Plasma treatment of cables, pipes and hoses for ink jet printing

TIGRES

Plasma for perfect adhesion

Introduction

Berrin Küzün

Dipl. Phys.-Ing.

Head of process engineering, project management, working with plasma and plasma coating since 2009.

Tigres GmbH

Sandhagenweg 2

21436 Marschacht (bei Hamburg)

Fon: +49 4176 948 7712

kuezuen@tigres.de

TIGRES

Plasma for perfect adhesion

Introduction

Peter van Steenacker

Electronics engineer

Sales Manager since 1998 for plasma systems. Extensive experience with plasma nozzles (APPJ), DBD-Plasma and vacuum plasma.

Extensive experience in lecturing regarding plasma treatment, with presentations, seminars, webinars and training.

Head of PlasmaXperience, the platform from TIGRES for plasma know-how

Tigres GmbH

Sandhagenweg 2

21436 Marschacht (near Hamburg)

Germany

Fon: +49 4176 948 77-28

Steenacker@tigres.de

TIGRES

Plasma for perfect adhesion

TIGRES GmbH

TIGRES GmbH has been established in **1993** as an **independend, family owned** technology based company

Targets:

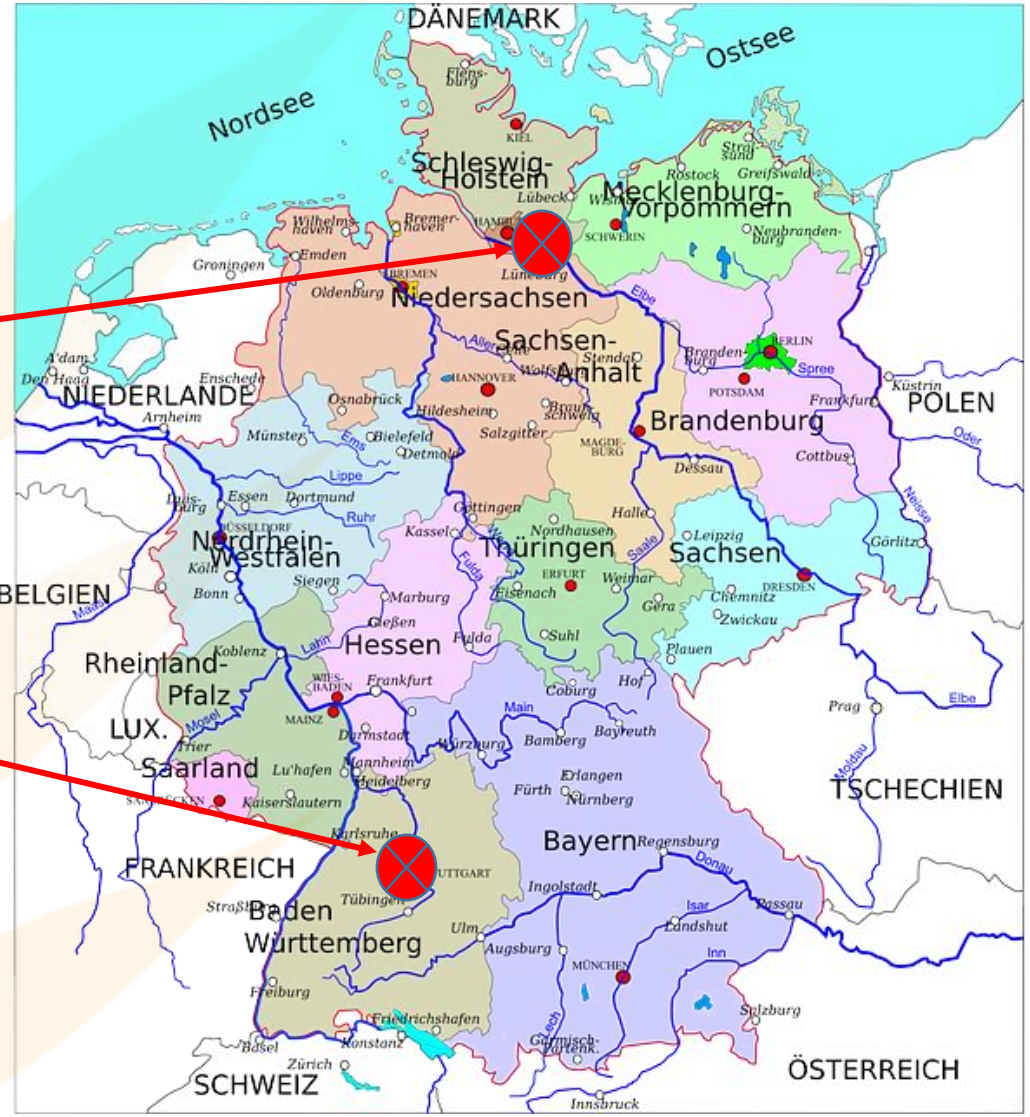
- ✓ **Development**
- ✓ **Production**
- ✓ **Sales**

of atmospheric plasma (AP) units

- ➢ AP Plasma devices for narrow and wide plasma application
- ➢ AP Plasma in different power categories
- ➢ AP Plasma with different temperatures
- ➢ Generators

TIGRES GmbH Germany

- Appr. 25 Empolyees
- Main office and production in Marschacht (near Hamburg)
- Sales office near Stuttgart
- Appr. 14 sales agents world wide



Picture from OpenClipart-Vectors auf Pixabay

Application cables & tubes, hoses, pipes and wires

Goal of customer: Improved **wettability** and **adhesion** of **ink** and **coating** and improved **adhesion of coextrusion**:

Technics: Mostly printing with **inkjet**, sometimes **coating**. **Coextrusion** with different polymers (Silicone, TPE etc.)

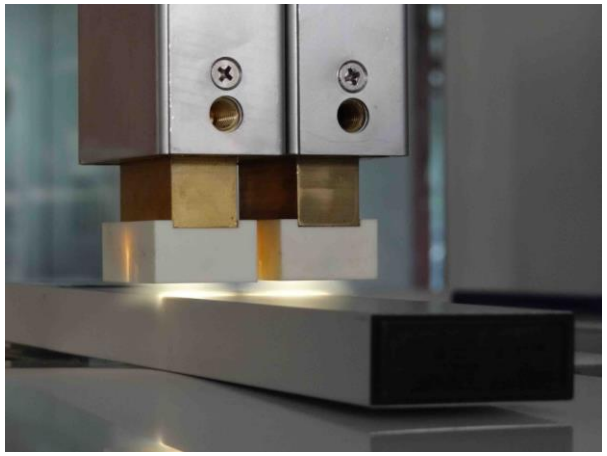
Cables, hoses and pipes:

- Diameter: app. 5 mm – 70 mm
- Speed: app. 0,5 - 300 m/min (depends on diameter)
- Area of treatment: Mostly 10-14 mm
- Material: PE, PP, Silicone (PA, FEP for coextrusion)

Wires, insulated cables, optical fibres without inner conductor:

- Diameter wires : app. 0,5 mm – 5 mm
- Speed up to 600 m/min, for wires up to 1.000 m/min
- Area of treatment: Mostly 360°
- Material: PE, PP, PTFE, FEP, PFA, ETFE, Silicone, TPE

Plasma for printing



Process preparation

- **Cleaning** like effect on contamination/residues in a controlled process
- Heating effect **dries moisture**
- **Removal** of **chem./phys. bound water** from surface (metals etc.)
- Ionisation **neutralisies static charges** from the surface of polymeres. **No dust attraction**, **no deflection of ink jet droplets** through electrostatic charges

Activation

- **Improvement of adhesion** of ink and varnish to the surface
- **Improved wettability** leads to increased sharpness, high resolution, color brilliance and intensity
  - **Saving of ink** (20%) possible

Application cables & tubes, hoses, pipes and wires

1. Question

What is the material to treat?

Choose the right tool for the specific material

Improvement of Adhesion/oxydation											
Method:	**DBD**	**T-Jet**	**CAT**	**T-Spot**	Key:						
Treating gas	Air	Air	Air	Air	good	mostly satisfying results					
Material:					average	results on average					
PE	good	good	good	good	poor	mostly poor results					
PEX	poor	average	good	good		Material, with mostly only one technic working well					
PP	good	good	good	good							
PET	good	good	good	good							
PA	average	average	good	good							
PA 6.6	average	average	good	good							
PVC	average	average	good	good							
Fluor polymers:											
FEP	average	average	poor	poor							
PVDF											
ETFE	average		average	average							
PFA	average		poor	poor							
PTFE	average		poor	poor							
Elastomere:											
Silicone	average	average	average	average							
TPE	poor	average	poor	poor							
TPU			poor	poor							
EPDM	good	average	good	good							
PUR	good	good	good	good							
Rubber	average	average	average	average							
gummi elasticum	average		average	average							

Application cables & tubes, hoses, pipes and wires

1. Question

What is the material to treat?

Choose the right tool for the specific material

Cleaning/Oxidation:				
Method:	**DBD**	**CAT**	**T-Spot**	**MEF**
Treating gas	Air	Air	Air	Air
Metals:				
Stainless steel	good	good	good	good
Aluminum	good	good	good	good
Copper	average	average	average	average
Silver				

Reduction:				
Method:	**DBD**	**CAT**	**T-Spot**	**MEF**
Treating gas	Forming gas	Forming gas	Forming gas	Forming gas
Metals:				
Aluminum	poor	poor	poor	poor
Copper	average	average	average	average
Silver	average	average	average	average

Key:	
good	mostly satisfying results
average	results on average
poor	mostly poor results
	Material, with mostly only one technic working well

Forming gas = N + appr. 2-3 % H

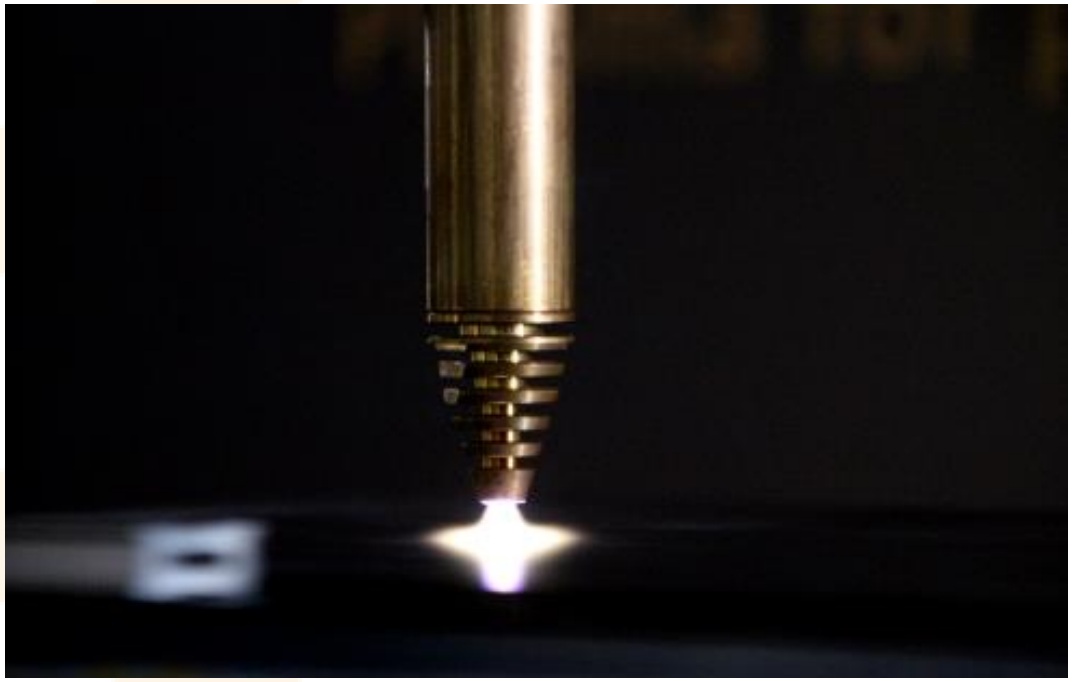
Cables & pipes: Application speed

2. Question

What is the speed of the application:

1. T-JET: 0,1 - 20 m/min
2. T-SPOT FD: 5 m/min – 250 m/min
3. T-SPOT SD: 2 m/min – 150 m/min
4. CAT600: 10 m/min – 300 m/min
5. CAT1000: 15 m/min – 400 m/min

(Rule of thumb)



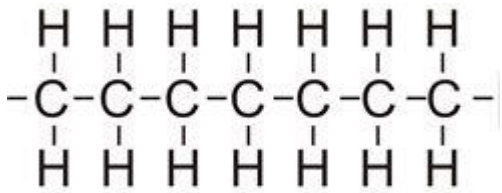
Adhesion theory

Effects multiply each other

1. Primary valency bonds
2. Secondary valency bonds
   1. Van der Waals interactions
   2. Dipol interactions
   3. Induction forces
   4. Dispersion forces
   5. Hydrogen bonds
3. Mechanical clamping
   1. Change of surface from semi-crystalline to amorph, (enables Polymer-Polymer-Interdiffusion)
   2. Electron/ion bombardment
4. Diffusion
   1. PVC with diffusion adhesives, solvent based
   2. PS with Cyanacrylat
   3. PMMA with UV adhesives
5. Electrostatic forces

Reactions on the surface

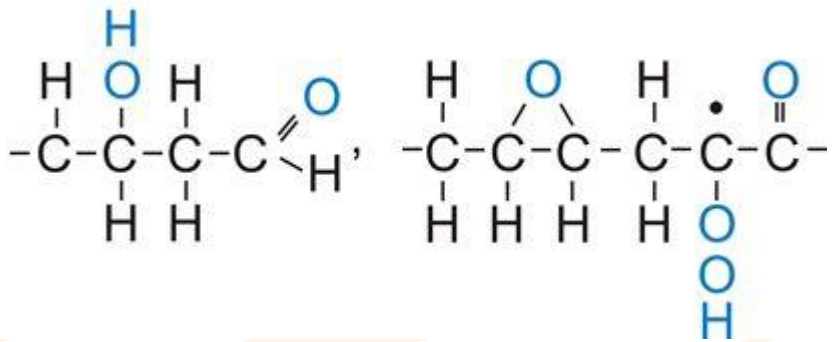
Polymer chain (PE)



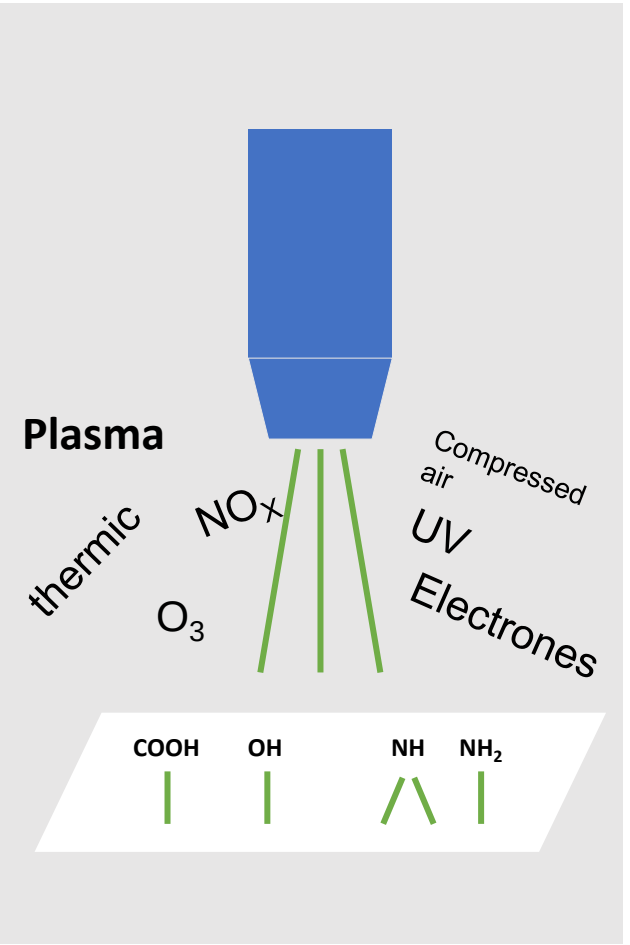
reactive species

•OH, •OOH, •O etc.

