Functional adhesive tapes for local anodizing of aluminum

Martijn Verhagen, Brussels 14-04-2015

Afera

Lohmann
The Bonding Engineers.

Rene Magritte,
Brussels, Belgium 1948
Source wikiart.org

Outline

- Anodizing
- Project introduction
- Work package: Adhesive development
- Work package: Anodizing tests
- Work package: Application tests
- Conclusion and next steps
- Acknowledgements

Anodizing

Definition: Anodizing is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts.*

- Total reaction:

$2\,Al + 3\,H_2O \longrightarrow Al_2O_3 + 3\,H_2$

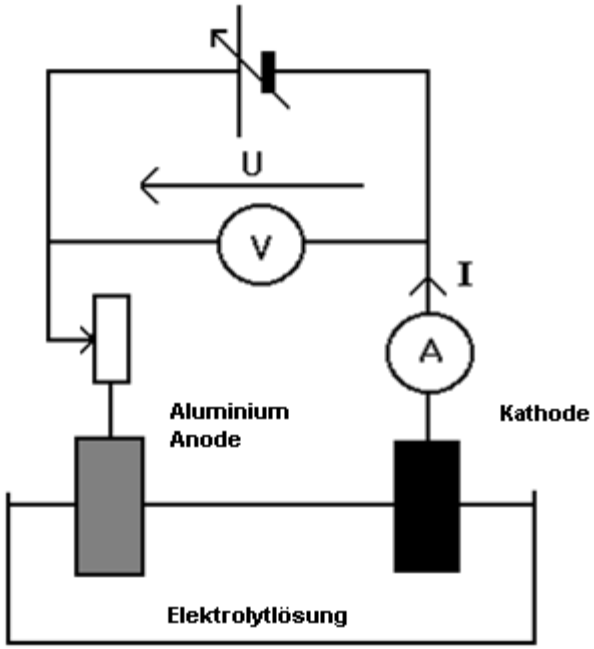
- Anode (Oxidation):

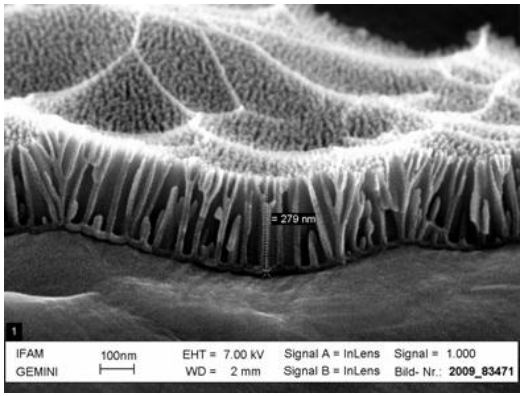
$2\,Al \longrightarrow 2\,Al^{3+} + 6\,e^-$

$2\,Al^{3+} + 9\,H_2O \longrightarrow Al_2O_3 + 6\,H_3O^+$

- Cathode (Reduction)

$6\,H_3O^+ + 6\,e^- \longrightarrow 3\,H_2 + 6\,H_2O$

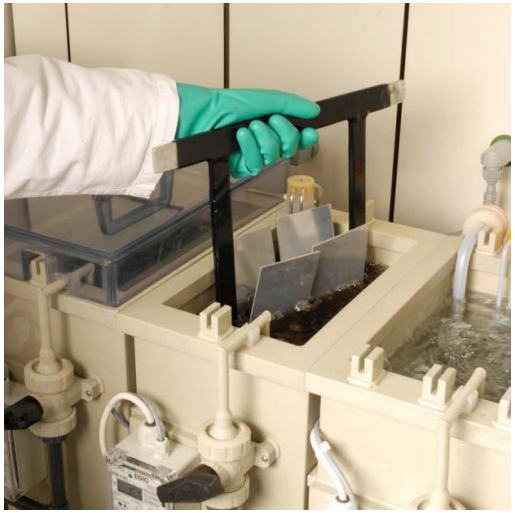




* Source: Wikipedia

Anodizing

Anodizing improves the corrosion protection of metals as well as improving adhesion of paints and adhesives



