Plasma for perfect tape bonding

TIGRES

Plasma for perfect adhesion

Introduction

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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

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TIGRES

Plasma for perfect adhesion

TIGRES GmbH

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

Targets:

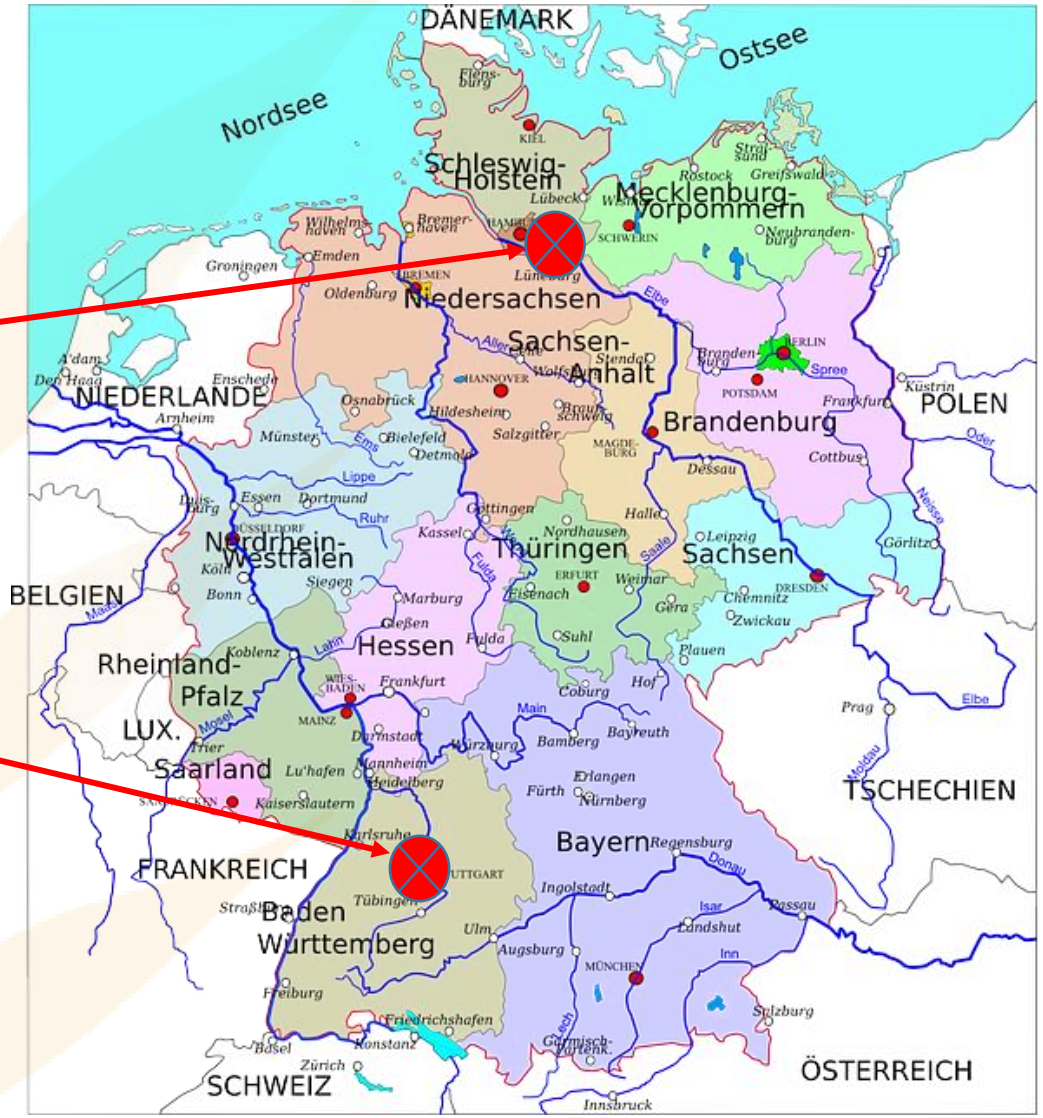
- ✓ **Development**
- ✓ **Production**
- ✓ **Sales**

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

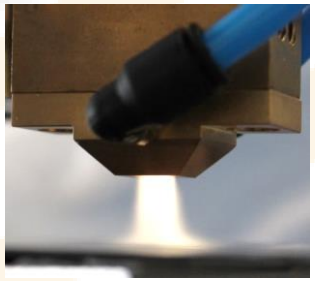
Plasma for cleaning, adhesion and coating

Preparation

„Cleaning“, partial heating, drying, ionisation, oxidation, reduction

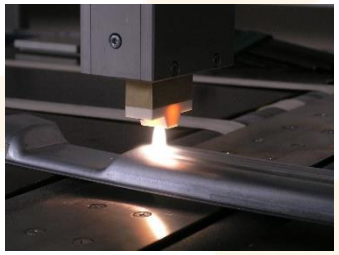
Activation

Improvment of adhesion and wettability (app. 80 % of all applications)



Coating

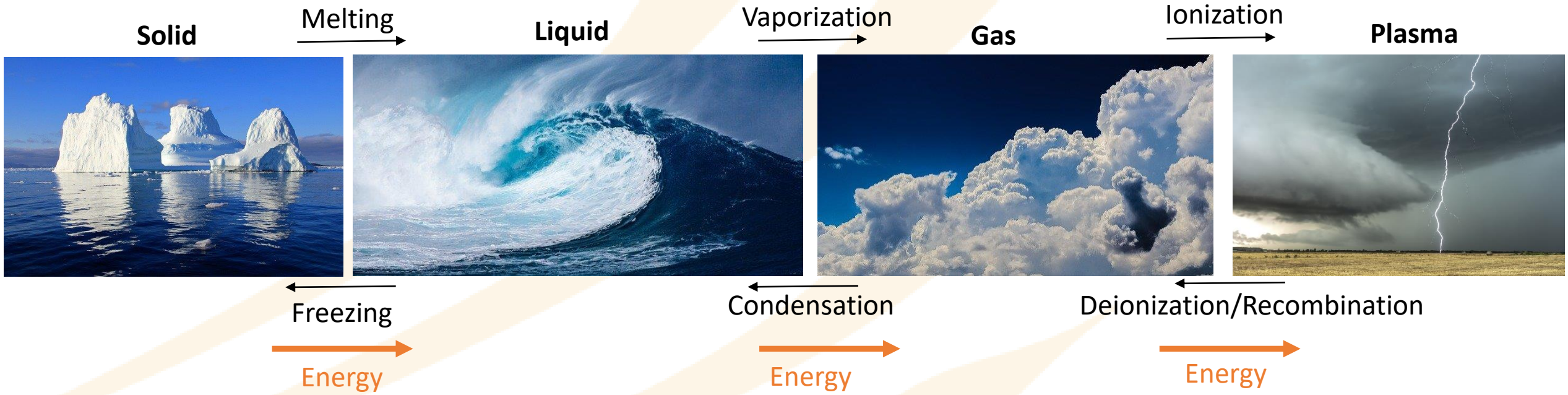
Plasma polymerisation, thin layers



Deburring

Removal of burrs and sharp edges

What is Plasma?

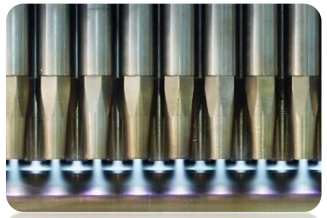


Plasma is an ionised gas.
More than 99 % of all visible mater in the universe is in the plasma state (Wikipedia).

Atmospheric plasma

TIGRES products:

MEF

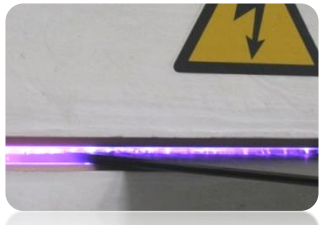


T-Spot

CAT

T-Jet

DBD



Plasma jets
(almost potential free)

Corona jets
Dielectric barrier discharge
DBD/Corona
(high voltage potential)

Atmospheric plasma

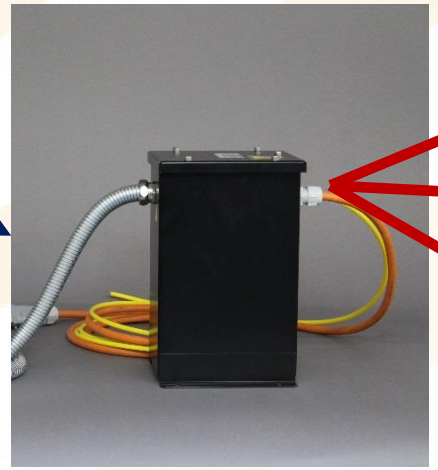
General structure of standard devices

Power supply

+

Tool

Generator + Transformer (internal / external)

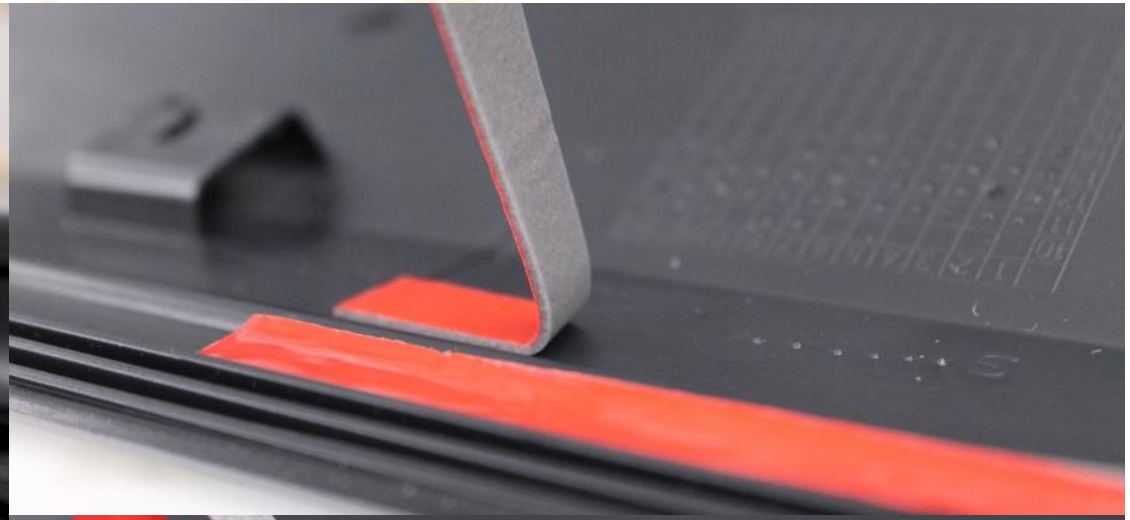


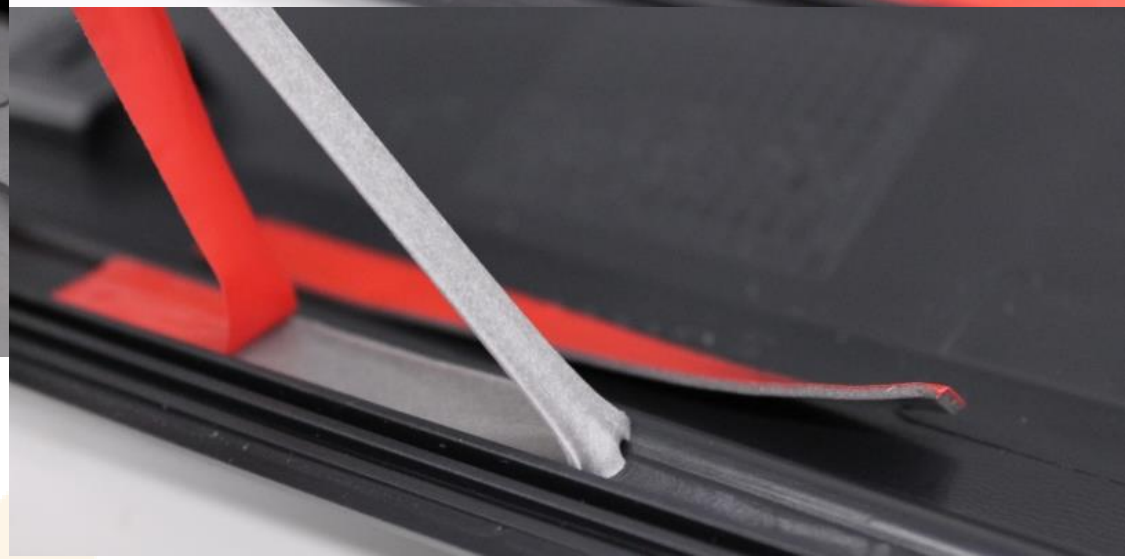
T-SPOT

CAT

MEF

Application example: Activation of PP+PE for tapes





System: CAT 600
Power: 600 W
Distance: 10 mm
Velocity: 20 m/min

The surface

Dust, dirt, oil etc. >1µm

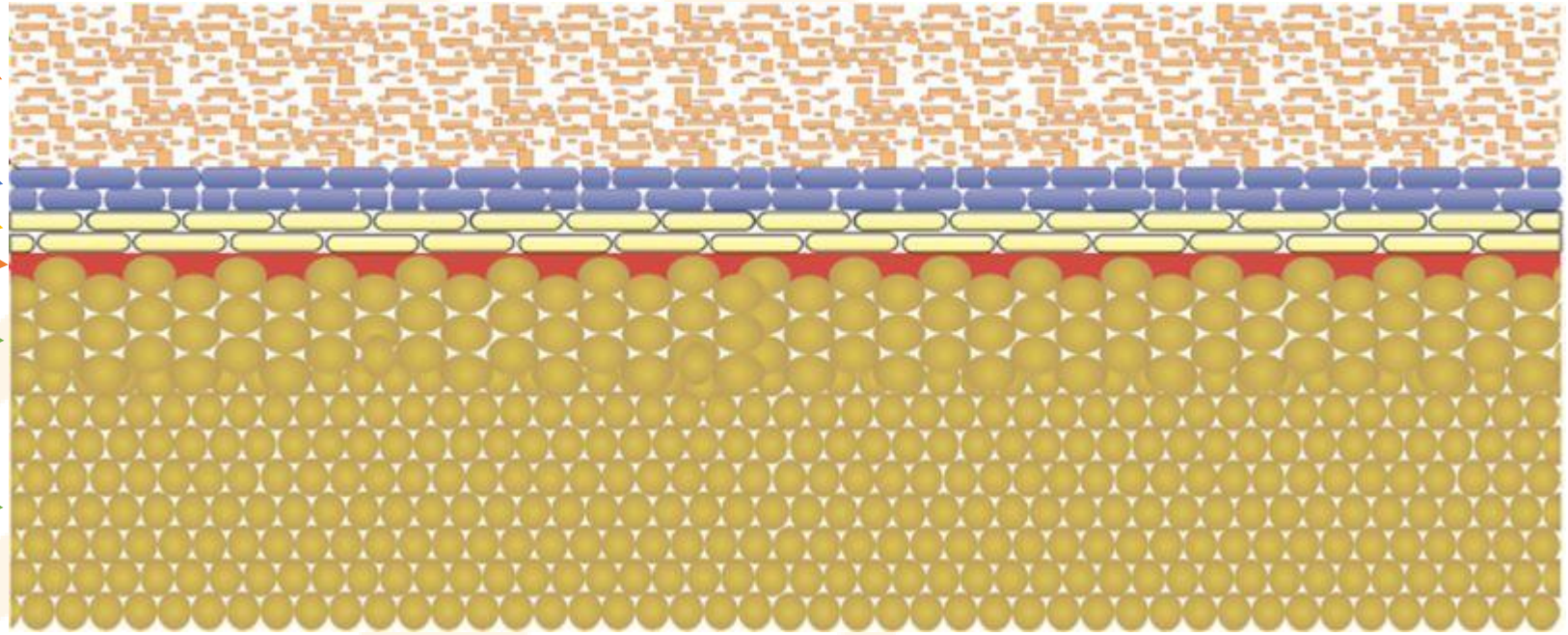
Gases, water 5-10 nm

Oxides, additives 5-10 nm

Boundary surface

Amorphous region >1 µm

Crystalline region



Picture: Dipl. Ing. (FH) Simone Fischer

The perfect surface

Dust free

Fat free

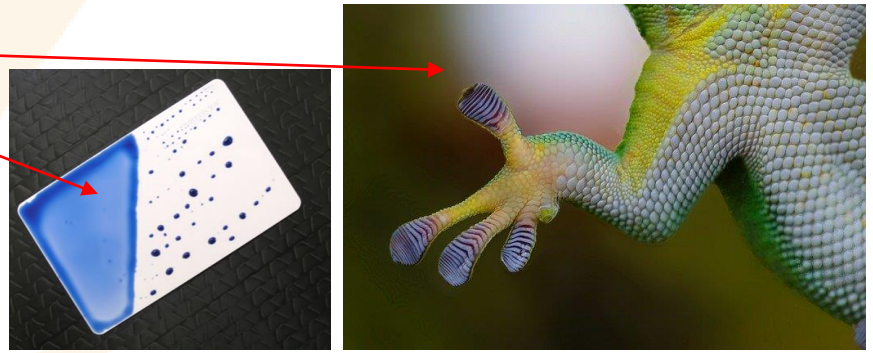
Dry

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
   2. PS with Cyanacrylat
   3. PMMA with UV adhesives
5. Electrostatic forces