Pre treatment



Picture: Dipl. Ing. (FH) Simone Fischer



- Radicals and photons, created by the plasma, break the polymer chains
- Oxygen and nitrogene is bounded to the polymer chain

⇨ Increase of surface energy of the Polymer

Effect of surface treatment on wettabilty

Influence of surface treatment on the wettablity of polymers

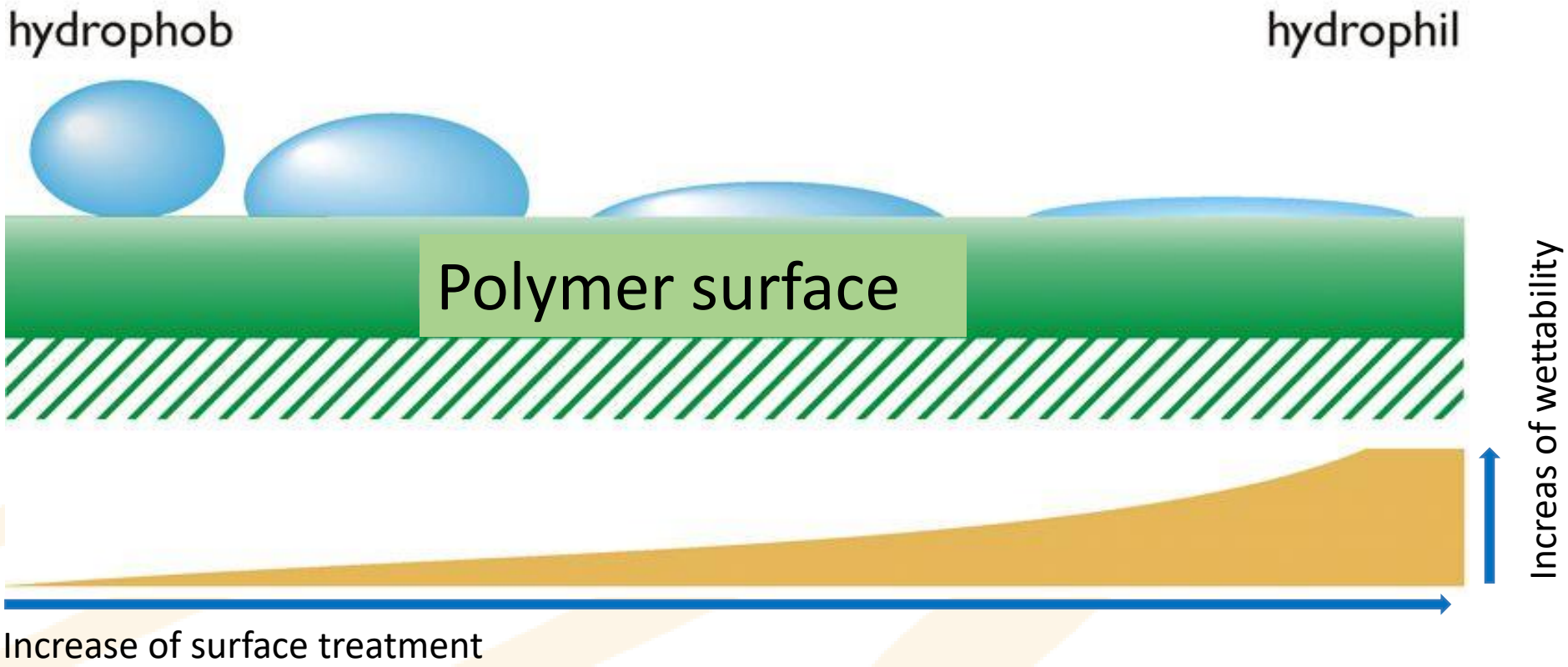


Bild: Dipl. Ing. (FH) Simone Fischer

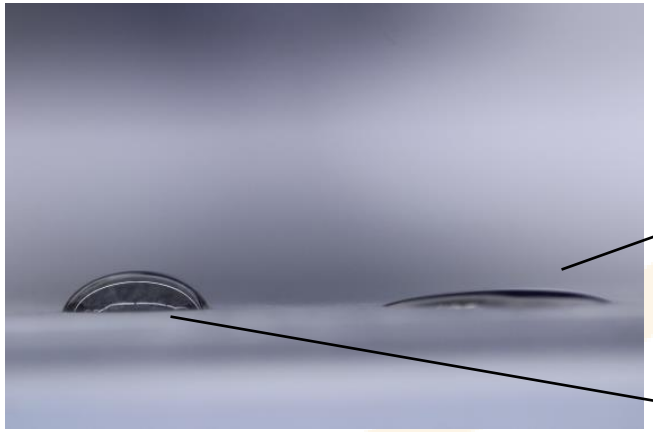
Test inks for measurement of surface energy

Definition:

- Measurement is done in **mN/m** or **dyne/cm**.
- ISO 8296: The film of the test ink has to have a sharp edge for 2-3 sek. or more
- ISO 8296 is defined for PE film
- Lifetime is 3 months according to the ISO 8296. More details in separat test ink slides.
- Test ink shop

Inkjetprinting and wettability

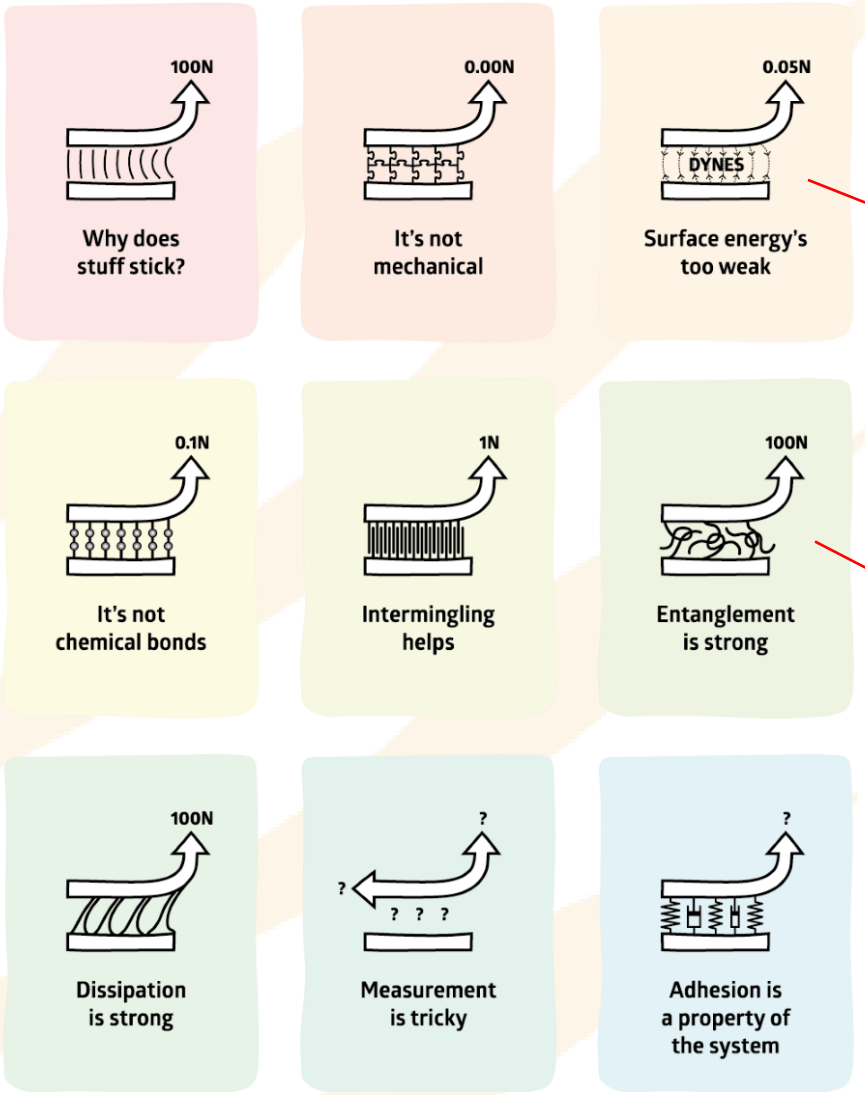
The plasma treatment improves the wettability and enables **bigger drop diameter** with a low contact angle on the surface.



This enables **overlapping droplets** and thus **sharp edges, bright color** and **good readability**.

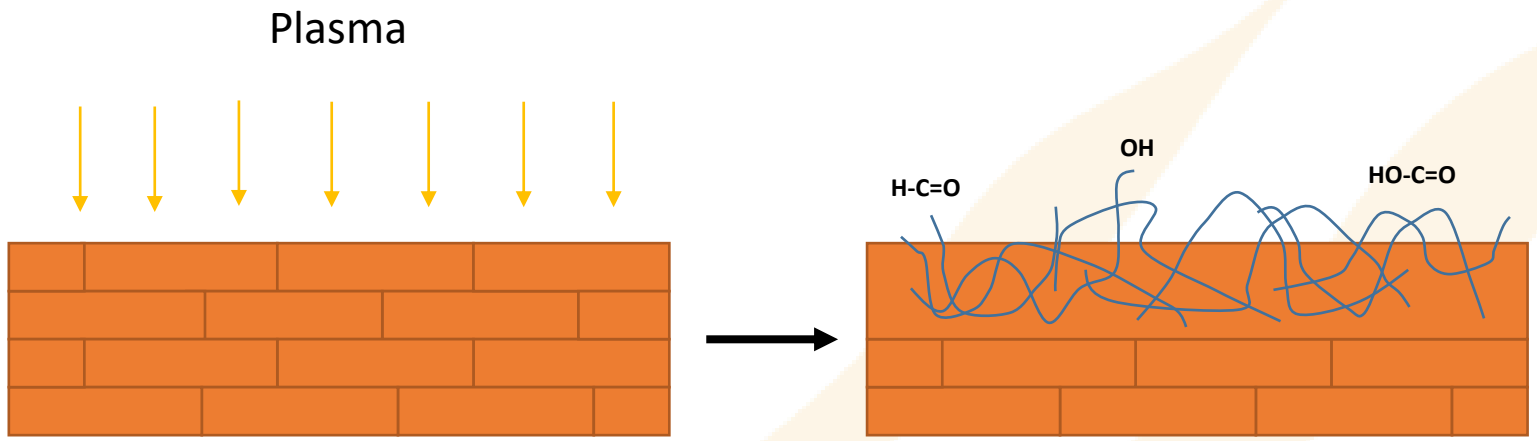
Adhesion: Why does stuff stick?

Prof. Steven Abbott
PhD in Chemistry
https://www.stevenabbott.co.uk/about-prof-steven-abbott.php



https://www.stevenabbott.co.uk/practical-adhesion/

Influence of plasma on crystallinity



Crystallin/partly crystallin surface

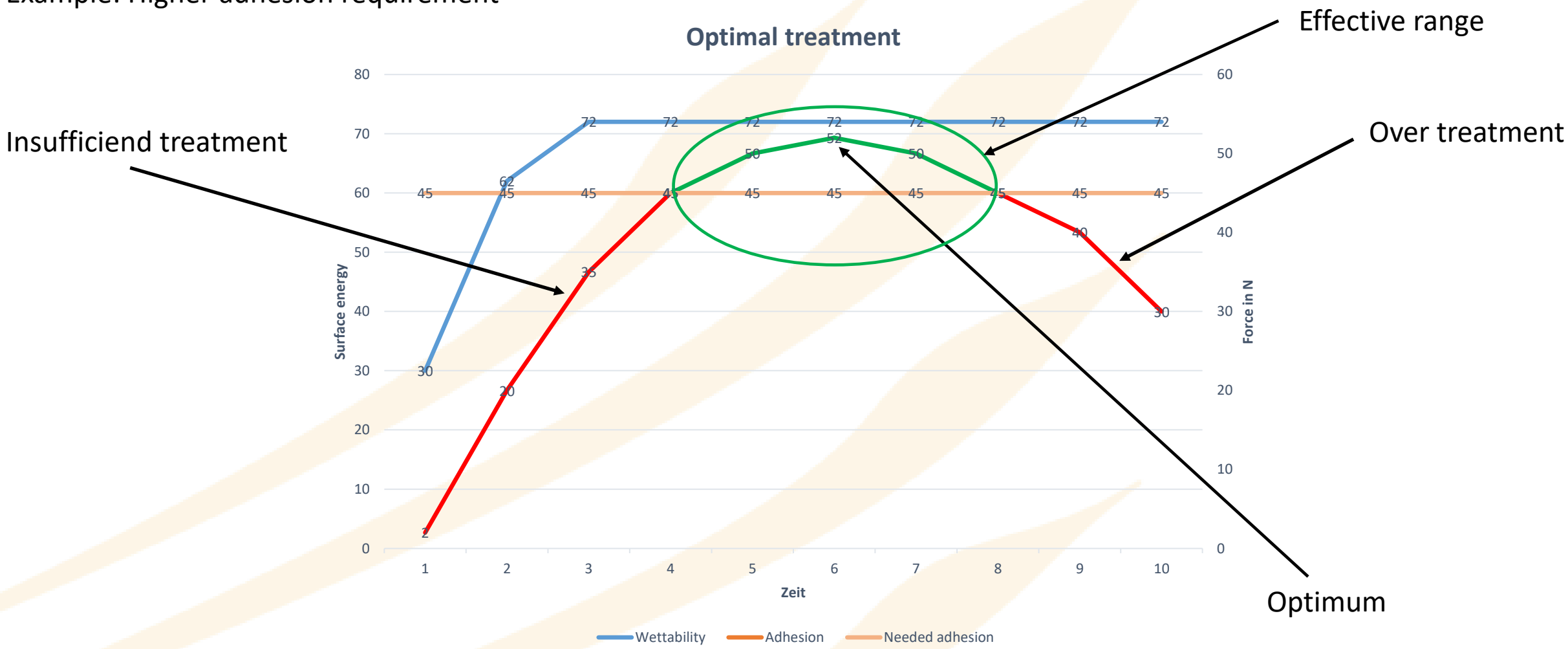
Amorphous surface

Effect of plasma treatment:
Surface gets more amorphous
Enables intermingling/Entanglement