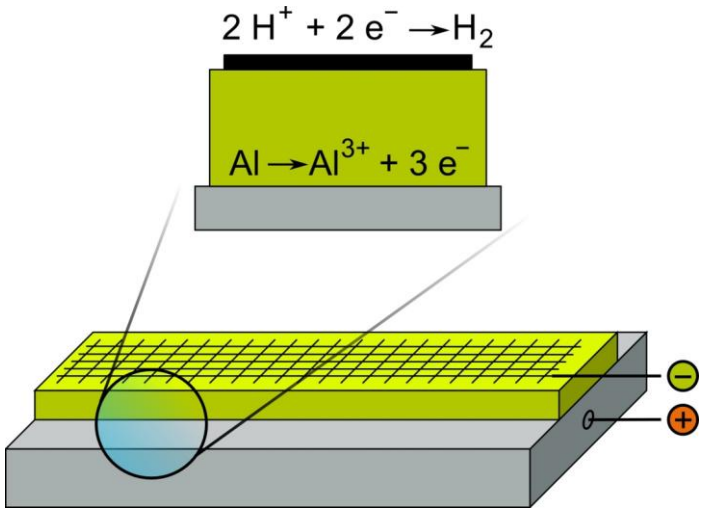
Methods of anodizing:

- Bath process
- Non-bath processes (Brush, PAC)

Pictures supplied by IFAM Bremen

Project idea

Bath free anodizing with a pressure sensitive tape



Advantages:

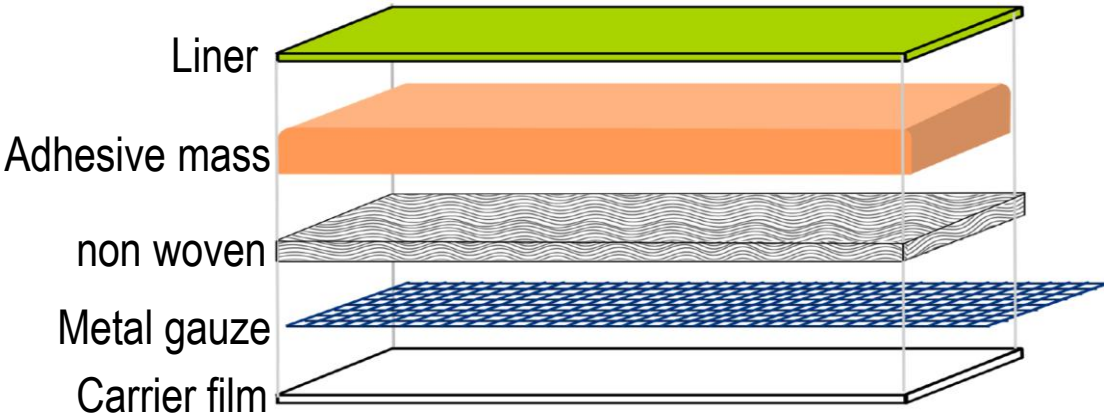
- Tailored to the surface size and geometry
- Time saving
- Limited usage of chemicals
- Easy and safe handling
- Residue free surface afterwards

Project break down

Work packages:

1. Definition phase
2. **Adhesive development**
3. Tape construction
4. **Anodizing process**
5. **Application tests**

Possible construction:



Work package: Adhesive Development, requirements for the adhesive

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Adhesive bonding technology

- Adhesion/Cohesion
- Residue-less removal
- Tackiness (self-sticking)
- Shelf life
- Broad application window (temperature & humidity)

Electrochemistry

- Electric conductivity
- Chemical stability during anodizing
- Structure of anodic oxide
- Rate of anodic oxide formation
- Water content

Target:

- Water-based system
- Suitable for PAA process (phosphoric acid anodisation)

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Work package: Adhesive development

- **Commercial available adhesives**

- Identified only 1 pressure sensitive adhesive that fit the pH requirement
  - Experimental product
  - pH: 1,5 – 2,5

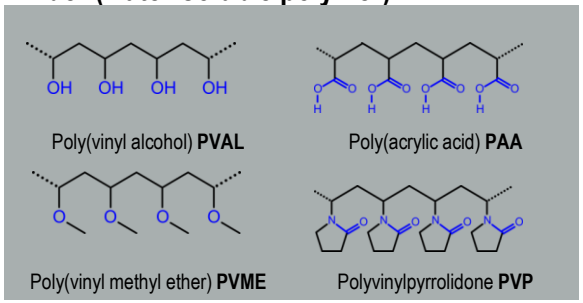
- Adhesive is compatible with phosphoric acid
- Adhesive is plasticized by the acid
- No clean removal from substrates
- Formulating with other components does not improve the performance