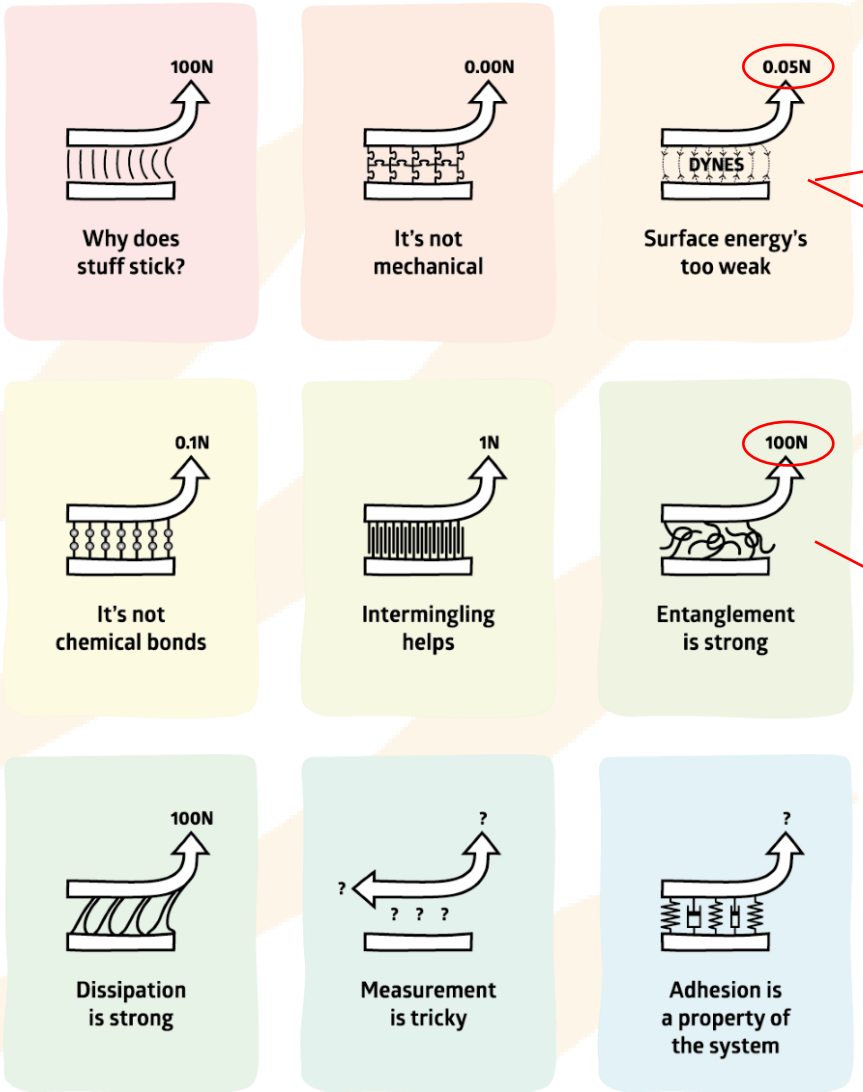
https://en.wikipedia.org/wiki/Van_der_Waals_force



https://pubmed.ncbi.nlm.nih.gov/25008078/

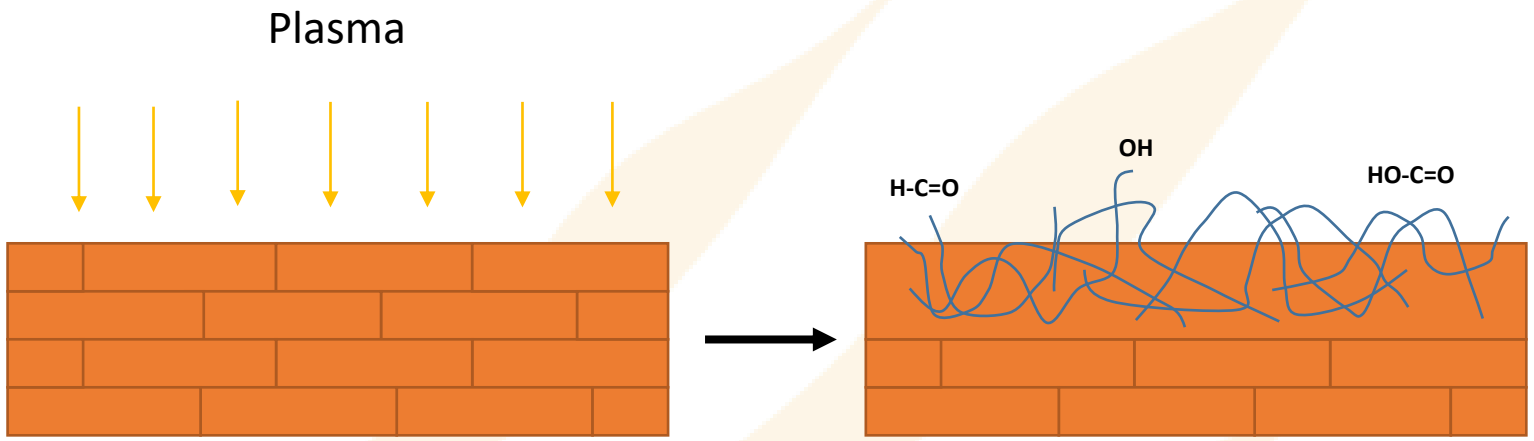
Adhesion: Why does stuff stick?

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

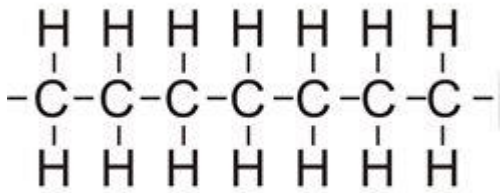
Amorphous surface

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

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

Reactions on the surface

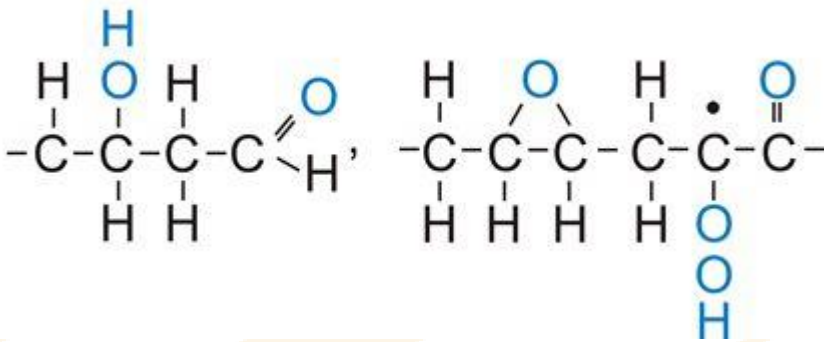
Polymer chain (PE)



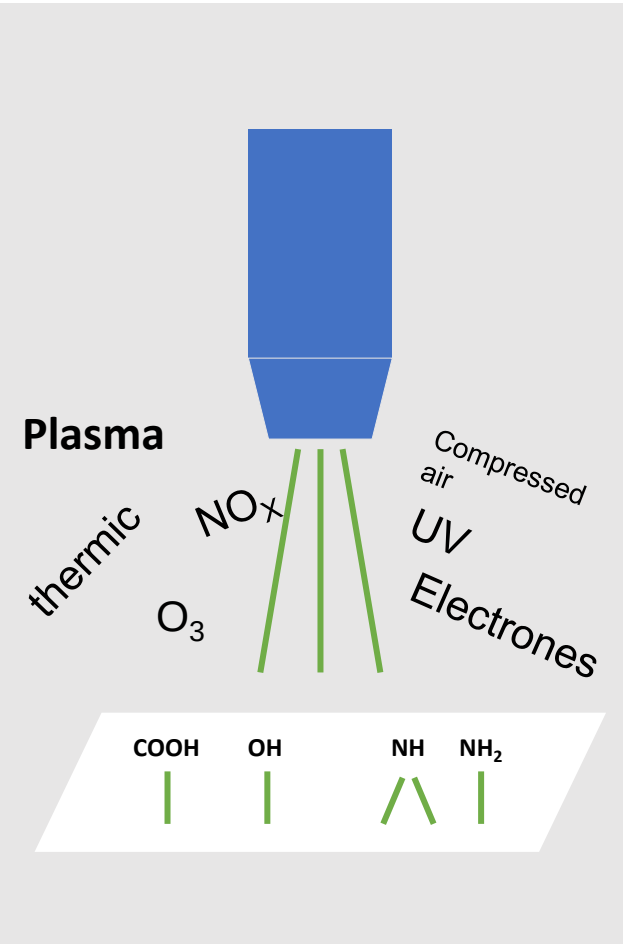
reactive species

•OH, •OOH, •O etc.

Pre treatment



Picture: Dipl. Ing. (FH) Simone Fischer

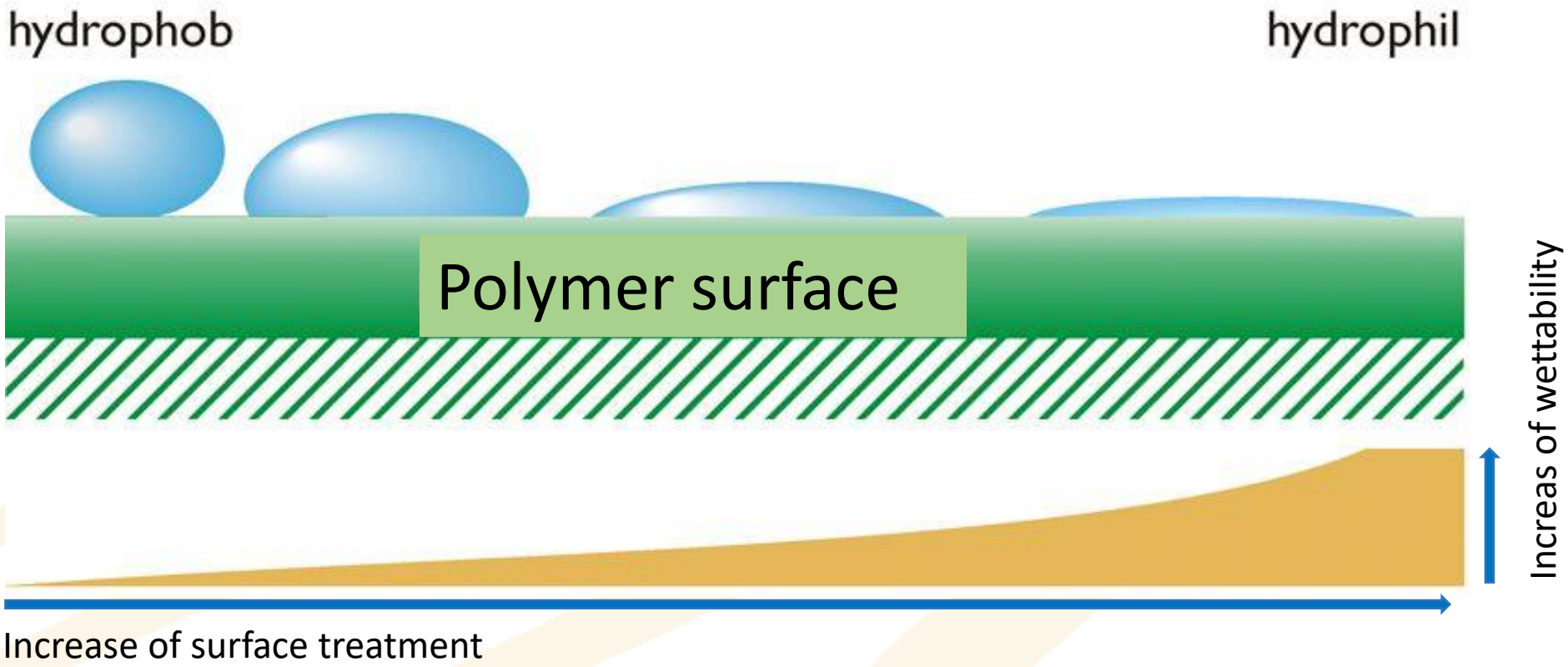


- Radicals and photons, created by the plasma, break the polymer chains
- Oxygen and nitrogene is bounded to the polymer chain

⇨ Increase of surface energy of the Polymer

Effect of surface treatment on wettabilty

Influence of surface treatment on the wettablity of polymers



Picture: Dipl. Ing. (FH) Simone Fischer

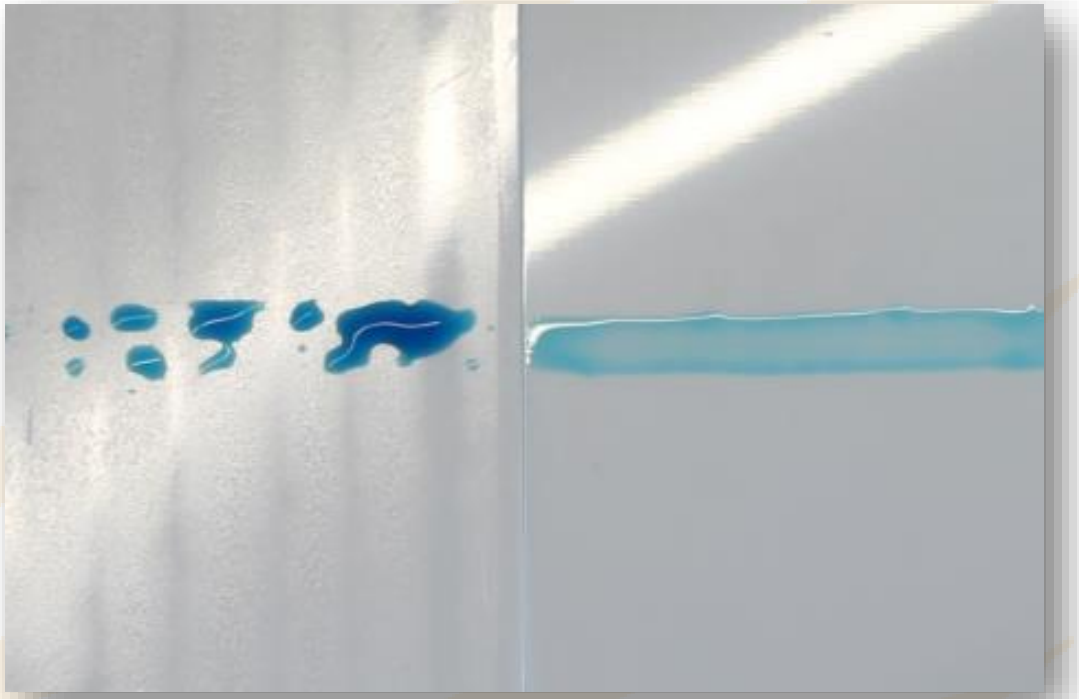
Test inks for measurement of surface energy

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

Wettability of surface

Low surface energy
Test ink stay for less than 2-3 sek.



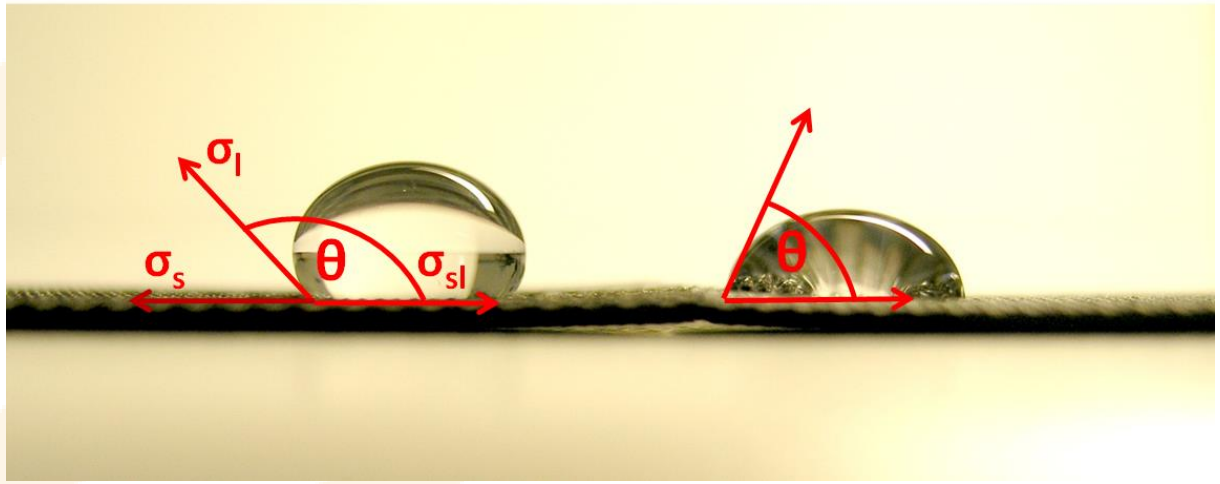
High surface energy
Test ink stay for 2-3 sek. or longer

Surface energy and material

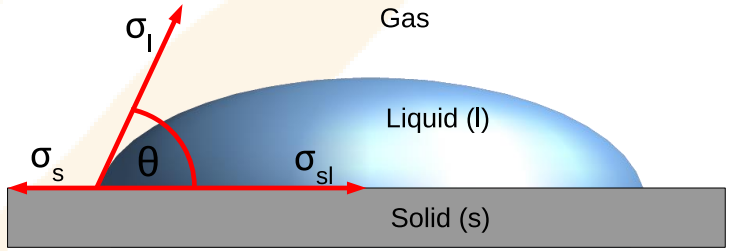
Typical surface energy of polymers:		Typical specified surface energy for:	
PTFE	< 18-19 mN/m	UV-Ink	Appr. 48 – 56 mN/m
Silicone	< 20 mN/m	Water based ink	Appr. 50 – 56 mN/m
PP	Appr. 29-31 mN/m	Coatings	Appr. 46 – 52 mN/m
PE	Appr. 30-32 mN/m	UV-glue	Appr. 44 – 50 mN/m
PS	Appr. 34-38 mN/m	Water based glue	Appr. 48 – 56 mN/m
PC	Appr. 35-44 mN/m	Solvent based glue	Appr. 38 mN/m
PUR	Appr. 43-47 mN/m		

Measurement of surface energy

- The contact angle can be measured very exactly with a contact angle meter
- It is possible to measure polar and disperse parts
- The polar part shows the polar interaction of dipols in the surface (oxygen)