Source: https://www.stevenabbott.co.uk/practical-adhesion/entanglement.php

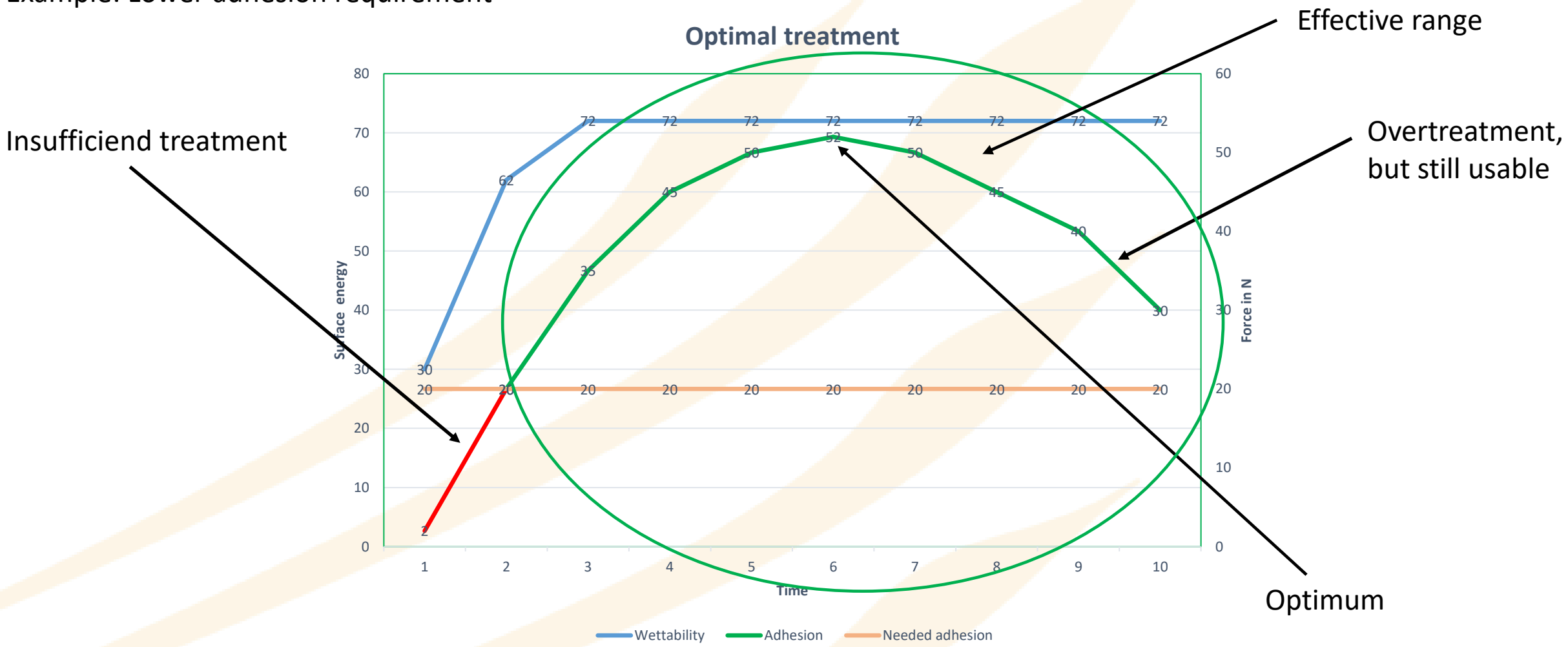
Optimising plasma: Finding the perfect plasma dose

Example: Higher adhesion requirement



Optimising plasma: Finding the perfect plasma dose

Example: Lower adhesion requirement



How to optimise plasma treatment?

Possibilities to influence the plasma dose:

☹ **Adjust distance of nozzle to surface**

Cons:

1. Normaly very smal process window of a few mm
2. Unpractical for different power levels with fixed nozzles

😐 **Change of treatment speed of nozzles or material**

Cons:

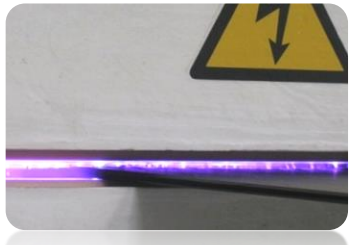
1. Only possible, if process speed can be achieved (f.e. to fast or to slow)
2. Difficult in some productions (f. e. extrusion)

☺ **Power adjustment via generator**

Advantage: Can be adjusted directly in generator according to the need, if process windows is suitable.
Can be adjusted on the fly, online. Also also via I/O and BUS.

Plasma tools, power ratio

DBD



1 W / 1 mm

1 W/mm

T-JET

600 W / 70 mm

8,5 W/mm

MultiMEF

200 W / 7 mm

28,6 W/mm

T-SPOT

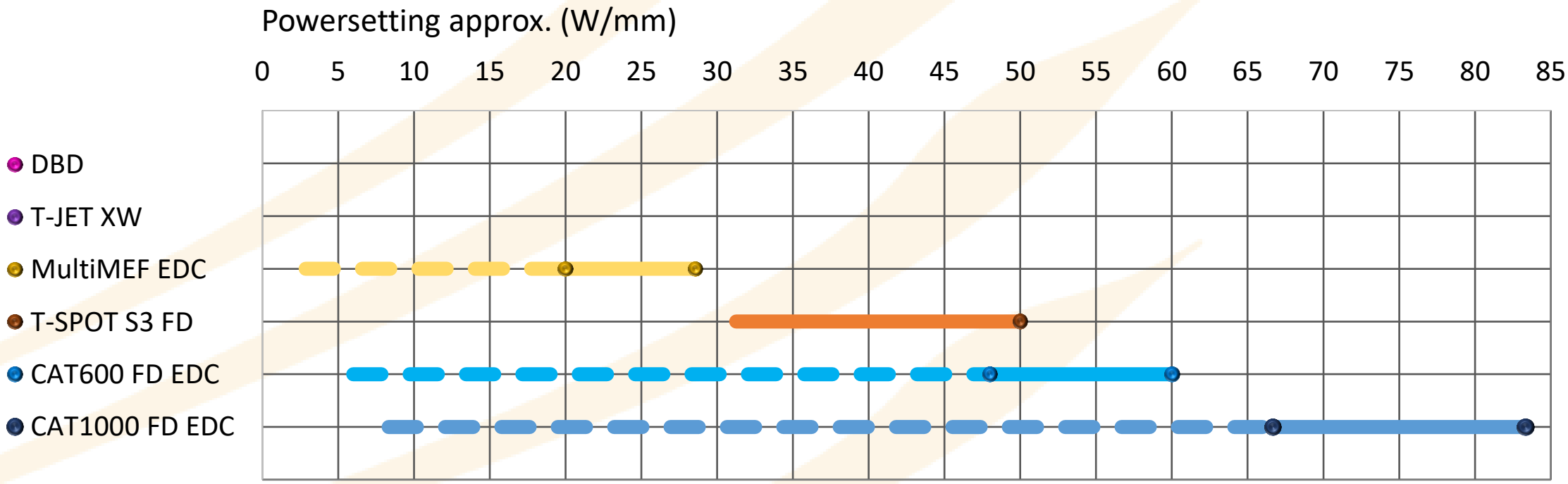
250 – 500 W / 10 mm

25 – 50 W/mm

CAT

600 o. 1000 W / 12 mm

50 o. 83 W/mm



Conclusion

- ✓A good wettability is often required, but not a sufficiend necessity for good adhesion
- ✓For optimal test results, a test series with different power settings is useful to find the optimal plasma dose
- ✓Power adjusable plasma generators enable an optimal plasma dose

<u>Proof of adhesion of application is necessary!</u>

Questions so far?

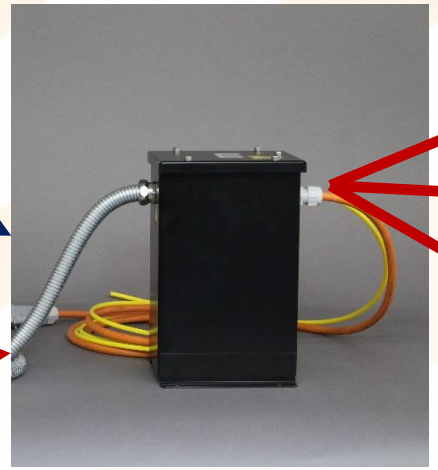
General structure of standard devices

Power supply

+

Tool

Generator + Transformer (internal / external)



T-SPOT

CAT

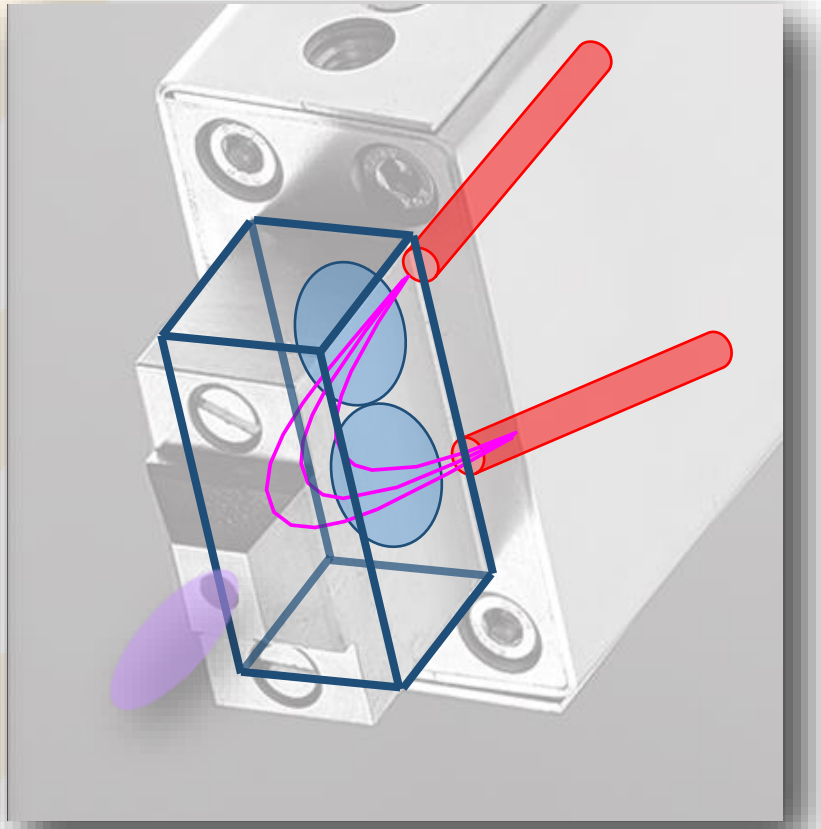
MEF

Tool CAT

Plasma is generated by two arcs, whereby the counter arc also acts as the counter electrode = minimizing the effects of wear on plasma generation (TIGRES patent).

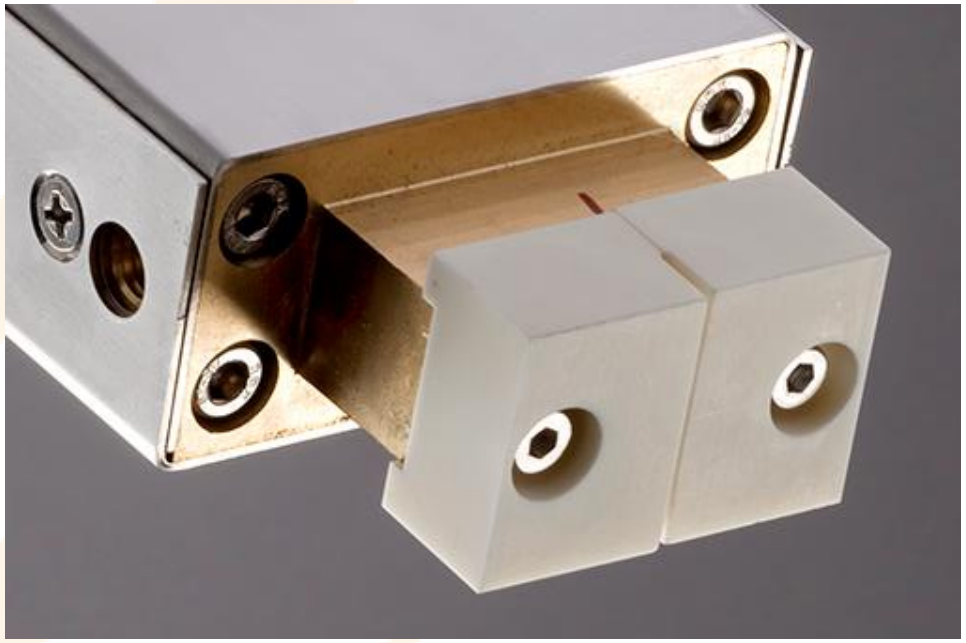
1000 [W] / Nozzle
50 [l/min] / Nozzle
(CAT 1000)
EDC

600 [W] / Nozzle
30 [l/min] / Nozzle
(CAT 600)
EDC



Tool CAT: Focus and Slot Nozzle

Focus Nozzle



Slot Nozzle

Application CAT: Tubes high speed

Treatment of tubes prior to inkjet printing

Material: **PEX**

Speed: **> 200 m/min**

Picture: Hewing GmbH

Application CAT: Inkjet on tubes highspeed

Application CAT: Coextrusion

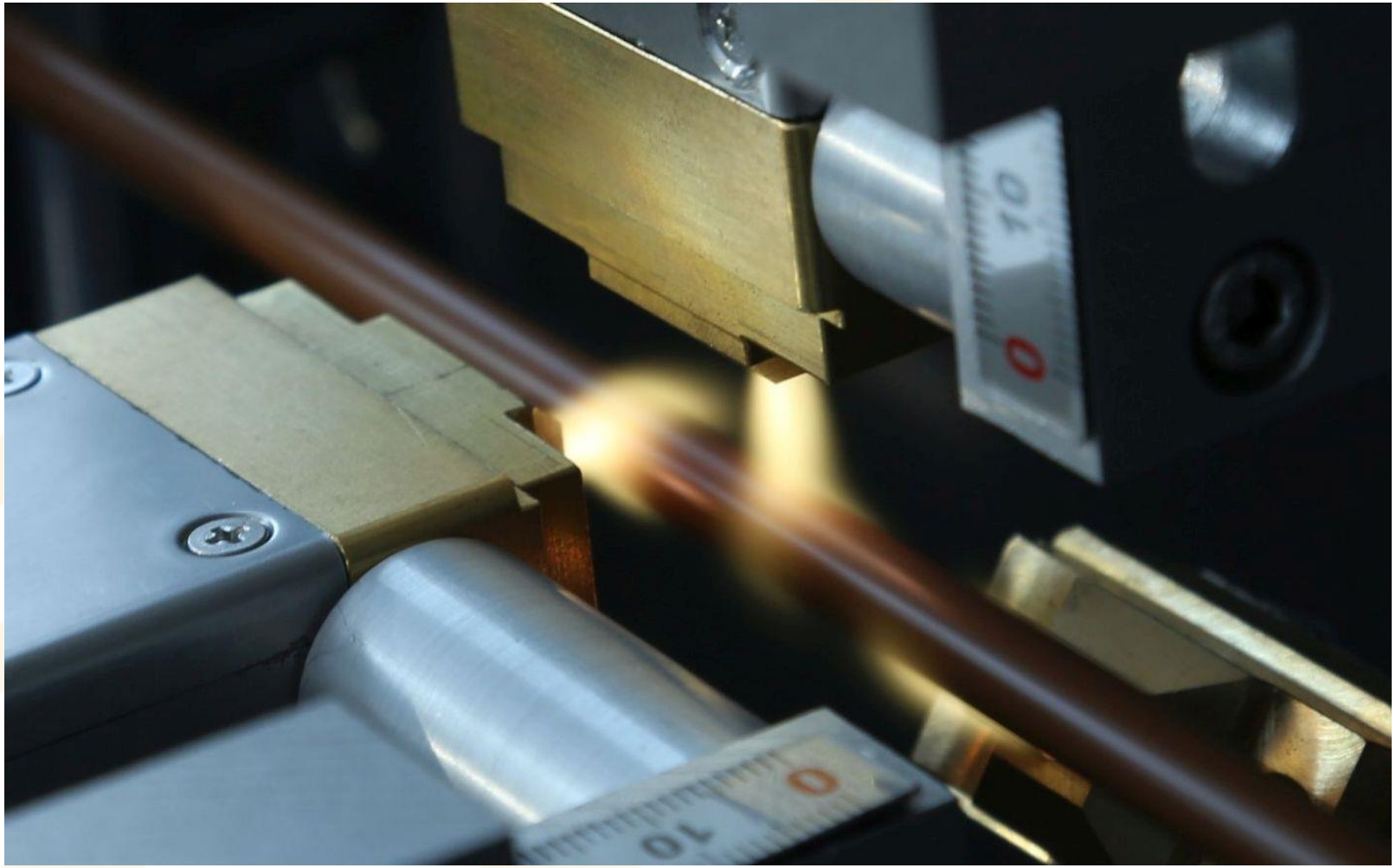
Pretreatment of **PA-tubes** prior to coextrusion