Work package: Adhesive development

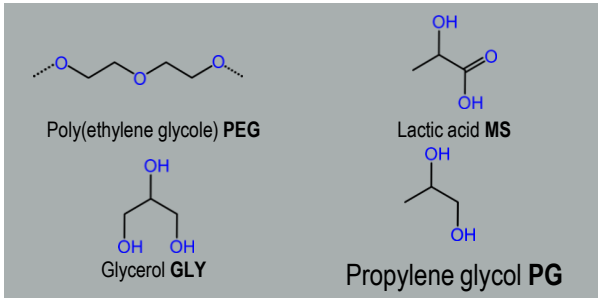
Self development of the adhesive

- **4 component types**

Binder (water-soluble polymer)



Softener



Electrolyte for anodising process

H_3PO_4

Phosphoric acid

Additives (solids)

- Fumed silica

  Adjustment of viscosity

Material	Function
PVAL	• Polymeric matrix
PAA	• Stability of the film • Possibility to cross link • Complex formation
PVP	• Stability of the film • Water binder
PVME	• Tackifier
Lactid Acid	• Tackifier
Glycerin	• Water binder
Fumed Silica	• Viscosity adjustment • Improvement of the cohesion

Work package: Adhesive Development, requirements for the adhesive

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Adhesive bonding technology	Electrochemistry

- **Adhesion/Cohesion**
- **Residue-less removal**
- **Tackiness (self-sticking)**
- Shelf life
- Broad application window (temperature & humidity)

- **Electric conductivity**
- Chemical stability during anodizing
- Structure of anodic oxide
- Rate of anodic oxide formation
- **Water content**

Target:

- Water-based system
- Suitable for PAA process (phosphoric acid anodisation)

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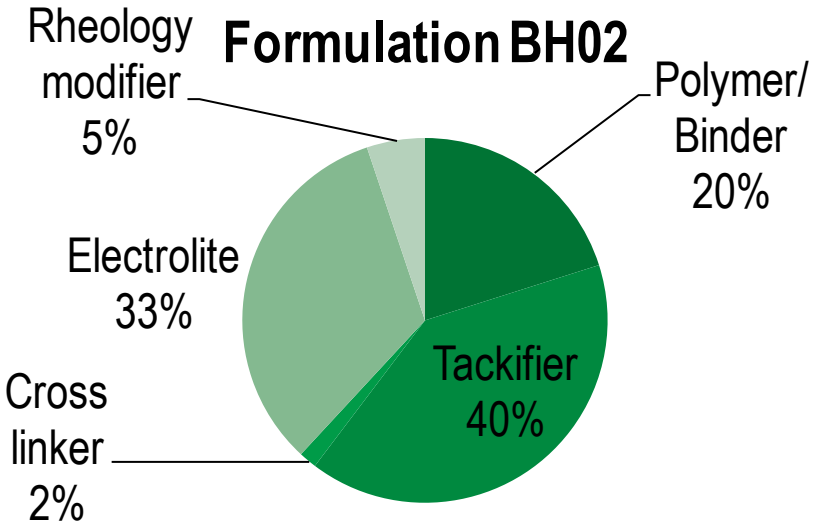
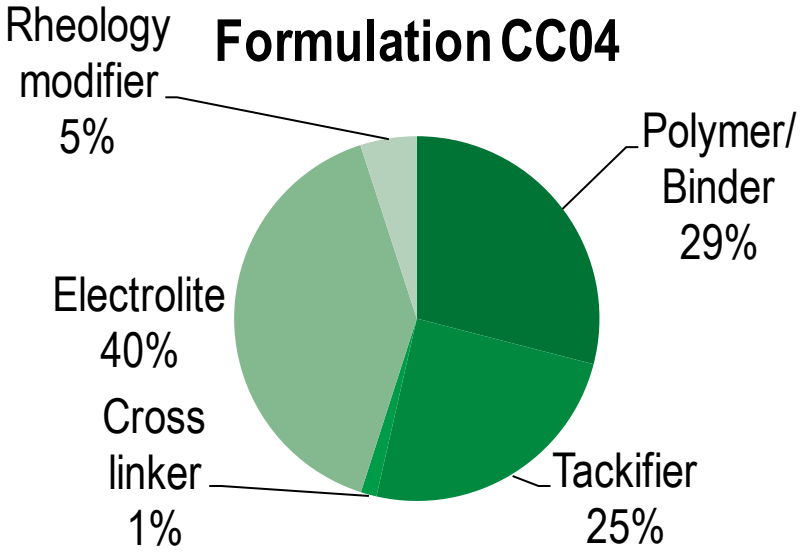
Work package: Adhesive development