Picture: Krüss, www.mobile-surface-analyzer.com



Young's equitation: $\cos\theta = (\sigma_s - \sigma_{sl}) / \sigma_l$

Simplification : $\sigma_s - \sigma_{sl} = \sigma_c$ = "critical surface energy"

σ_l : surface free tension of the liquid
σ_s : surface free energy of the solid
σ_{ls} : interfacial free energy solid/liquid
θ : contact angle

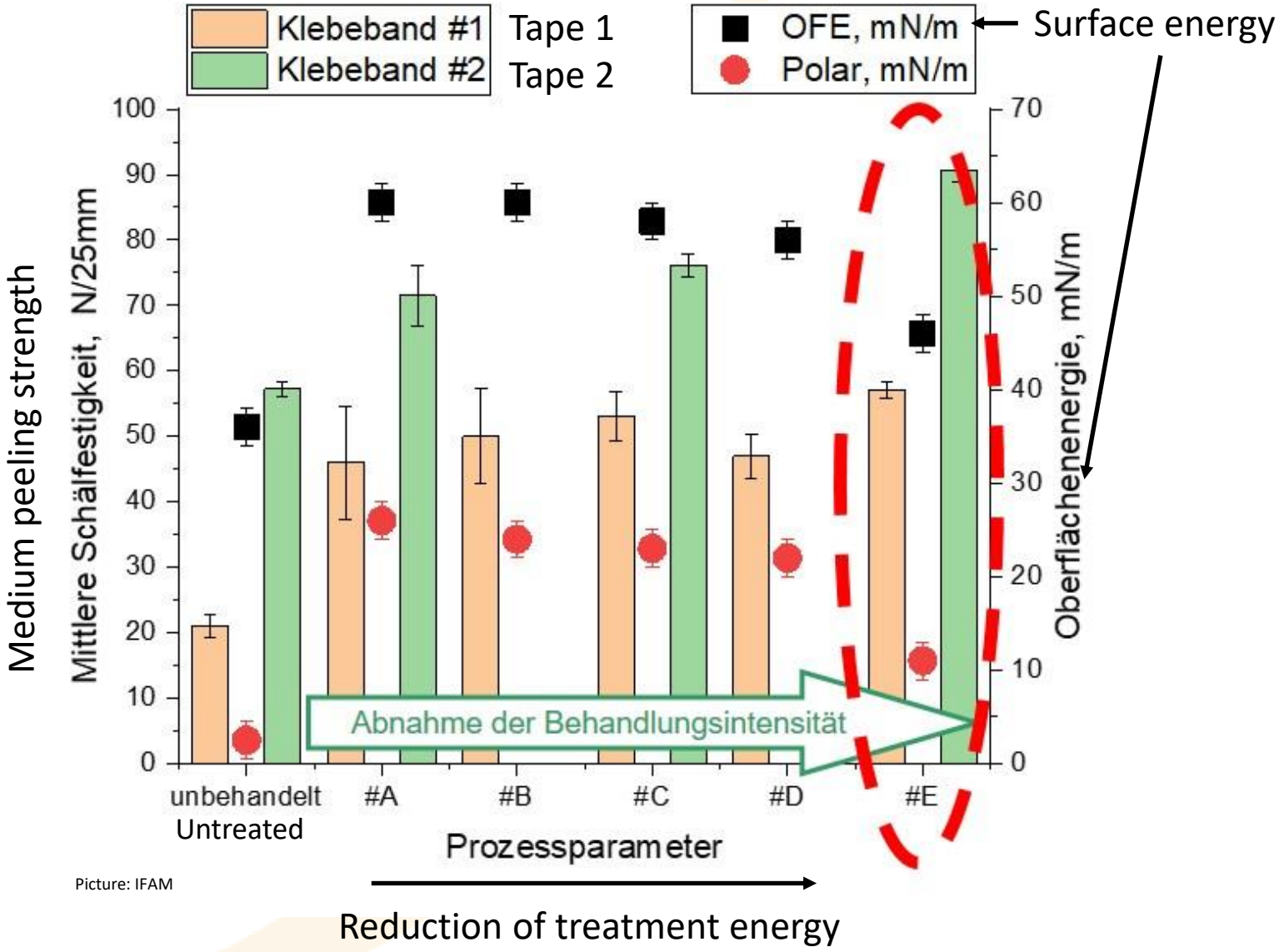
What wettability (doesn´t) show

Read more (german only):
https://www.plastverarbeiter.de/106103/wie-lange-sind-plasmaaktivierte-polymeroberflaechen-offen/

„However, within the scope of the tests carried out, no, often postulated, simple correlation between the surface energy and adhesion of the adhesives or strength of the resulting adhesive bonds could be determined. “

PDF of Fraunhofer IFAM:
https://www.ifam.fraunhofer.de/content/dam/ifam/de/documents/Klebtechnik_Oberflaechen/PLATO/plastverarbeiter-2020-beitrag-fraunhofer-ifam.PDF

Material: Varnish



Picture: IFAM

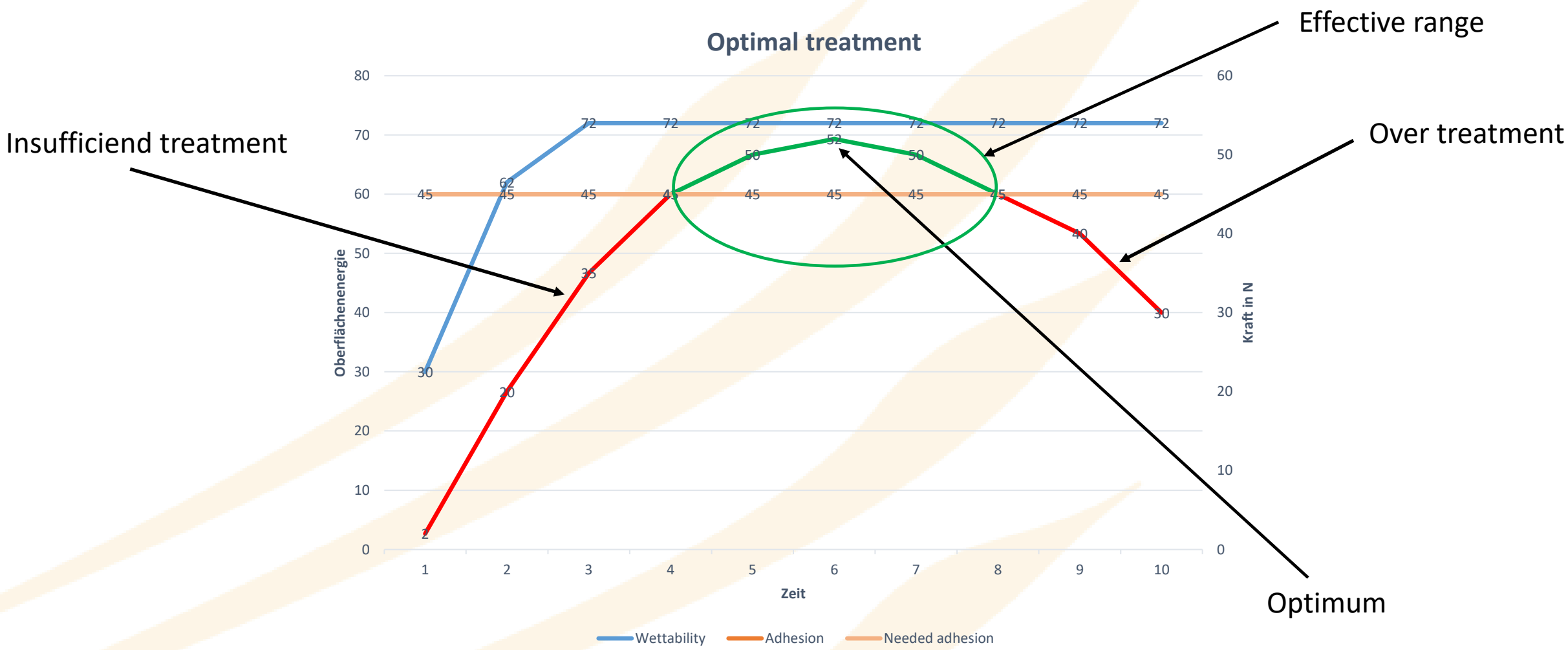
What wettability really means…

Adhesion is influenced by:	**Measurable by test ink:**
ADHESION:	
Primary valency bonds	No
Secondary valency bonds	**Yes**
Electrostatic forces	No
Diffusion	No
Mechanical clamping	No?
COHESION:	
Orientation of boundary layer	No
Strength and deformability of adherent layer	No
TESTING TECHNIQUE:	
Tension distribution in sample	No

Conclusion wetability:

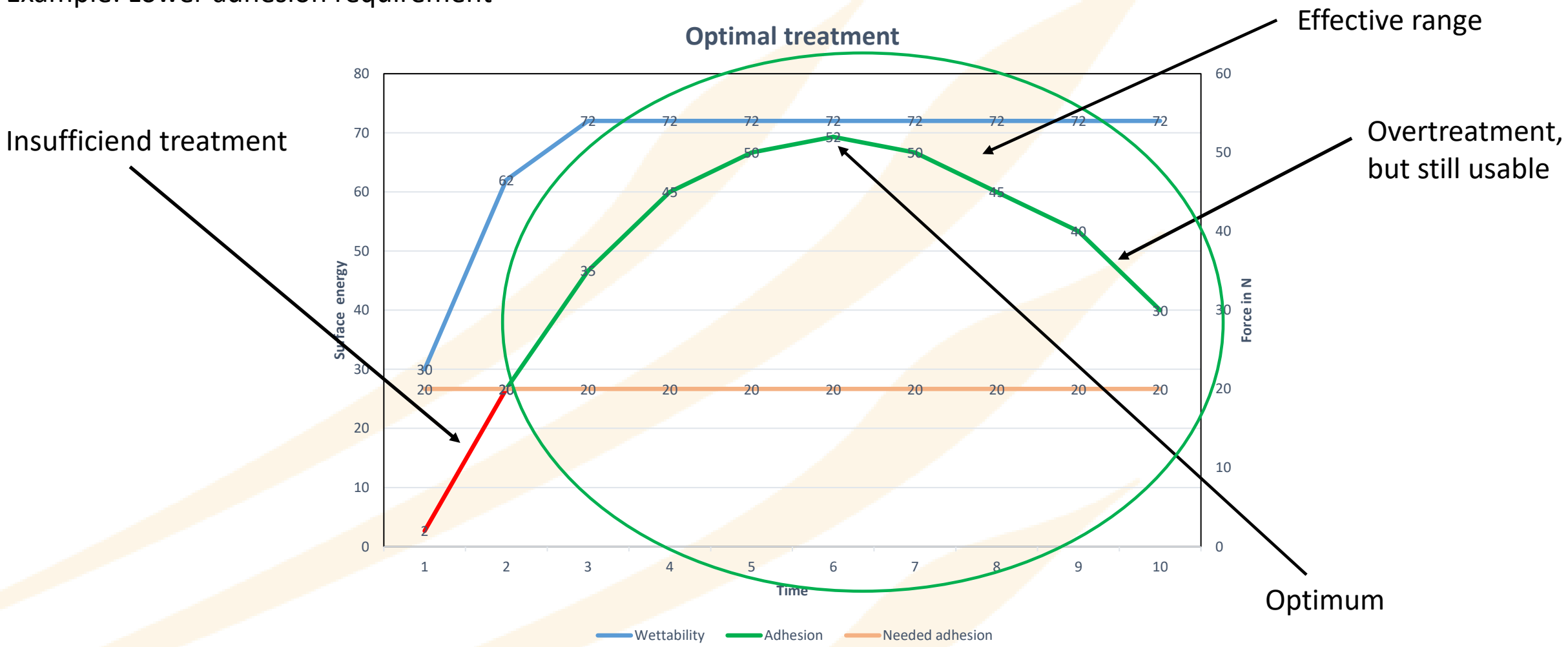
A good wettability is required, but not a sufficiend necessity for good adhesion

Optimising plasma: Finding the perfect plasma dose

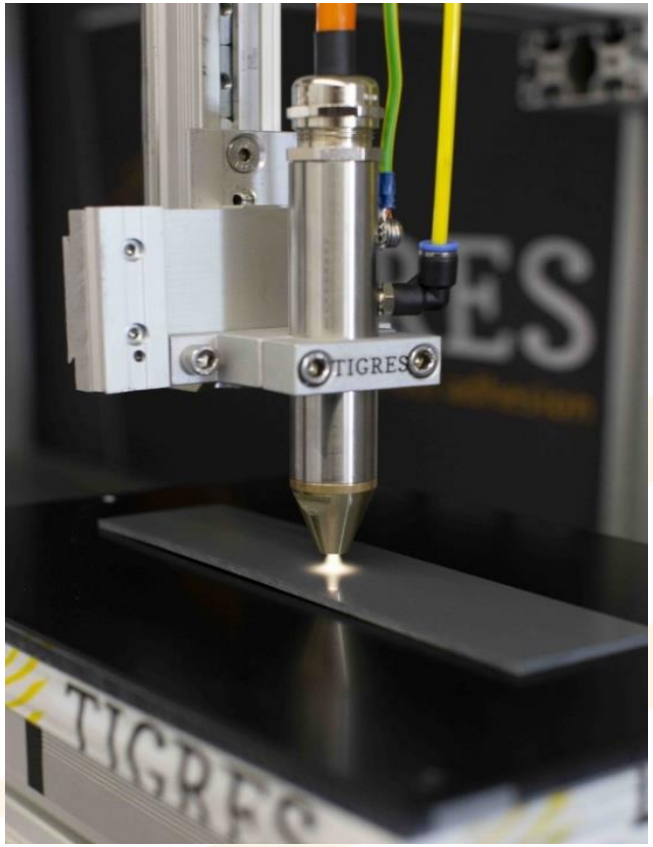


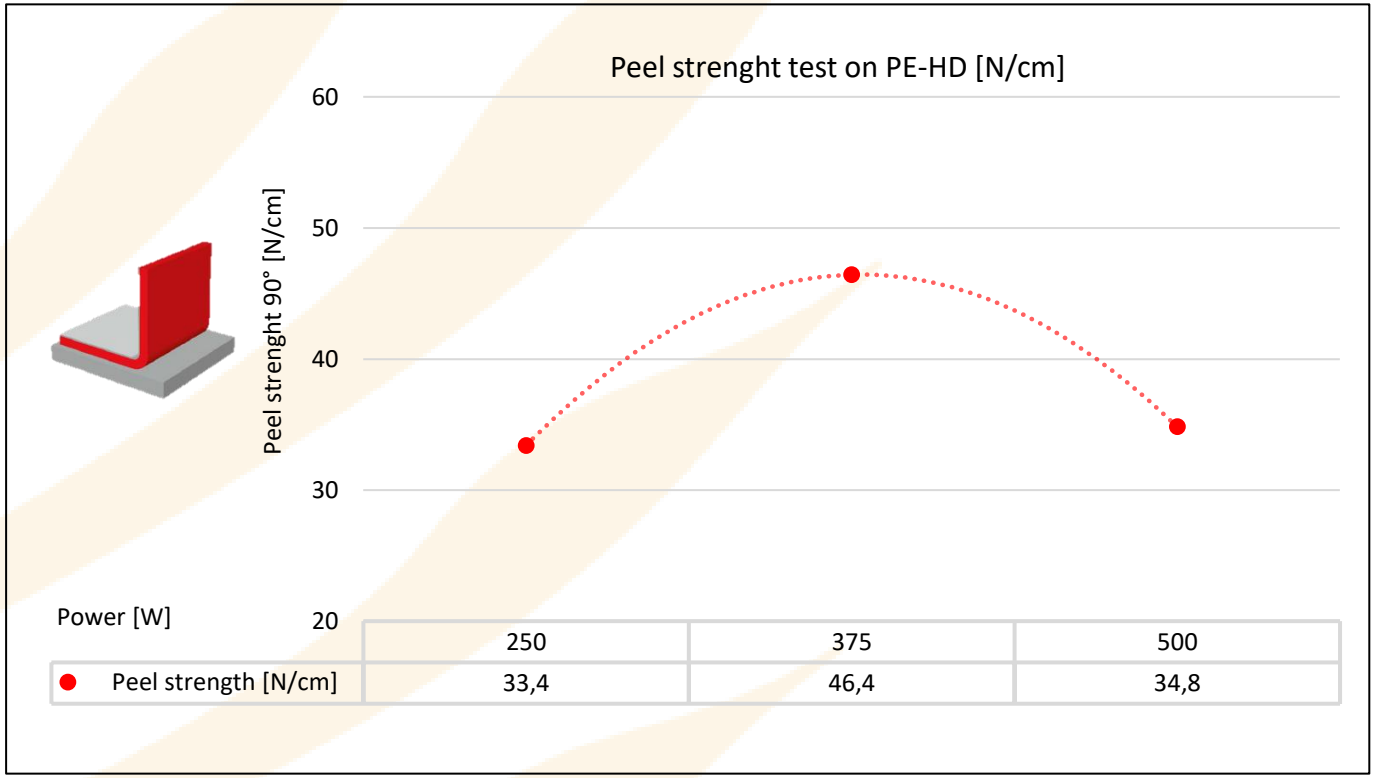
Optimising plasma: Finding the perfect plasma dose

Example: Lower adhesion requirement



Influence of power on adhesion

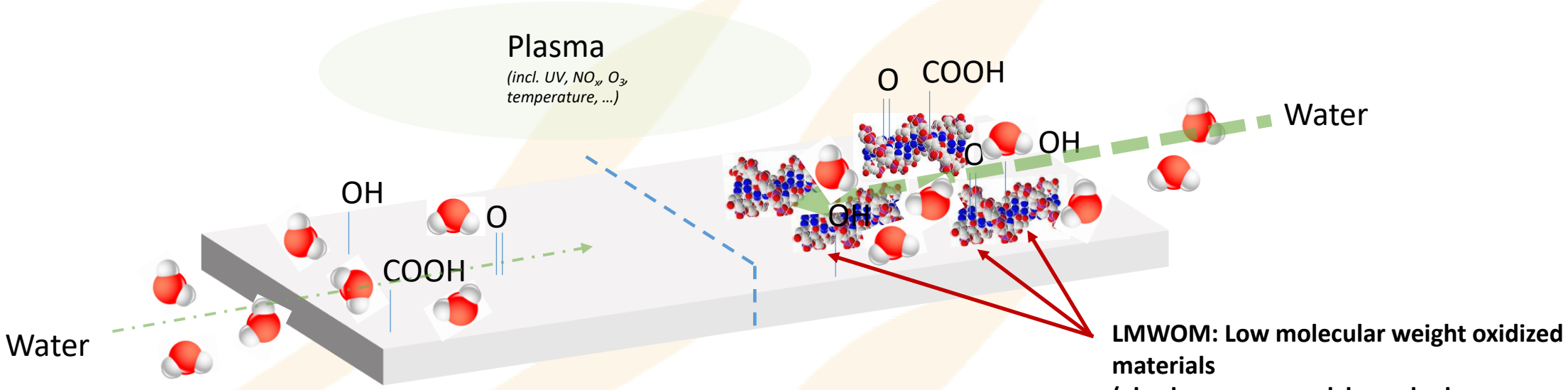




Power [W]	250	375	500
Peel strength [N/cm]	33,4	46,4	34,8

Over treatment

What happens when you over treat?



