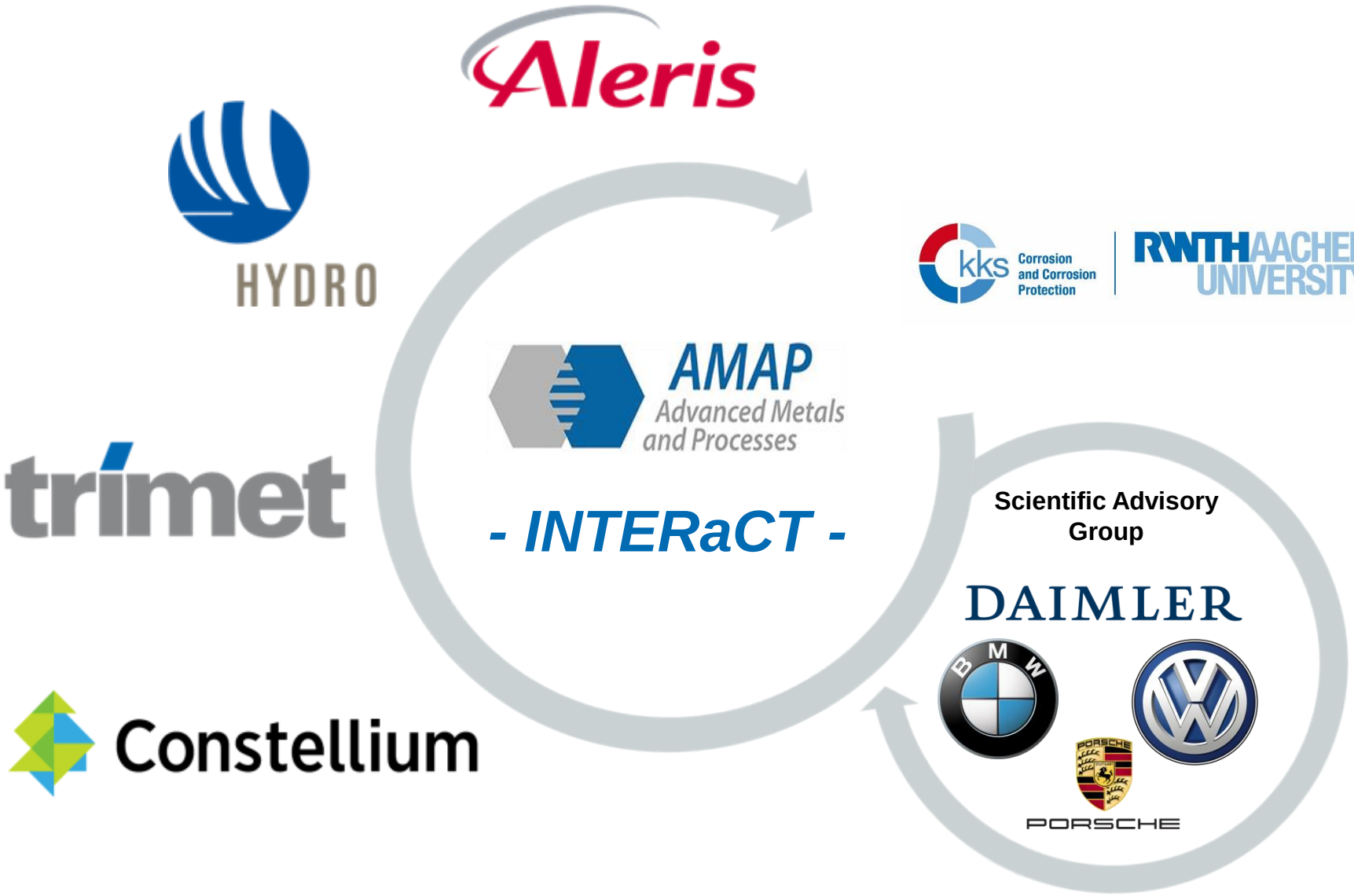
AMAP *INTERaCT*

Intergranular **C**orrosion **T**esting of 6000 Aluminum Alloys

Consortium


Aleris
HYDRO
kks Corrosion and Corrosion Protection
RWTH AACHEN UNIVERSITY
AMAP Advanced Metals and Processes
trimet
- INTERaCT -
Scientific Advisory Group
DAIMLER
BMW
PORSCHE
Constellium

