Laser and plasma surface treatment of aluminum substitutes wet-chemical processes for fiber metal laminates

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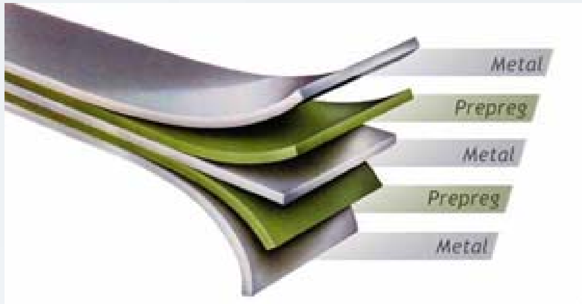
Agenda

- Fiber metal laminate / GLARE processing
- Requirements for pre-treatment
- Process overview
- Pre-treatment by
  - Atmospheric pressure plasma
  - Functional tapes
  - Laser
- Results of mechanical testing
- Conclusion

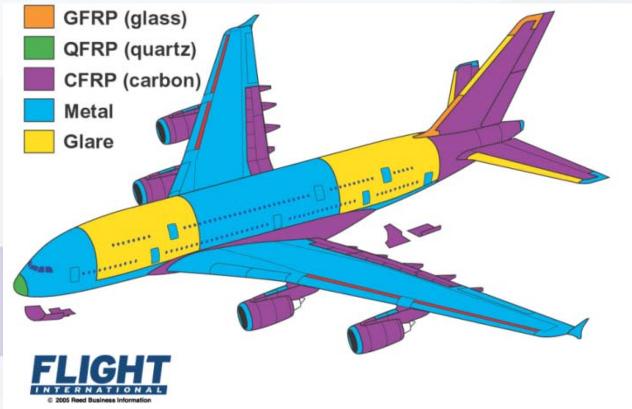
GLARE am A380
(source: fokker.com)

Fiber metal laminates

Hybrid laminates



Lagenaufbau von FMLs
(source: theatlasgroup.biz)



Material mix @A380 8airbus)
(source: flightforum.ch)

- Fiber reinforced metal laminates (FML)
  - Aluminum, titanium, steel, … +
  - Aramid, glass, carbon fibers, …
- Glass fiber reinforced aluminum (GLARE)
  - Aluminum sheets (AA2024) 0.3 mm – 0.4 mm
  - uni-directional S-glass fiber prepreg + epoxy resign 0.13 mm
  - Fiber orientation based on loading condition

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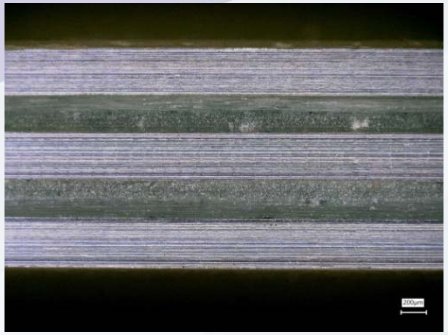
Fiber metal laminates

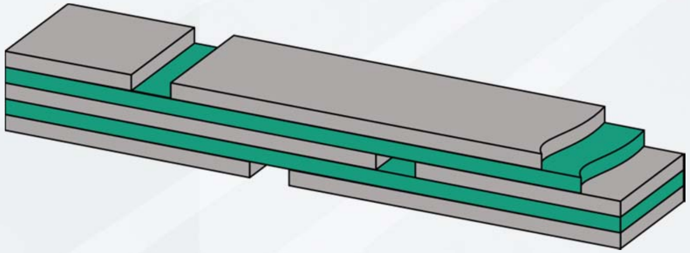
GLARE - Advantages

- Density of GLARE approx. 10% lower than monolithic aluminum
- High corrosion stability
  - Corrosion attack will be limited by prepreg layer
- Higher damage resistance
- Higher fatigue properties based on reduced crack growing

stacking AA2024



Cross section



schematic image of splice

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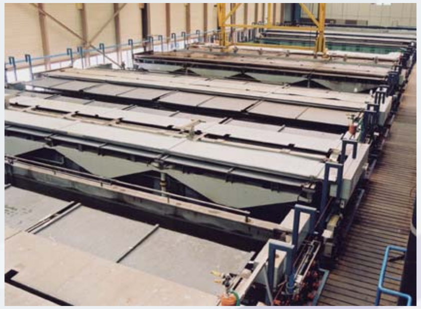
Fiber metal laminates

GLARE – Production steps

Coil-delivery ->

Part cutting by milling->



PSA-treatment ->

Primer-coating ->

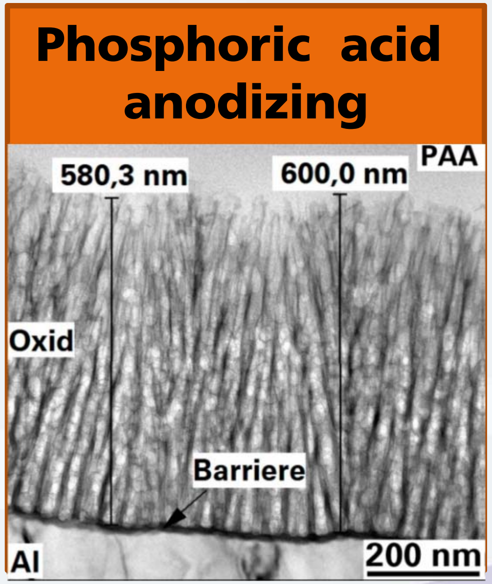
-> Lay-up (manually)