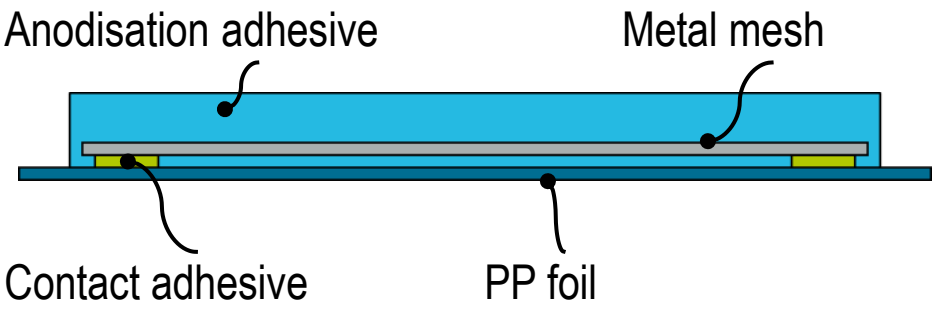


Coatweight wet	2200 g/m2
Coatweight dry	1300 g/m2
Peel force (AFERA 5001)	2,75 N/25mm
Failure mode	Clean Peel
Electrical conductivity	1,2 mS/cm
Water content	15%



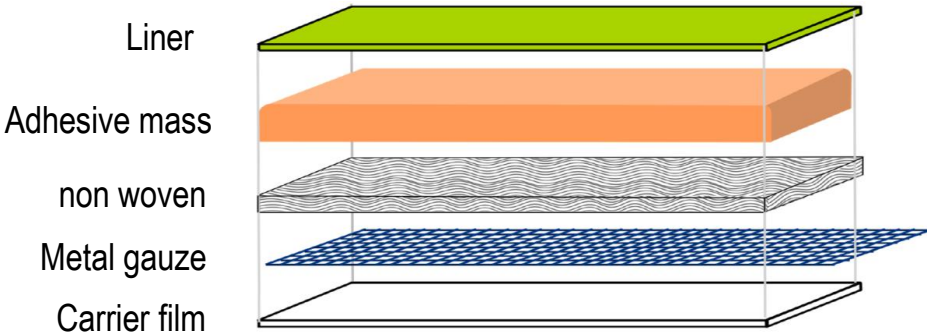
Work package: Anodizing process

Adhesive tape on lab scale



- Flexible set-up
  - Easy application
- High application weight (≈ 1500 g m^{-2})
- No separating fleece
- Storage in aluminum pouch
  - Constant water content

Possible construction:

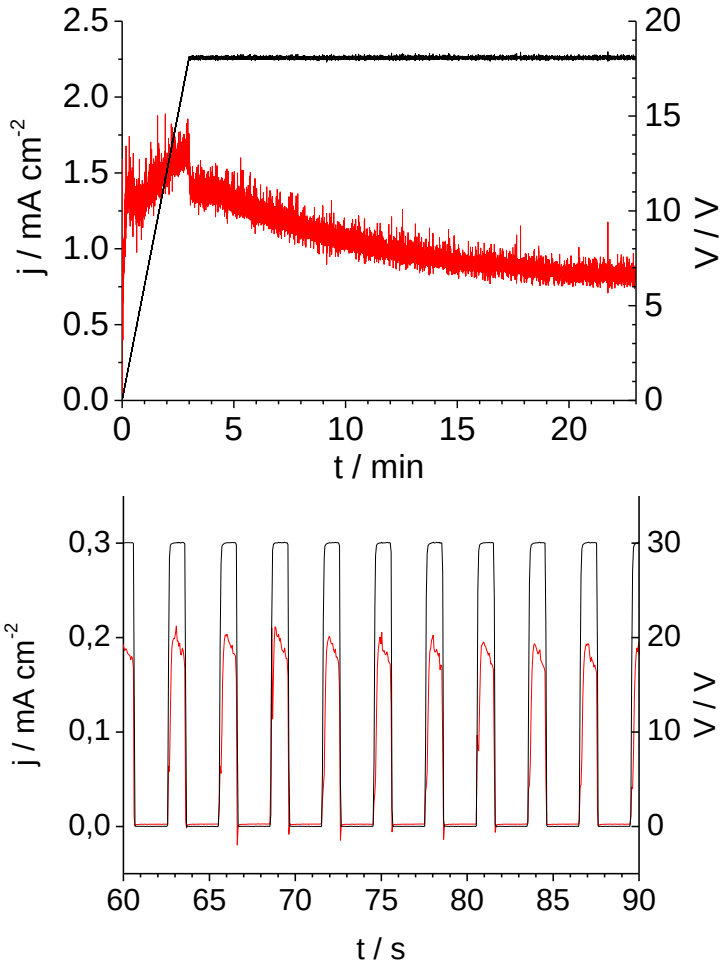


Work package: Anodizing process

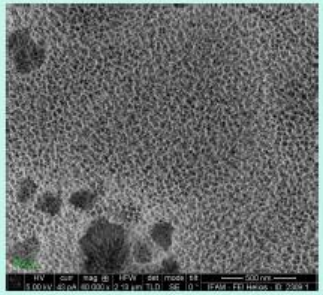
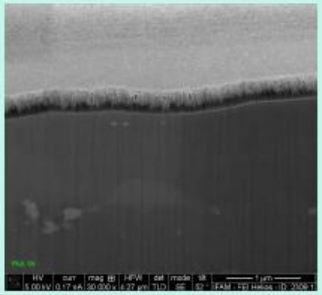
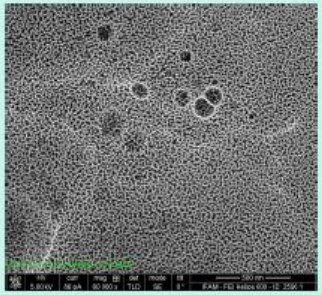
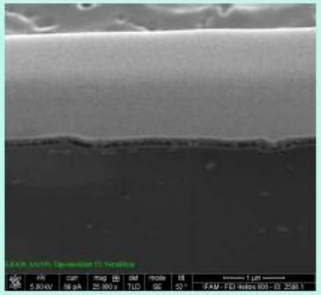
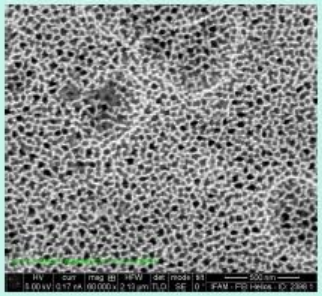
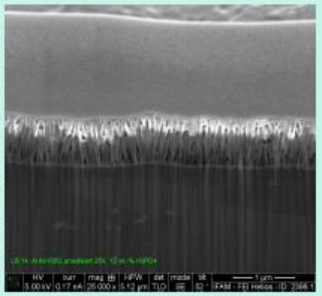
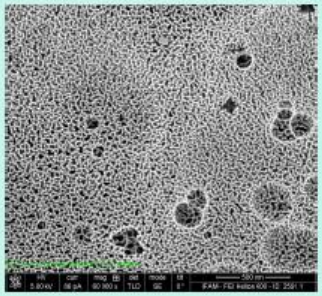
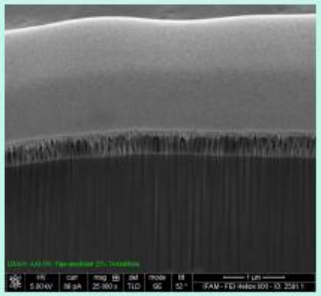
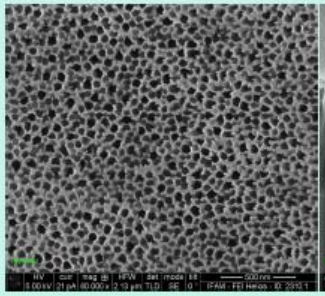
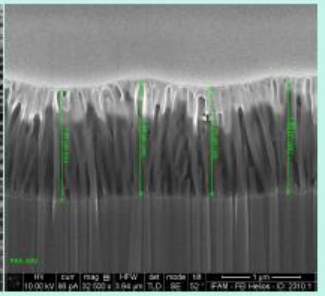
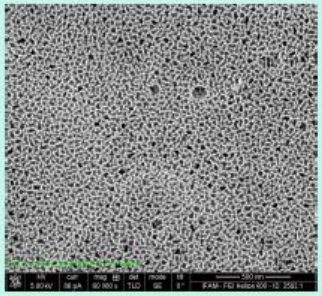
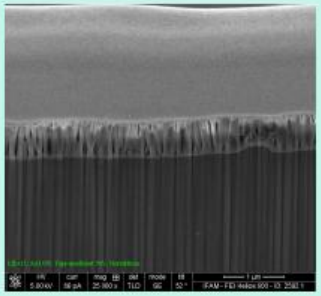
Anodizing parameters