Objectives

- **Main Goal 1**: Understanding the influence of the allowed parameter variation on the test results of ISO11846 Method B

  WP 1.1 “Reference“ Conditions → defined by the consortium

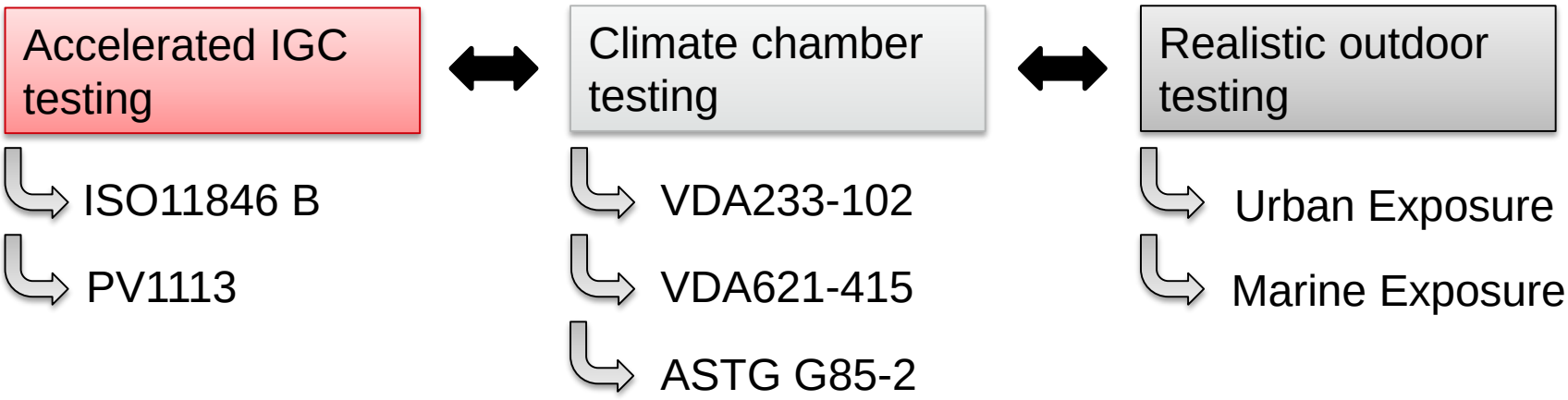
  WP 1.2 Volume-to-Surface Ratio R

  WP 1.3 Surface Treatments

  WP 1.4 Solution Temperature

  WP 1.5 Post-etching with HNO_3 / Storage Time

- **Main Goal 2**: Methodical investigation and comparison of established testing methods



Overview Corrosion Tests

Test	Type	Environment	Duration
ISO 11846 Method B	Permanent immerison	30g/l NaCl + 10ml/l HCl pH~1	24 hours
PV1113	Permanent immerison	100g/l NaCl + 25ml/l HCl pH<1	2 hours
VDA233-102	Cyclic testing	1% NaCl, pH: 6,5-7,2	12 weeks
VDA621-415	Cyclic testing	5% NaCl, pH: 6,0-7,0	10 weeks
ASTM G85-A2	Cyclic testing	5% NaCl, pH: 2,8-3,0	10 weeks
Urban Exposure	Natural weathering	3% NaCl (weekly)	1 year
Marine Exposure	Natural weathering	Splash zone / permanent immersion	1 year

Materials

- AA6014 and AA6016 each in high Cu and low Cu
  - T4
  - BH (20min / 185°C, cooling in air)
  - T6 (2h / 205°C , cooling in air)

Alloy	Si	Fe	Cu	Mn	Mg	V
6016 High Cu	1.38	0.20	0.1620	0.061	0.31	---
6016 Low Cu	1.49	0.19	0.0023	0.078	0.38	---
6014 High Cu	0.7	0.17	0.3	0.15	0.65	0,1
6014 Low Cu	0.7	0.17	0.1	0.10	0.65	0,1

Main Goal 1:
Parameter Study ISO11846 Method B

- WP 1.1 "Reference“ Conditions → defined by the consortium
- WP 1.2 Volume-to-Surface Ratio R
- WP 1.3 Surface Treatments
- WP 1.4 Solution Temperature
- WP 1.5 Post-etching with HNO_3 / Storage Time