Picture: tesa SE

State 1:

Activation & Hydrophilisation

State 2:

Over treatment creates Polymer-Debris

Over treatment leads to high surface tension, but creates also:

- water solvent debris (→ allows moist to penetrate in boundry layer – leads to weak boundry layer
- Degradation of surface

Overtreatment: Example tesa-tape

Used materials: PP GF30 and tesa ACX® 7076

Used plasma technic: T-Jet Corona

Type of break:
(A) Adhesive break
(M) Mixed break
(C) Cohesive break

Number of treatments	Cleaning	T-Peel [N/cm] after 3d/RT	Surface energy [mN/m]	T-Peel [N/cm] after 240h 40° C/100% rel. H - immidiatelly	T-Peel [N/cm] after 240h 40° C/100% rel. H - reconditioned
1 x	tesa cleaner	40,9 (C)	44	32,1 (M)	39,4 (C)
3 x	tesa cleaner	42,2 (C)	48	8,9 (A)	19,5 (A)

Picture: tesa SE

The correct plasma dose is crucial for the optimal adhesion

TIGRES

Plasma for perfect adhesion

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:

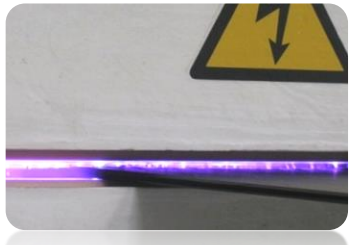
1. Only possible, if process speed can be achieved (f.e. to fast or to slow)
2. Difficult in some productions (f. e. extrusion)

☺ **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

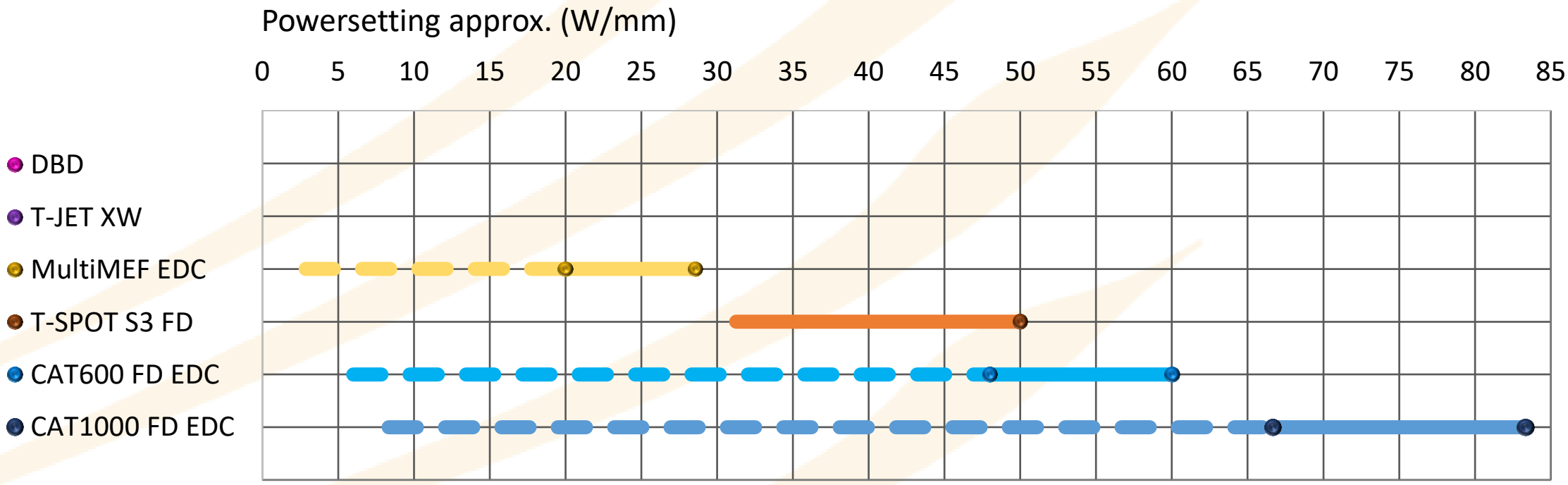
250 – 500 W / 10 mm

25 – 50 W/mm

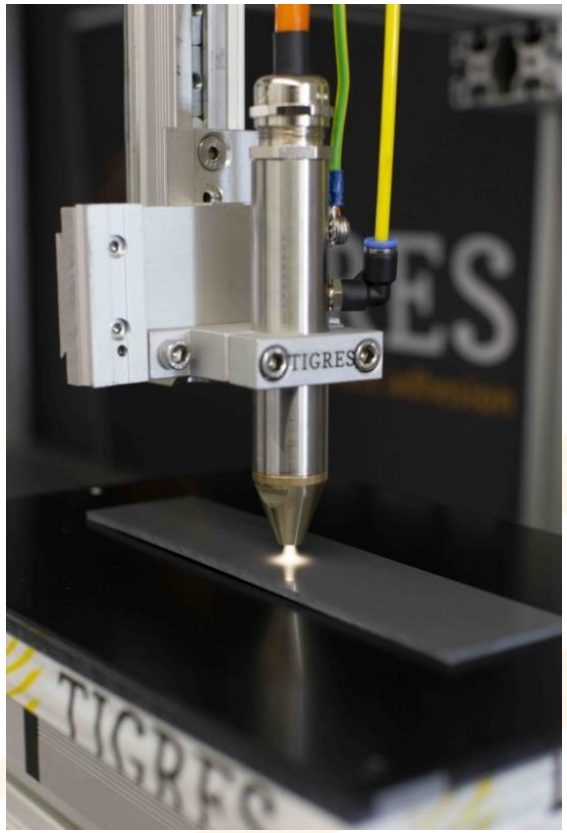
CAT

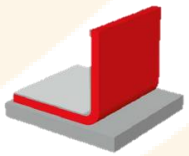
600 o. 1000 W / 12 mm

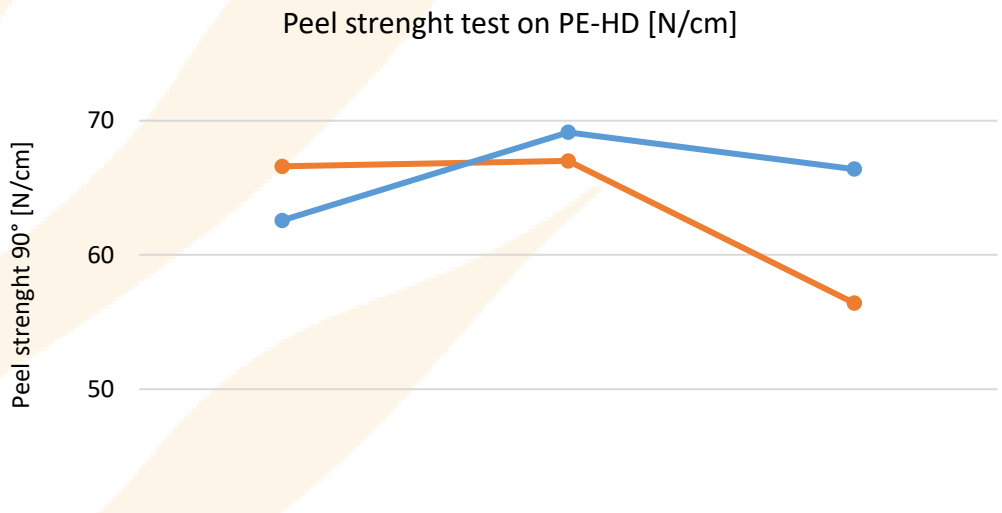
50 o. 83 W/mm



Influence of power and speed on adhesion







Power [W]	250	375	500
Plasma treatment at 20 m/min	66,6	67,0	56,4
Plasma treatment at 40 m/min	62,6	69,1	66,4

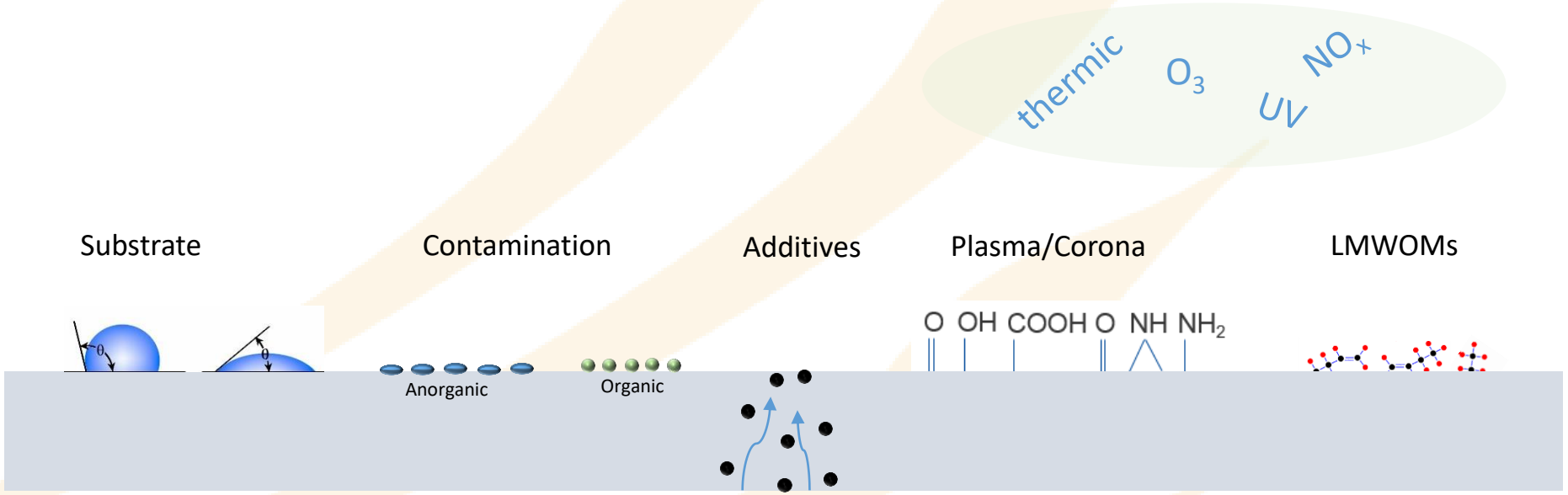
Conclusion

- ✓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 adjustable plasma generators enable an optimal plasma dose

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

Questions so far?

Complexity at the surface



Picture: tesa SE

The surface: Contamination

Typical contamination of the surface:

- Oil
- Grease
- Additives
- Finger prints
- Slip additives
- Release agents
- Oxydes
- Dust

Cleaning with plasma

Oxidation processes:

-Oxidation of organic material into vapour, CO_2 and organic particles

$(-CH_2 - CH_2-)_n+3nO_2 \rightarrow 2nCO_2+2nH_2O$

Kinetic energy:

-Acceleraction of particles (+100 eV) removes particles

?

Thermal/kinetic energy:

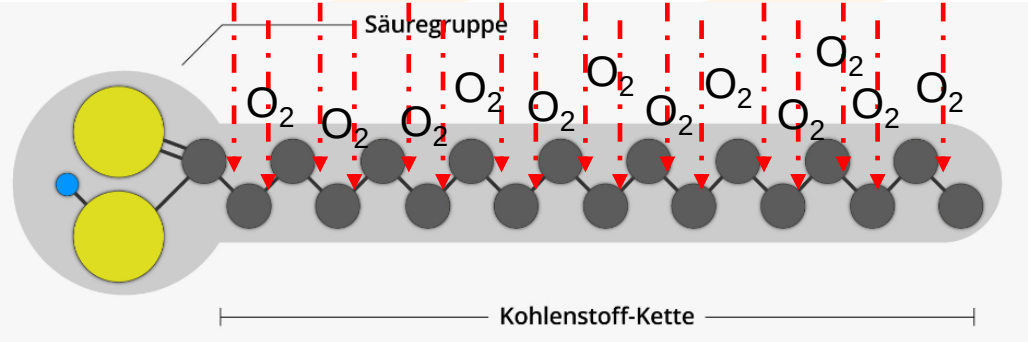
-High plasma temperature and air pressure has cleaning effects

Effect of plasma on contamination

Cleaning	Fine cleaning	Ultra-fine cleaning
Contamination: [g/m²]	Contamination: [mg/m² - µg/m²]	Contamination: [ng/m² - Molecules]

1 g/m² ≈ 1 µ Layer thickness
> 6.600 Layers of molekules!