Material:

PA

Speed:

App. 10-20 m/min



Tool T-SPOT S3

The classic construction, a long-lasting standard solution that requires only minimal service

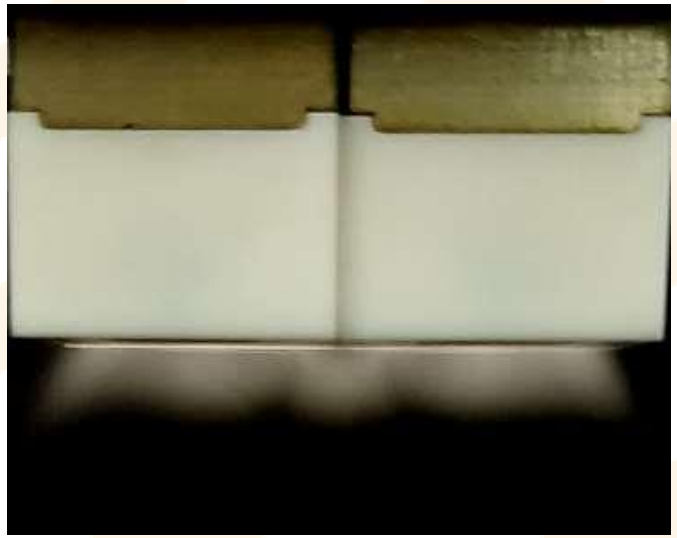
Power:

300 - 500

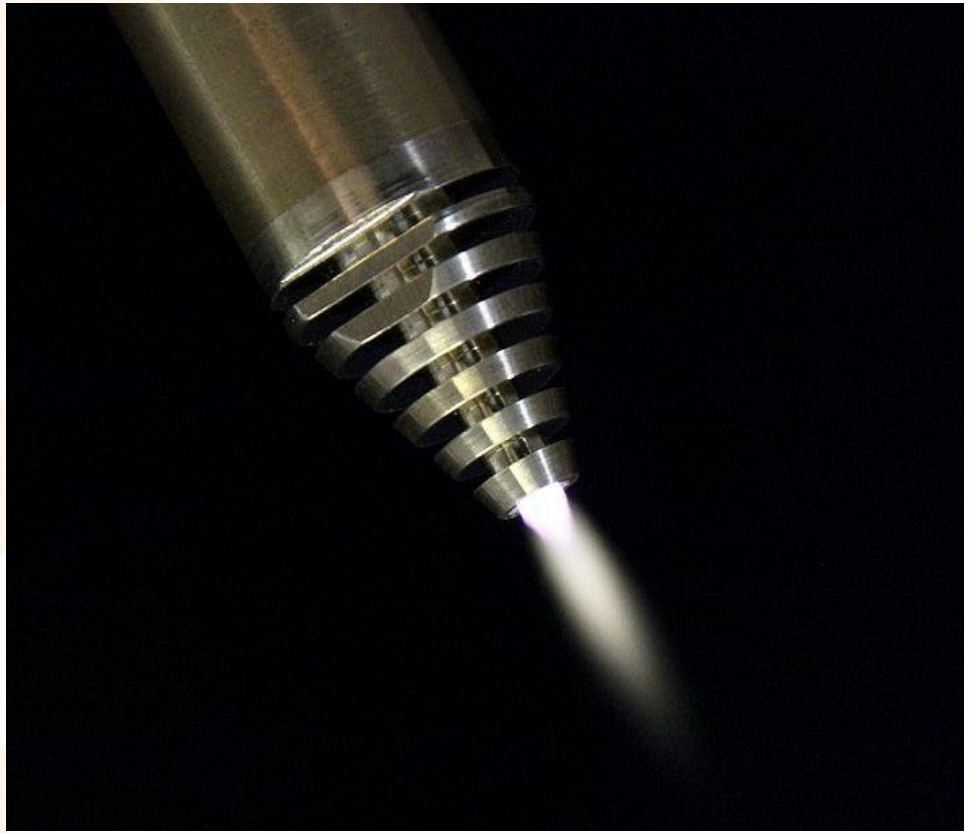
W per nozzle

30 l/min per nozzle

(T-SPOT S3)



Treatment width slot nozzle:
App. 20 mm per head
Depth: app. 1-8 mm



Treatment width focus nozzle:
App. 8-12 mm per head
Depth: app. 5-15 mm

Life time electrode: up to 2.000 h

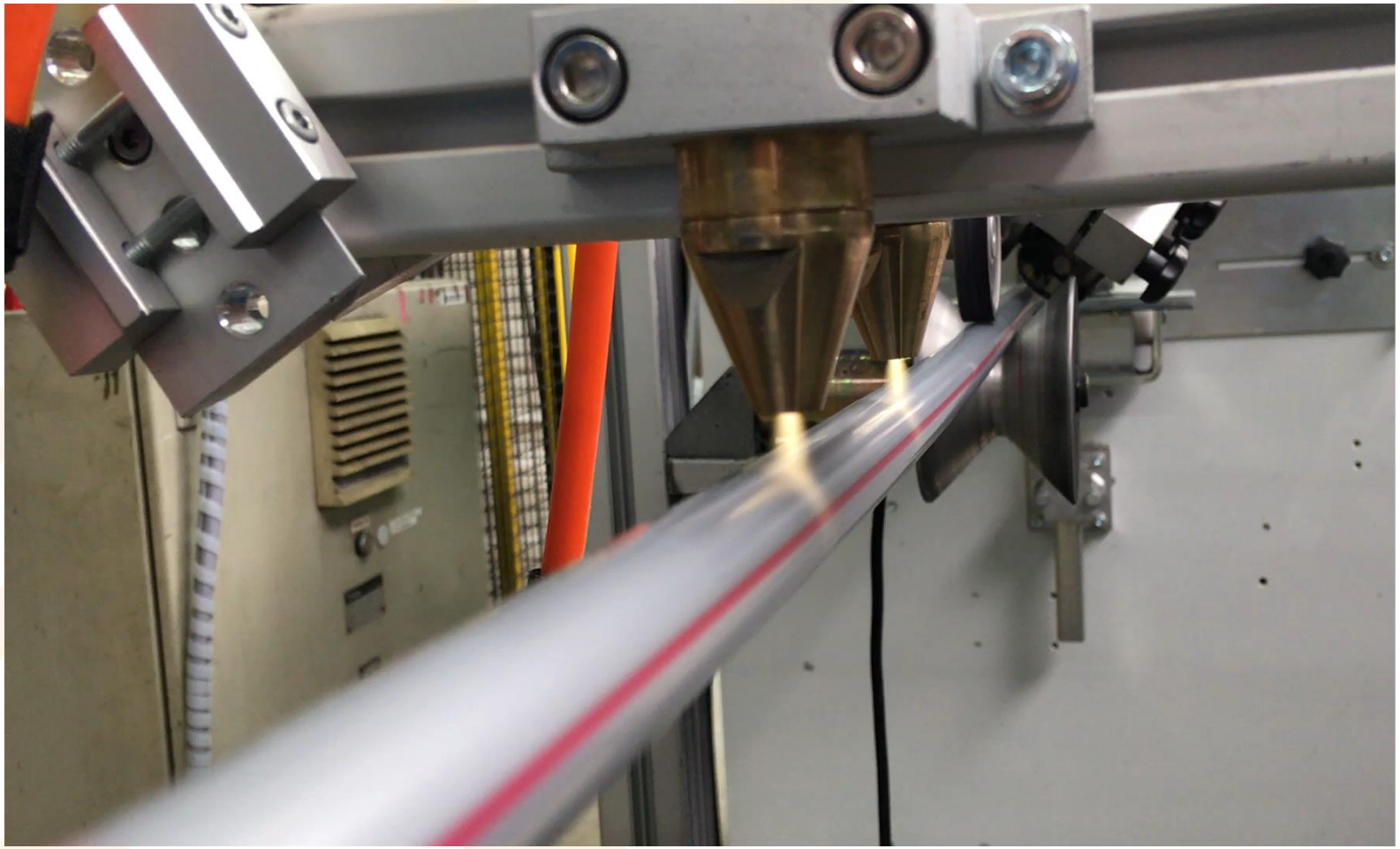
Application T-SPOT: Tubes

Treatment of tubes prior to inkjet printing

Material: PE

Speed: 30 m/min

Tape test ok with one nozzle and 60 % power



Picture: Roth Werke GmbH

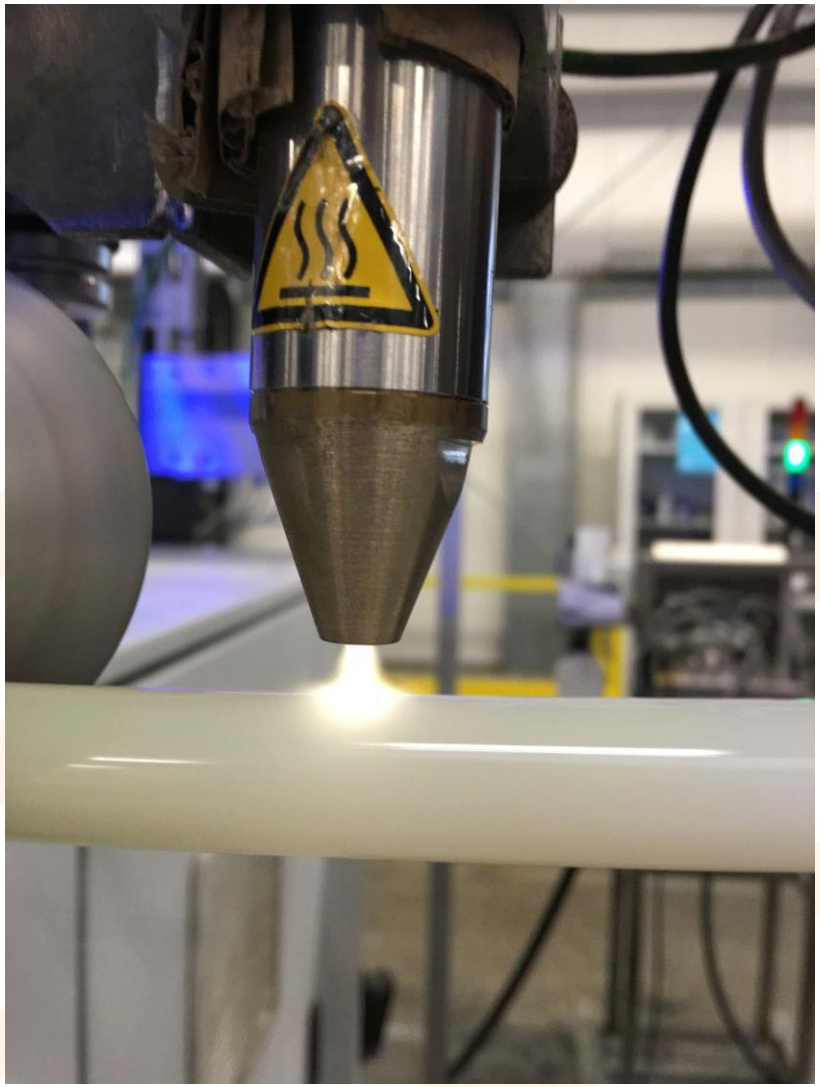
Application T-SPOT: Tubes

Treatment of tubes prior to inkjet printing

Material: **PEX**

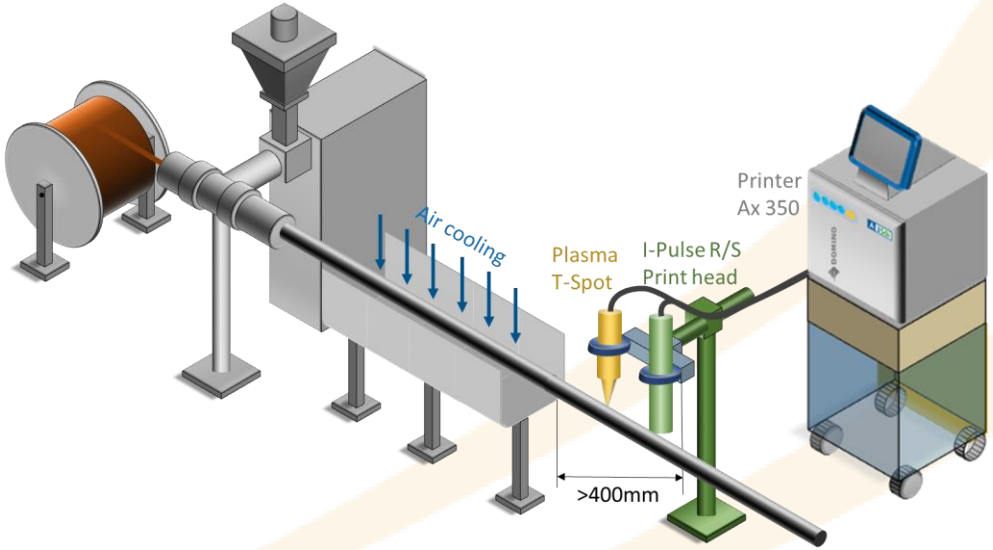
Speed:

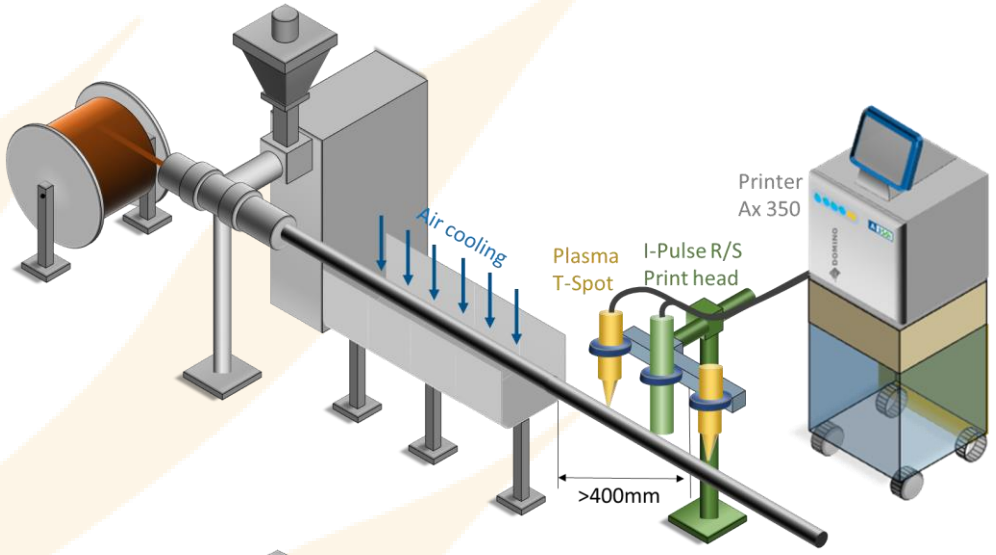
> 200 m/min

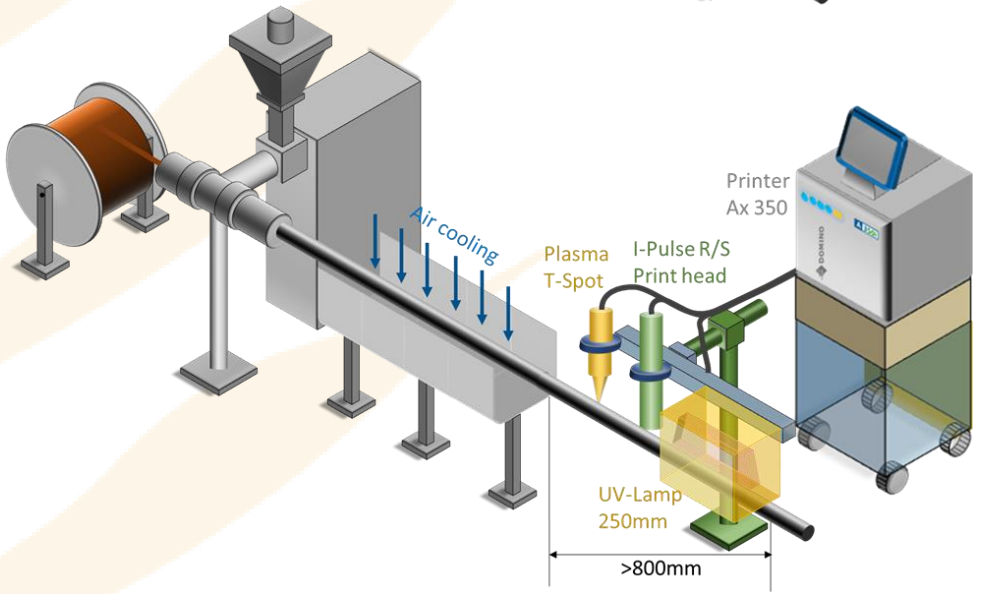


Picture: Becker Plastics GmbH

Tools T-SPOT: Different treatment modes







Pictures: Domino Deutschland GmbH

Tools T-SPOT: Different treatment modes

Solution	Ink 2WT854	Plasma Ink 2WT854	Pre-/post plasma Ink 2WT843	Plasma & UV curing Ink 2WT848
Adhesion	Poor	Moderate	Moderate	Excellent
Abrasion	Easy to remove	With thumb	With thumb	Excellent
Transfer print	Yes	Depends	Depends	No
Tape test	80% on tape	30% on tape	0% on tape	0% on tape
Needle test	poor	<10 cycles	<30 cycles	>60 cycles o.k.
Enhanced abrasion test	Removes	<50 cycles	<100 cycles	>400 cycles o.k.
Aging test	Not tested	Not tested	Not tested	Blue wool scale: 7-8 = 24M
Isopropanol resistance	No	No	Some	Efforts need to remove it
Surface overstretching	Print removable	Print removable	Print removable	No impact to removability
Investment	Low	Moderate	Moderate	High
Wearing parts	Maintenance	+ Electrodes	+ Electrodes	+ UV-lamps, electrodes
What to consider e.g. air extraction	./.	May air suction	May air suction	Air suction needed

Picture: Domino Deutschland GmbH

Tool T-SPOT, UV-Printing on pipes

Treatment of pipes prior to inkjet printing

Material: **PEX**

Diameter: **10-25 mm**

Speed: **10-20 m/min**

Picture: Domino Deutschland GmbH

Tool T-SPOT, UV-Printing on pipes

Treatment of pipes prior to inkjet printing

Material: **PEX**

Diameter: **10-25 mm**

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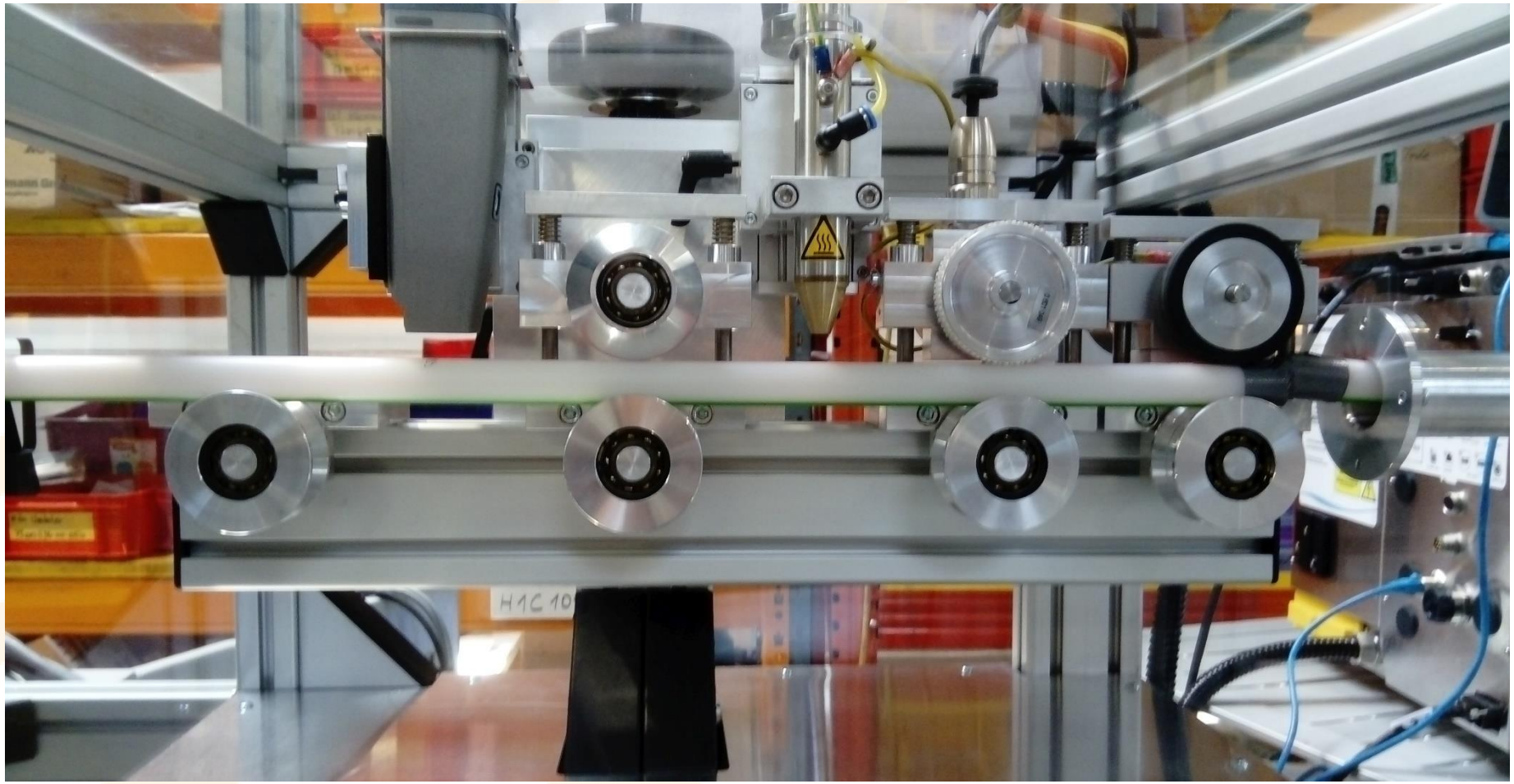
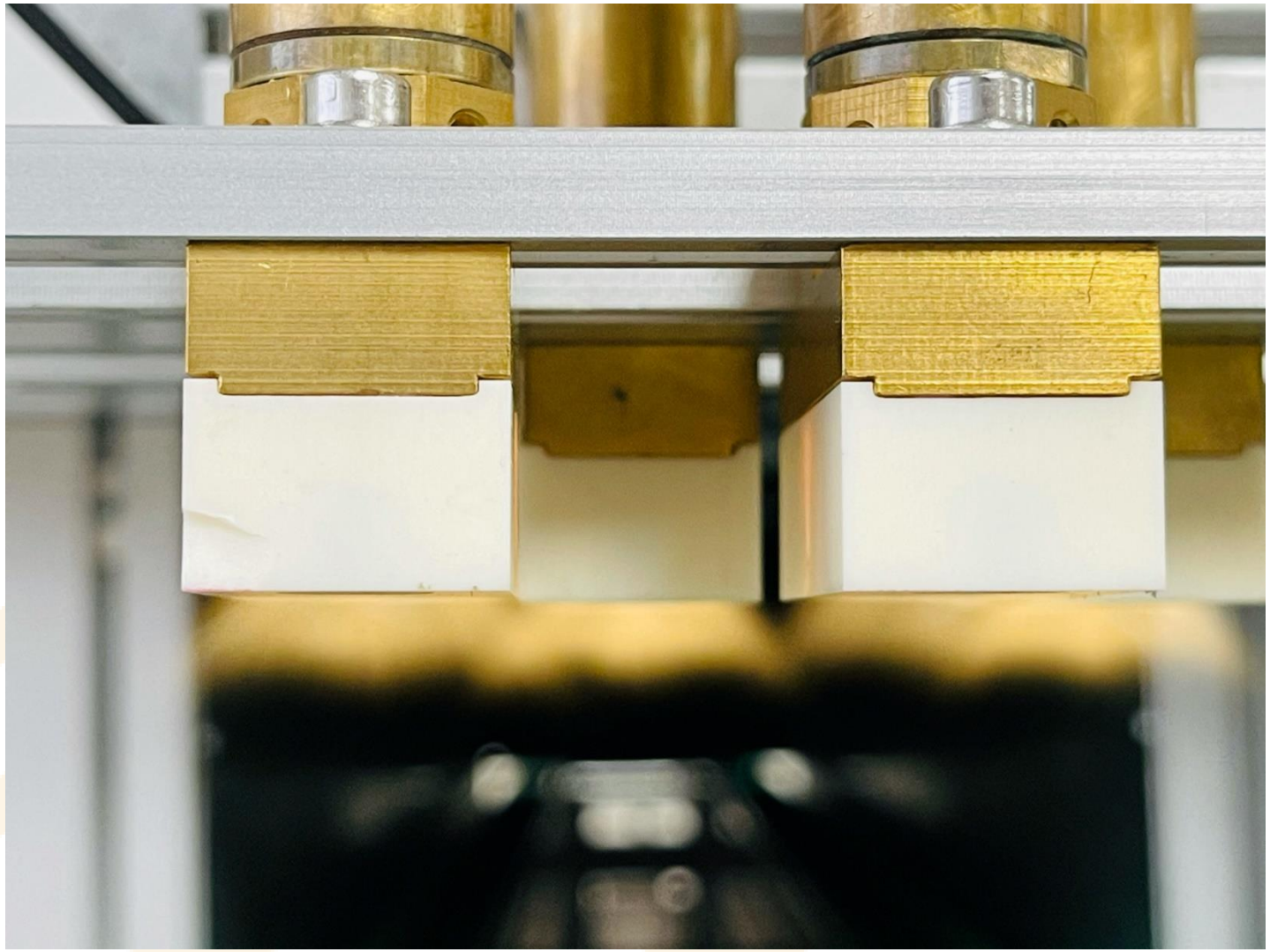


Picture: Domino Deutschland GmbH

Tool T-SPOT: Adhesion of ink jet on PE

Picture: Wiedenbach Apparatebau GmbH / Domino Industrial

Standard tool T-SPOT S3 SD



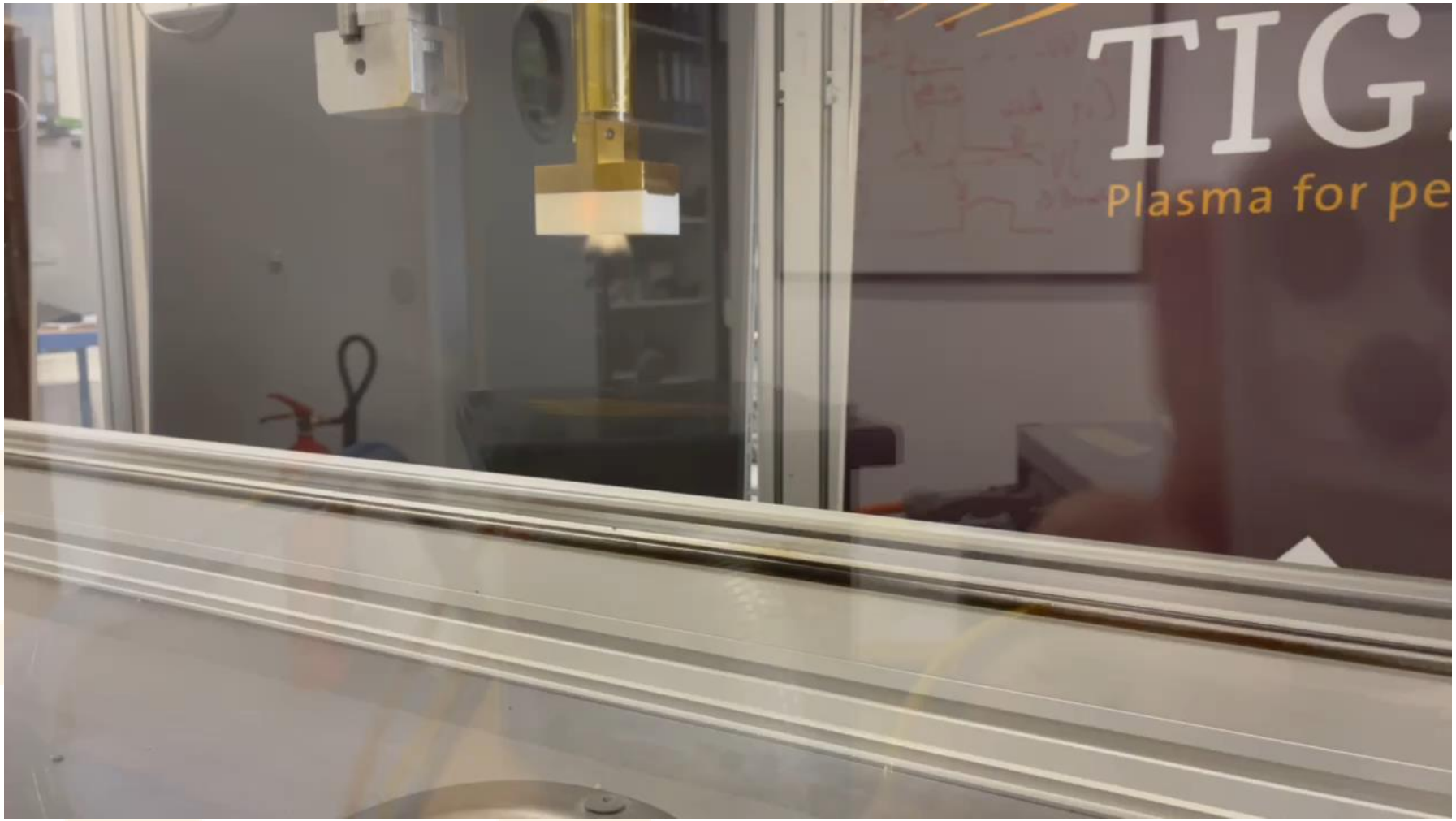
Standard tool T-SPOT S3 SD: Pipe treatment

Tool:
T-SPOT S3 SD

Material: **PP**

Treatment width pasma:
App. 20 mm

Speed: **2 – 10 m/min**



Corona: Tool T-JET

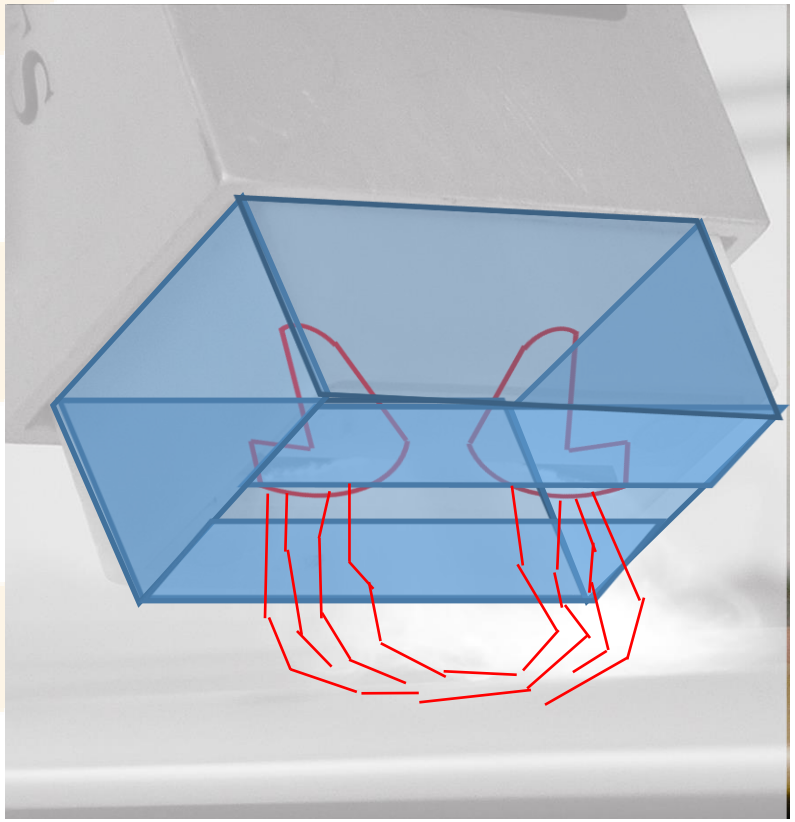
Counter electrode free corona treatment

Treatment speed up to app. **20 m/min.**

Plastics/nonconductive materials only!