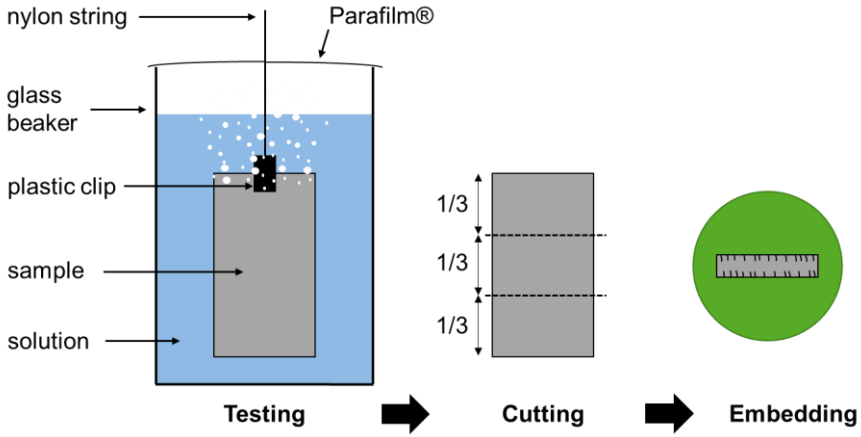
<u>Reference Conditions:</u>

30g/l NaCl + 10ml/l HCl (pH~1)