- Constant current (DC) anodizing
  - Starting point: bath anodizing
  - Resistance similar to bath treatment
    - Increased (specific) resistivity
    - Decreased distance anode/cathode
  - Current density ≈15% compared to typical bath anodizing

- Pulsed potential anodizing
  - Improved mass transport and heat transport expected
  - Practical tests not yet successful



Work package: Anodizing process

	Bath anodizing		Tape anodizing	
5 V				
25 V				
50 V				

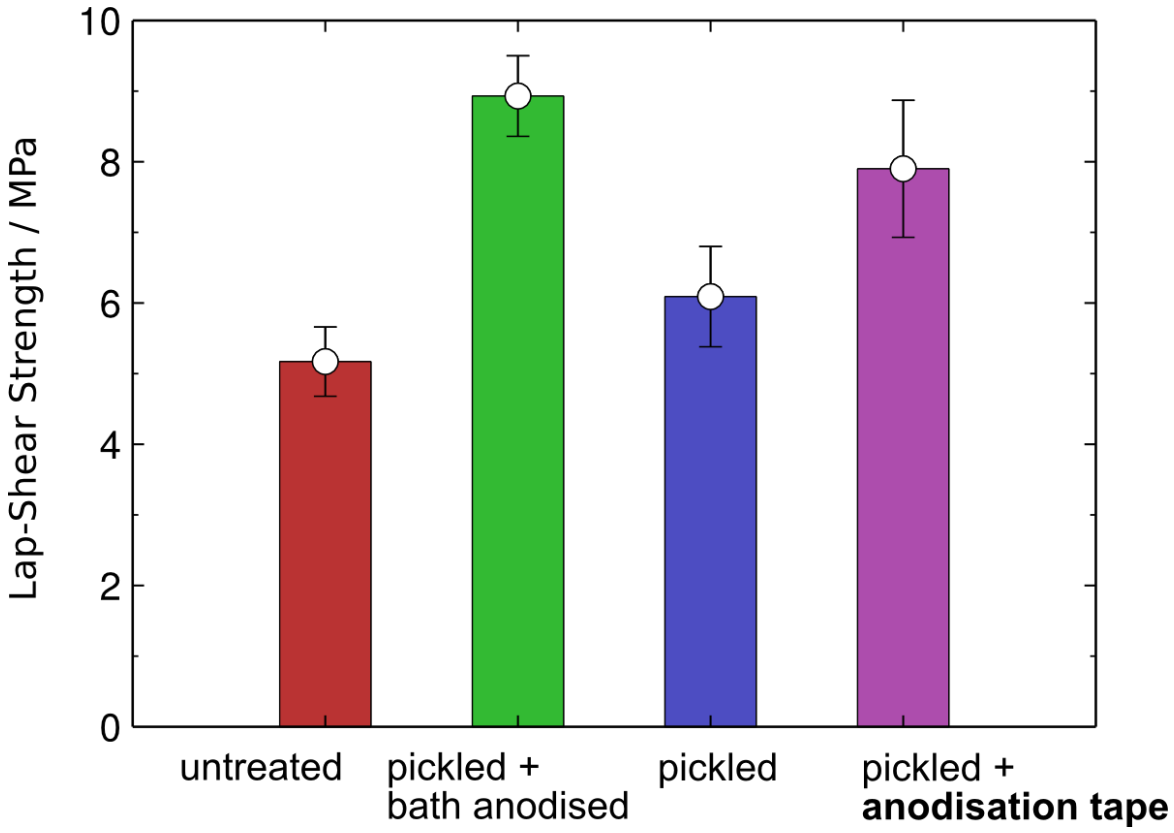
Work package: Anodizing process

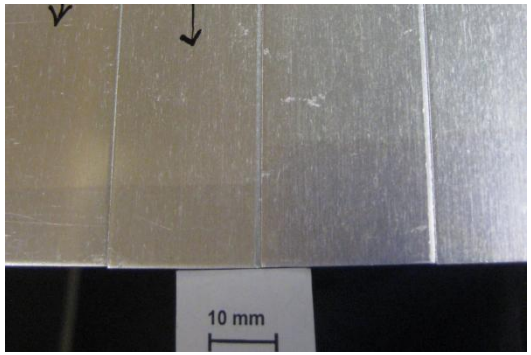
Evaluation of surface morphology

- **Thickness of oxide and pore surface smaller for tape anodizing in comparison to bath anodizing**
- **Increasing humidity increases the oxide layer thickness for both methods**
- **Higher current increases the oxide layer thickness for both methods**
- **Longer exposure time increases the oxide layer thickness for both methods**

