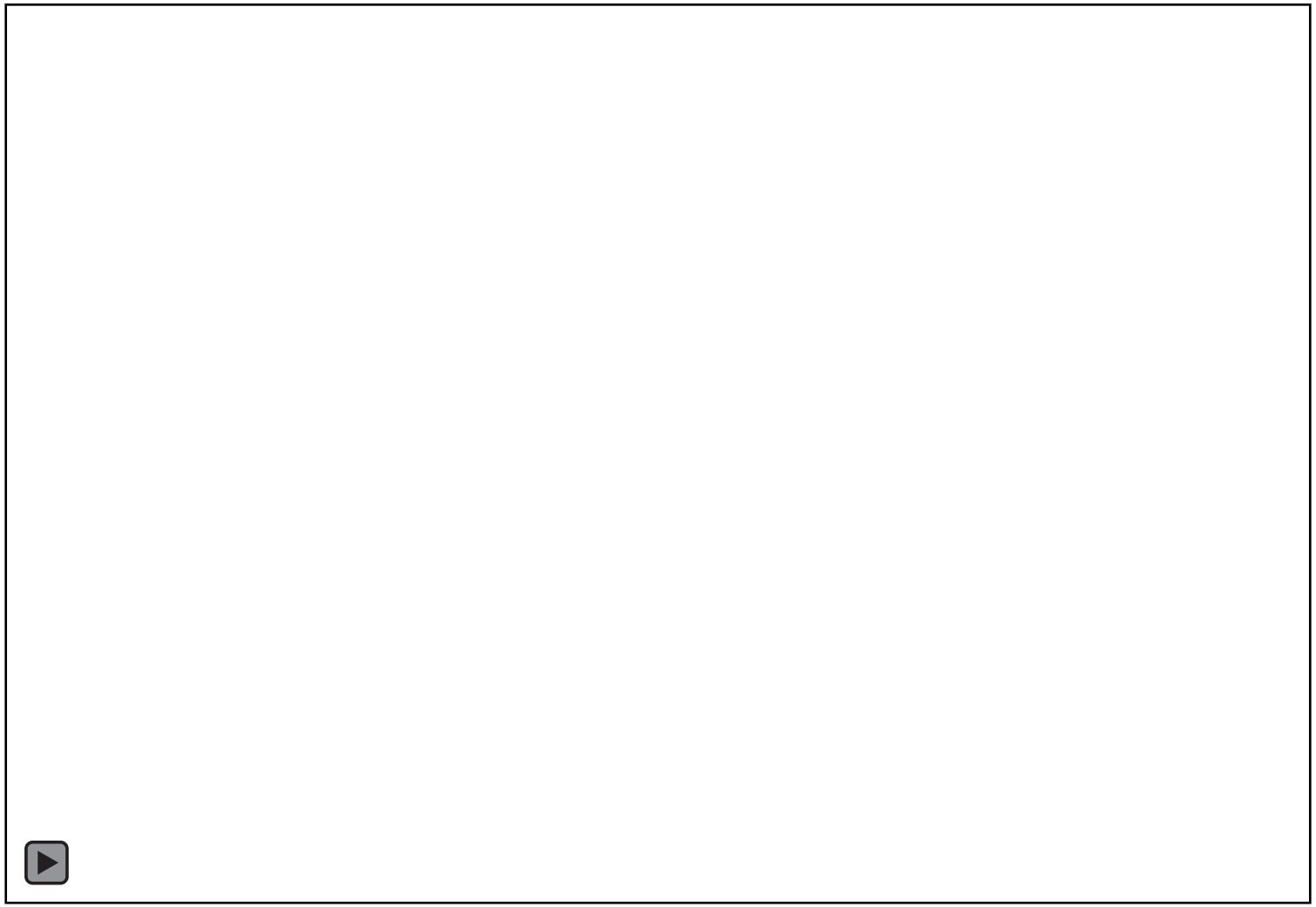


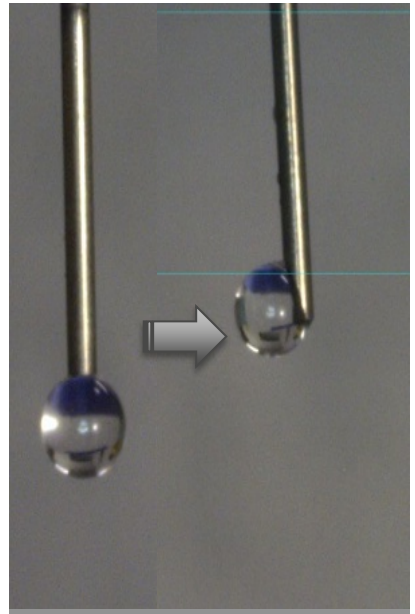

Layer thickness 20 -600 nm

# Openair-Plasma® coating

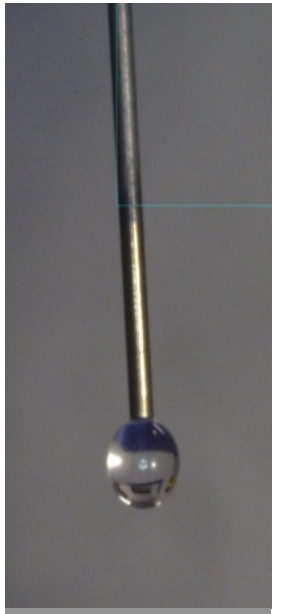


plasmatreat

# Superhydrophobic non-stick Coatings

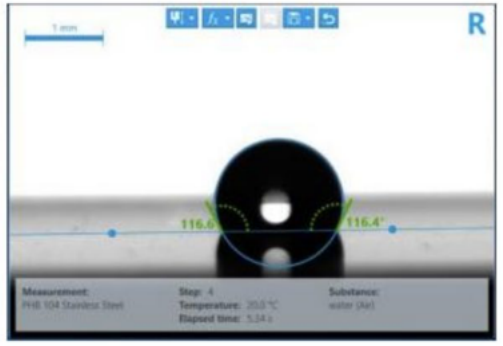


Untreated

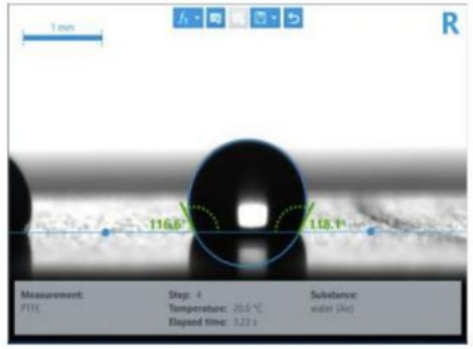


100 nm plasma coating

Dispensing ~100 µL of DMSO



PHB 104 coating on stainless steel

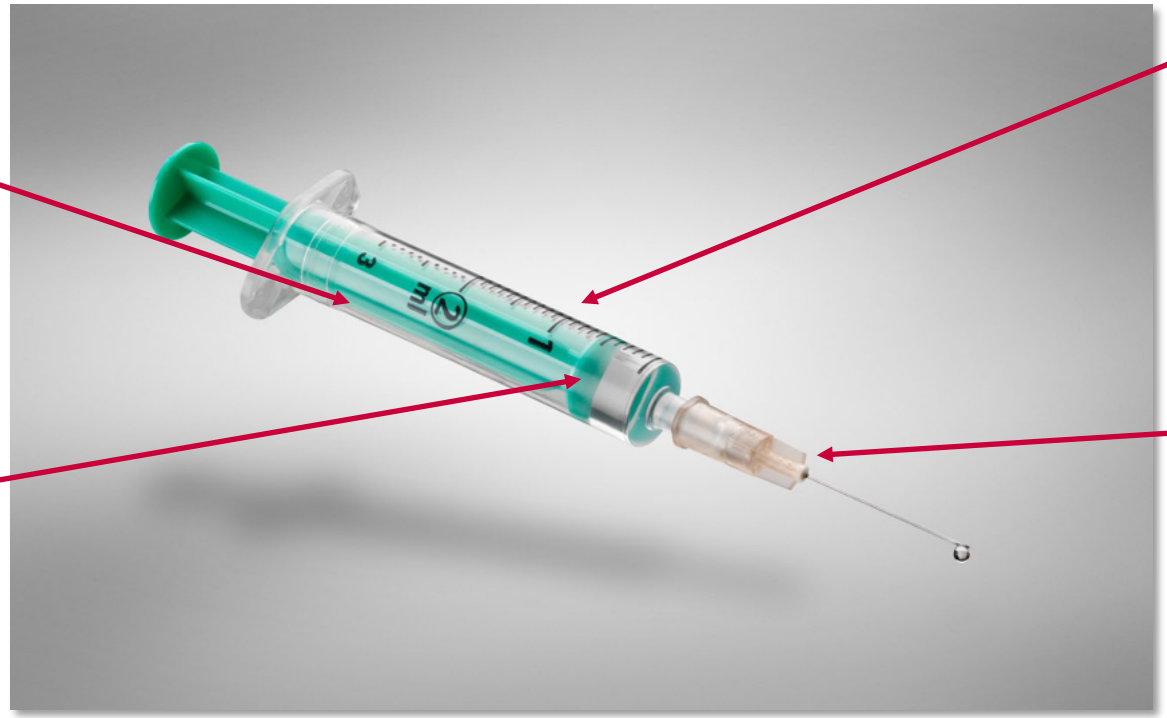


PTFE coupon

# Syringe applications

Activation of the inside of the syringe before spraying the silicone coating (glass, plastic)

(EPDM) piston - low CoF coating



Activation before (pad) printing - better wettability / ink adhesion (Materials: COC, COP, PP)

Fixation of cannulas

- Gluing (plastic)
- Overmolding (after PlasmaPlus® coating of the cannula)

plasmatreat


Job van Galen

+31 6 48 42 37 25

Job.van-galen@plasmatreat.com

www.plasmatreat.com


Let’s connect!