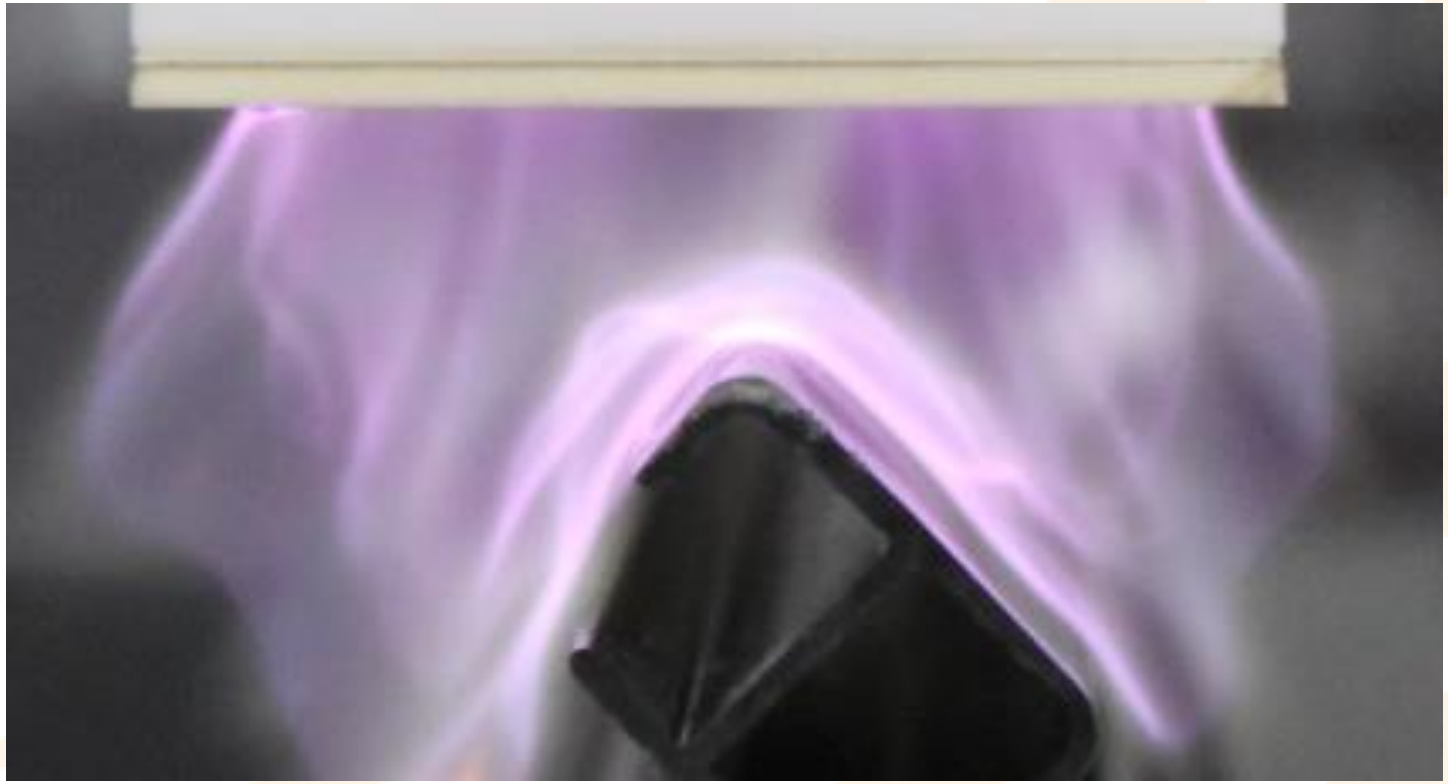
Standard version:
400 W/Nozzle
no compressed air needed
Treating width: app. **50 mm**

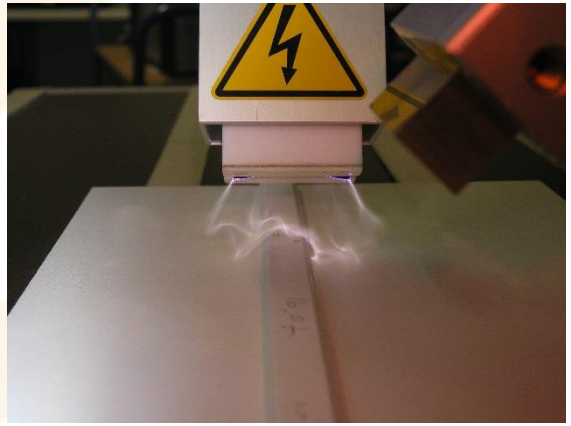
New:
XW version:
600 W/Nozzle
no compressed air needed
Treating width: app. **70 mm**



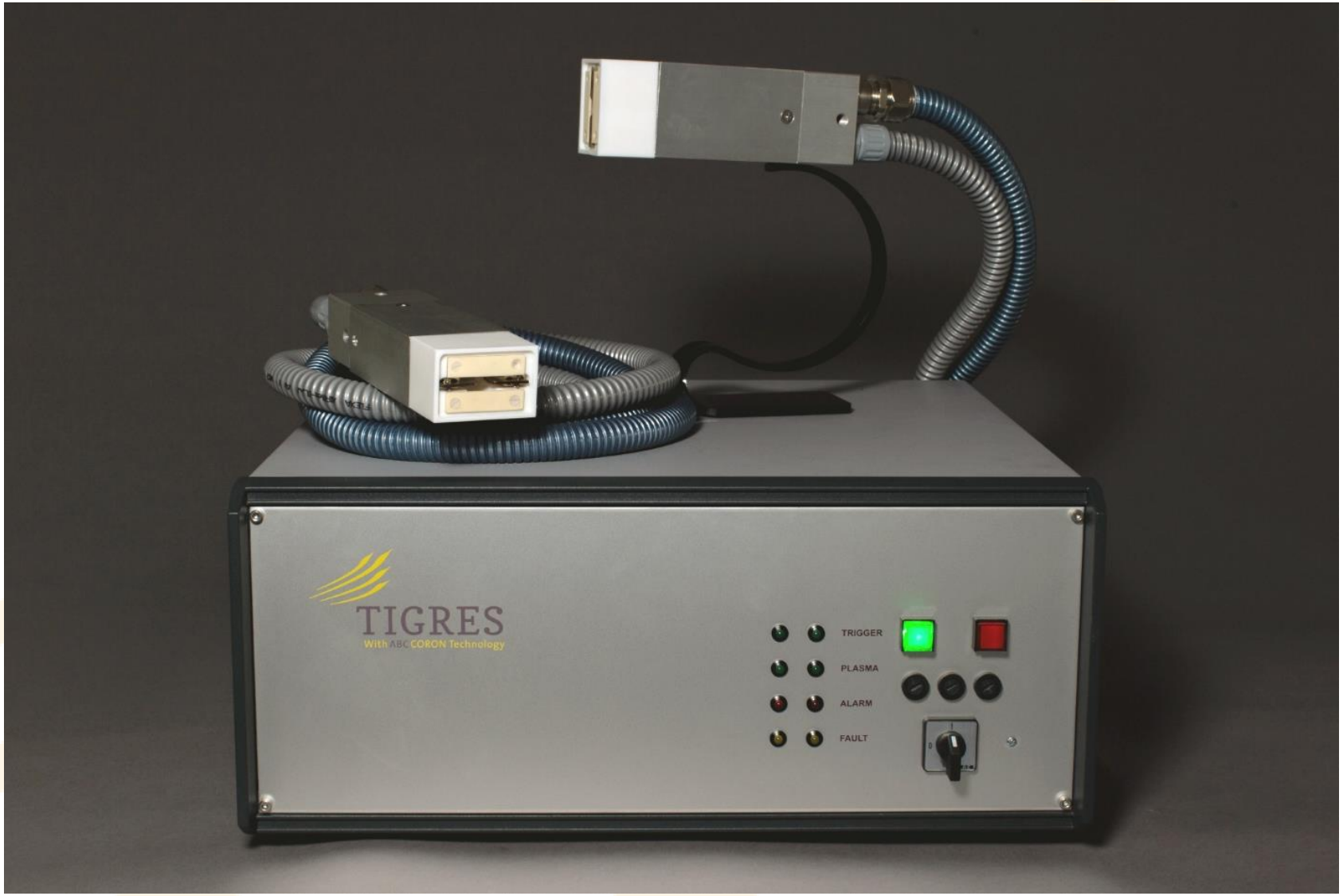
Tool T-JET

Indirect corona treatment with very little heat being transferred to the surface - ideal for pretreating heat-sensitive substrates.