Molecule fragmentation with plasma



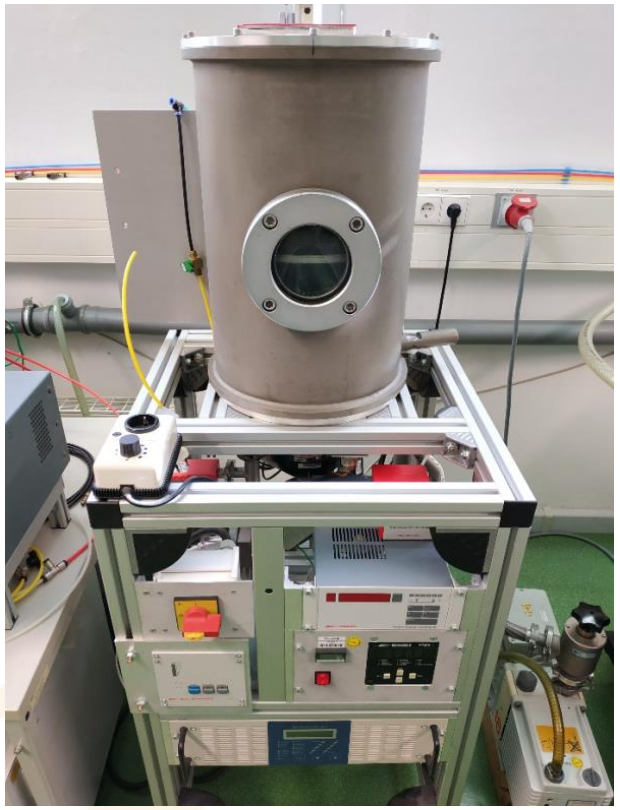
→ $xCO_2 + yH_2O$

Size comparison for a carbon single bond: 0,15 nm

Pictures: tesa SE

The surface: Cleaning with plasma

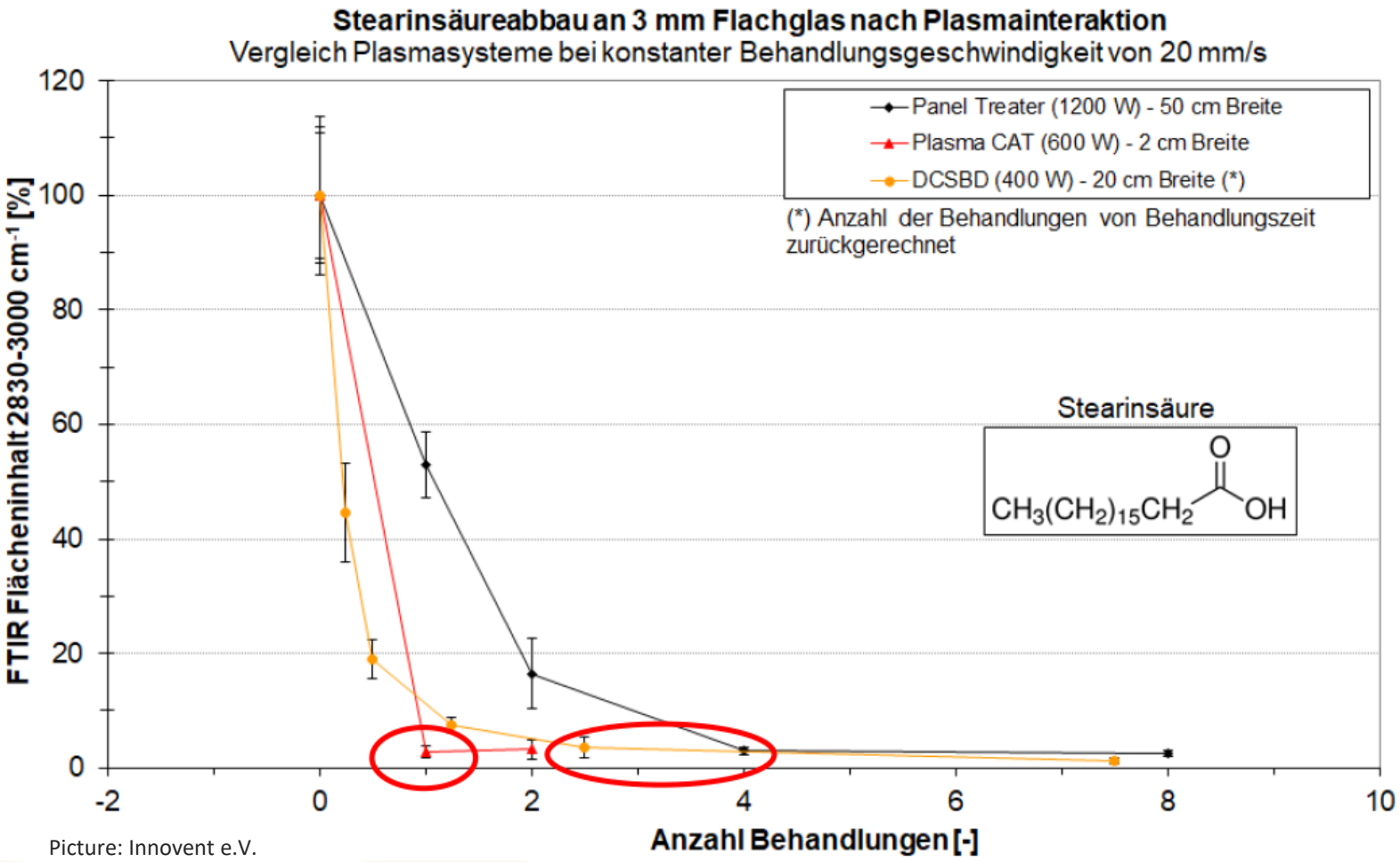
Contamination stearic acid app. 100 nm



Picture: Innovent e.V., Dr. Oliver Beier

FTIR Spektroskopie

Reduction of stearic acid on 3 mm glas after plasma at 20 mm/s

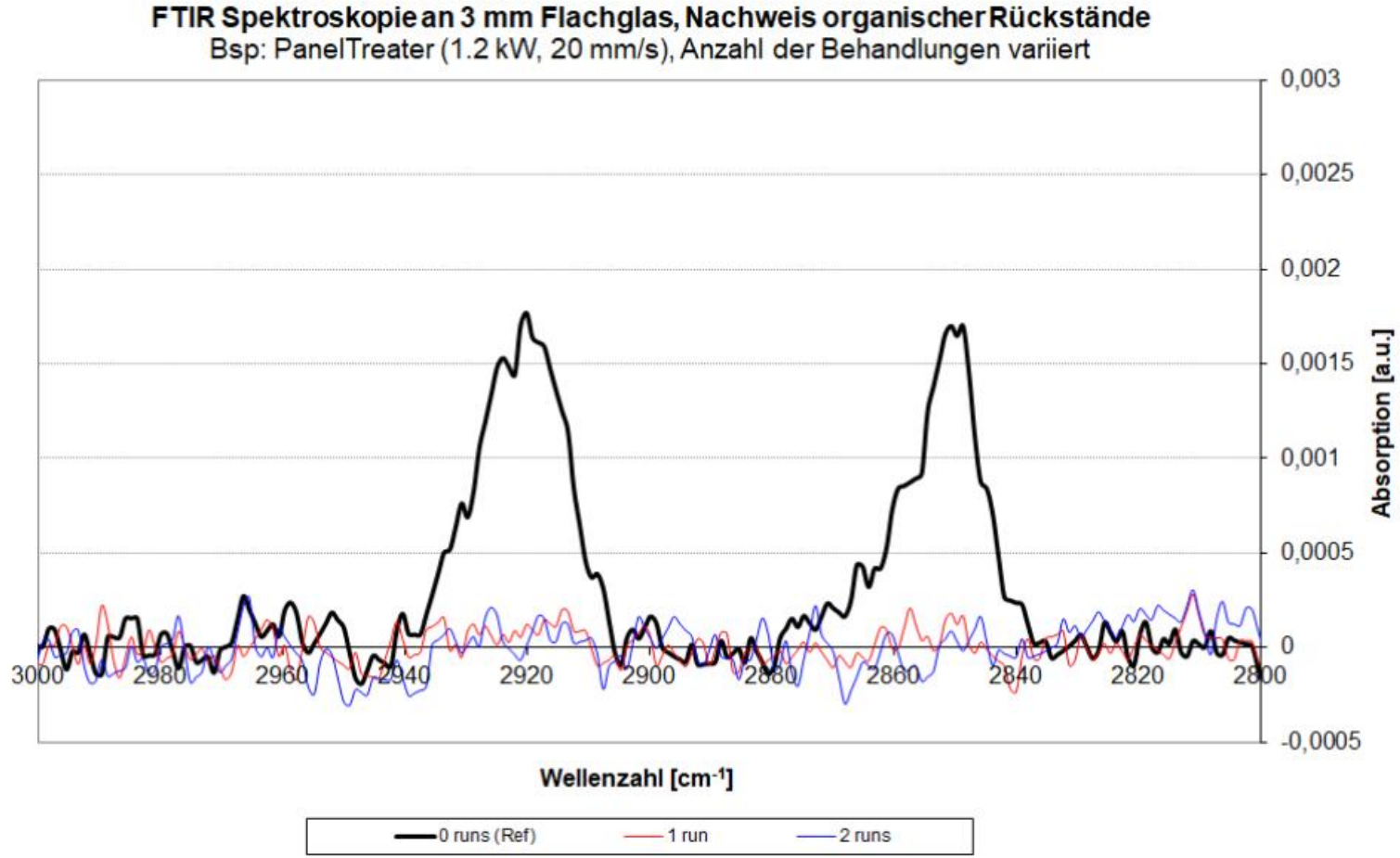


Picture: Innovent e.V.

The surface: Cleaning with plasma

FTIR Spektroskopie

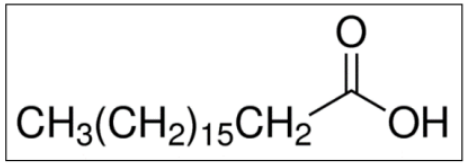
FTIR Spectoscopy on 3 mm glas, proof of organic residues



Picture: Innovent e.V.

The surface: Cleaned vs. plasma treated

Cleaning of Stearic acid

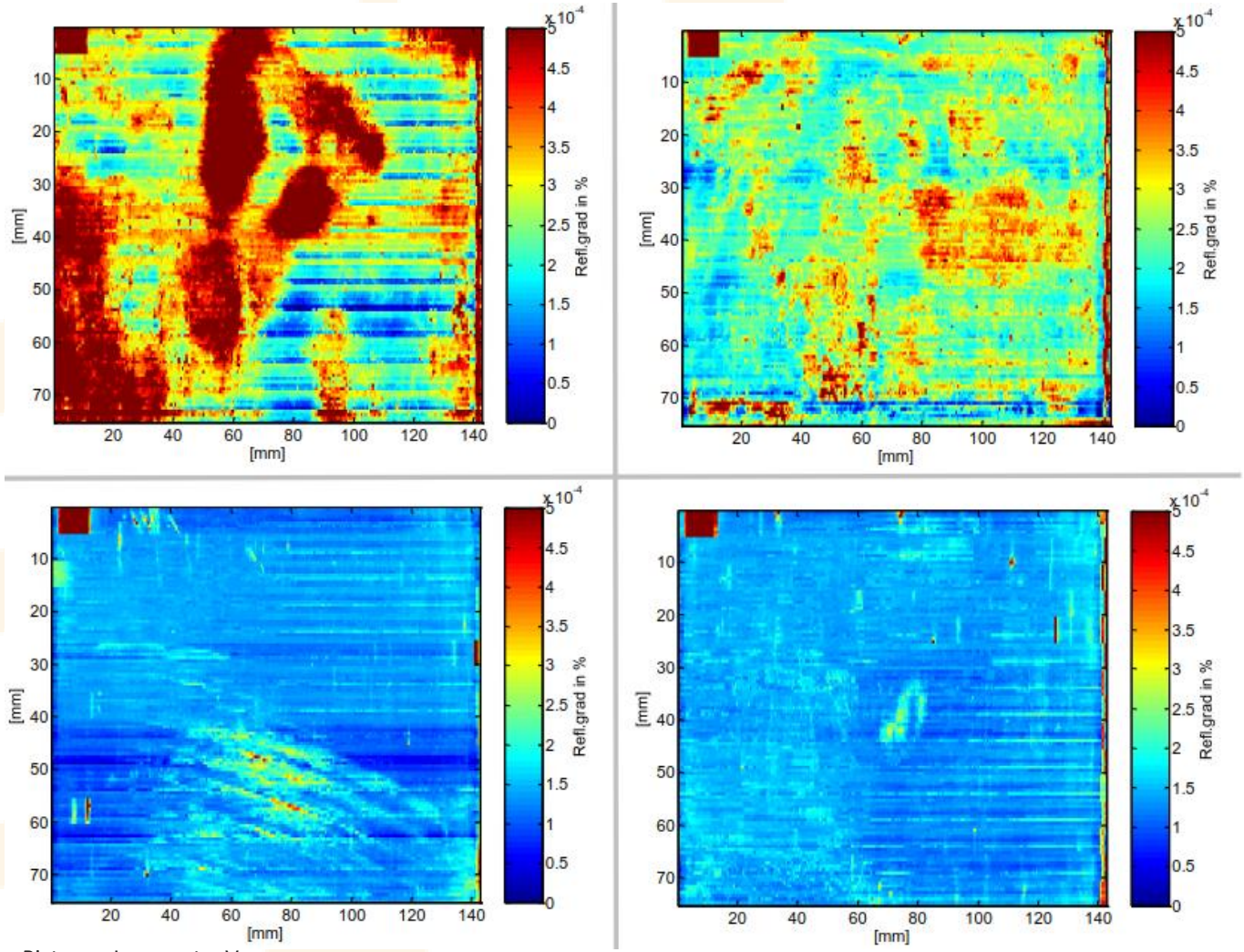


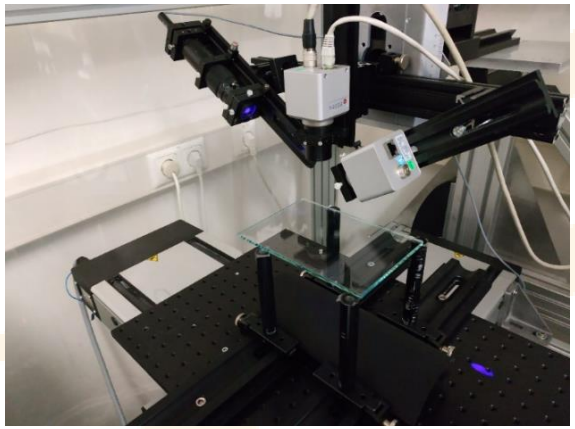
Laser scanning

Glas contaminated

Before Plasma

After Plasma (DCSBD, 10 sec, 400 W)

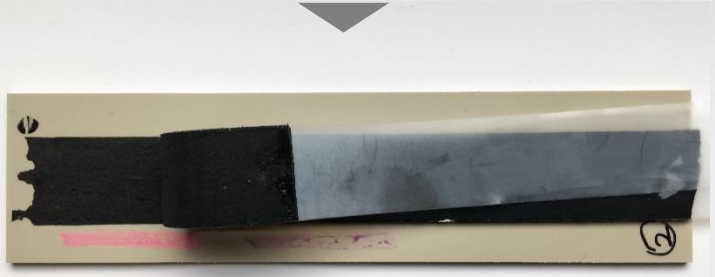




Glas chemical cleaned

Pictures: Innovent e.V.

The surface: Cleaned vs. contaminated

Polypropylen cleaned	Polypropylen contaminated
	
Plasma & bonding with tape ACX^{plus} 7812	
	
Break: cohesive	Break: adhesive

Pictures: tesa SE

Can surface energy predict bonding?

The surface: Cleaned vs. contaminated

Condition	Surface energy [mN/m]	Bonding f. T-Peel 90° [N/cm]	Break type
Polypropylen cleaned [with Isopropanol]	30	12	A[100%]
Polypropylen cleaned & plasma treated	→ 44	→ **78**	**K[100%]**
Polypropylen contaminated [Silikone system PDMS – 1h block storage 40°C]	< 30	5	A[100%]
Polypropylen contaminated & Plasma treated	→ > 48	→ 9	A[100%]

Plasma: TIGRES T-SPOT S2: v = 40 m/min, d = 5 mm, PWR = 60 % r = 6 mm
Break type: Adhesion break [A], Mixed break [M], cohesion break [K]
Measurement: T-Peel 90°, 300 mm/min, Delay 3d

Adhesion force doesn´t correlate with surface energy!

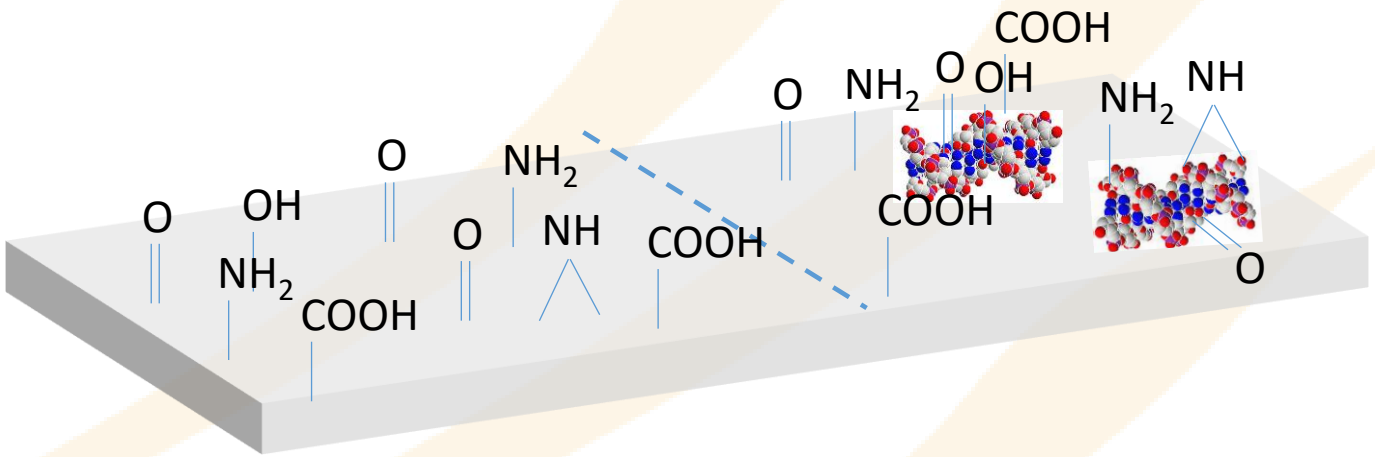
Contaminations can not be safely identified with surface energy values!

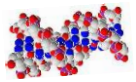
Bilder: tesa SE

The surface: Cleaned vs. contaminated

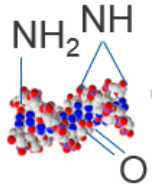
Surface free of contamination

Surface with contamination





= Contamination, org. molecule



Pictures: tesa SE

Clean surfaces are functionalised with plasma

Also Contaminations are functionalisied and show high surface energies.

This doesn´t show a good adhesion or cleaning of the contaminated surface.

Cleaning with plasma

Why then is plasma used for cleaning?

The surface: Cleaned vs. contaminated

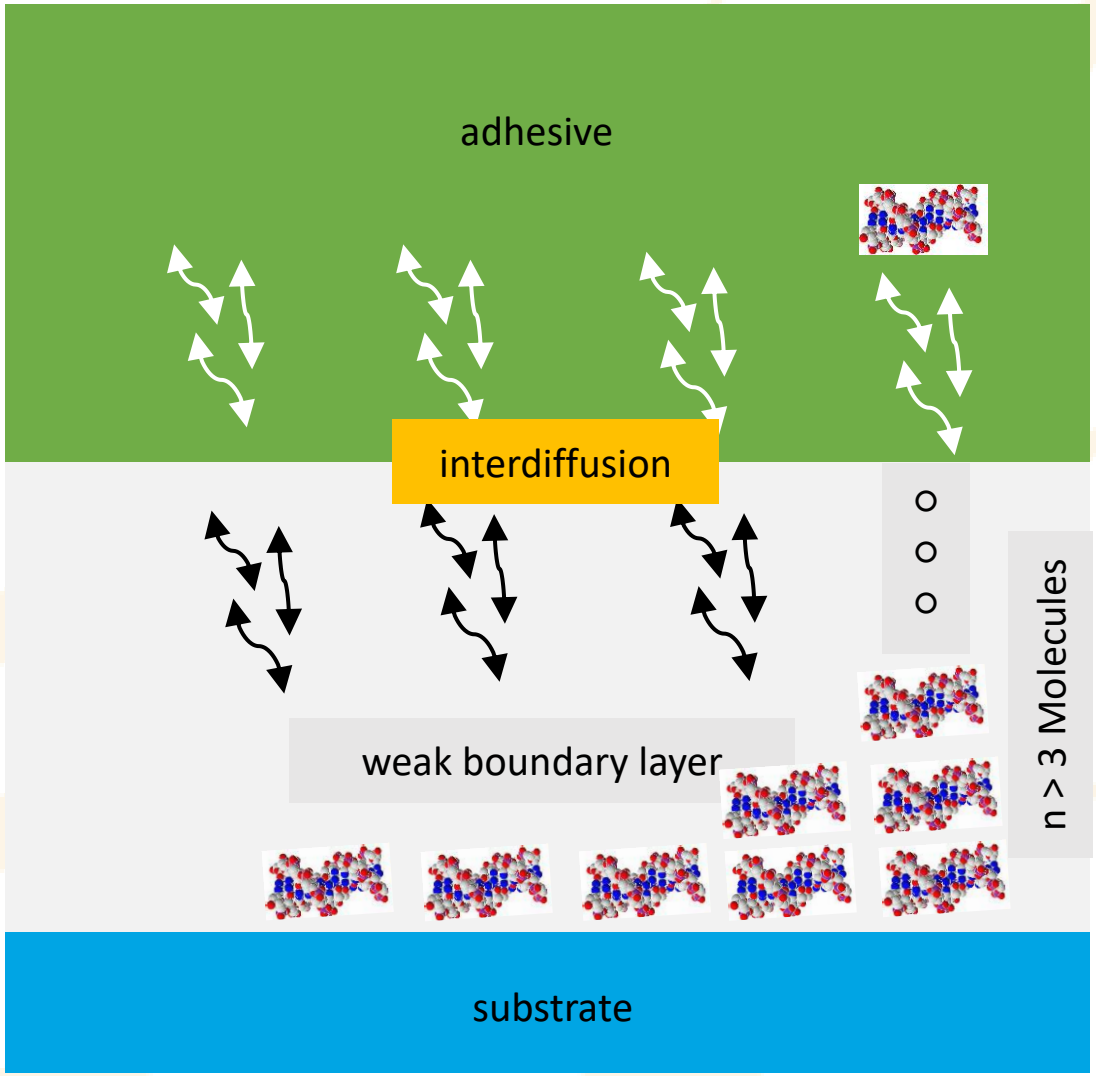
Condition	**Surface energy** [mN/m]	**Adhesion T-Peel 90°** [N/cm]	**Break type**
Polypropylen cleaned [with Isopropanol]	30	12	A[100%]
Polypropylen cleaned & plasma treated	44	**78**	**K[100%]**
Polypropylen contaminated [Silikone system PDMS – 1h block storage 40°C]	< 30	→ 5	A[100%]
Polypropylen contaminated & Plasma treated	> 48	→ 9	A[100%]

Plasma: TIGRES T-SPOT S2: v = 40 m/min, d = 5 mm, PWR = 60 % r = 6 mm
Break type: Adhesion break [A], Mixed break [M], cohesion break [K]
Measurement: T-Peel 90°, 300 mm/min, Delay 3d

Pictures: tesa SE

Why the does plasma often work on contaminations?

