Plasma and Surface Technology

Pre-treatment of CFRP for improved adhesive bonding performance

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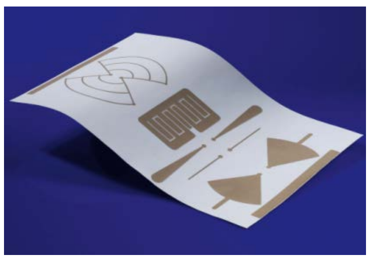
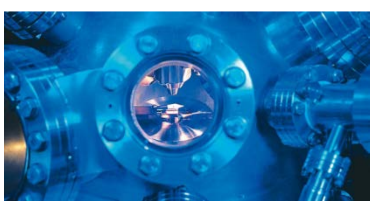
Fraunhofer IFAM – Adhesive Bonding Technology and Surfaces

Materials → Manufacturing semifinished parts → Surface modification → Assembly and joining technologies → Repair processes → Quality assurance





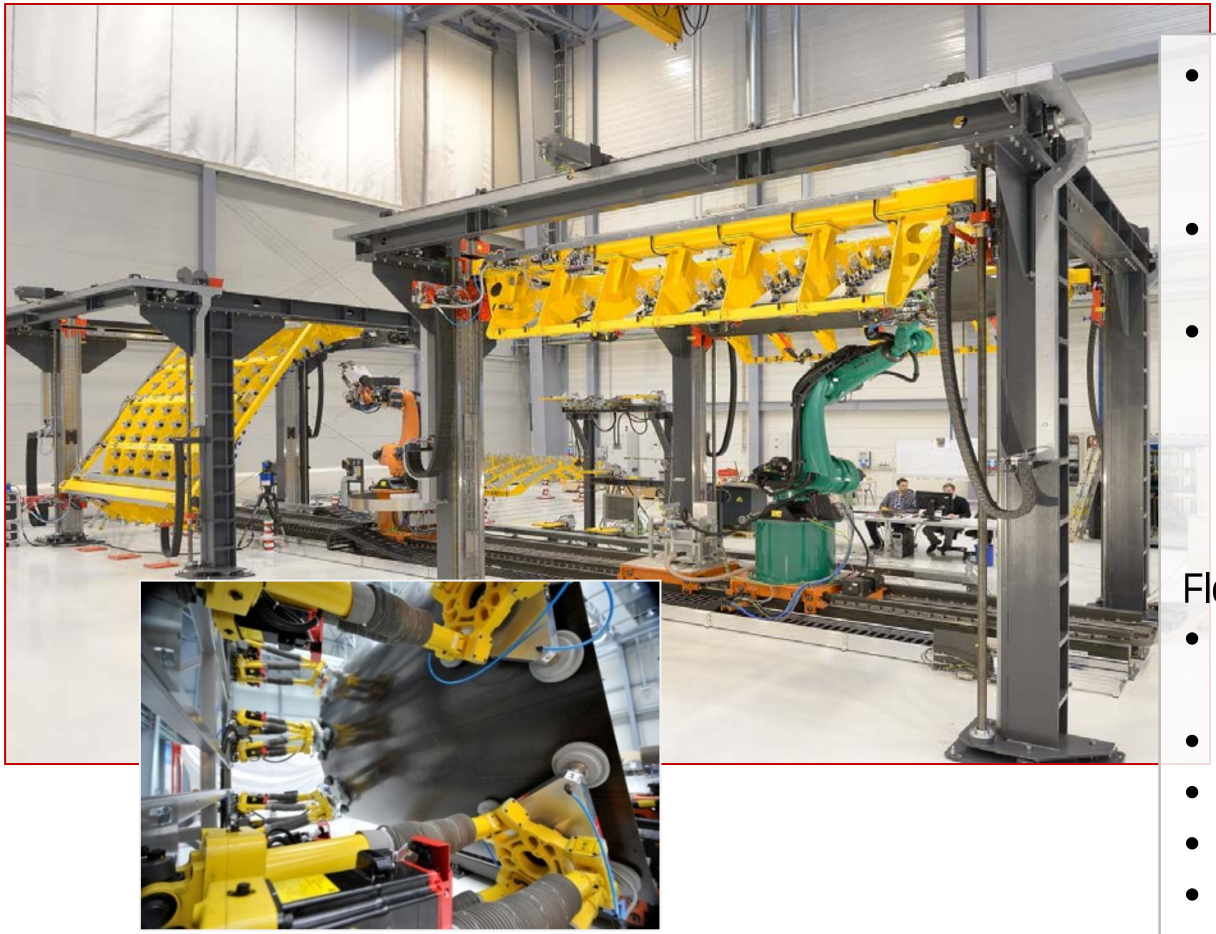
Manufacturing technology and applied material research for the areas of application

Adhesive Bonding Technology, Surface Technology and Fiber Reinforced Plastics

Development focus:

- Materials
- Production integration
- Rapid processes
- Reliability and quality

Automated Assembly Processes



- adaptive setting of form and position of CFRP parts by hexapods
- vacuum grabs for part handling
- grabs with integrated force-displacement sensors; tension controlled assembly processes

Flexible assembly processes:

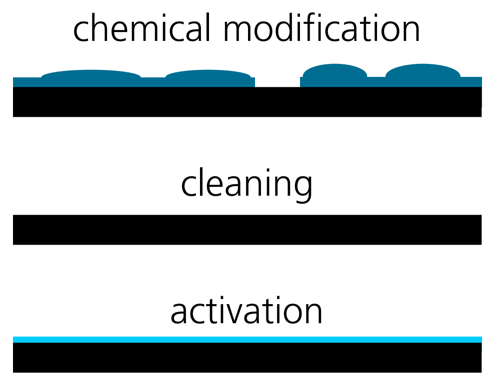
- short cycle time with reduced manual work
- tolerance adjusted assembly
- sealing of joints and rivets
- high process safety
- hard- and software solution for sensor-guided CAD/CAM-systems

Surface Pre-Treatment of CFRP – Why?

Pre-Treatment for adhesive bonding:

- Residues of release agents
- → Low adhesion forces

- Development of combined processes
  - Conversion of contaminations
  - Cleaning (abrasive and non-abrasive)
  - Surface activation



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Surface Pre-Treatment of CFRP – Why?

Increasing use of thermoplastic matrices

- variation of wetting properties of matrix-polymers

surface energies (untreated)

Polymer	Surface Energy [mN/m]	Water Contact Angle [°]
PP	31	102
PE	32	96
PPS	38	80
Epoxy	45	76

source :https://www.accudynetest.com/polytable_03.html?sortby=number%20ASC

PRE-TREATMENT OF CFRP -
MECHANICAL ACTIVATION

GRINDING

- removal of contamination and substrate material
- manually or automatically
- Hard particles or fibers as abrasive

- formation of dust / particles
- Release of fibers / deterioration of substrate
- Pre- and Post-Cleaning with organic solvents needed

Manual grinding with abrasive paper and solvent cleaning is the actual process for CFRP pre-treatment in aircraft and wind power industry.

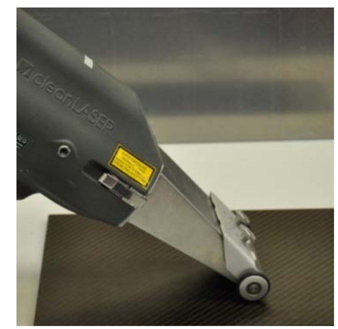
Technologies and Fields of Application

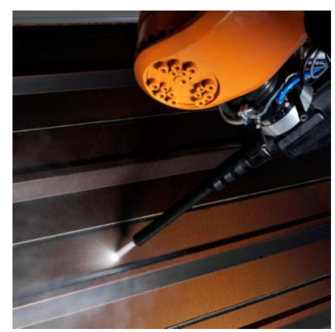
<u>Technologies:</u>

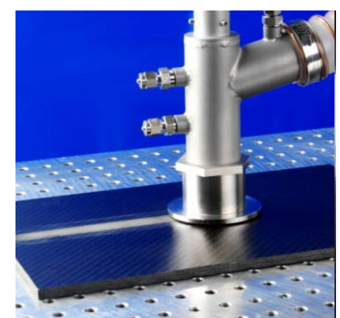
- Low pressure plasma
- Atmospheric pressure plasma
- VUV-excimer technology
- Laser surface treatment
- Blasting. CO_2-Snow, VacuBlast
- Flame treatment
- Bath processes (e.g. ultrasonic)