-> Autoclav

-> finished GLARE part

Quelle: Fokker

Requirements for surface pre-treatment



State of the art pre-treatment:

- 4-step wet-chemical pre-treatment
  - Cleaning, etching, anodizing, primering

→ Specific surface (~4 µm ablation), defined oxide layer

→ Treatment time, human safety, costs, environment protection, legal requirements

Requirement:

- Pre-treatment with dry (physical) processes
- Active (oxide layer) and passive (adhesion) corrosion resistance
- Production factors (automation, time in m²/min, costs, safety)

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Process developments

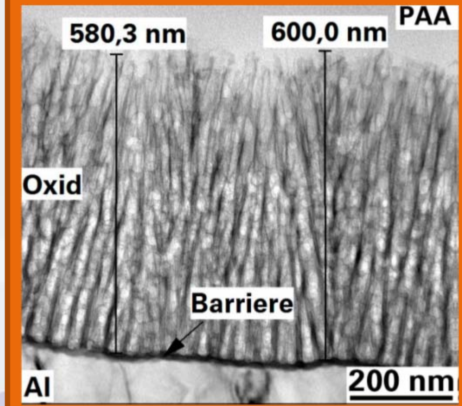
Plasma treatment

- Surface activation by atmospheric pressure plasma
- Treatment of large areas

Functional tapes

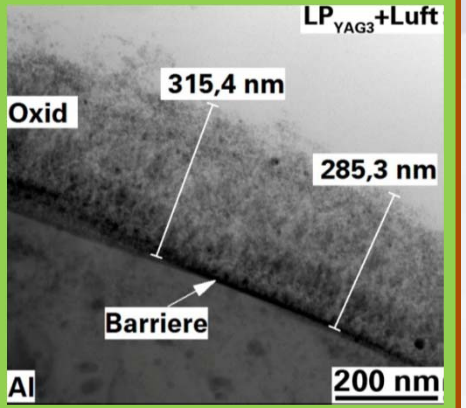
- Bath-free anodizing
- Local pre-treatment (repair, edge preparation)

Phosphoric acid anodizing



- Wet-chemical process
- Several baths for cleaning, etching, anodizing

Laser structuring



- Material ablation
- short heat treatment
- Limited working areas using pulsed laser

Primer coating (CrVI) or Cr - free

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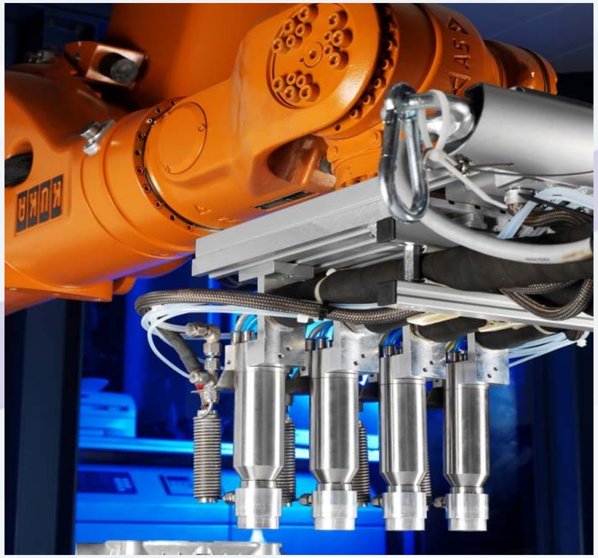
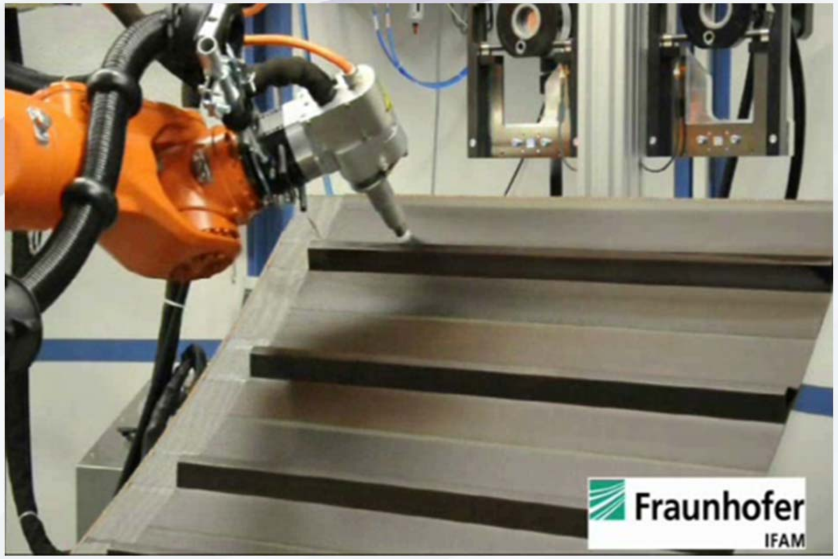
Atmospheric pressure plasma technique