Corona: Tool T-JET

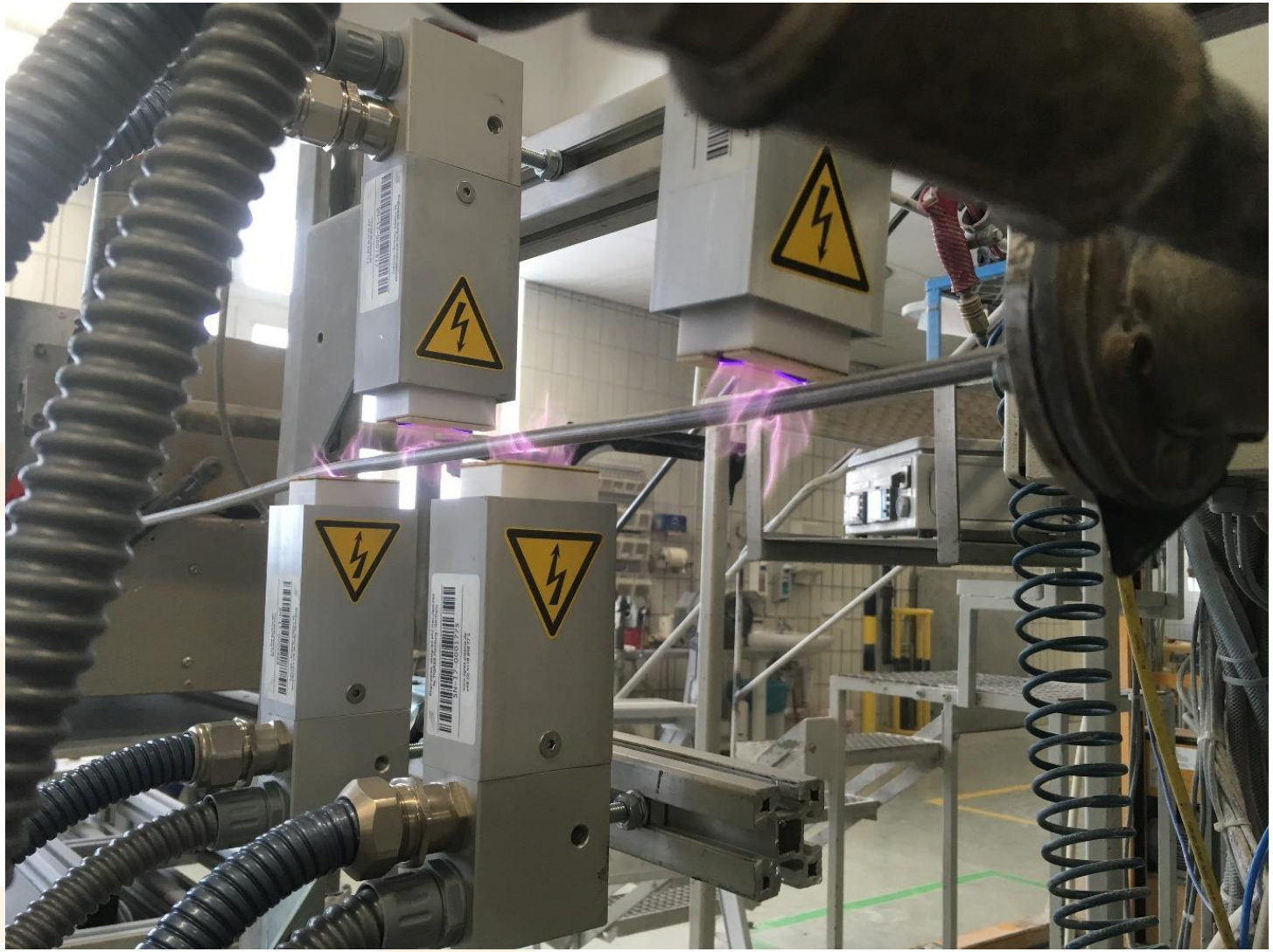


T-JET: Treatment of hoses prior to coextrusion

PA is pretreated prior to coextrusion with silicone

Diameter: App. **5-25 mm**

Speed: App. **5-15 m/min**



T-JET: Treatment of hoses prior to printing

Habia Cable

Pretreatment of **FEP** prior to ink jet printing

Diameter: App. **5 - 30 mm**

Speed: **< 10 m/min**

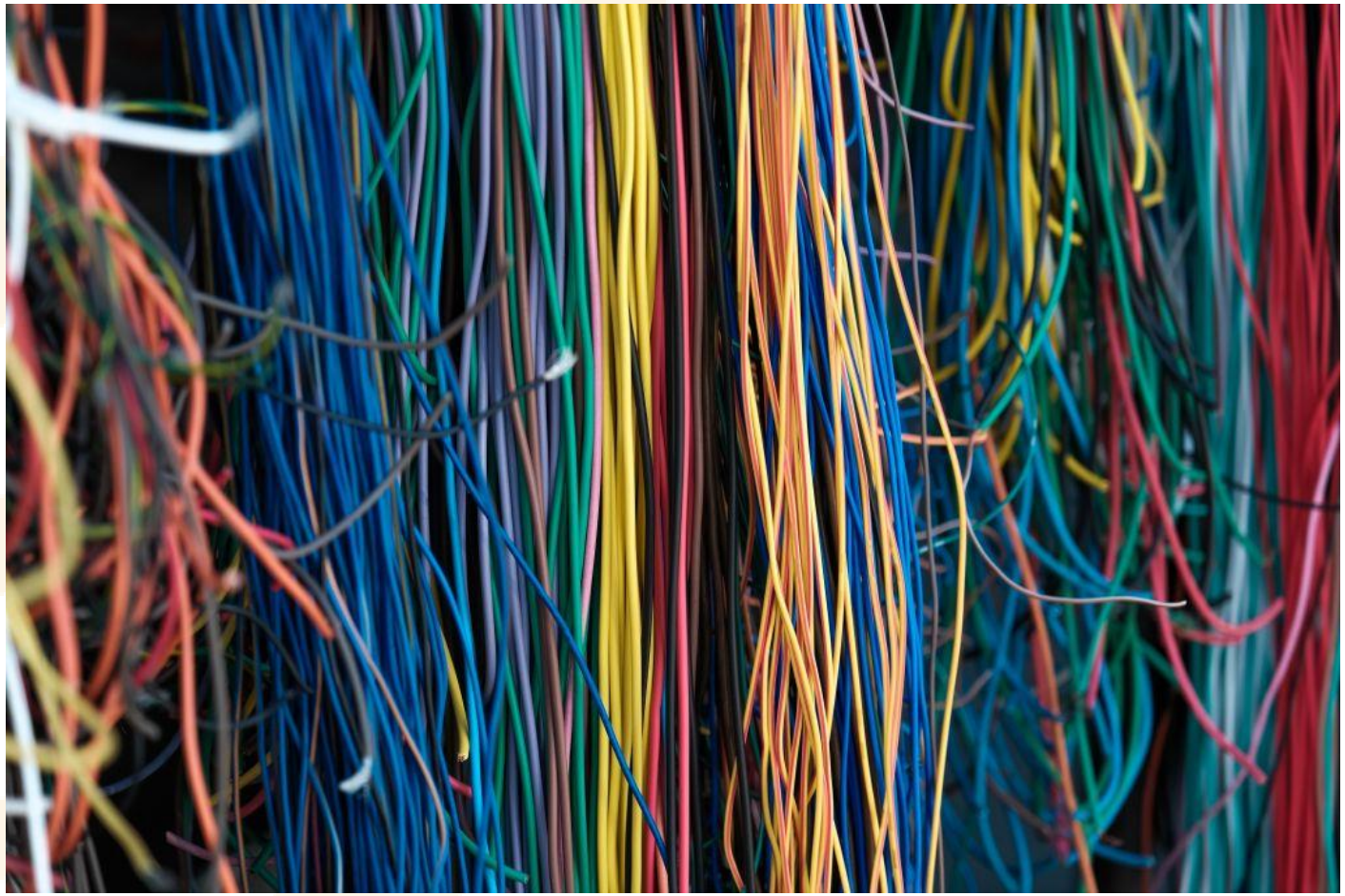
Picture: Habia

Treatment of hoses and cables – stations and shieldings

Application wire

Important to know:

- Material
- Outer diameter
- Inner conductor yes/no
- Speed
- Thickness of isolation
- Area of treatment
- Purpose of treatment (Printing etc.)



Scope of application DBD: Treatment of cables and wires

Treatment of cables with insulation and inner conductor

Station MDK

Diameter of wire: Up to 15 mm

Insulation > 0,5 mm

Very robust solution

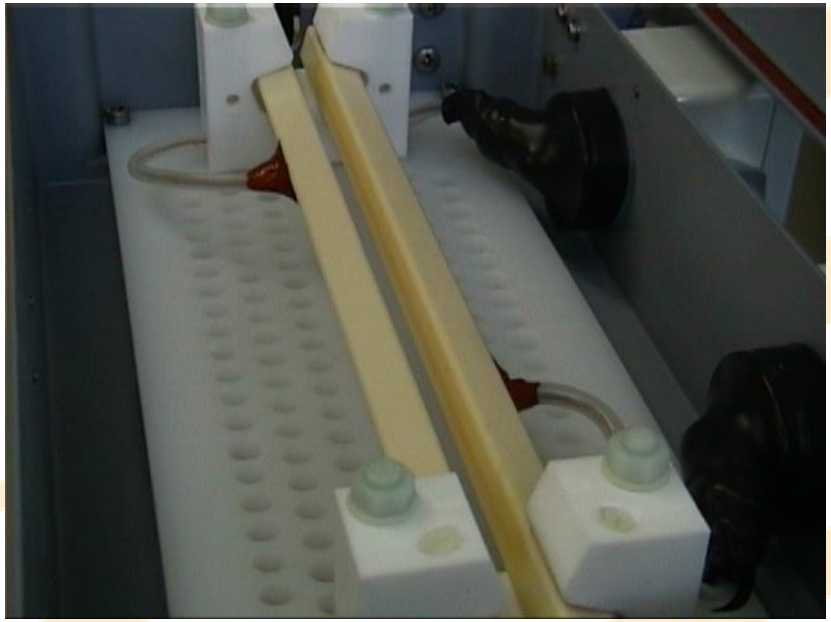
- ✓ 360 ° treatment
- ✓ Wide power adjustment
- ✓ Forced treatment
- ✓ Low treatment temperature
- ✓ Leak detection

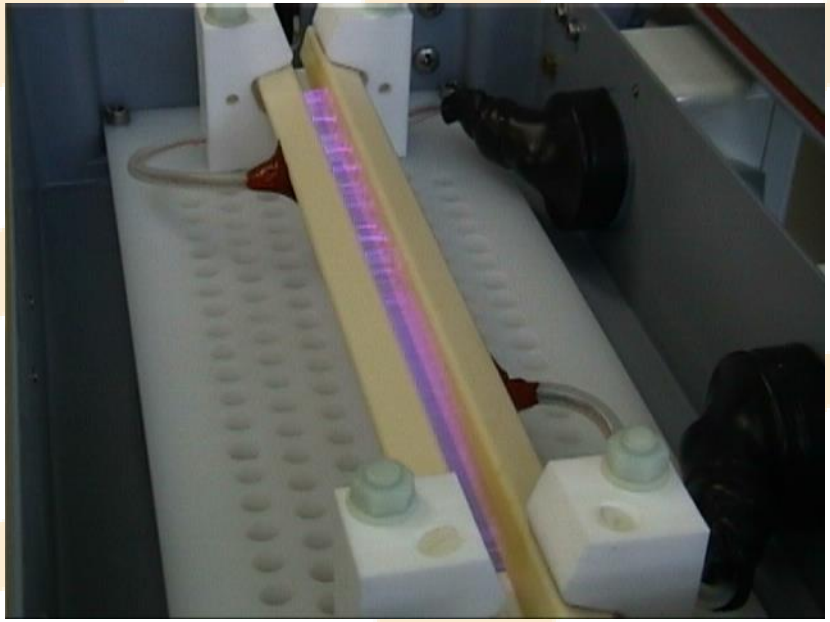
Scope of application DBD: Treatment of cables and wires

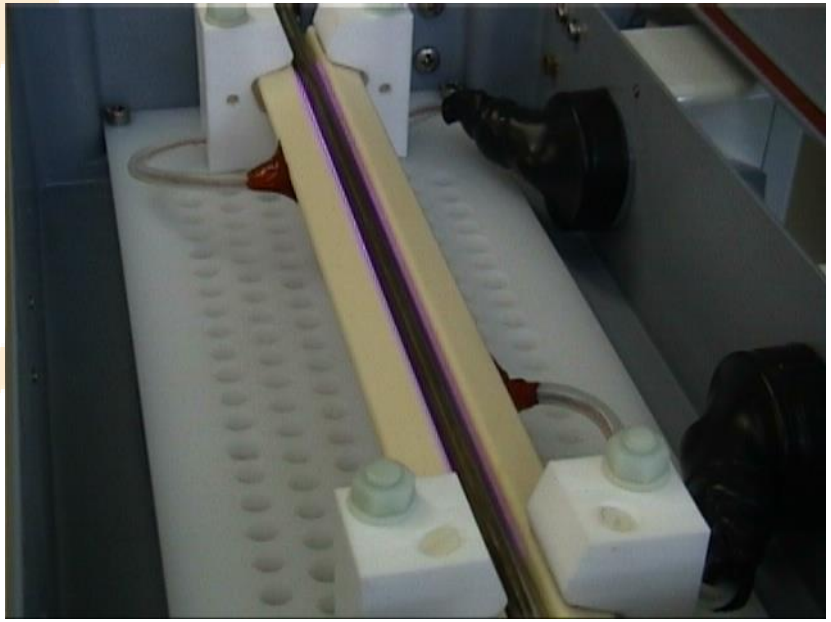
Treatment of cables without or very sensitive insulation or without inner conductor. Usable for fluor polymers.

SKD: Up to 4 mm

SKD-V: Up to 10 mm. Up to 4 mm 360° treatment

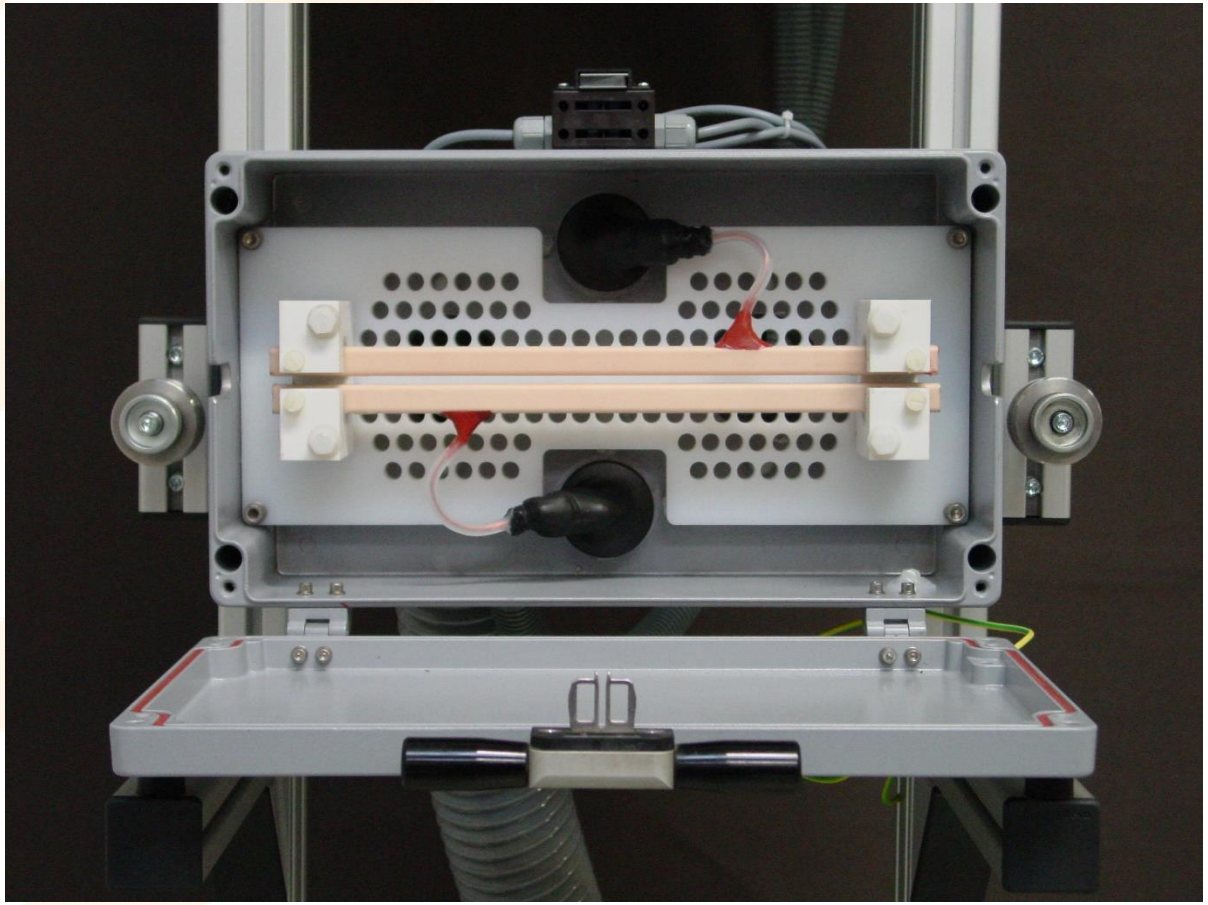






Scope of application DBD: Treatment of cables and wires

SKD: Treatment of cables without insulation or without inner conductor (i.e. fibre optics)



Especially for fluor polymers

Application cables and fibres

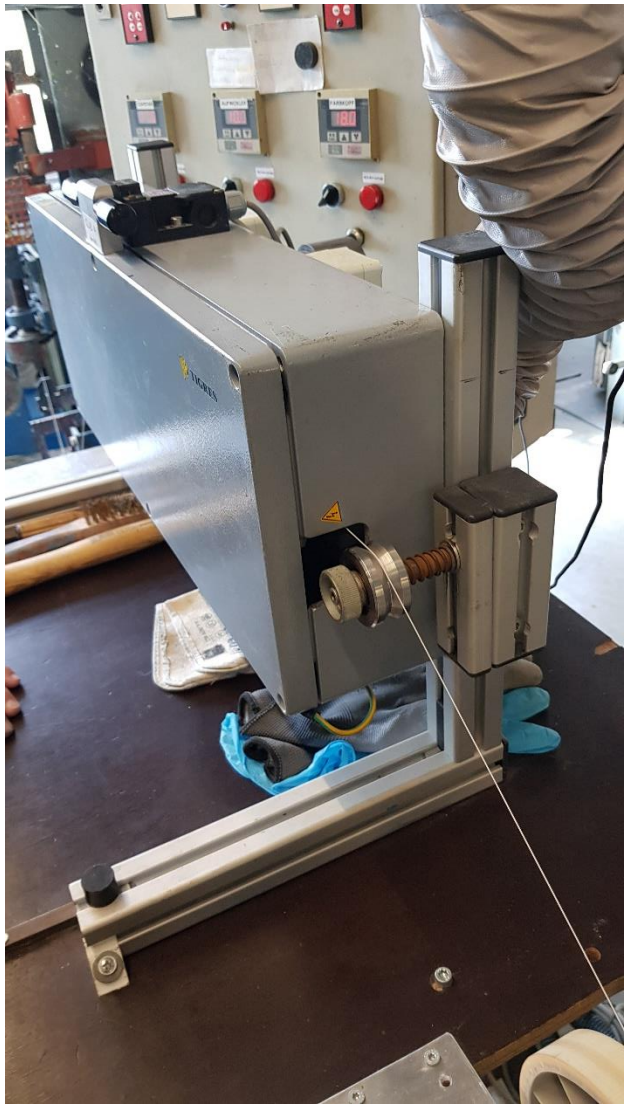
Habia Cable

Pretreatment of **PTFE** prior to inkjet printing/coating

Diameter: **< 4 mm**

Speed: **< 15 – 20 m/min**

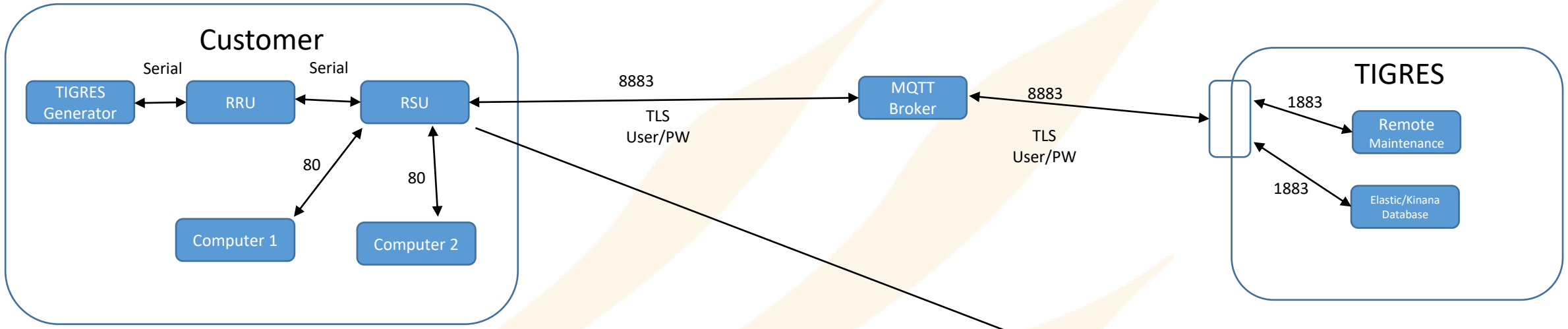
Picture: Habia



M-Generator

- ✓ Modular, compact design
- ✓ Up to **two/four nozzles per generator** (M2/M4), mixing of nozzles types possible (f.e. T-SPOT and CAT), **each nozzle separatly controlled and adjustable**
- ✓ High prozess reliability by **monitoring of relevant system values for each single nozzle**
- ✓ SQI (System quality index): **Monitoring index of closed loop controller** to ensure homogenius plasma power
- ✓ Efficient trouble shooting by **detailled error log with functionality analyses and full text diplay**
- ✓ Real time **remote monitoring and maintenance** via Remote Service Unit RSU