Work package: Application testing

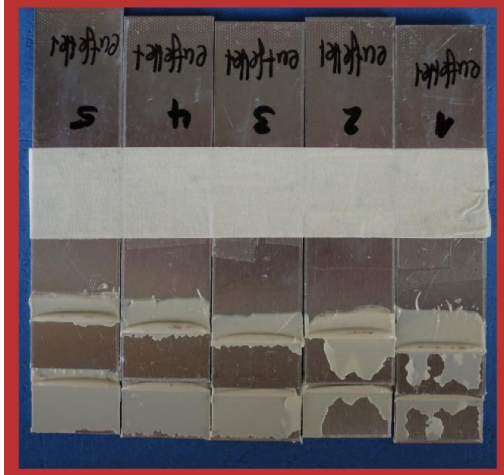
Lap shear: Bonding of aluminium test panels with a PUR adhesive





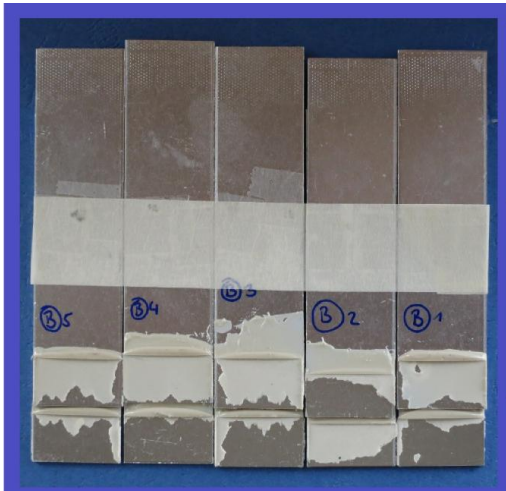
Substrates: AA2024 (clad), adhesive: Macroplast UK8303/UK5400 (Henkel), curing: 7 d @ RT