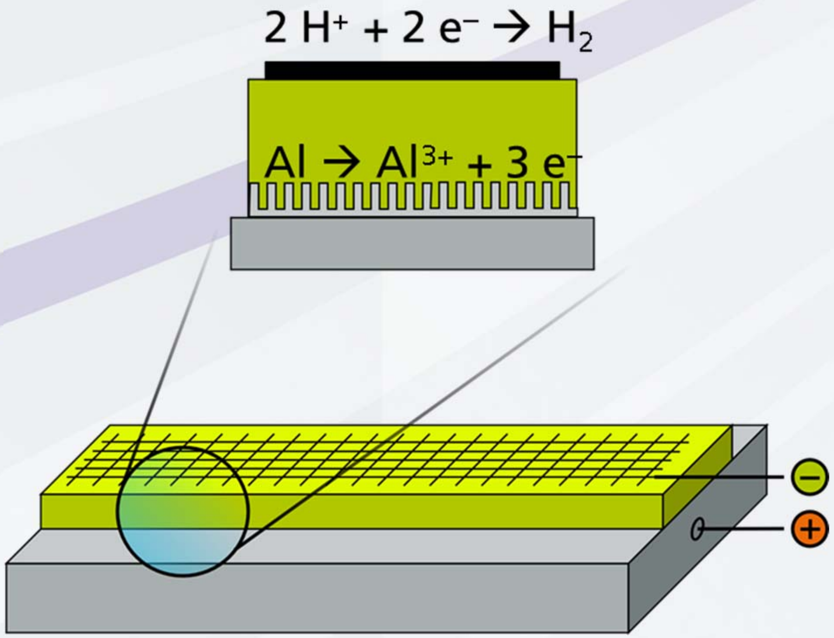
- Ideal for Inline-processes
- Application with robot coupling
- Treatment of small areas, lines or large surfaces
  - 0.04 - 0.4 m^2 min^{-1} (CO_2-plasma pre-treatment, 4 – 40 nozzles per side)





Functional tapes

- Simple handling
- Save and clean process
- Environment friendly
- No contamination
- Especially for local treatment



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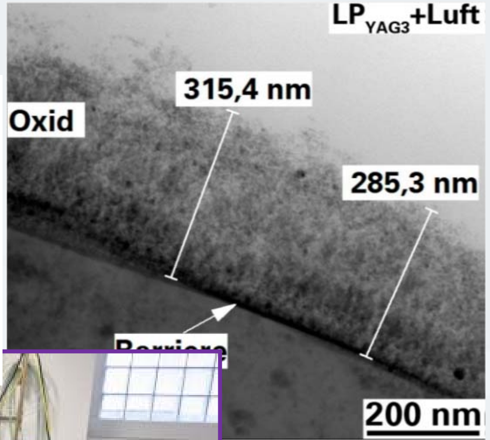
Laser pre-treatment

Pulsed laser
Working field:
110 x 110 mm²
Pl: 50 W
v: up to 5 m/s



Ablation depth: typ. 5 µm

Continuous wave laser
Working field:
100 x 100 mm²
Pl: 2000 W
v: up to 15 m/s

- Very short interaction times generate material ablation

Productivity

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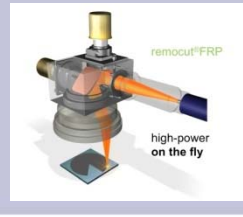
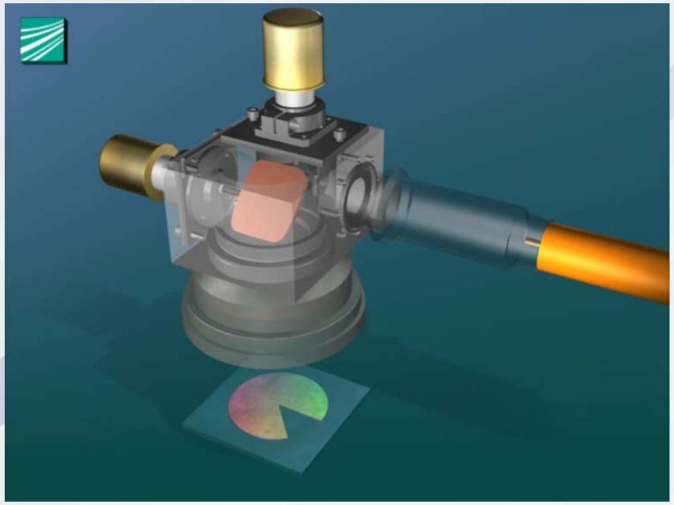
Laser pre-treatment (cw-laser)

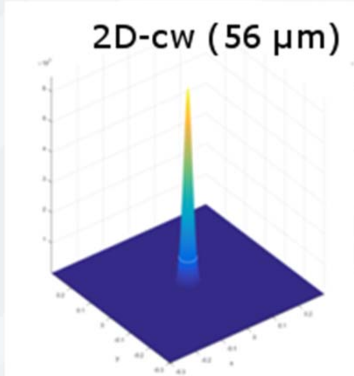


Pre-treatment with brilliant cw fiber laser

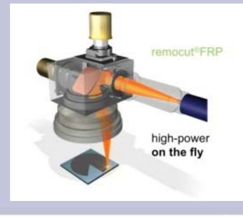
- characteristics:
  - combination of melting and sublimating
  - High scanning speeds realize short interaction times
  - Line scanning on the surface