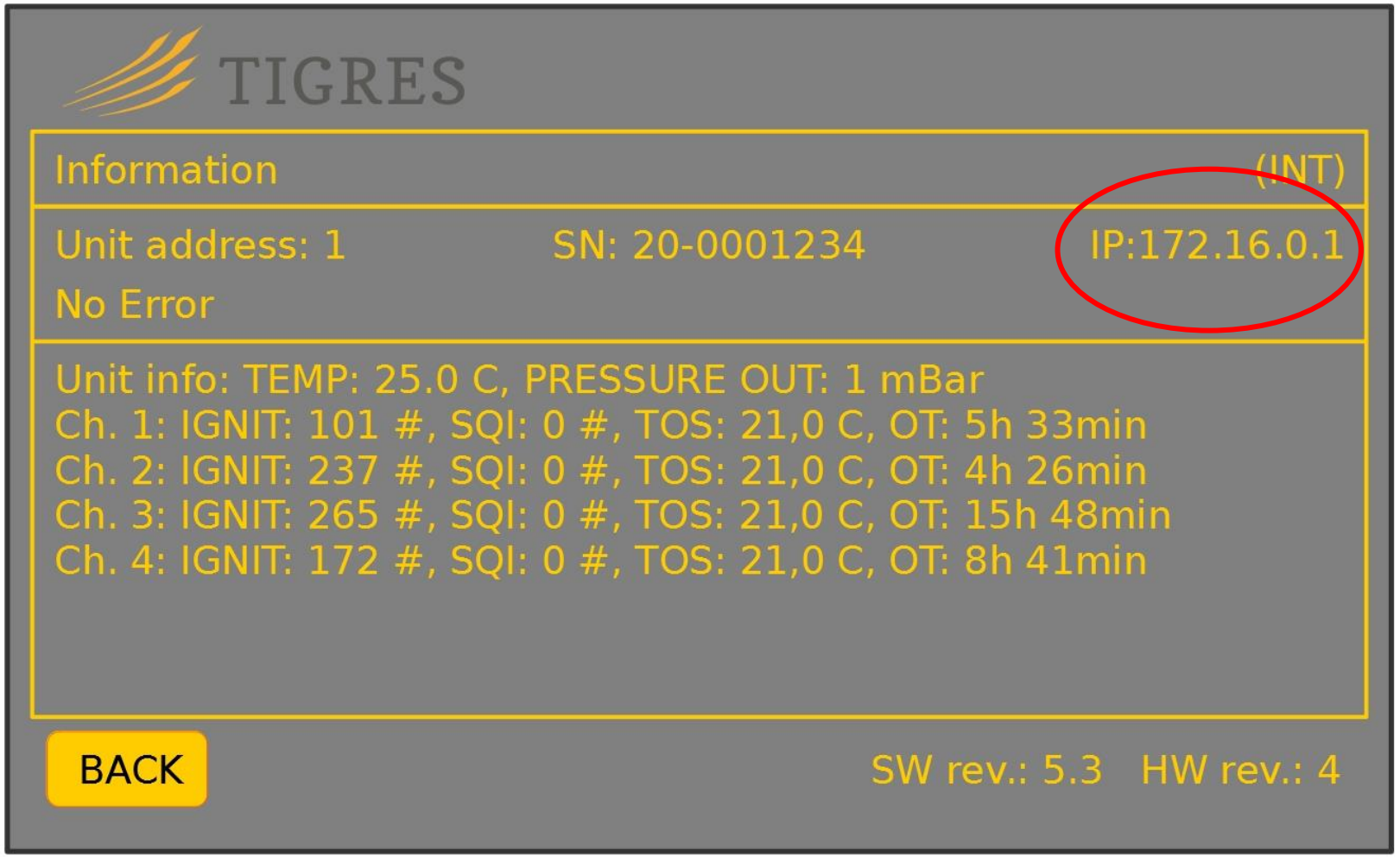
Remote maintenance with Remote Service Unit RSU



- RSU delivers data only to TIGRES after installation about condition of generator
- Access to generator only by TIGRES, only by approval of customer

RSU = Remote Service Unit
RRU = Round Robin Unit, Switch box
ACU = Analog Control Unit

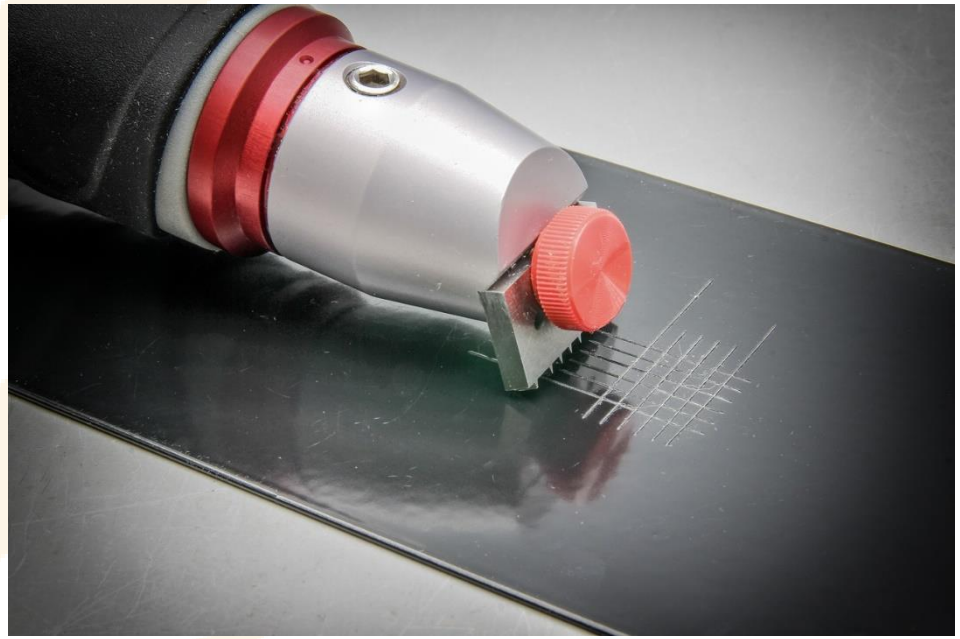
Remote maintenance with RSU



Conclusion: Perfect printing with TIGRES plasma treatment

Advantages of plasma treatment for printing, coating and coextrusion

- ✓ Optimised adhesion
- ✓ Optimised cross cut test
- ✓ Higher process reliability
- ✓ Better wettability
- ✓ Up to 20 % less ink needed (Inkjet)



Maintenance

Maintenance

- Build for 100ED (24/7)
- Wearing parts: Electrodes
- Lifetime electrodes:
  - T-SPOT: Up to app. 2.000 h
  - CAT: Up to app. 10.000 h
  - MEF: Up to app. 2.000 h
- Electrodes can be changed by maintenance personnel. Video instruction available.

Application: Safety

1. **Exhaustion** recommended for removal of:
    1. Nitrous gases
    2. (Ozone only for corona system, mostly if using DBD corona)

2. **Protection against contact**:
    1. Heat
    2. (Electricity) Corona!

3. **EMC** (electromagnetic compatability):
    1. Shielding (Corona, mostly DBD)
    2. Sufficient grounding

Testing TIGRES Plasma: On site, with test equipment, in the lab

Testing at **your production facility**:
We support you with process consulting and in the testing with plasma systems at **your production facility**.

Rental systems:

More than 20 **rental systems are available for testing**. Training included (Videokon).

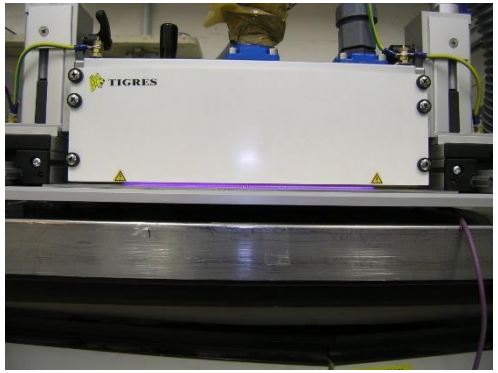
T-SPOT

CAT

MEF

T-JET

DBD



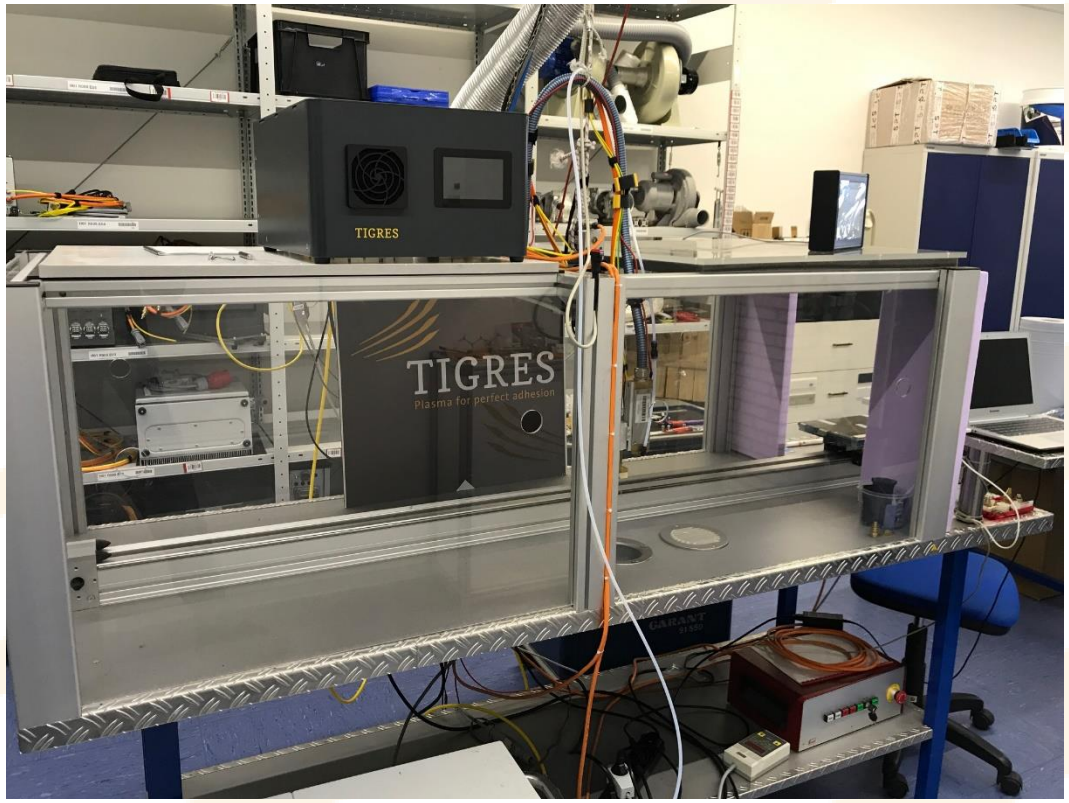
Testing TIGRES Plasma: In the lab

Processing of your samples:

Processing and analysing of samples for or with you, with verification and documentation of the results.

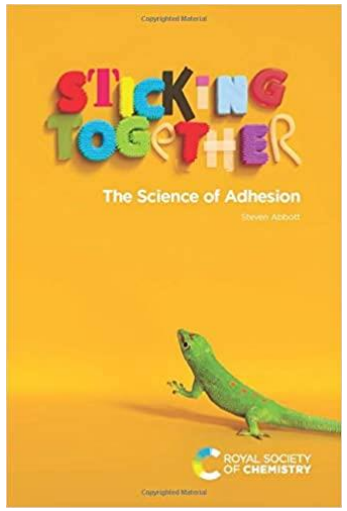
Practical training how to use plasma equipment for:

Activation, Cleaning, Deburring and plasma coating



TIGRES: Literature

For beginners: „**Sticking together - The science of adhesion**“,
in english by **Prof. Steven Abbott**, PhD in Chemistry:



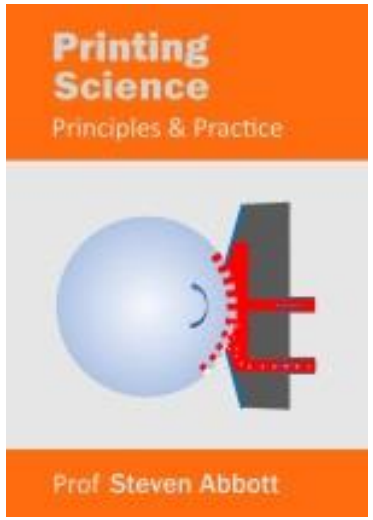
https://amzn.to/3ppgWRE

All the books in englisch by Steven Abbott:

https://www.stevenabbott.co.uk/books.php/

TIGRES: Literature

Free book „**Printing Science**“ in englisch from **Prof. Steven Abbott**, PhD in Chemistry



https://www.stevenabbott.co.uk/practical-coatings/the-book.php

All the books in englisch by Steven Abbott:

https://www.stevenabbott.co.uk/books.php/

TIGRES Webinare: Next webinar

Next webinar:

Tuesday, **23.11.21**, 14:00 CET in german

Thursday, **25.11.21**, 16:00 CET in english

Plasma treatment for perfect adhesion of tapes

Register:

https://www.tigres-plasma.de/en/webinars

TIGRES: Archive webinars

Already held webinars can be watched anytime:

https://www.tigres-plasma.de/en/webinars/182-webinar-archiv

TIGRES: Linkedin

Please connect with TIGRES to stay in contact and get information about webinars, seminars, shows and plasma related content:

TIGRES GmbH

https://www.linkedin.com/company/tigresgmbh

Thank you for your attention!

Contact:

Peter van Steenacker

+49 4176 948 7728

Steenacker@tigres.de

LinkedIn

Tigres GmbH

Sandhagenweg 2

21436 Marschacht

TIGRES

Plasma for perfect adhesion

Made in Germany

www.tigres-plasma.de

tigres@tigres.de

Tel. +49 4176 948 77 0