Diffusion in the Bulk of the adhesive is neccessary!



Pictures: tesa SE

Interdiffusion depends strongly of the contamination and the type of glue/media

Conclusion cleaning with plasma: Yes, but...

1. Cleaning:
   - Yes, but: Removal/Hydrophilizising of thin layers of organic components (*Fine* cleaning, especially in vacuum plasma). Test of application is necessary!

2. Electrostatic neutralizing:
   - Plastcis don´t attract dust – side effect of plasma treatment

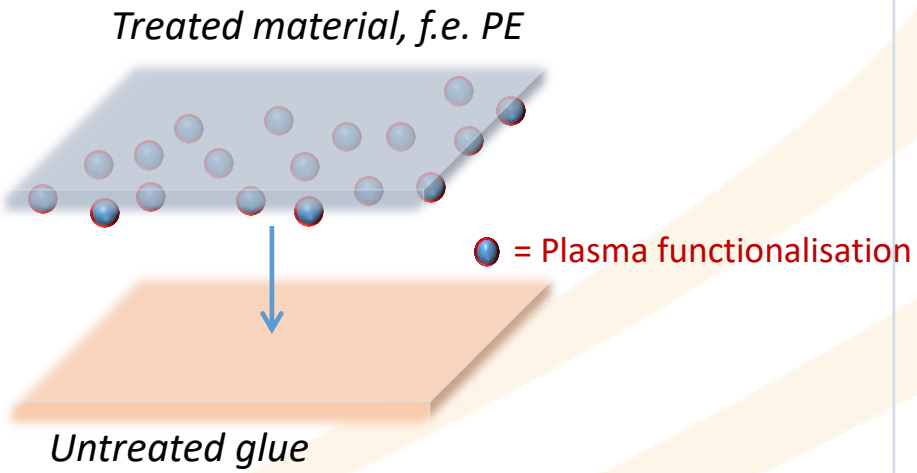
Conclusion plasma for cleaning:
If plasma works it is:

1. Simple and easy to use
2. Cost effective
3. Reproduceable
4. More environment friendly

Special: Treatment of adhesive in PSA applications

Option 1: Standard plasma treatment

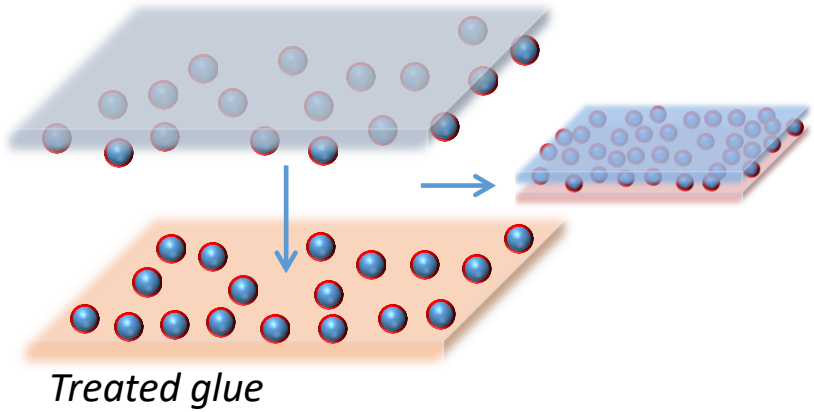
Single sided treatment



Option 2: tesa

Double sided treatment

(Patent Application EP2705103 (B1))



Amount of chemical → functionalities significantly higher

Significant improvement of all adhesive properties

Special tesa: Activation of tape glue side

Advantage of double sided plasma treatment:

- Double sided treatment increases **amount of functional groups**
- Allows a broader spectrum of **glue-material combinations**
- Curing time is reduced from 72 h to 5-30 min (app. 80-95 % of adhesion values)
- For the same adhesion results smaler tapes can be used
- Difficult to treat materials can be used (POM, PMMA, ABS, …)
- On some materials only tape side needs to be treated

Special: Double- and single sided treatment with tesa tapes

Tape K1

(Plasmabehandlung nach Verfahren PV1, Verklebung sofort nach Behandlung)

[0172]

Tape K1
Material:
Double sided treatment
Only material treated
Only glue treated

Adhesion force N/cm

PP	PET	CFK	KTL
45,53	47,10	38,16	37,58
3,95	9,61	7,16	3,97
17,71	12,11	12,47	14,81
2,98	25,85	37,16	36,98

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Surface energy material: Polar materials

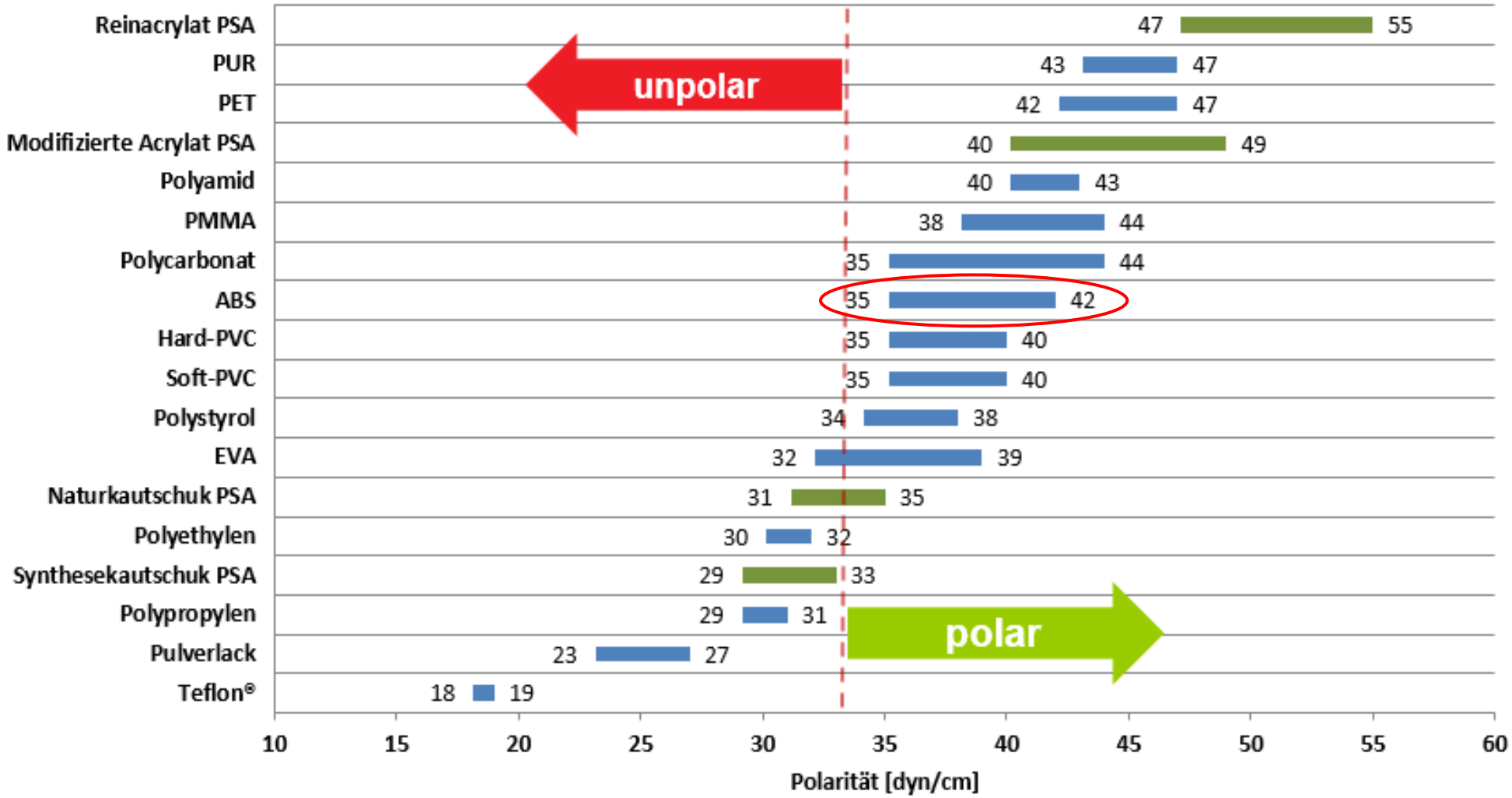

Bild: tesa SE

Special: Double- and single sided treatment with tesa tapes on ABS

Tabelle 9

Tape	Material:	Klebkraft [N/cm] EPDM	PE	ABS	ASTM-Stahl	Lack 1	Lack 2
K1	Double sided treatment	42,16	42,98	42,55	44,41	39,99	40,54
	Untreated	1,93	0,62	13,70	5,38	3,21	4,87
	Only material treated	5,78	5,78	3,90	5,30	4,44	4,25
	Only glue treated	1,10	0,71	11,47	43,22	2,85	4,00
K2	PV1	35,69	17,05	33,97	33,26	26,71	30,82
	Nichts behandelt	1,95	1,78	11,90	12,39	6,34	10,70
	Nur Substrat behandelt	18,61	14,16	13,66	13,19	12,61	12,19
	Nur Klebmasse behandelt	0,96	1,93	8,75	19,54	6,35	8,11
K3	PV1	87,53	76,85	84,87	84,65	81,76	83,81
	Nichts behandelt	3,11	2,38	38,11	49,67	11,91	30,21
	Nur Substrat behandelt	61,65	64,85	43,25	73,14	37,47	39,20
	Nur Klebmasse behandelt	3,63	2,80	65,86	83,01	5,57	26,45
K4	PV1	68,61	62,80	71,62	71,53	74,18	73,36
	Nichts behandelt Nur Substrat	1,62	2,07	12,52	25,74	8,66	17,27
	behandelt Nur Klebmasse	30,42	28,05	30,63	32,55	33,2	33,17
	behandelt	3,36	2,02	10,27	69,17	9,63	17,57
K5	PV1	39,25	30,17	37,80	39,38	38,20	38,10
	Nichts behandelt	0,69	0,63	9,95	28,25	2,15	17,17
	Nur Substrat behandelt	24,04	22,69	25,70	30,90	24,69	27,37
	Nur Klebmasse behandelt	0,60	0,56	1,51	38,74	2,15	2,76

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Special: Impovent curing time with double sided treatment of tesa tapes

Tabelle 14

Tape K1	Treatment	Lagerzeit nach Verklebung vor der Messung wie angegeben, bei 23°C/ 50%rF	Klebkraft [N/cm] EPDM	PE	ABS	ASTM-Stahl	Lack 2
K1	ohne	3 Tage	1,93	0,62	13,70	5,38	4,87
	PV1	5 min	45,99	37,27	25,65	32,32	29,17
	PV1	3 Tage	42,16	42,98	42,55	44,41	40,54
	PV1	5 min	19,09	25,10	17,72	14,37	23,07
	PV1	3 Tage	35,69	17,05	33,97	33,26	30,82
K3)	ohne	3 Tage	3,11	2,38	38,11	49,67	30,21
	PV1	5 min	51,63	47,82	86,45	90,37	84,82
	PV1	3 Tage	87,53	76,85	84,87	83,01	83,81
K5	ohne	3 Tage	0,69	0,63	9,95	28,25	17,17
	PV1	5 min	21,09	34,47	42,90	43,74	42,59
	PV1	3 Tage	39,25	30,17	37,80	39,38	38,10

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Special: Distance of double- and single sided treatment

Tabelle 15

Untergrund	Klebeband	Prozessgas	Abstand zur Klebemasse-oberfläche [mm]	Abstand zur Oberfläche des Untergrunds [mm]	F [N/cm]
ASTM-Stahl	K2	ohne Behandlung	-	-	10,70
ASTM-Stahl	K2	Luft	5	8	33,14
ASTM-Stahl	K2	Luft	8	8	35,85
ASTM-Stahl	K2	Luft	11	8	33,69
ASTM-Stahl	K2	Luft	14	8	32,87
ASTM-Stahl	K2	Luft	17	8	32,67
PP	K3	ohne Behandlung	-	-	4,48
PP	K3	N2	5	6	83,55
PP	K3	N2	11	12	82,63
PP	K3	N2	17	18	82,86
PP	K3	Luft	5	6	79,85

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Special: Distance of double- and single sided treatment

Untergrund	Klebeband	Prozessgas	Abstand zur Klebemasse-oberfläche [mm]	Abstand zur Oberfläche des Untergrunds [mm]	F [N/cm]
PP	K3	Luft	8	9	83,90
PP	K3	Luft	11	12	83,21
PP	K3	Luft	17	18	57,52

[0184] Hier wird nachgewiesen, dass das Verfahren robust ist gegen Variation von Abständen und Betriebsgas. Das Prozessfenster ist überraschend groß.

[0185] Bemerkenswerterweise kann bei Betrieb mit N2 ein größerer Behandlungsabstand genutzt werden als mit Luft.