Parameter	
Wavelength	1070 nm
Laser power	350 - 2000 W
Scan speed	6 – 15 m/s
Fokus diameter	56 µm

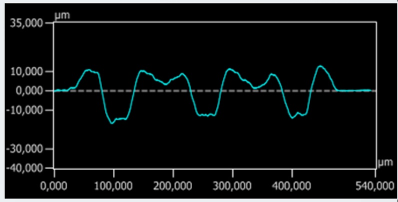


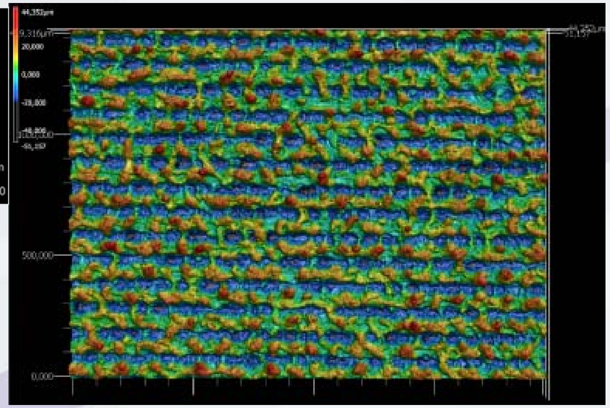
Laser pre-treatment (cw-laser)



Results

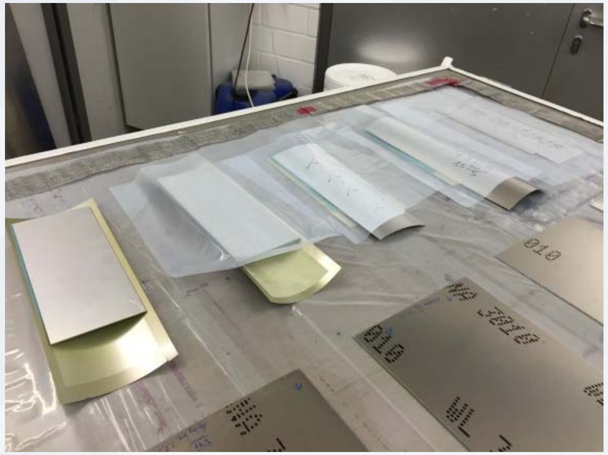
- Large area pre-treatment
- Ablation depth: > 15 µm
- Scan speed: 10 m/s





material: AA2024 uc
thickness: 0,3 mm

No acceptable deformation!



- Further decrease of interaction time using higher scanning speed

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Laser pre-treatment (cw-laser)

Laser pre-treatment using 1D – scanning

„State of the art"

Pulsed laser@5m/s

cw laser@15m/s

Ablation depth:

≤ 5 µm >15 µm

„High-end" System

1D-cw-Remote @ 300 m/s

Productivity

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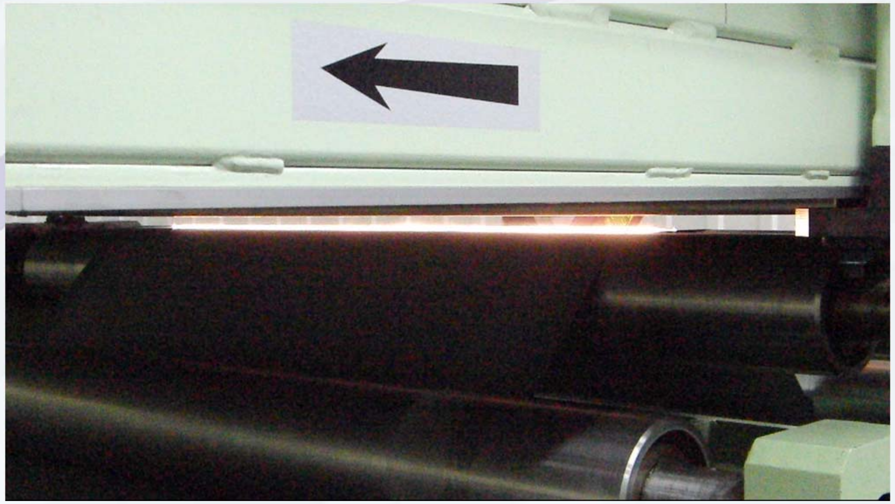
Laser pre-treatment (cw-laser)

Principle

- Combination of „laser beam scanning“ and „laser beam switching“
- Proven technology: laser treatment of electrical ferritic sheets („laser magnetic domain refinement“)