<u>Applications:</u>

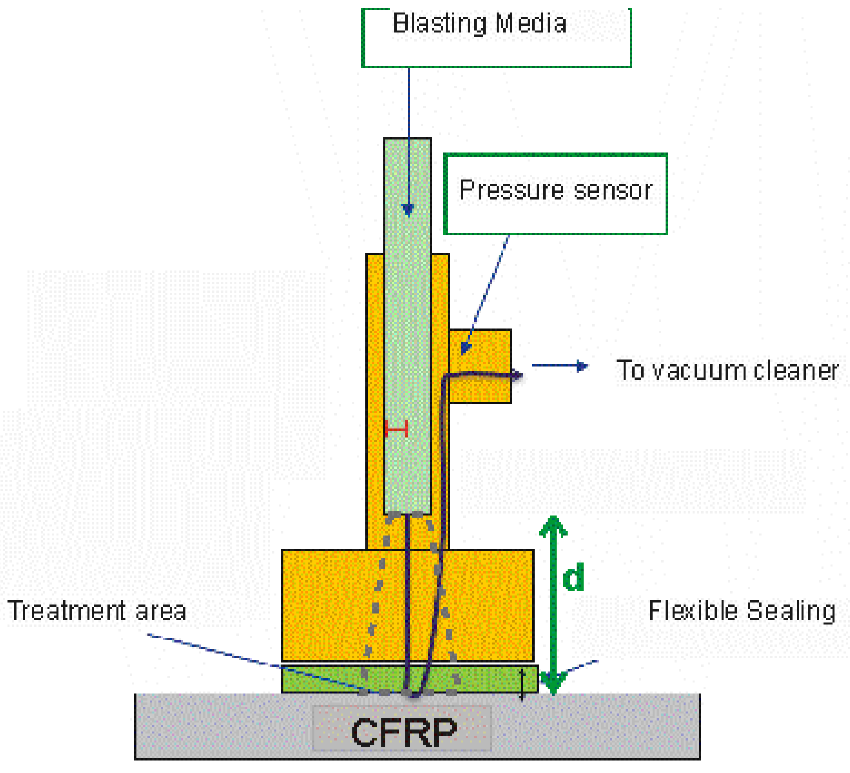
- Cleaning and activation
- Functional coatings







Vacuum-Blasting



Principle:

- Industrial vacuum cleaner is used to generate a reduced pressure in the treatment chamber
- Blasting media is injected by the pressure differences
- The reduced pressure prevents the emission of blasting media and dust

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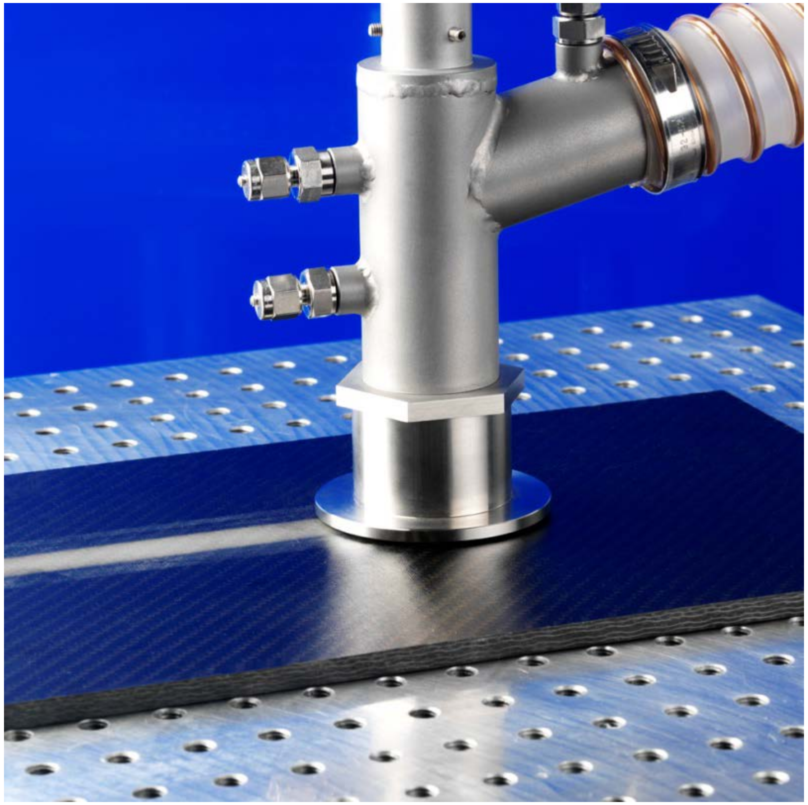


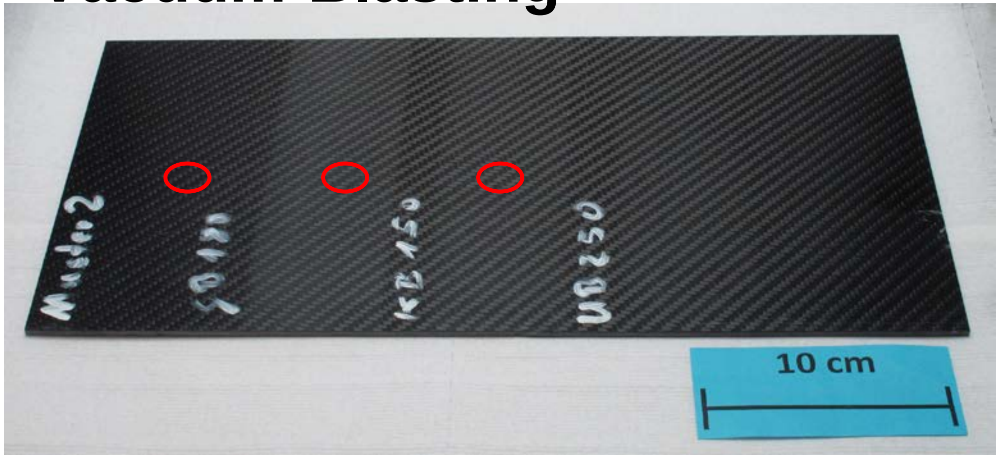
Advantages:

- Emission-free cleaning methode
- moderate noise emission
- Automated and manual use possible
- Line, local and area treatment

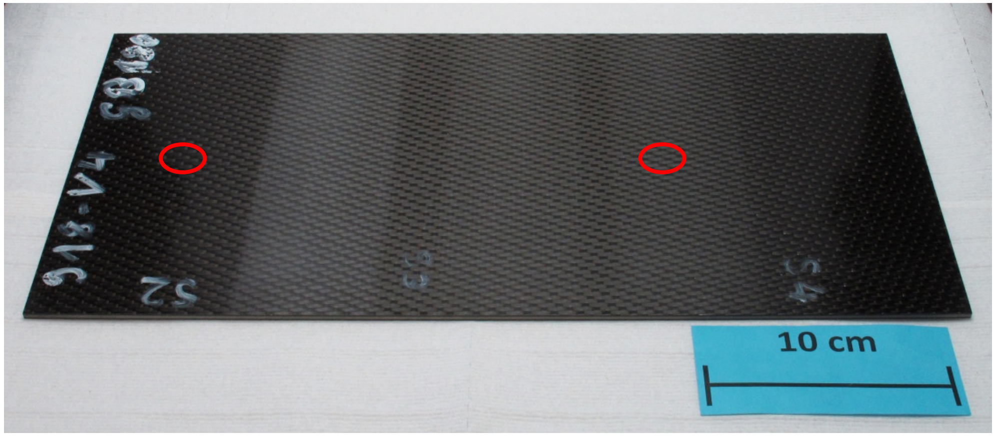
Disadvantages:

- Limited usability for complex shapes

Vacuum-Blasting



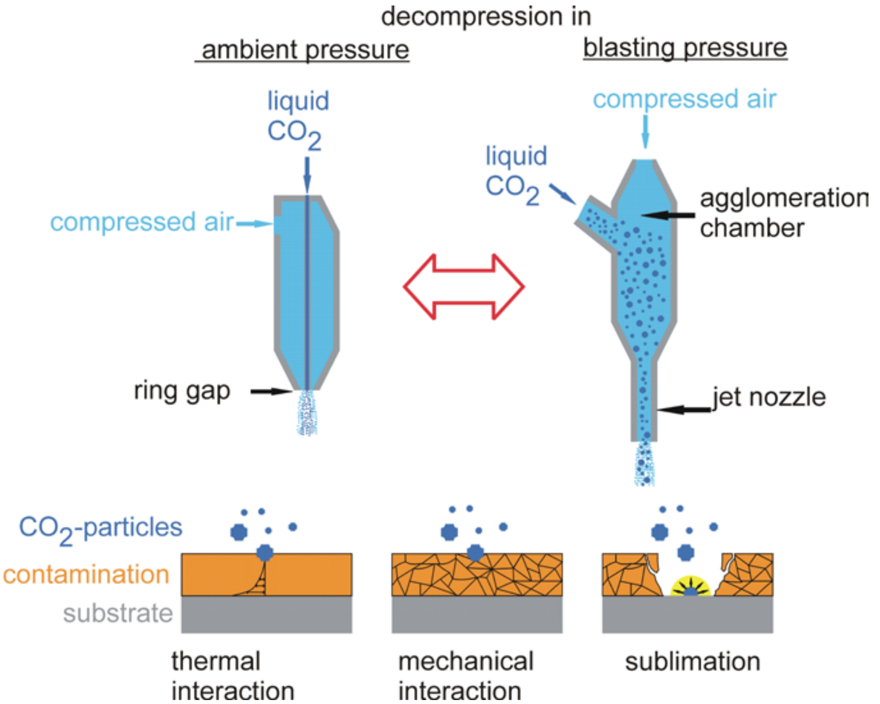
CFRP Samples after Vacuum-Blasting with different treatment intensities



CFRP Samples after Vacuum-Blasting with different treatment intensities

Vacuum-Blasting

CO_2-Snow-Cleaning



Principle:

- thermal interaction: embrittlement of contaminations
- mechanical interaction: abrasion due to CO_2-snow cristalls
- sublimation:
  solution of contamination due to sublimations of CO_2-snow

CO_2-Snow-Cleaning

- <u>Advantages:</u>
- Compatible with Inline-Processes
- Robot-based handling system
- Line, local and area treatment
- Manual use possible

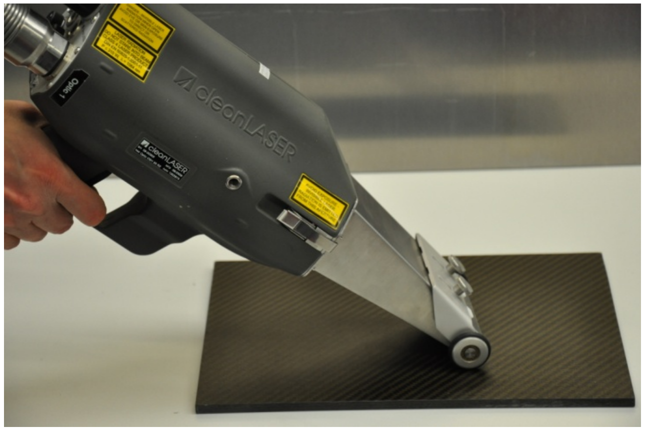
- <u>Disadvantages:</u>
- Limited usability for complex shapes
- Noise emission

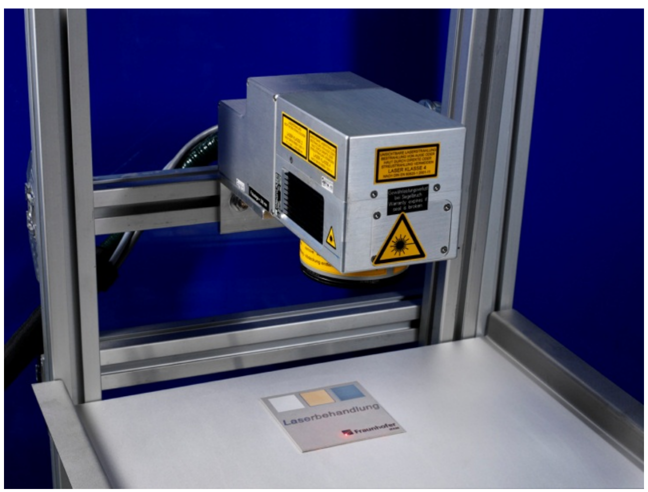
Laser-Surface-Treatment

Principle:

- focused laser beam evaporates contaminations
- high power density, but short pulses can be used with low total heat transfer to substrate material
- depending on optical properties of the substrate material the absorption can stop immediately at the interface

Laser-Surface-Treatment





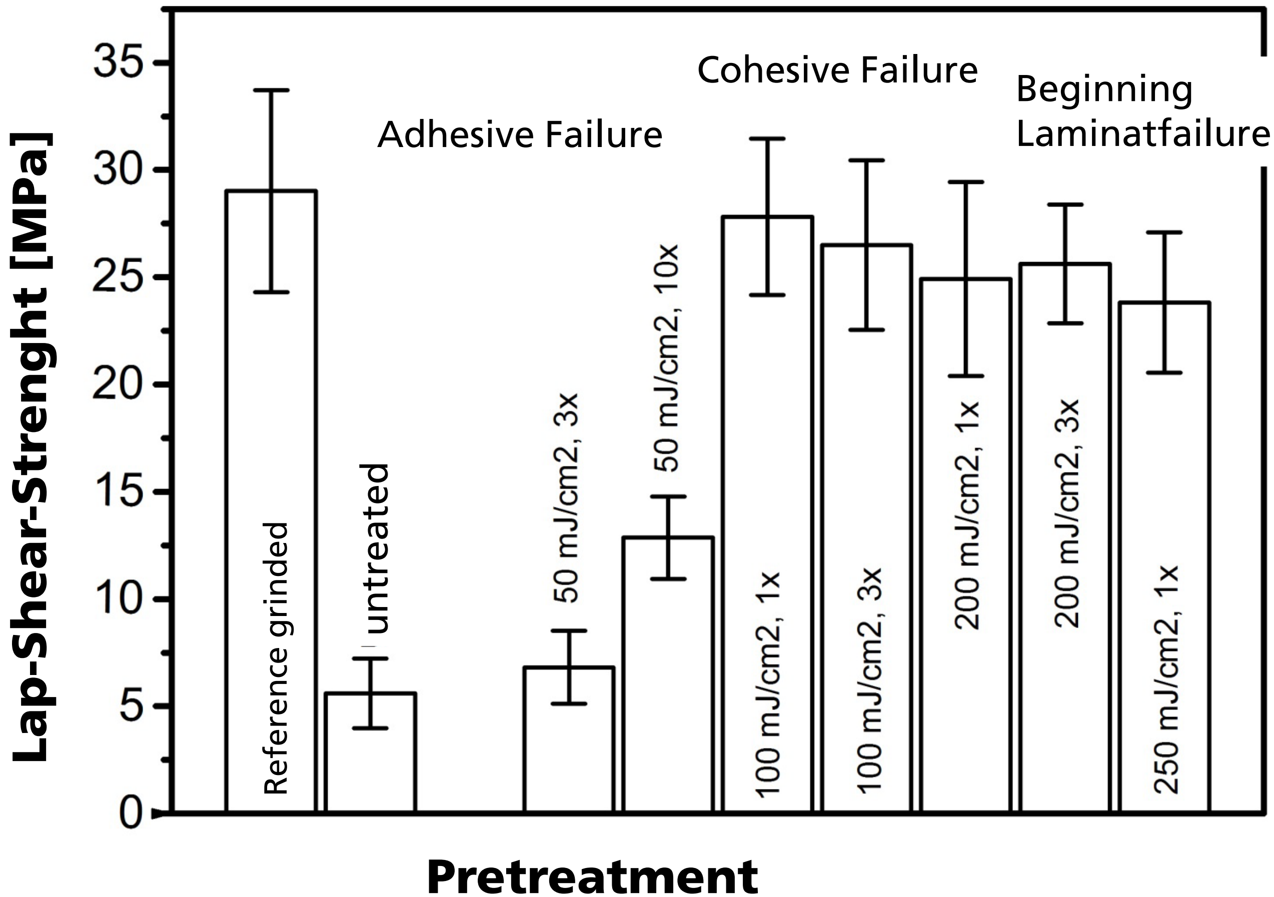
Advantages:

- No cleaning medias (solvents e.g.)
- Low noise
- integrated gas extraction
- High reproduceability
- Automated and manual handling

Disadvantages:

- High safety requirements

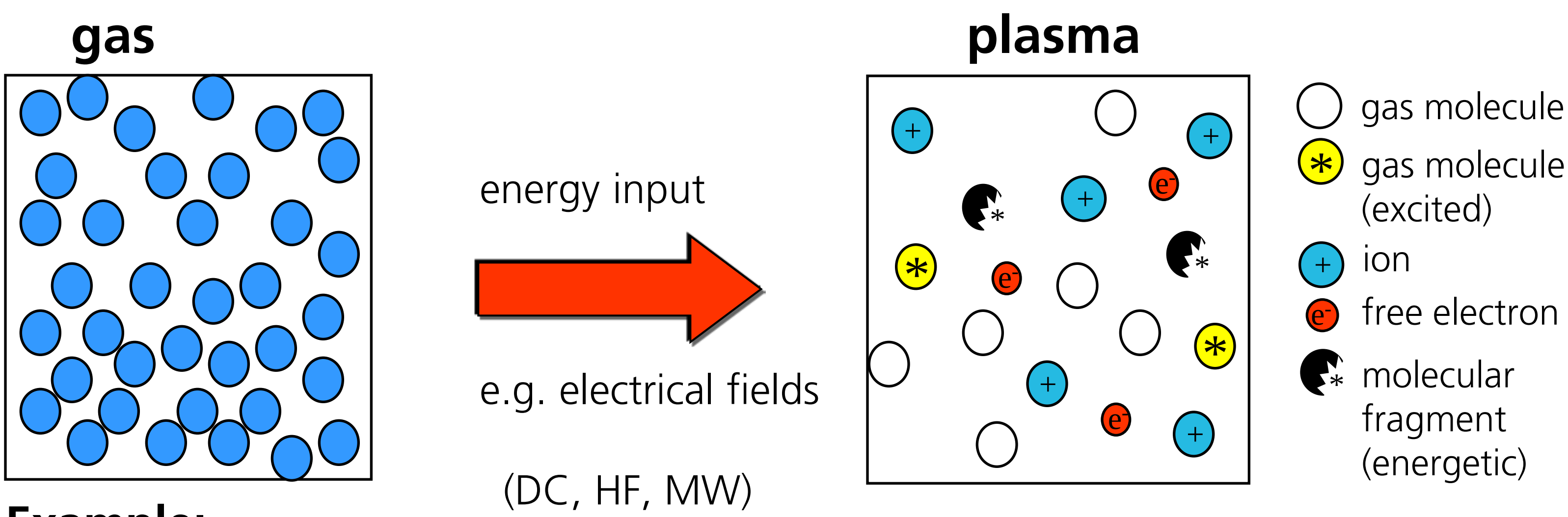
Laser-Surface-Treatment



Example:

- CFRP: high degree of release agent residues
- Lap-Shear-Test with epoxide adhesive (Aircraft industry)
- UV-Laser cleaning with 248nm variation of intensity
- Treatment Capacity up to serveral cm^2/s

Basics of Plasma Technology

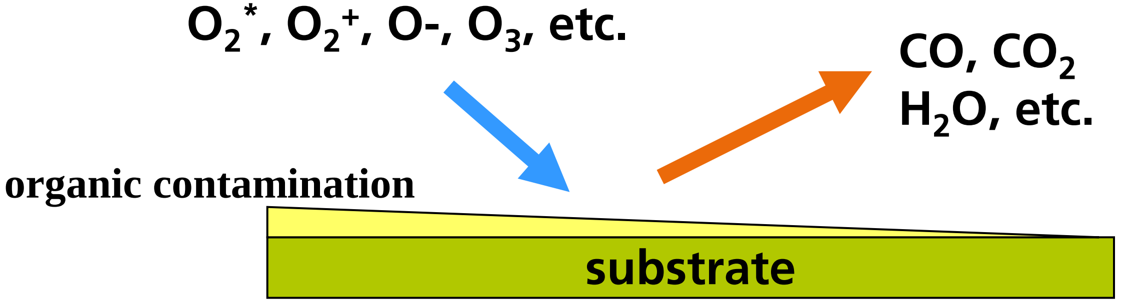


Example:

O_2-molecules

O_2^*, O_2^+, O-, O_3, etc.

plasma cleaning



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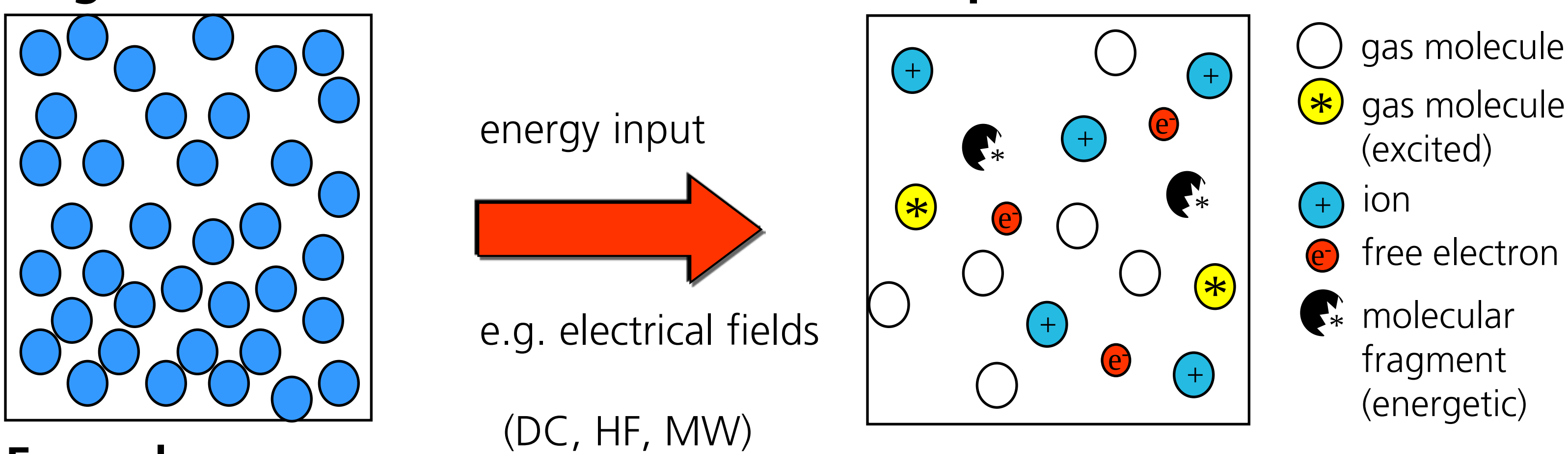
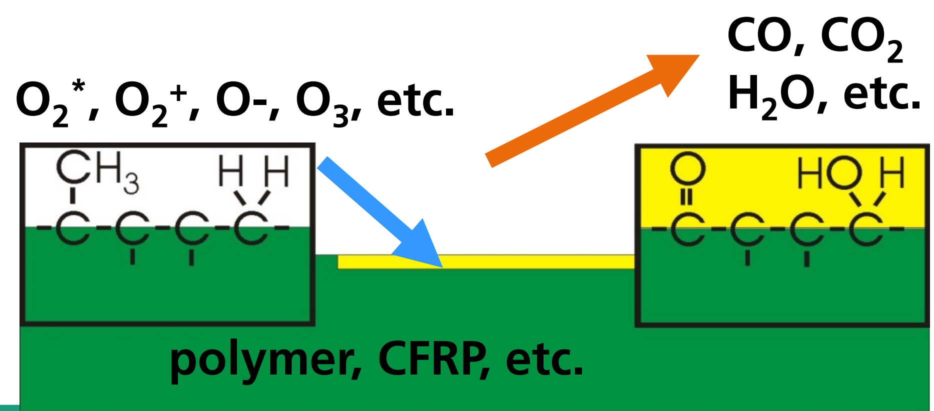
Basics of Plasma Technology

gas **plasma**



Example:

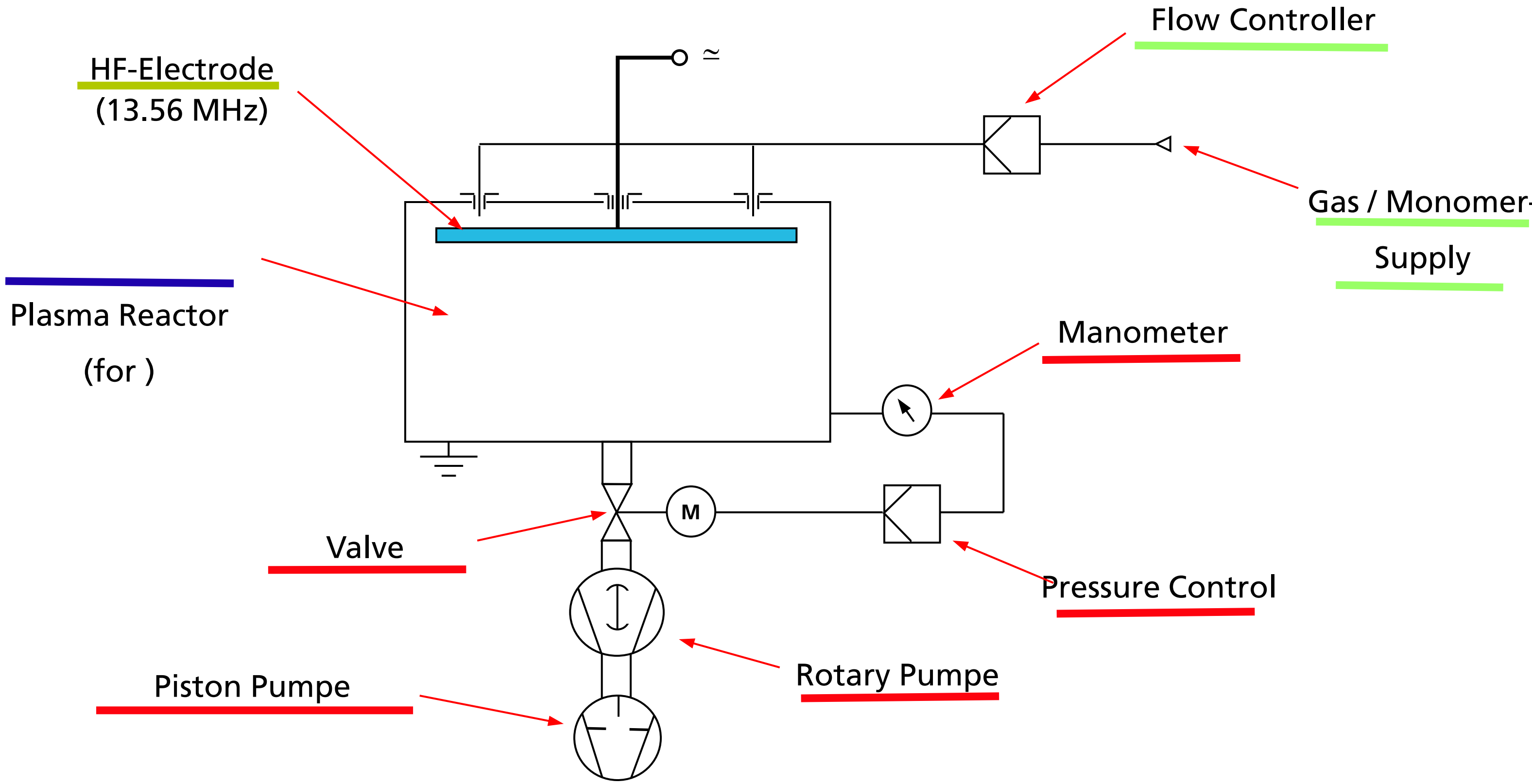
O_2-molecules



plasma activation

adhesion: bonding / painting

Low Pressure Plasma Devices



Vacuum Vessel **Vacuum Generation** **Gas Supply** **Power Supply**

Low Pressure Plasma Technology

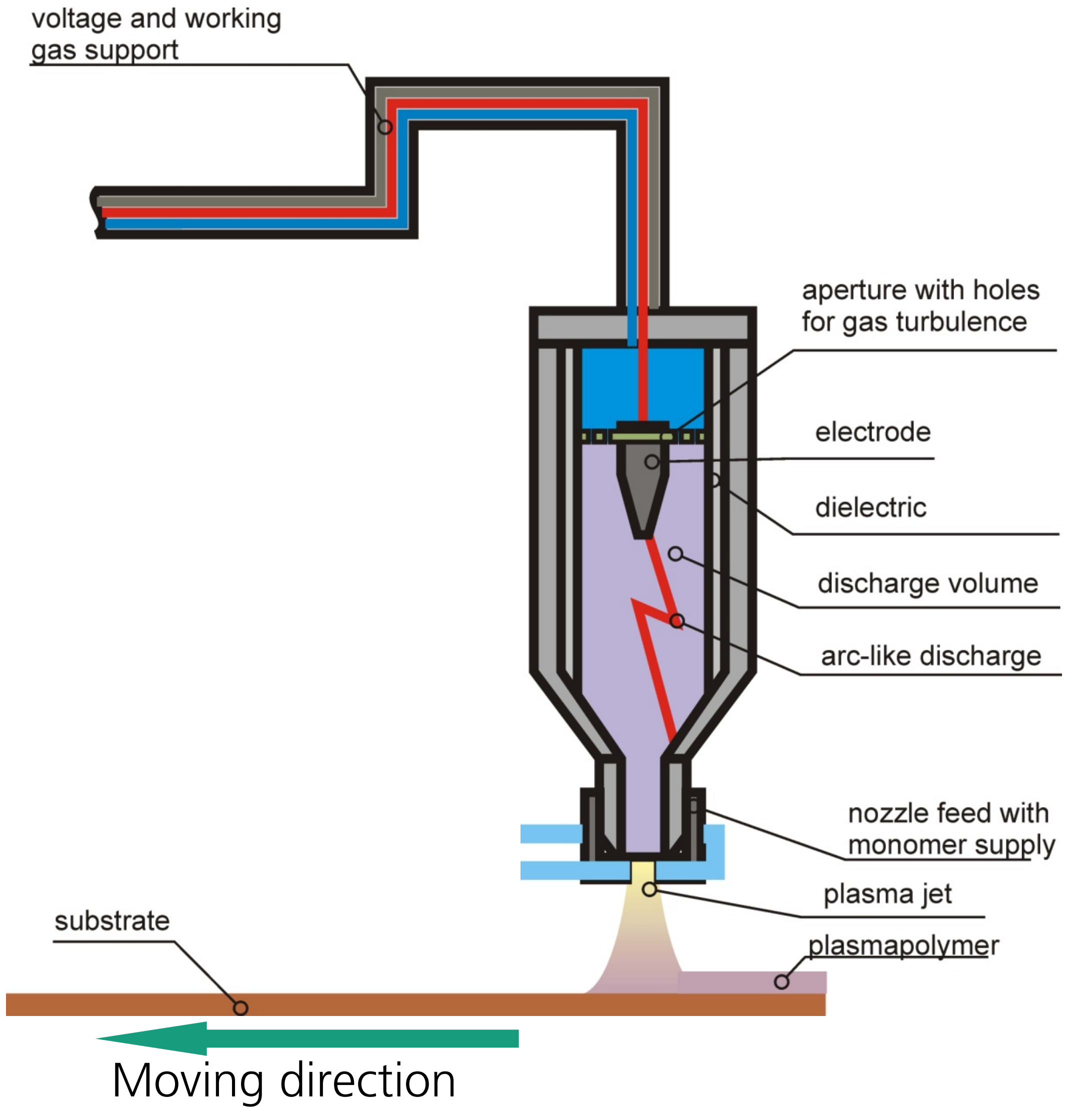
Advantages:

- Ideal for complex shaped 3-dimensional parts
- Cold coating system
- Eco-friendly
- Excellent coating quality

Disadvantages:

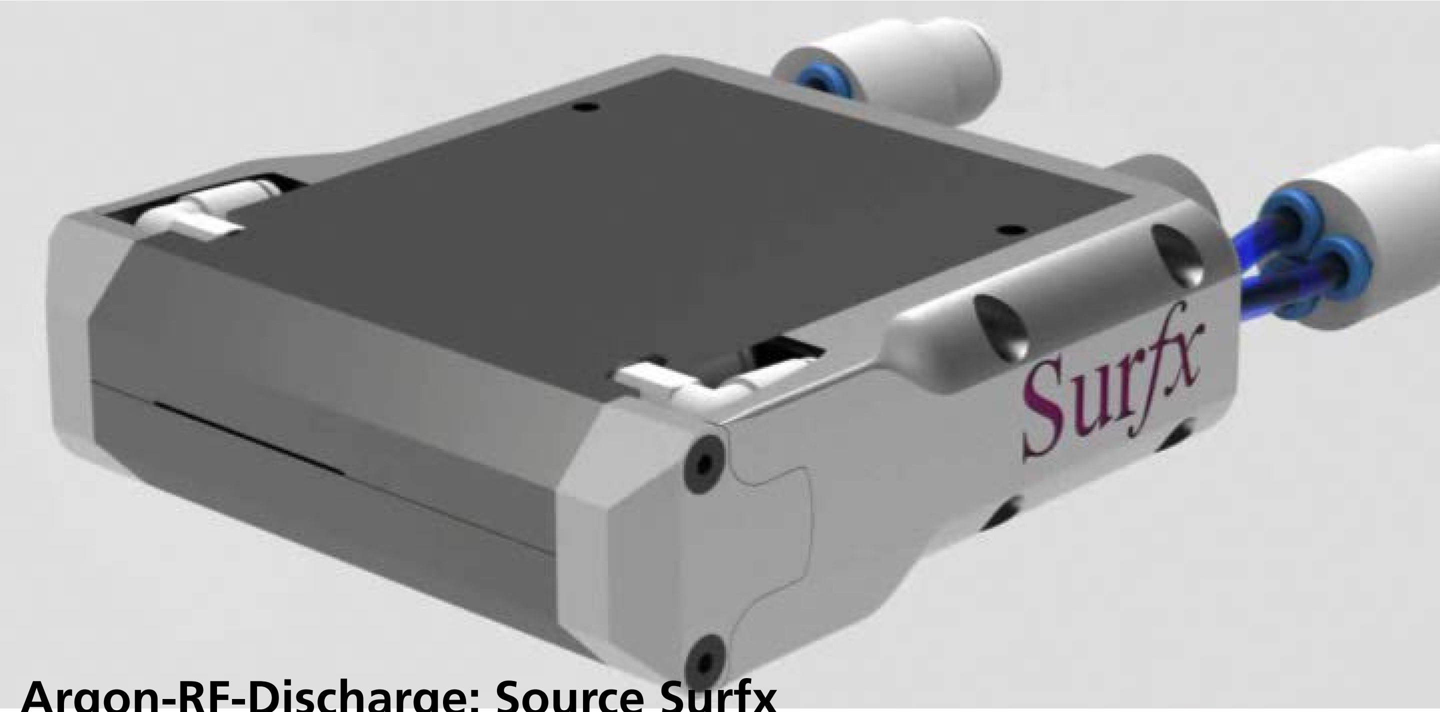
- Vessel-based process
- Limited component size: 2,5 m x 1,1 m