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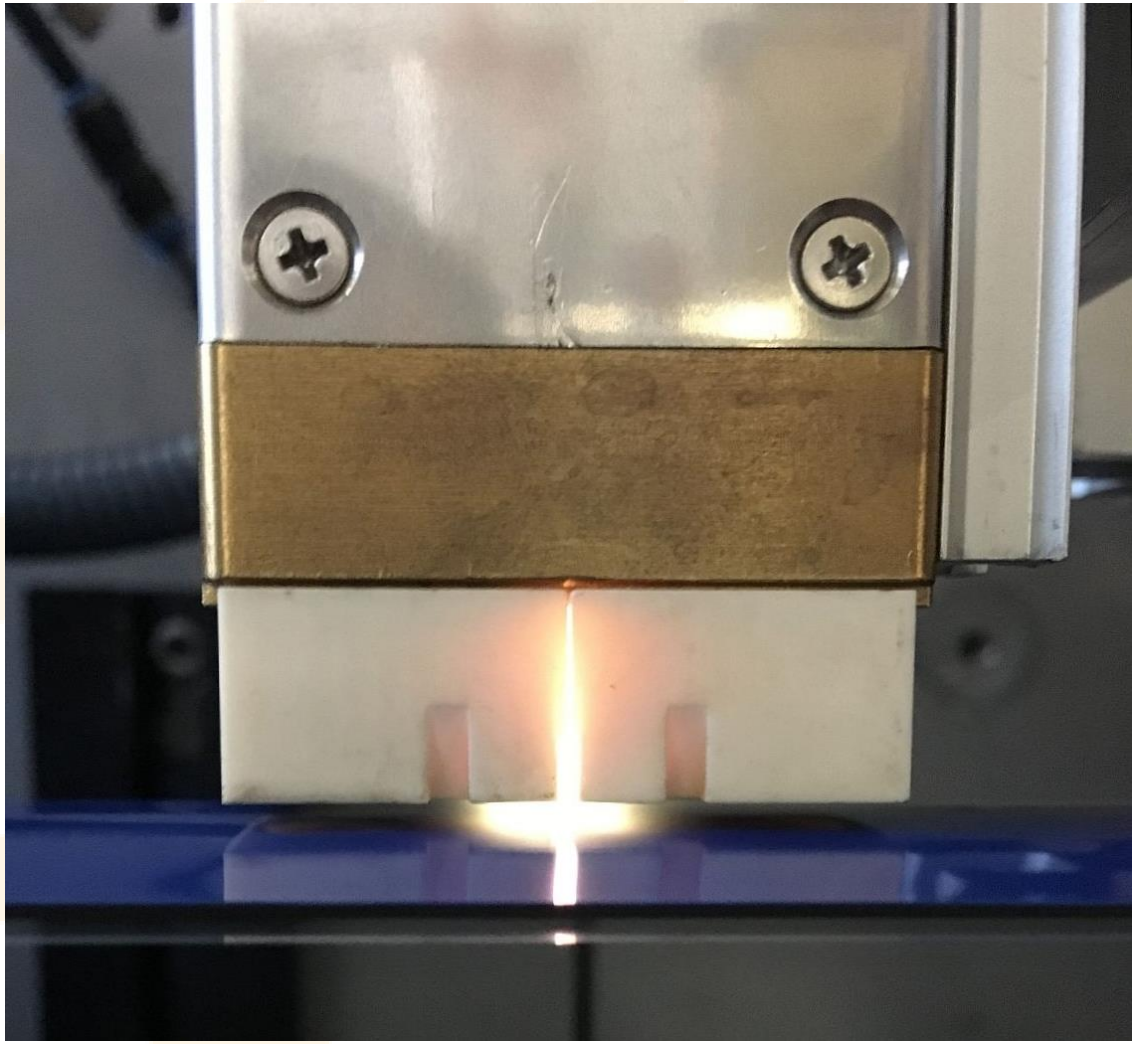
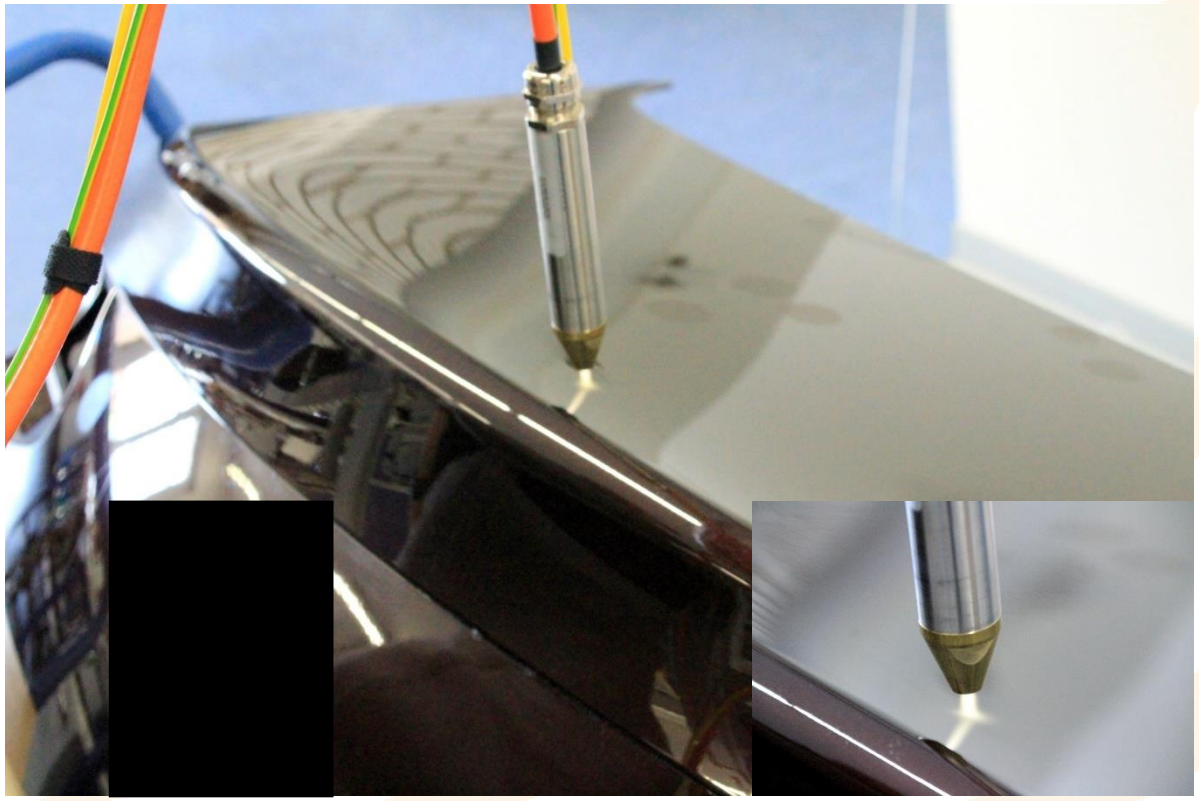
Special: Double sided treatment



Special: Double sided treatment

Application:



Material and glue have eventually to be treated with different power settings for optimal results

Special: Double sided treatment for consumer products

Gluing of electronic products

Up to now mostly primers are used for adhesion improvement

- Expensive
- Harmful to environment and health
- Difficult to apply and need a lot of maintenance

- Plasma coating is expensive, complex and needs high maintenance

Alternative double sided plasma treatment

- ✓ **Easy and clean process**
- ✓ **Cheap**
- ✓ **Environmently friendy, climate neutral**
- ✓ **Reliable and reproduceability**
- ✓ **Full control and monitoring of all relevant parameters**

Conclusion plasma treatment for tapes

Surface quality:

- ✓ The surface to be treated should be dry, fat free and dust free

Plasma dose:

- ✓ 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 adjustable plasma generators enable an optimal plasma dose

Cleaning:

- ✓ Cleaning with plasma is possible, but has to be tested

Highest adhesion and instant adhesion, also for difficult material

- ✓ Double sided treatment with tesa tapes enable higher adhesion forces and shorter curing time, also for difficult material

Lifetime of treatment

The lifetime of the treatment can vary a lot, between minutes (silicone) and years (PS)

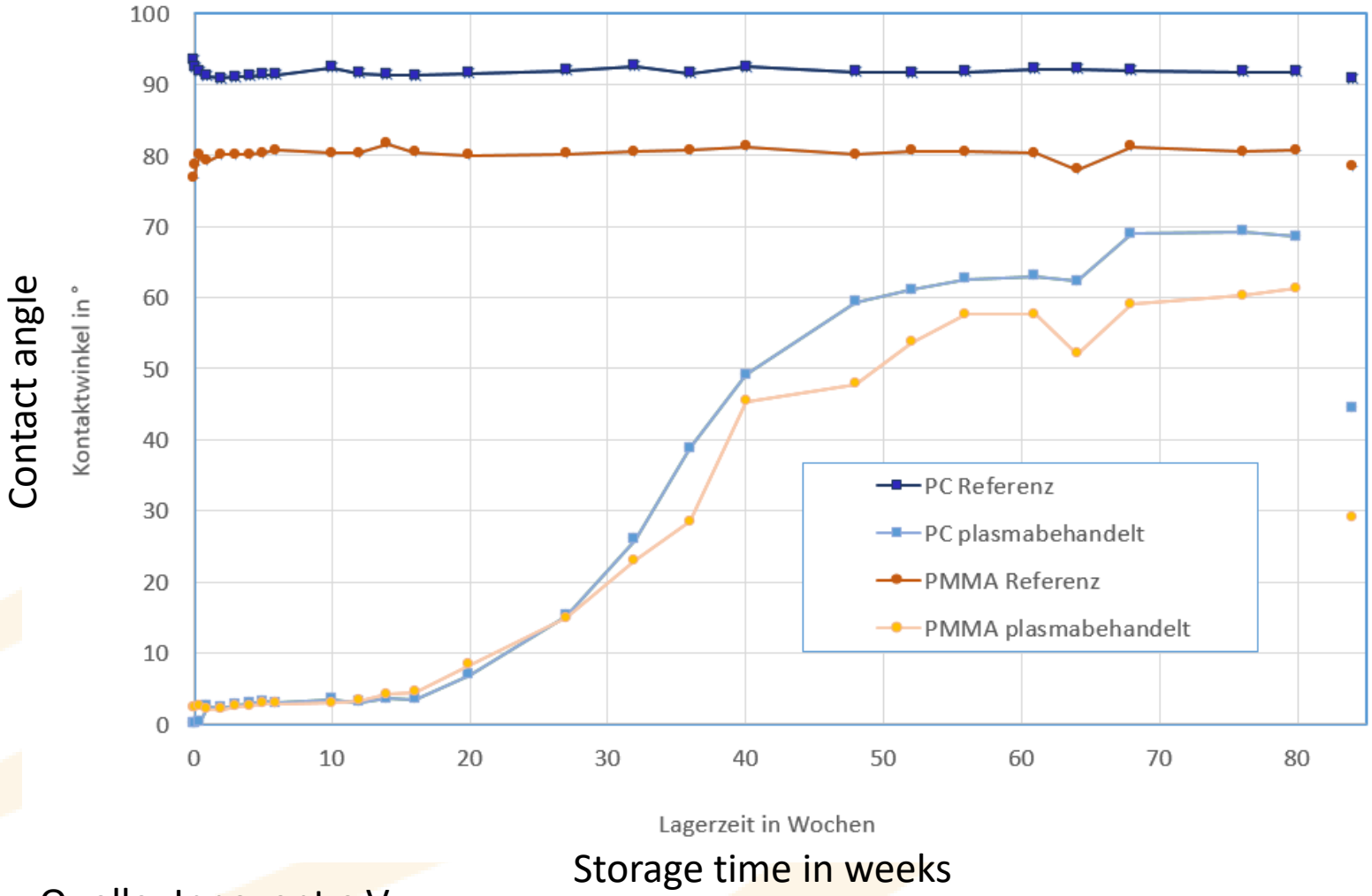
Mostly days to weeks.

Influences:

- Material
- Treatment method
  - Plasma versus Flame
  - Electrons, ions and photons etc.
- Additives (slip agents, antistatics etc.)
- Age of polymer when treated (f.e. PE film)
- Humidity
- Temperature
- Etc.
- Storage: In aluminum foil

If possible, the application should be done directly after the treatment

Lifetime of treatment in reality



Quelle: Innovent e.V.

Not all Plasmas are the same

Different types of plasma can have different effects

Differences can be:

- Atmospheric or vacuum plasma
- Material of electrodes
- Frequency of plasma
- Temperature of plasmas
- Treatment in primary or secondary plasma
- Created radicals
- Created reaction produtcs (O^3, NOx etc.)
- UV-Proportions
- Exposure time: Treatment processes need time. F.e. 2 x 500 W can be better than 1 x 1.000 W. The plasma dose can therefore, with same end results, be different
- Etc.

Overview procedure on material – adhesion and wettability

Improvement of Adhesion/oxydation							Key:	
Method:	**DBD**	**T-Jet**	**CAT**	**T-Spot**	**MEF**	**O^3**	good	mostly satisfying results
Treating gas	Air	Air	Air	Air	Air	Air	average	results on average
Material:							poor	mostly poor results
PE	good	good	good	good	good	good		Material, with mostly only one technic working well
PEX	poor	average	good	good	good			
PP	good	good	good	good	good	good		
PC	good	good	good	good	good	good		
PMMA	good	good	good	good	good	good		
PEEK	poor	poor	average	average	average			
PET	good	good	good	good	good	gut		
PS	good	good	good	good	good	good		
POM	poor	poor						
ABS	good	good	good	good	good	good		
ABS/PC	good	good	good	good	good	good		
PA	average	average	good	good	good			
PA 6.6	average	average	good	good	good			
SAN			good	good	good			
PVC	average	average	good	good	good			
Fluor polymers:								
FEP	average	average	poor	poor	poor			
PVDF								
ETFE	average		average	average	average			
PFA	average		poor	poor	poor			
PTFE	average		poor	poor	poor			
Elastomere:								
Silicone	average	average	average	average	average			
TPE	poor	average	poor	poor	poor			
TPU			poor	poor	poor			
EPDM	good	average	good	good	good			
PUR	good	good	good	good	good			
Rubber	average	average	average	average	average			
gummi elasticum	average		average	average	average			
Others:								
UV-Coating	good	good	good	good	good			
Powder-Coating	good	good	good	good	good		Wax and PE-particles can disturb adhesion	

Overview procedure on material – cleaning and reduction

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

Plasma: Tool T-SPOT S3

Plasma power:

App. **250 - 500 W per nozzle**,

(app. 375 – 500 W for slot nozzle)

Nozzles are convertible

HV-Cable length: 2 m

Compressed air:

App. **30 l/min** per nozzle

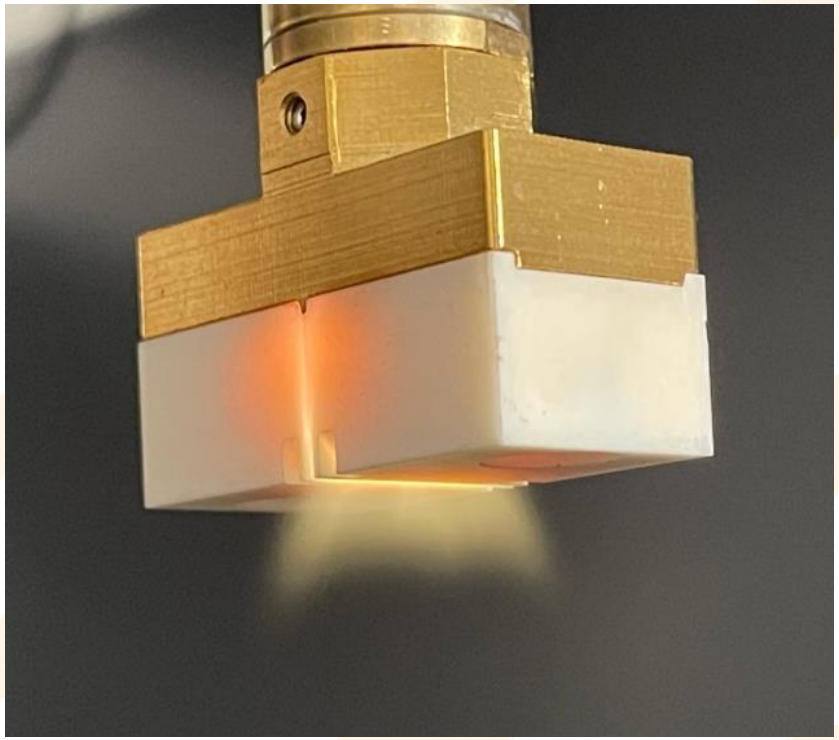
Weight:

App. **200 g**, focus nozzle (FD)

App. **315 g,** slot nozzle (SD)

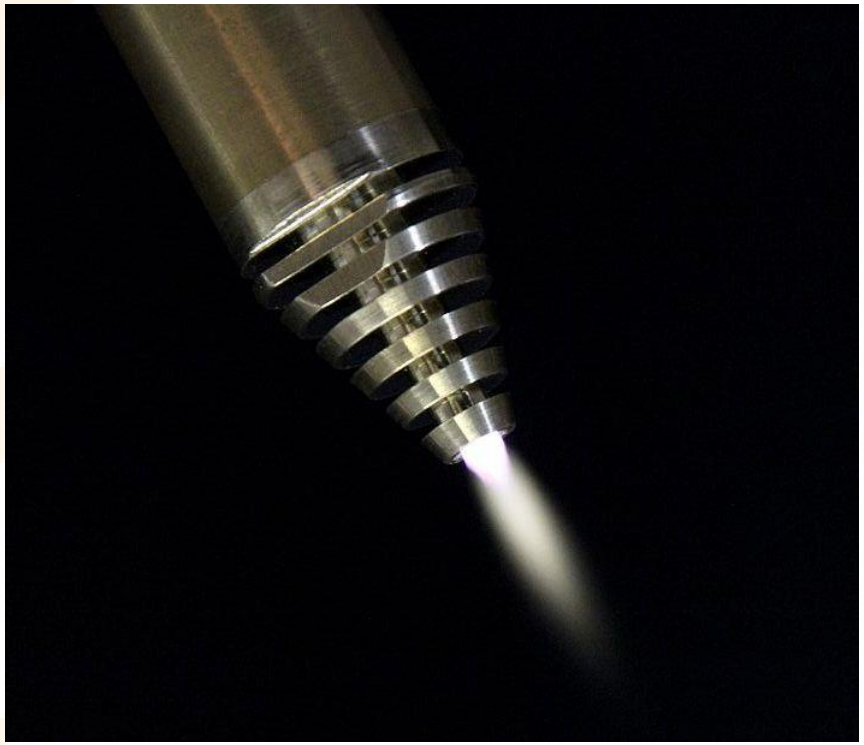
Lifetime electrode:

Up to **3.000 h**



Treatment width slot nozzle:

Up to 25 mm per head
Depth: app. 1-8 mm



Treatment width focus nozzle:

App. 8-12 mm per head
Depth: app. 5-15 mm

Corona: Tool T-JET

Counter electrode free corona treatment

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

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

T-JET: Tape application

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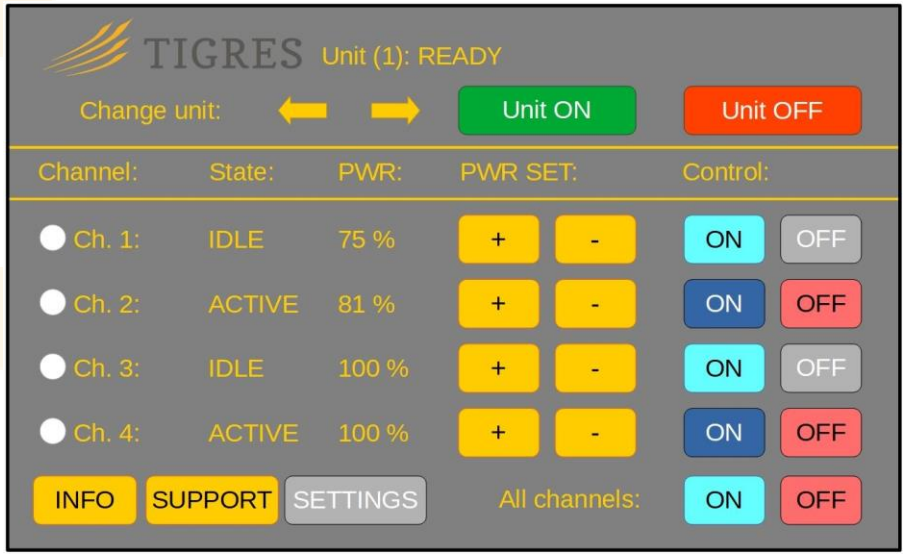
Fax: +49 2175-1800 399
Mail: info@dollberg-maschinenbau.de
www.dollberg-maschinenbau.de

Video: Dollberg Maschinenbau GmbH

M-Generator

- ✓ Modular, compact design
- ✓ Intuitive usable touch panel, external panel available
- ✓ 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 with RSU
  - ➢ Full industry 4.0 functionality



Process reliability: Real power control

Key Feature #1: Real Power Control for each plasma head

The M-Generator controls each plasma head individually with a closed loop controller.