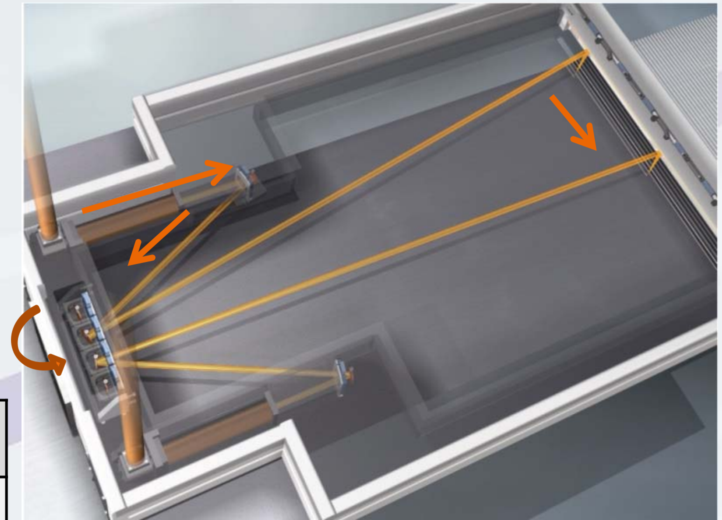


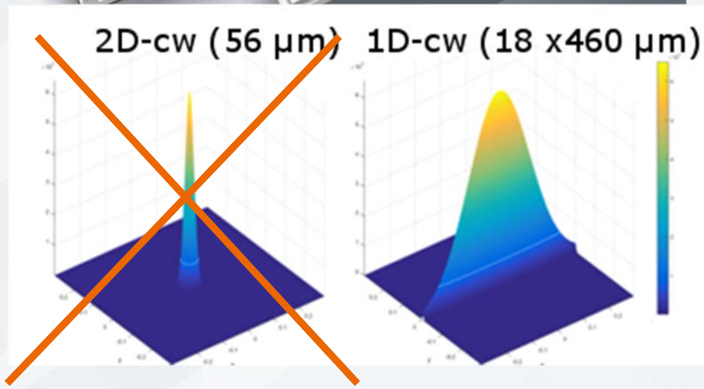
Laser pre-treatment (cw-laser)

Principle

- quick 1D-beam deflection (up to 300 m/s)
- continuous material movement
  (up to 80 m/min)
- Programmable line distance and length
- Modified laboratory system

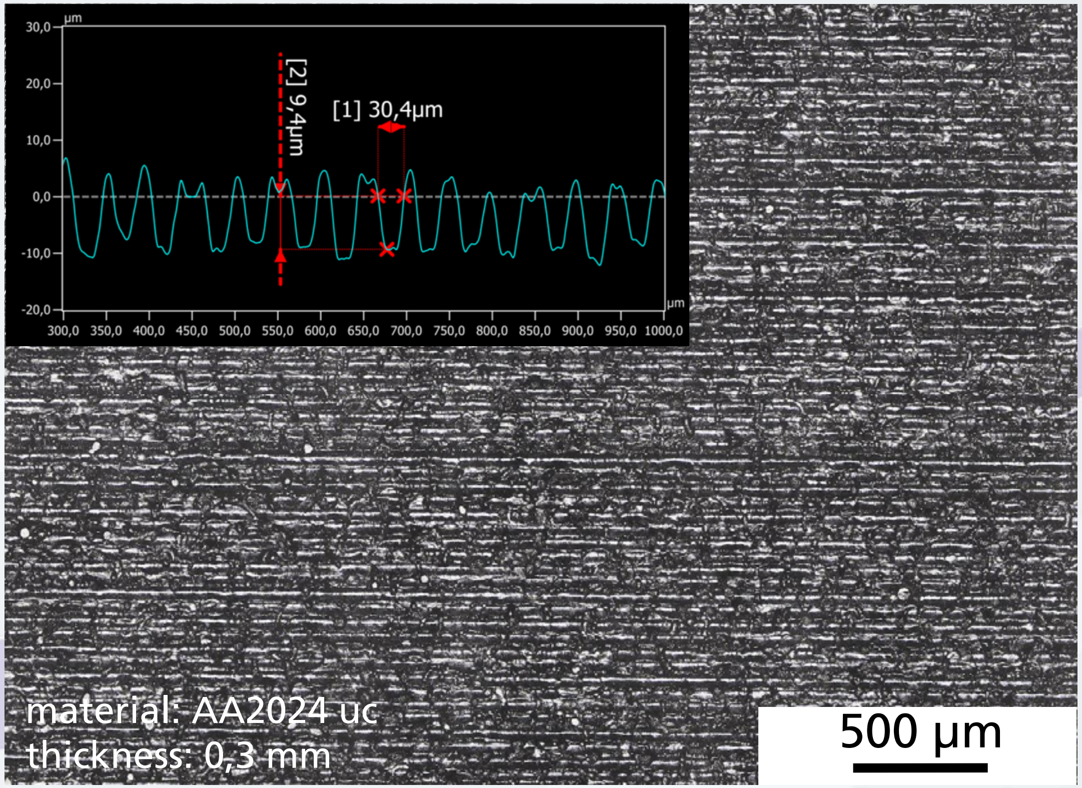
Parameter	
Wavelength	1070 nm
Laser power	2000 W
Scan speed	up to 300 m/s
Fokus diameter	ellipse (a = 18 µm, b= 460 µm)
Step-by-step material transport	





Laser pre-treatment (cw-laser)

Structuring results@AA2024uc



Parameter setup:

- P = 5000 W
- Scan speed:
  v = 150 - 300 m/s
- Line distance: 50 µm

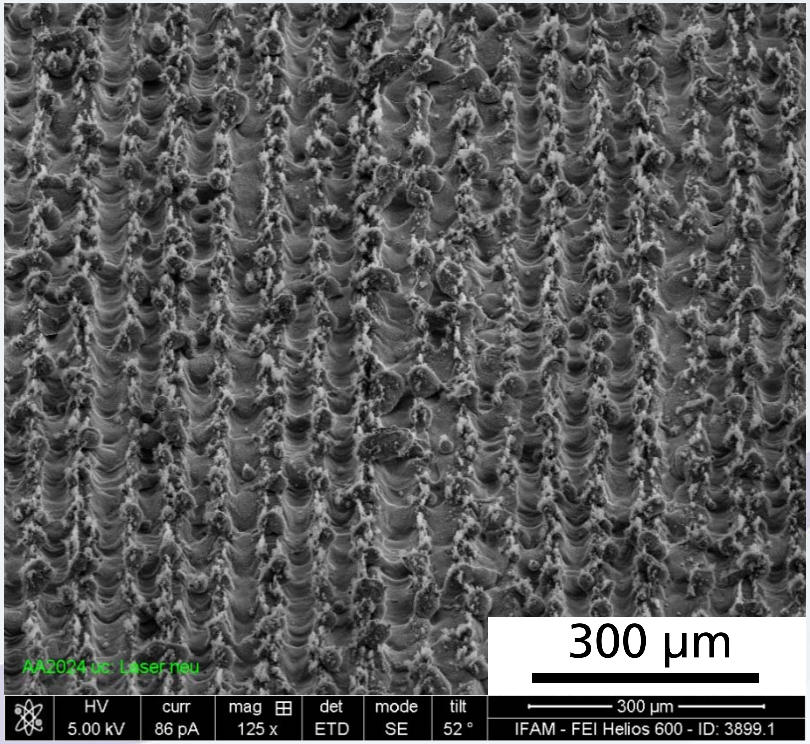
Results:

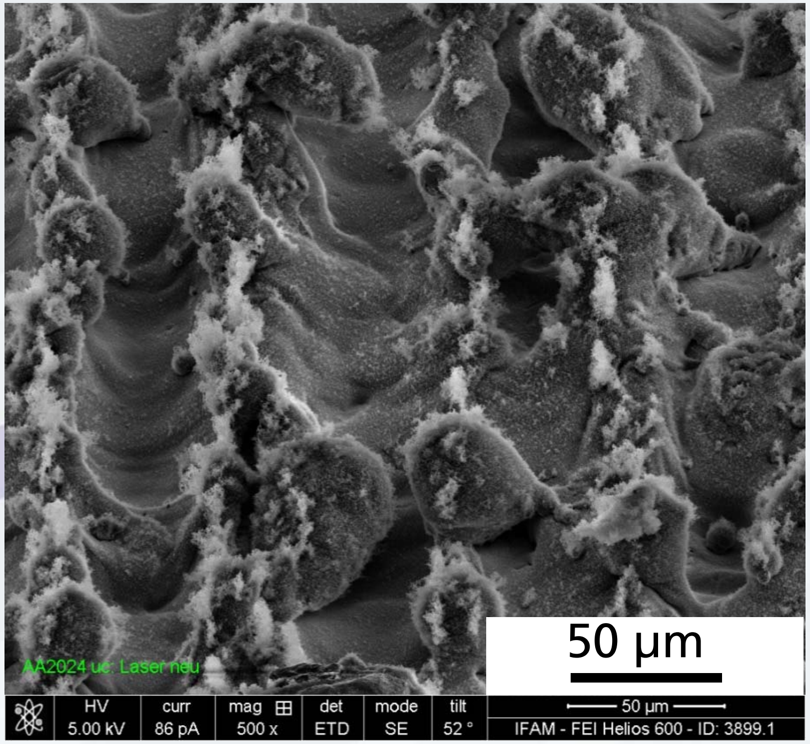
- Line width:
  28 - 41 µm
- Ablation depth:
  8 – 15 µm

Minimized deformation!

Laser pre-treatment (cw-laser)