Atmospheric pressure plasma (APP) jets



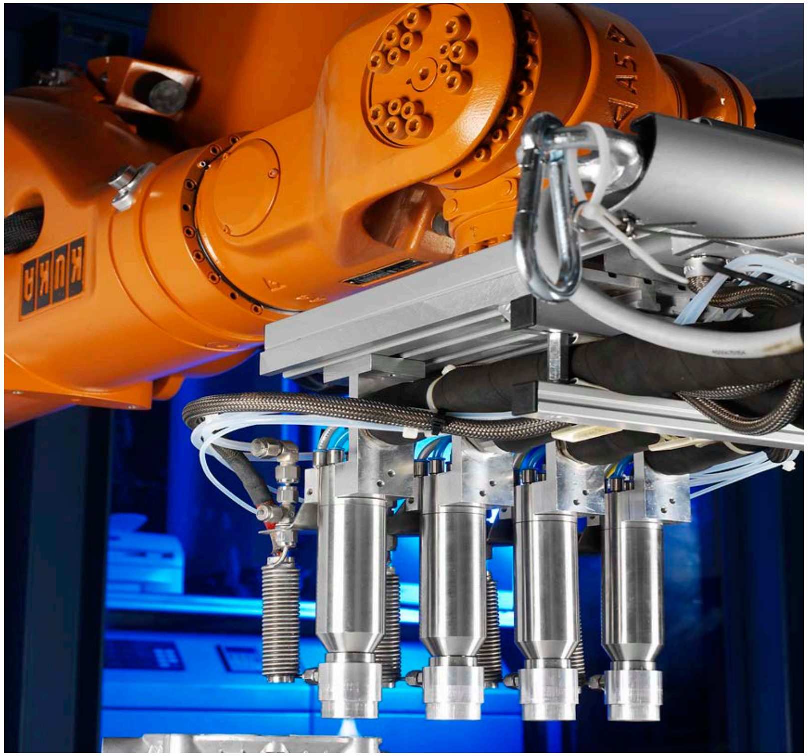
Atmospheric pressure plasma (APP) jets - Handheld

Helium Piezo-Discharge:
Source Relyon



Argon-RF-Discharge: Source Surfx

Atmospheric Pressure Plasma (APP) Technology



Advantages:

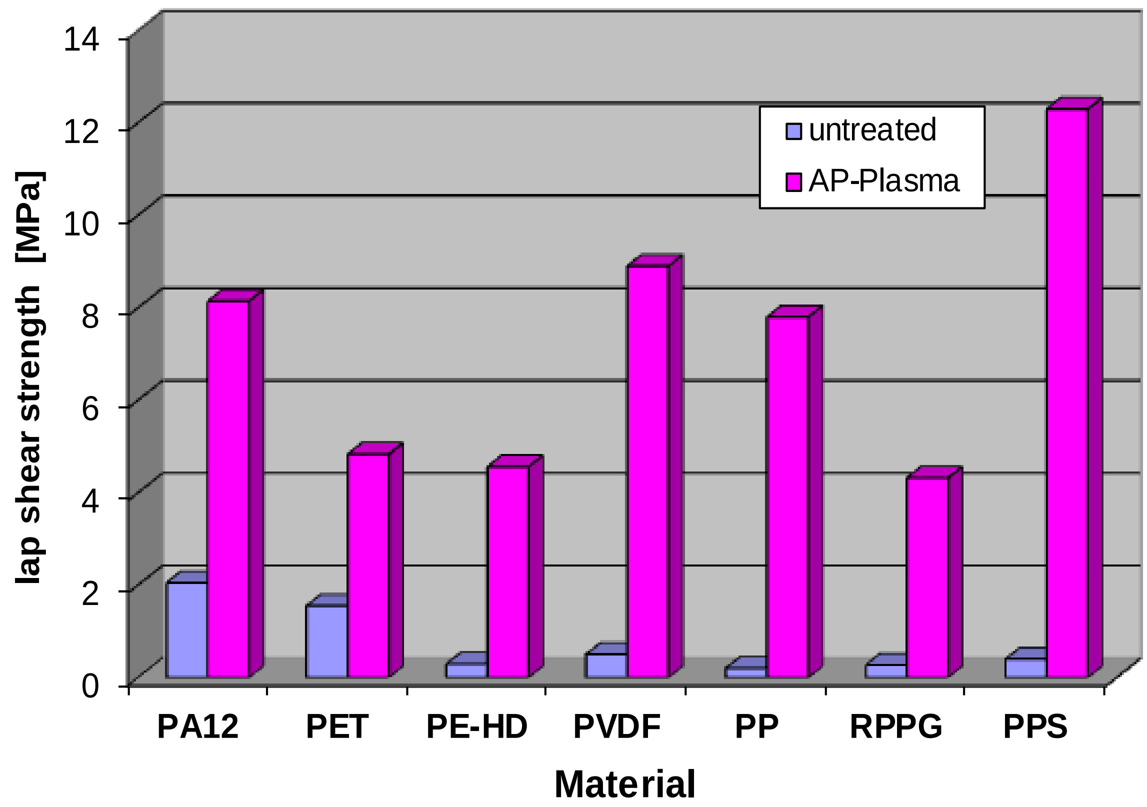
- Ideal for in-line-processes
- Robot-assisted guidance possible
- Treatments of small areas, tracks and large areas possible
- Movable system / Handheld

Disadvantages:

- limited by complex 3-dimensional parts

Surface Activation of Polymers

- Generation of oxygen containing functional groups
- Improvement of wetting behavior
- Reactivity of the surface

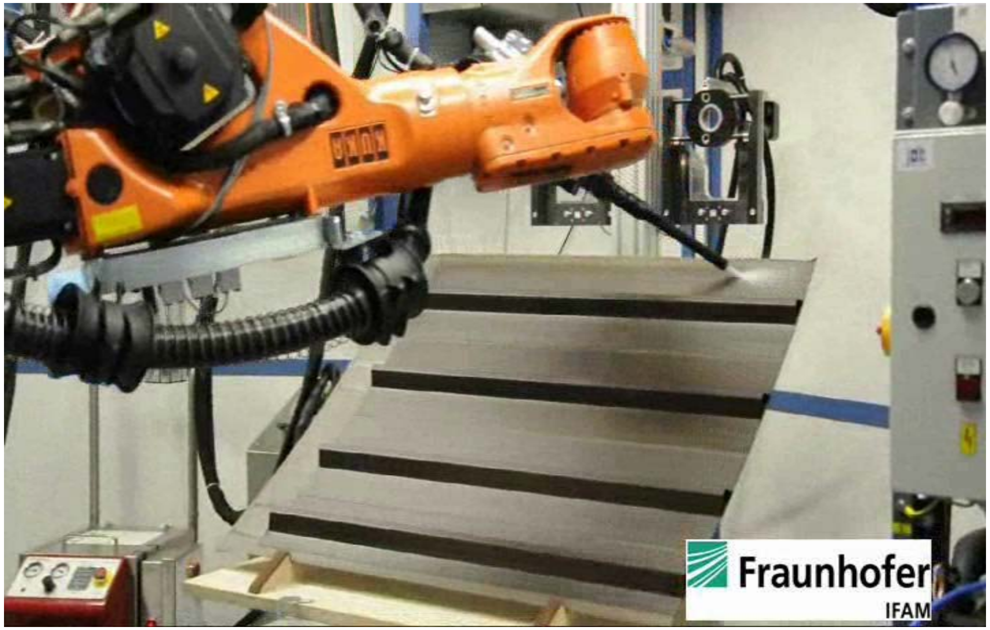


- 2K-PU-Adhesive: Bonding Strength higher than Material Strength

Surface Pre-Treatment of CFRP

Pre-Treatment for adhesive bonding:

- Residues of release agents
- → Low adhesion forces



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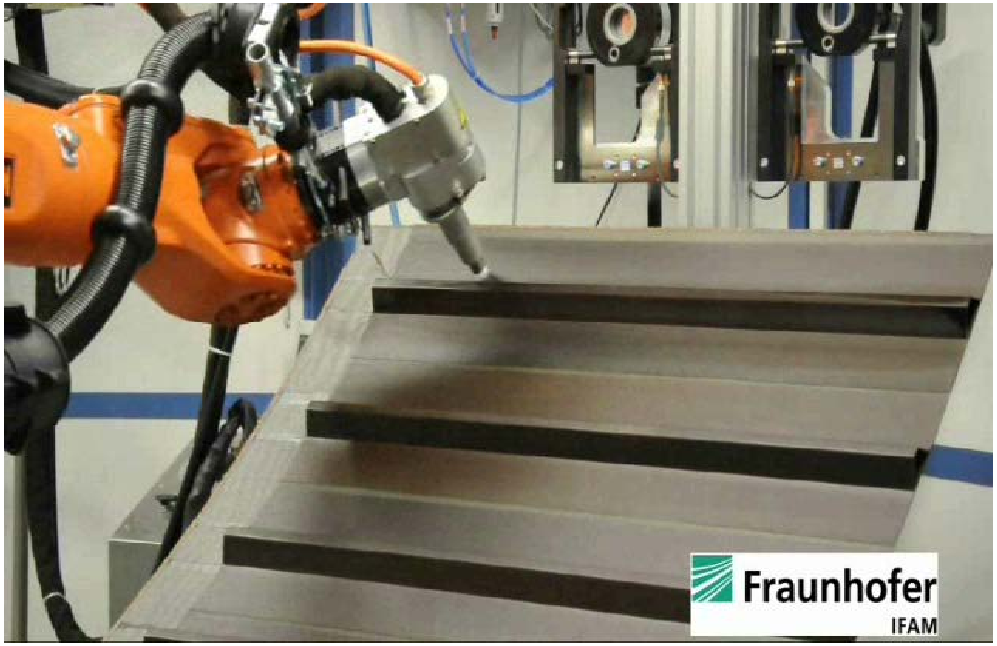

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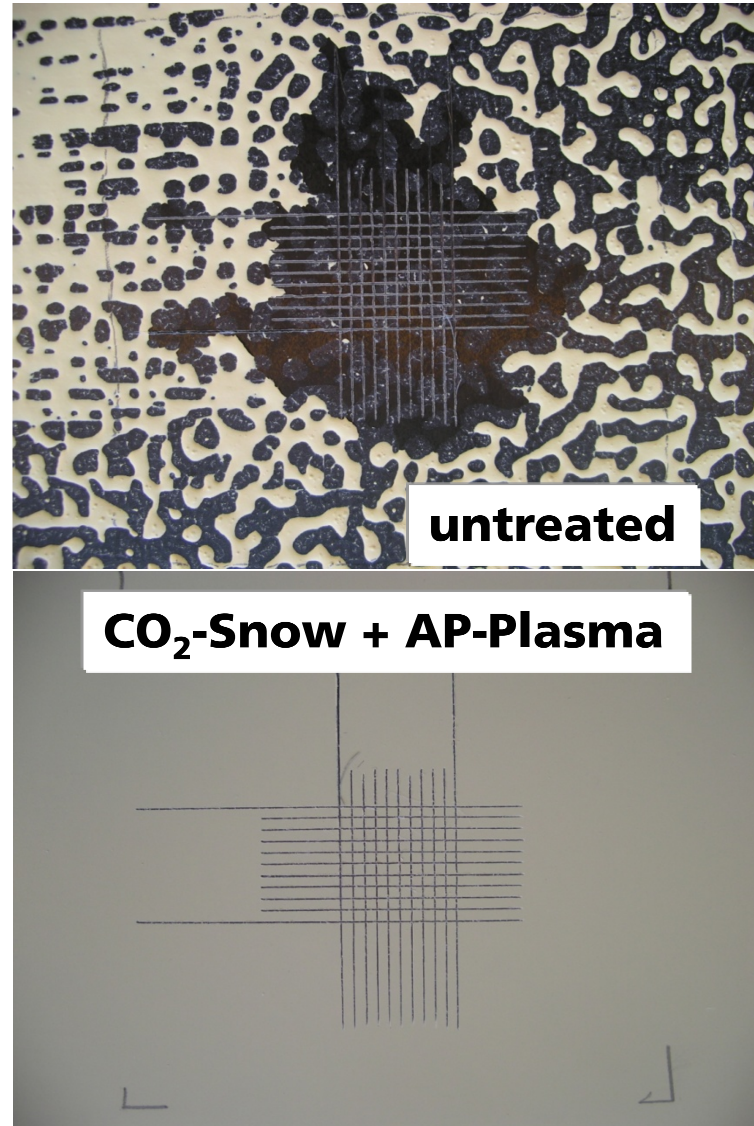
Paint Adhesion on CFRP

Paint Adhesion on Aircraft CFRP:

- Duromer matrices / thermoplastic
  - Peel-Ply with release agent
  - fluor-polymer release film
  - **- silicon-organic release agent**

  strong variation of contamination

- AP-Plasma- and CO_2-Snow parameter studies
- different paint systms (VOC / WB)
- Adhesion test (cross cut, pull-off)
- Open time ageing