The controller not only measures the plasma power, but controls the power of the plasma within a specified window.

The controller turns off the plasma when the specified setpoint cannot be maintained.

What is controlled?

✓ Current

The frequency controls the current

Monitored:

✓ Line voltage measurement

Process reliability: Real time controller monitoring SQI

Key Feature #2: Real time monitoring with System Quality Index (SQI)

The M-Generator controls the plasma discharge and calculates an SQI factor.

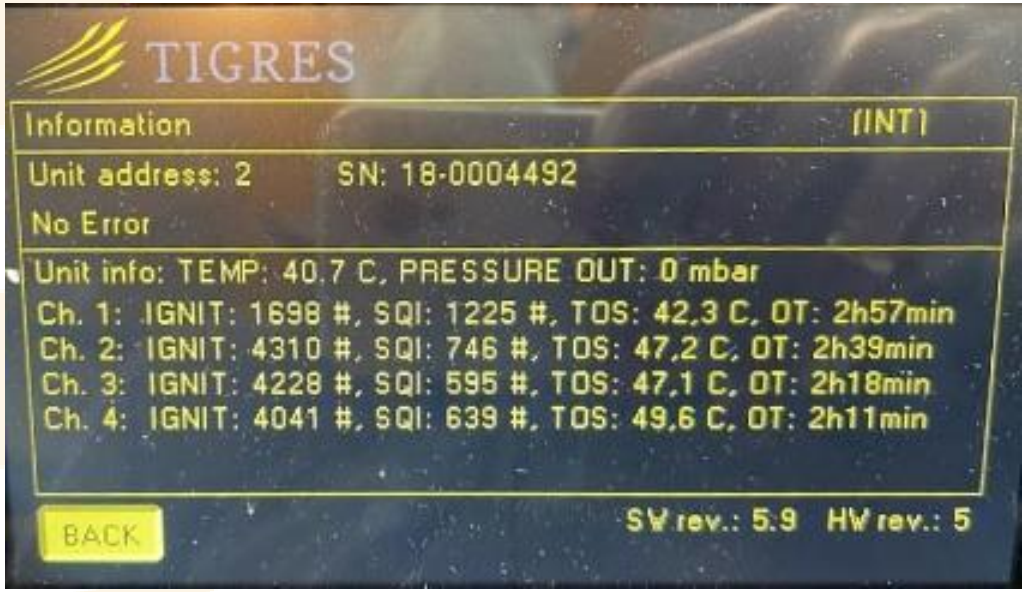
1. DC-Current feedback output stage
2. Working frequency (controls the DC-current)
3. Setpoint control values: Input display/interface (f.e. 500 W)

4. Primary current

Out of the values 1 and 3 the SQI factor is calculated.

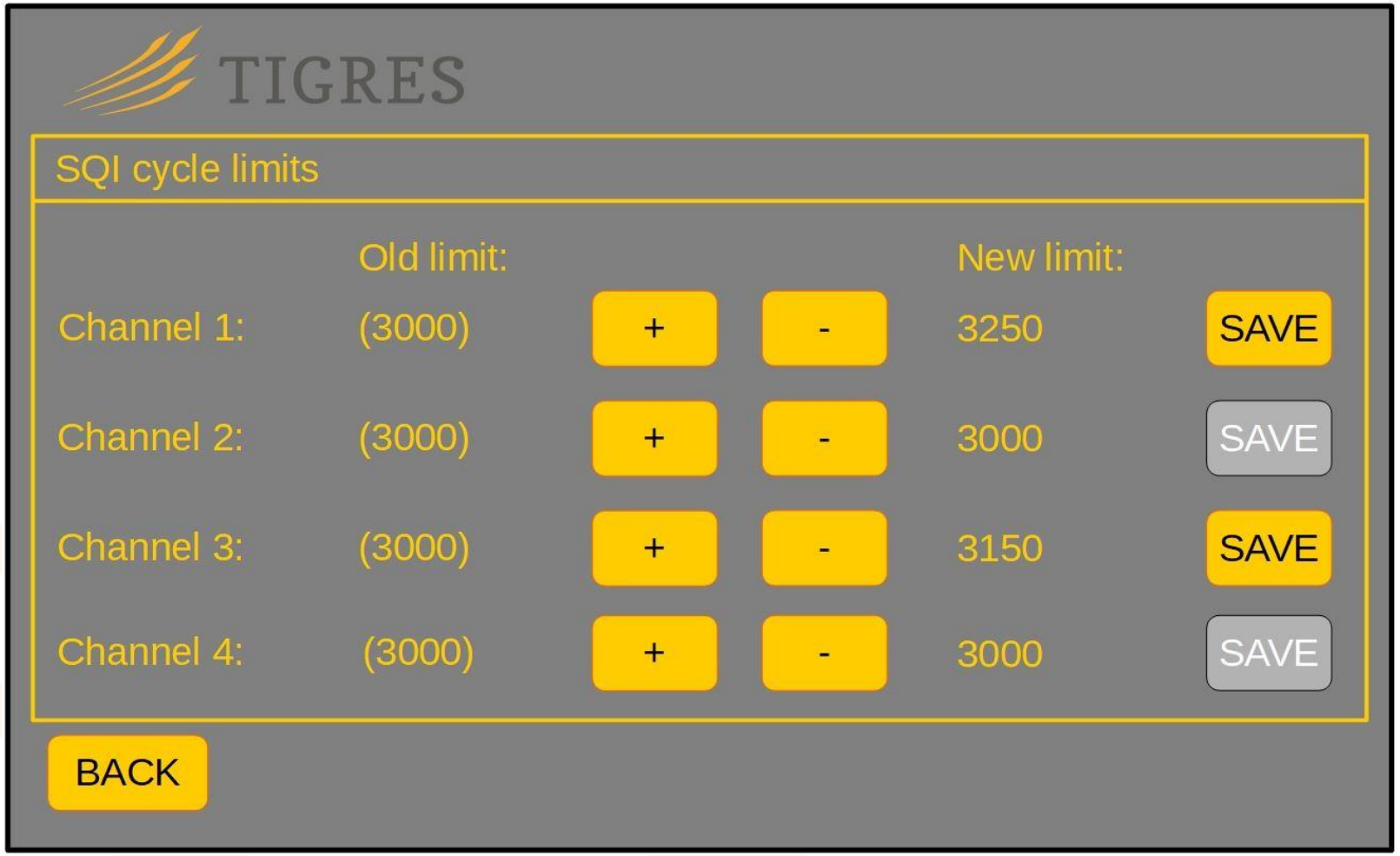
The SQI factor is a value which shows how hard the controller has to work to maintain the adjusted power.

The limit of the SQI can be adjusted in the display/BUS to the need of the application.
(Very low for very sensitive processes, very high for very insensitive processes)



Process reliability: Real power monitoring with SQI

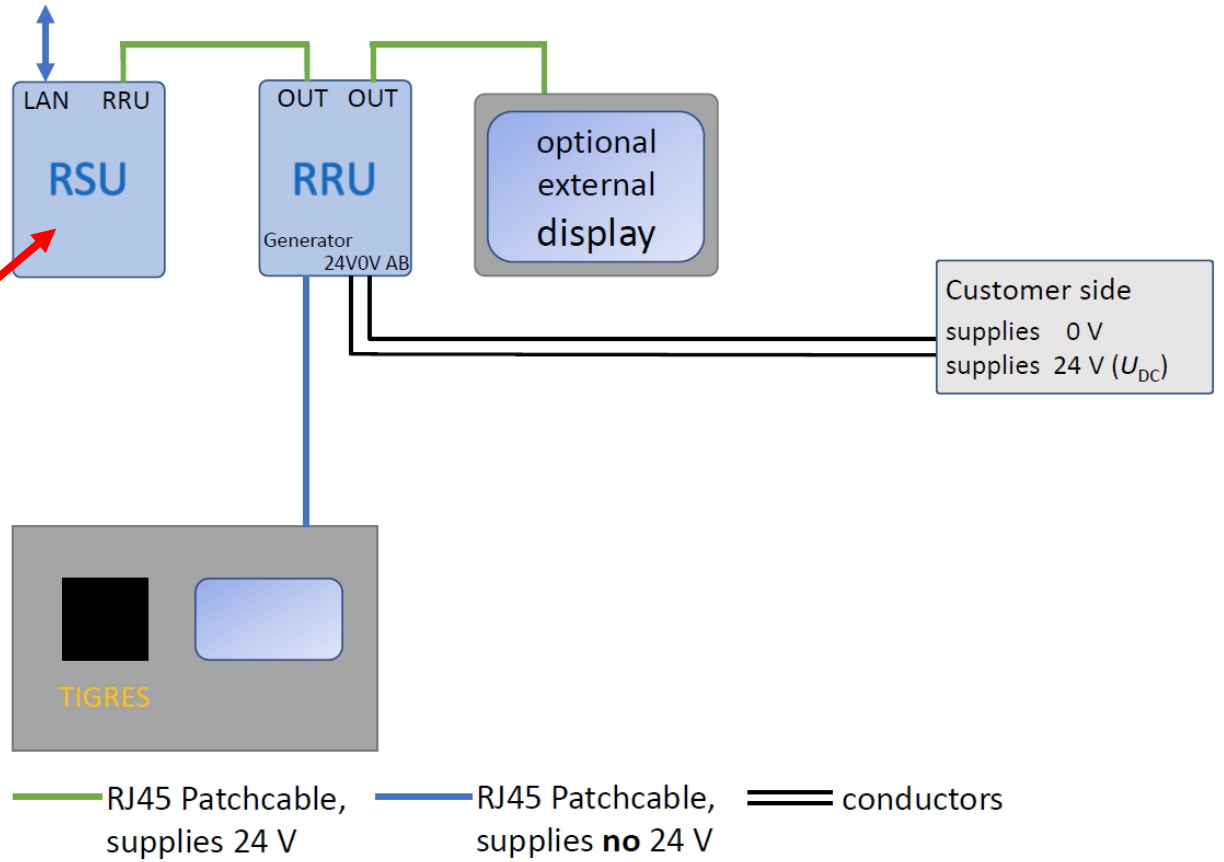
Key Feature #2: Real time monitoring with System Quality Index (SQI)



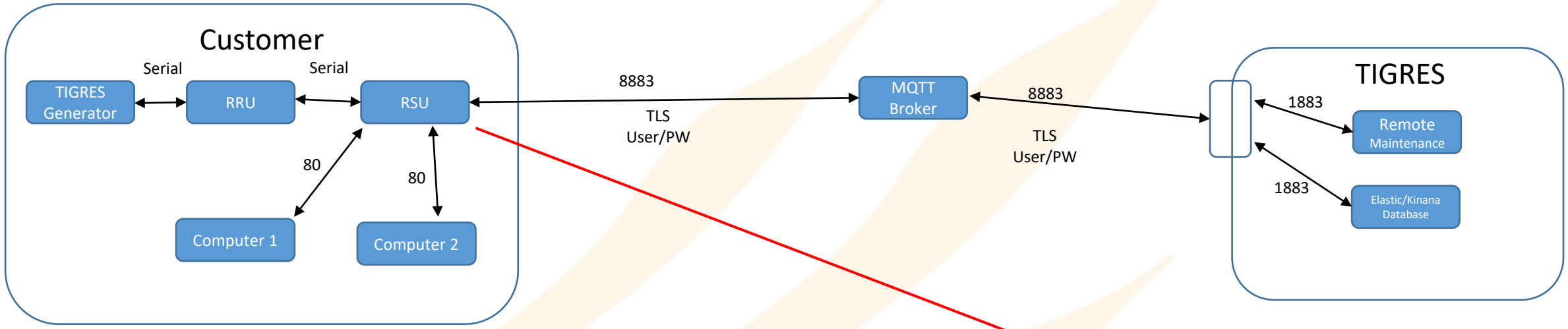
TIGRES Remote Service Unit RSU in real time

TIGRES RSU (Remote Service Unit)
Enables online process monitoring
For:

- ✓ Start up
- ✓ Diagnoses
- ✓ Remote service
- ✓ Service support
- ✓ Parameter setting



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

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:

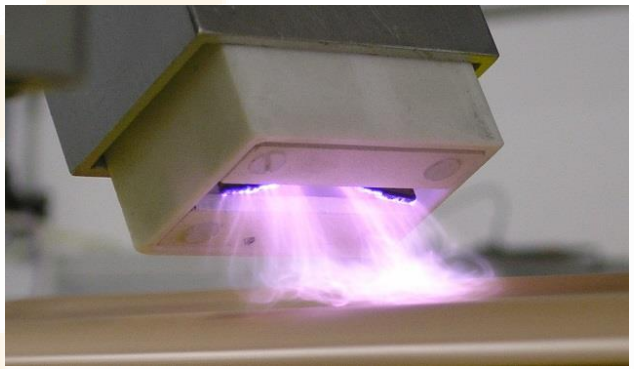
More than 30 **rental systems are available for testing**. Training included (Videokon).

T-SPOT

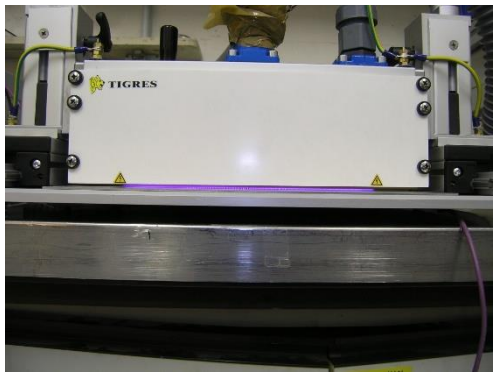
CAT

MEF

T-JET



DBD



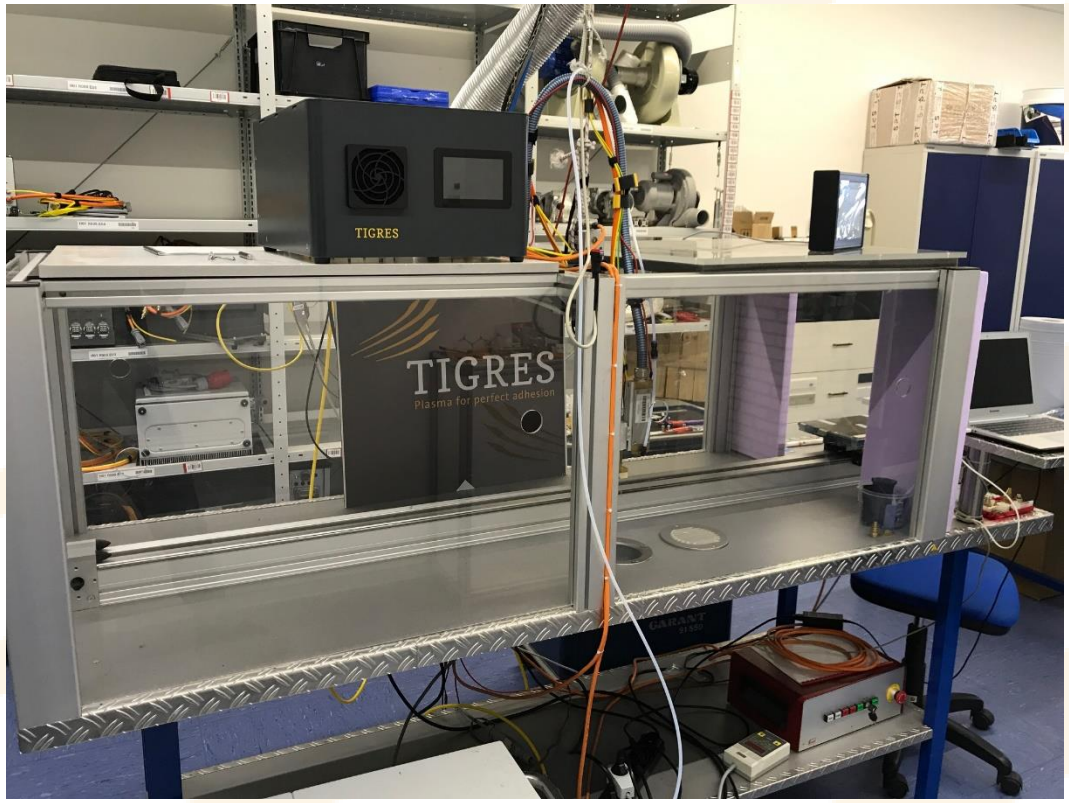
Testing TIGRES Plasma: In the lab

Processing of your samples:

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

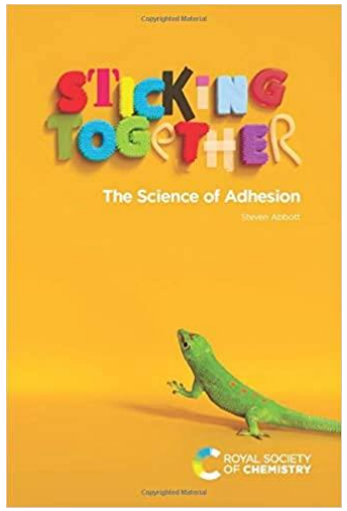
Practical training how to use plasma equipment for:

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: 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 you attention!

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