Structuring results@AA2024uc

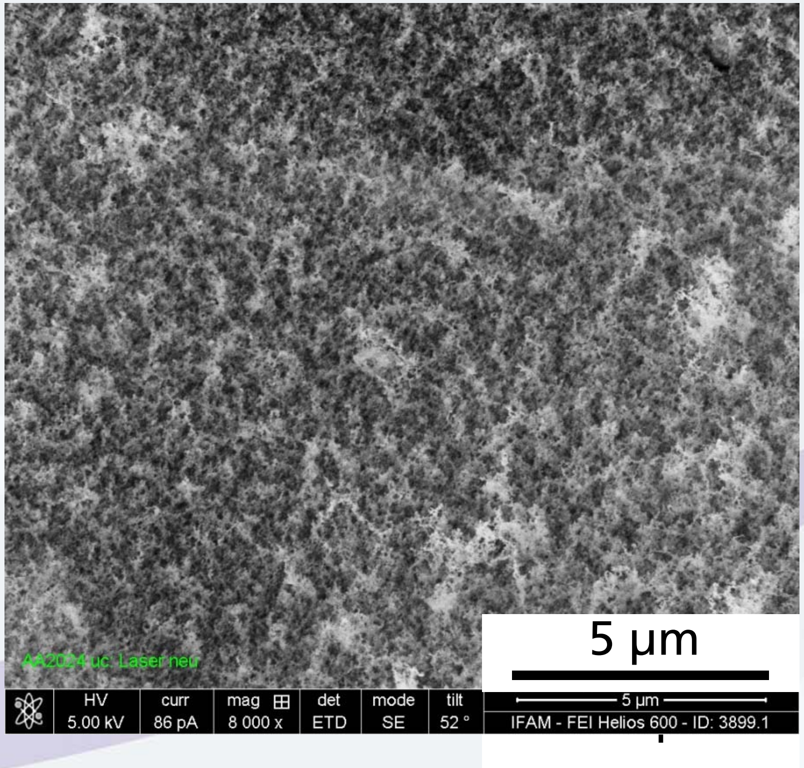


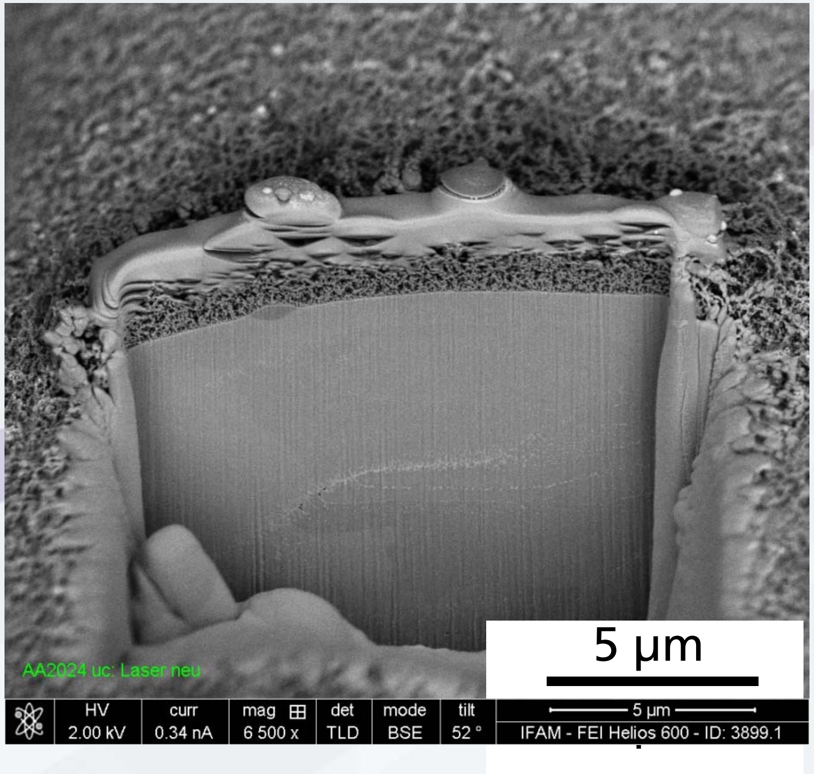


Complete line processing with artificial oxide layer

Laser pre-treatment (cw-laser)

Structuring results@AA2024uc





Enlargement of oxide layer thickness

Laser pre-treatment (cw-laser)

Testing of adhesion properties

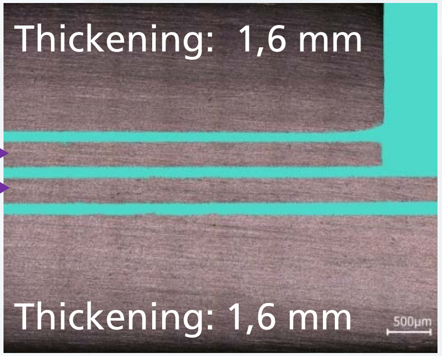
- Tensile shear test specimens (DIN EN 2243-1) thickening on both sides
- Peel test specimen (DIN EN 2243-2)

Pk.	Pre-treatment	Primer
B	Non treated	---
LM	Solvent	ja
TSA	Wine-sulfur-anodizing	ja
pw1	pw-Yb:YAG (fiber laser)	ja
pw2	pw-Nd:YAG (rod laser)	ja
cw1	1D-cw-Remote	ja
cw2	1D-cw-Remote	ja