Work package: Application testing



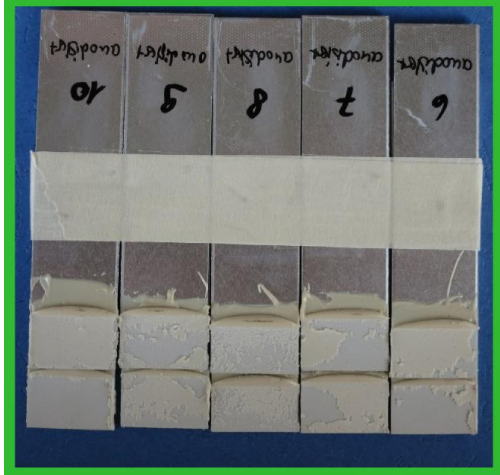
Al2024 clad
untreated

adhesion failure
100 %



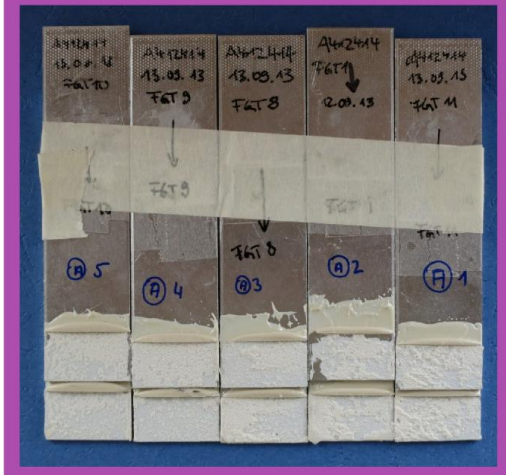
Al2024 clad
pickled only

adhesion failure
100 %



Al2024 clad
pickled +
bath anodisation

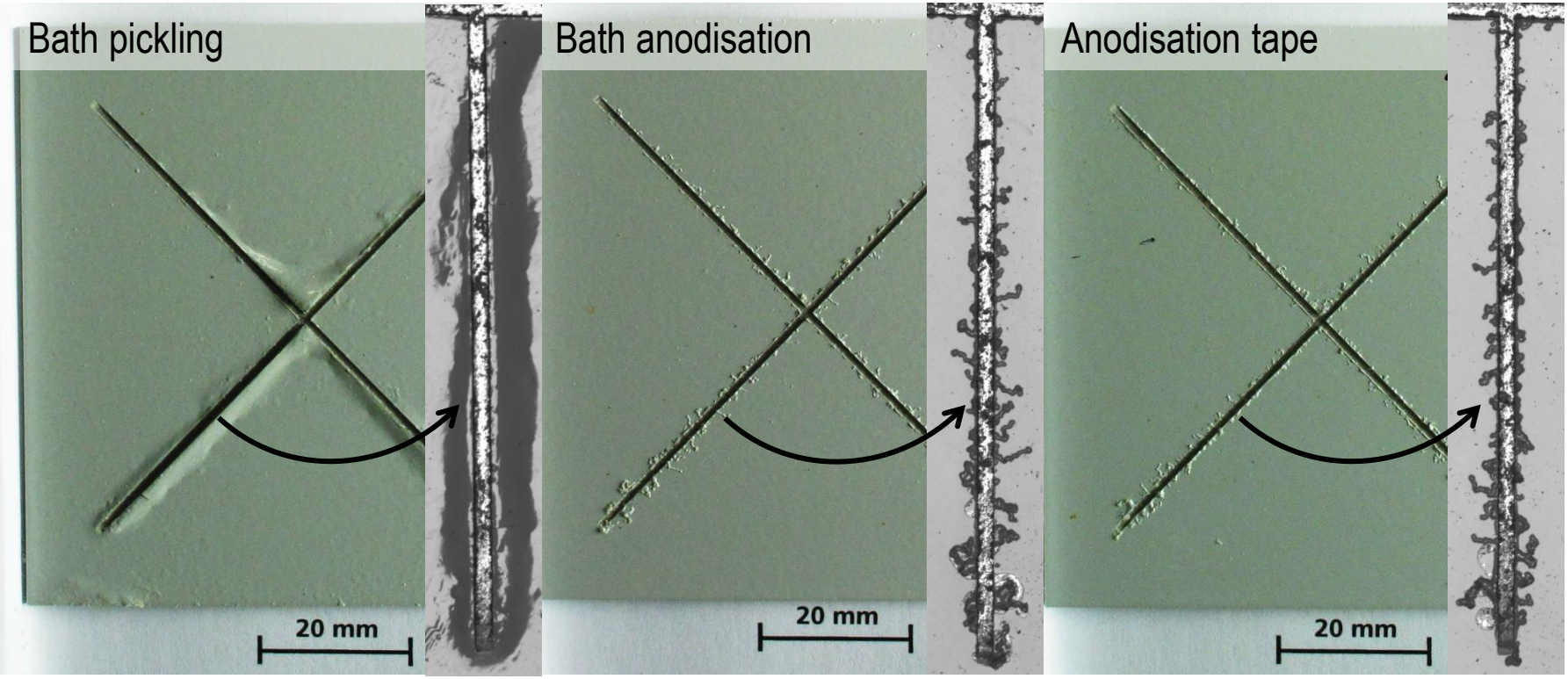
adhesion failure
0 %



Al2024 clad
pickled +
anodisation tape

adhesion failure
< 5 %

Work package: Application testing



- Pickled only: Extensive paint delamination
- Anodizing tape: Comparable to bath treatment

Pickling: TSNC; bath anodisation: H_3PO_4/H_2SO_4; anodisation tape: 33wt% H_3PO_4, 18 V, 23 min; Paint: Chromate-free primer + topcoat, AA2024 clad, 1000 h

Conclusion

- **Anodizing with a tape is possible**
- **Similar conditions (voltage, time) to bath anodizing can be used**
- **Although differences in oxide layer in comparison to bath anodizing, the oxide layer is suitable for painting and adhesion**

Next steps

- **Further optimization of tape construction**
- **Further optimization of anodizing process**
- **Identification of pilot applications**
- **Transfer from lab to industrial production process, by means of a new project or secondary partners**

Acknowledgements

Lohmann
The Bonding Engineers.

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AIRBUS

alu finish

HYDRO

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Ingenieurbüro Peter Schrems

DFO

AiF

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by the German Bundestag

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Thank you very much
for your attention!

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