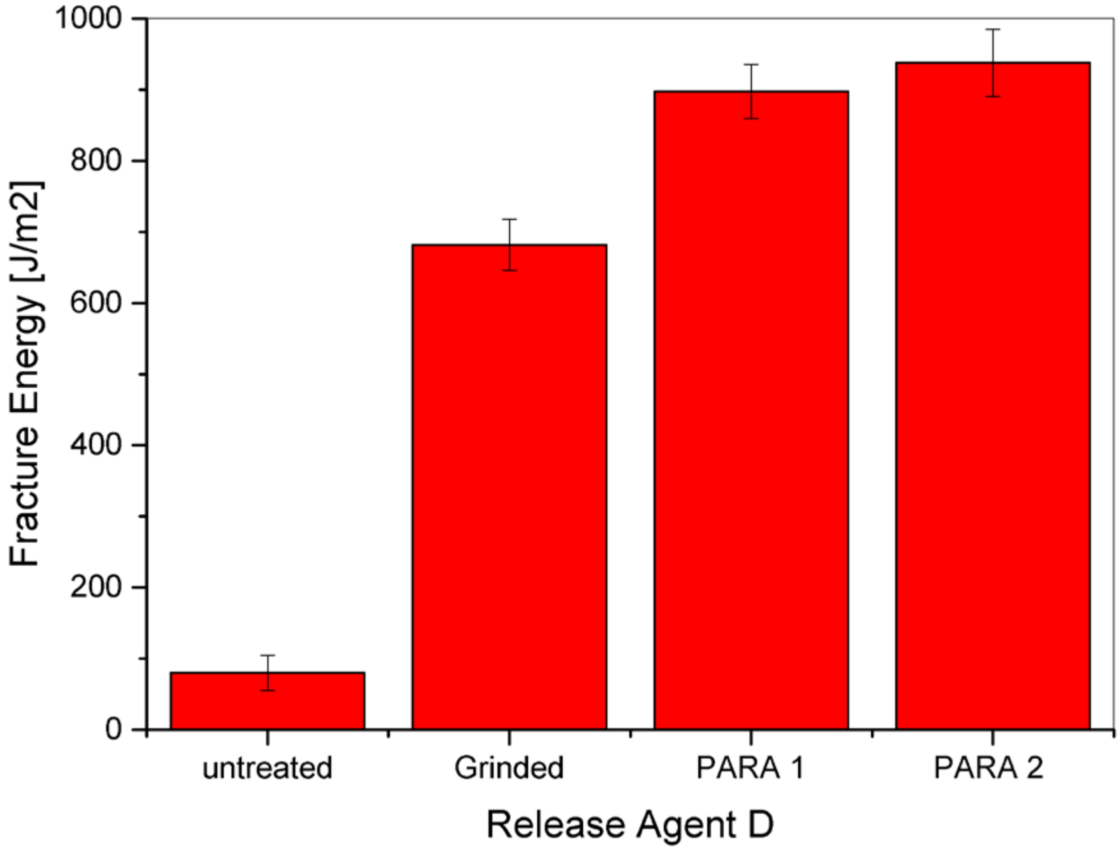


Surface Pre-Treatment of CFRP

Adhesive Bonding of EP Materials

- Variation CFRP-Surfaces

  - Release Agent D

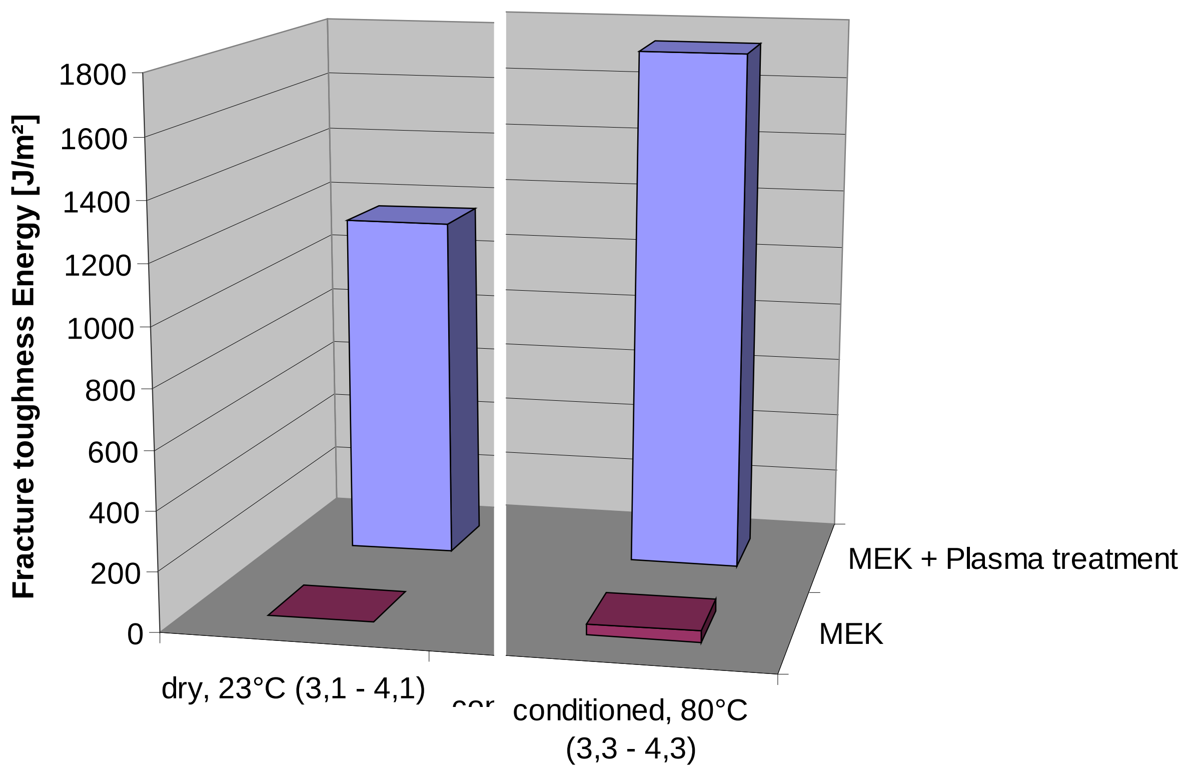


- CO2-Snow + APP-dapted
- Film Adhesive
- G1C-Testing
- Open time / Exposure

Surface Pre-Treatment of CFRP

Adhesive Bonding of PPS Materials

- Adhesive Film FM300K → Influence of Precleaning



Surface Pre-Treatment of CFRP

Adhesive Bonding of PPS Materials

- Adhesive Film FM300K $\rightarrow$ Influence of Precleaning

- Open time up to 2000h (external pre-treatment possible)

Adhesive failure

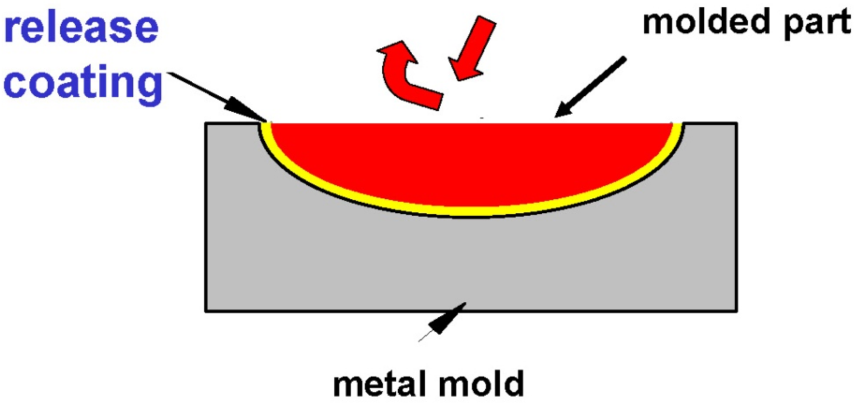
component failure, interlaminar inside the composite

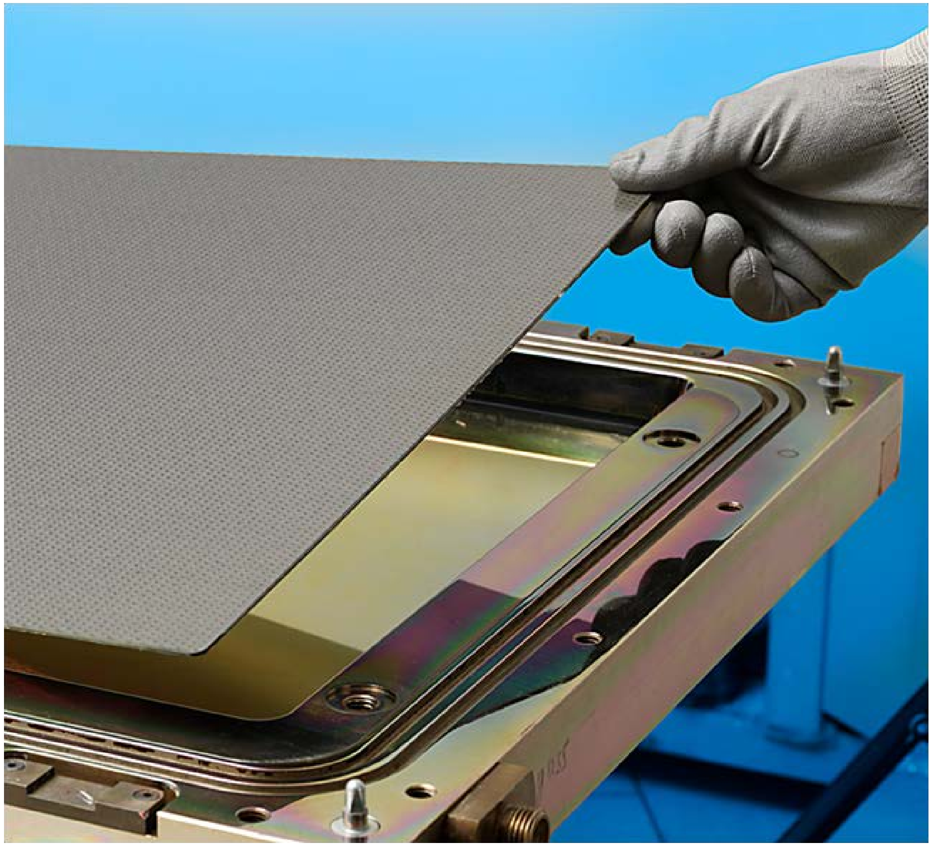
Hydrophobic Coatings

1. Permanent Release Layers

Plasma polymer coatings for the substitution of release agents

- process cost & effort
- cost & effort for surface cleaning
- quality controll





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Flexible Release Film for CFRP Production

- Thermoset Materials
- Direct release with filn
- No transfer of release agent
- Mechanical Protection by film
- Combination with In-Mould:
  - Paints
  - Function Coatings
  - …