Material: AA2024 uc ; 0,3 mm
Adhesive: GF-Epoxy resin
Primer: Cr(VI) - Primer

Autoclav - run

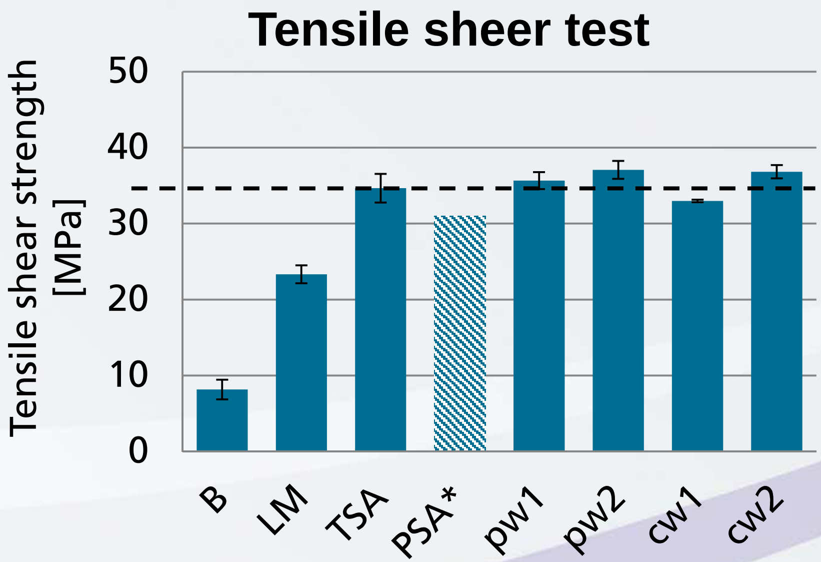
Pre-treated foils

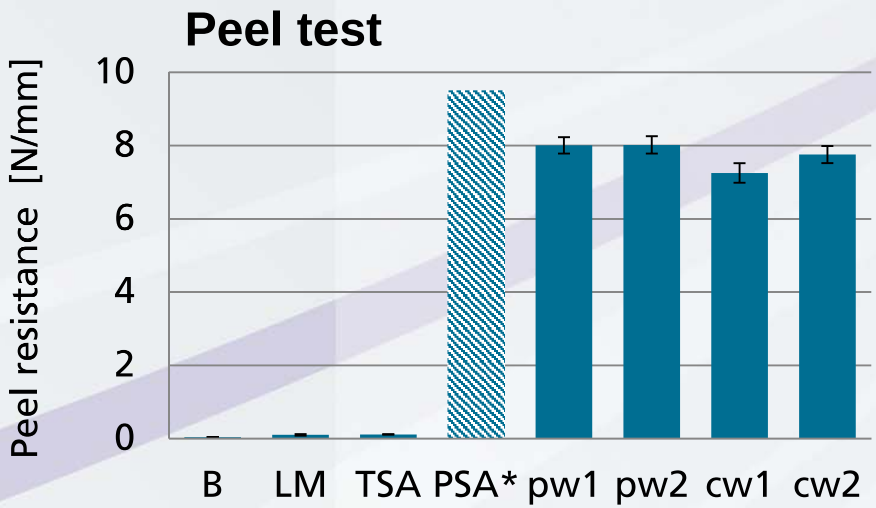


Cross section tensile test spec.

Laser pre-treatment (cw-laser)

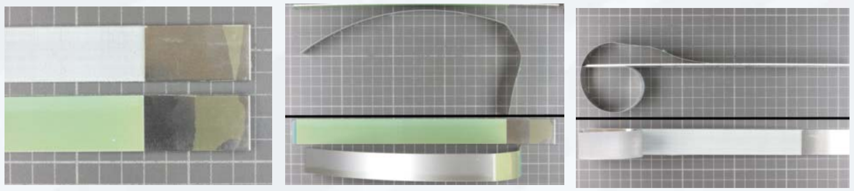
Results of adhesion tests





LM (adhesion) TSA (cohesion) cw1 (cohesion)

*) PSA-reference AA2024 unclad



comparison (cw1- TSA)

TSA (adhesiv zw. AA2024/Primer)

cw1 (cohesion)

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Comparison and conclusion

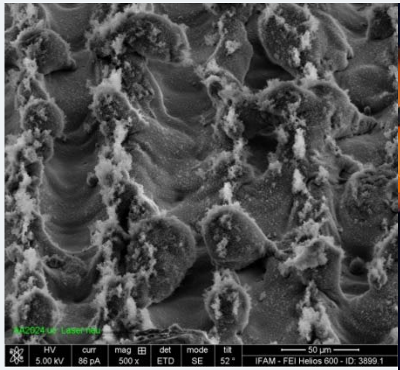
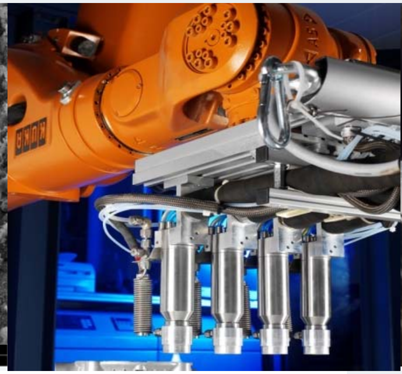
Comparison of processes

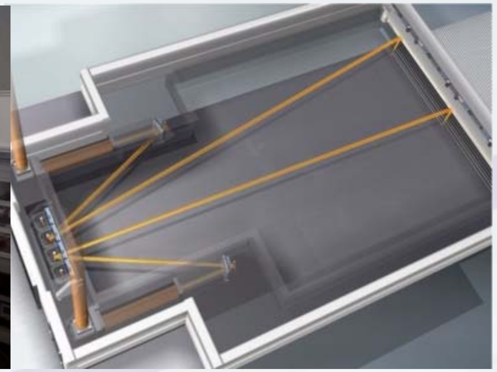
process	Tensile sheer strength [MPa]	Peel resistance [N mm^{-1}]
Laser	37	7.8
mech. blasting + Plasma	35	7,7
grinding + functional tape	31	7,2
PSA	31	9.5

Conclusion:

- Processes can fulfill the adhesion requirements
- Material removal is needed for good adhesion and corrosion behavior
- Kind of primer influences the pretreatment processes
- Optimization to increase corrosion resistance is needed
  - successful: Filliform + salt spray testing;
  - under investigation: Bondline corrosion

Thanks to

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