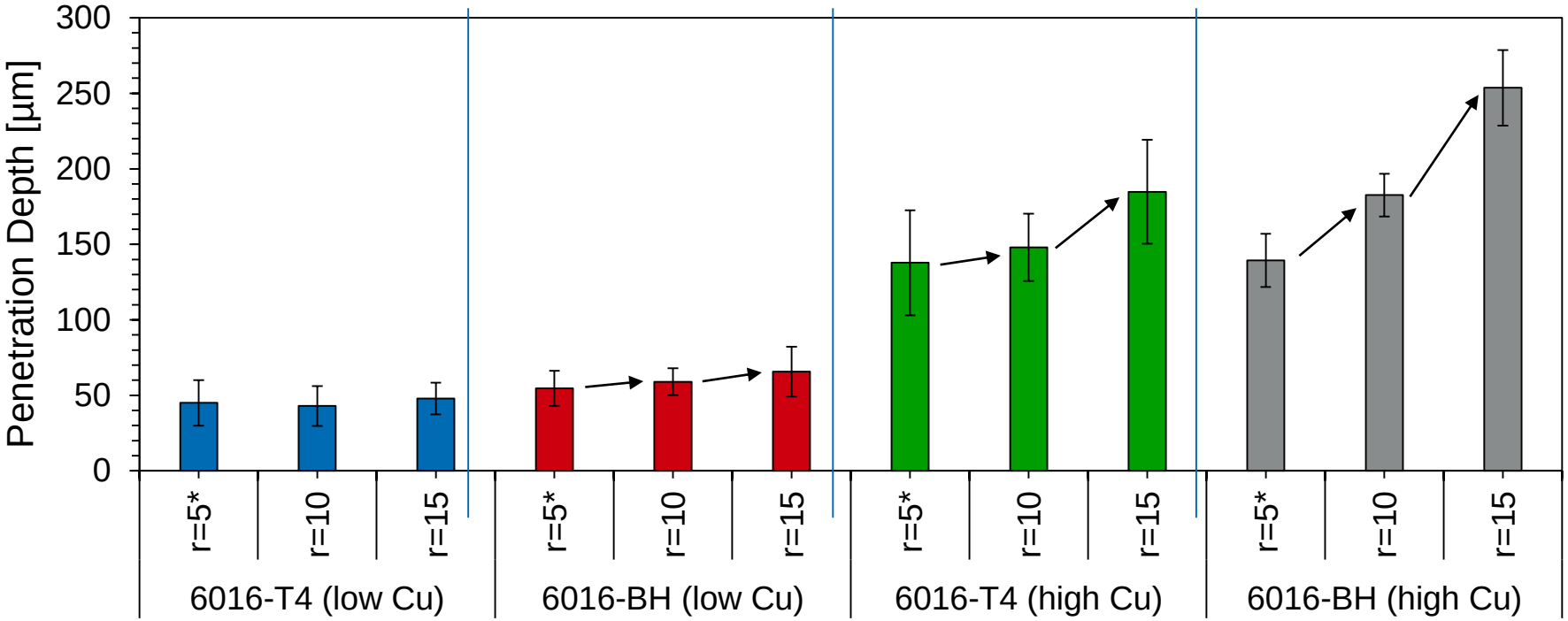
T = 30°C, t = 24 h

Vol./Surface ratio R = 5

Etching: 2 min @ 50°C in 5 wt.% NaOH



Results: WP 1.2 Volume-to-Surface Ratio

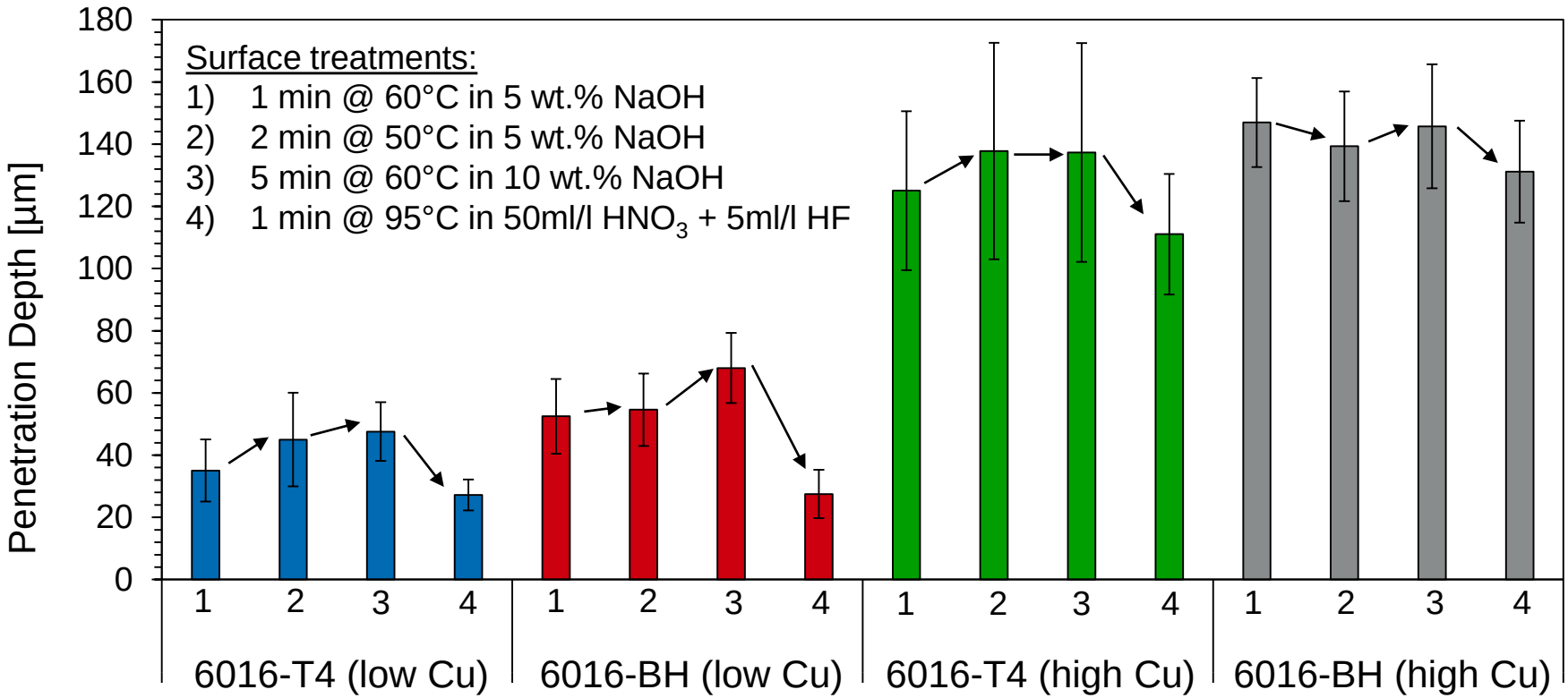


The volume-to-surface ratio can significantly influence the results!

Higher amount of HCl (delayed pH shift)

$$2Al+6HCl+12H_2O \rightarrow 2Al(H_2O)_6Cl_3+3H_2$$

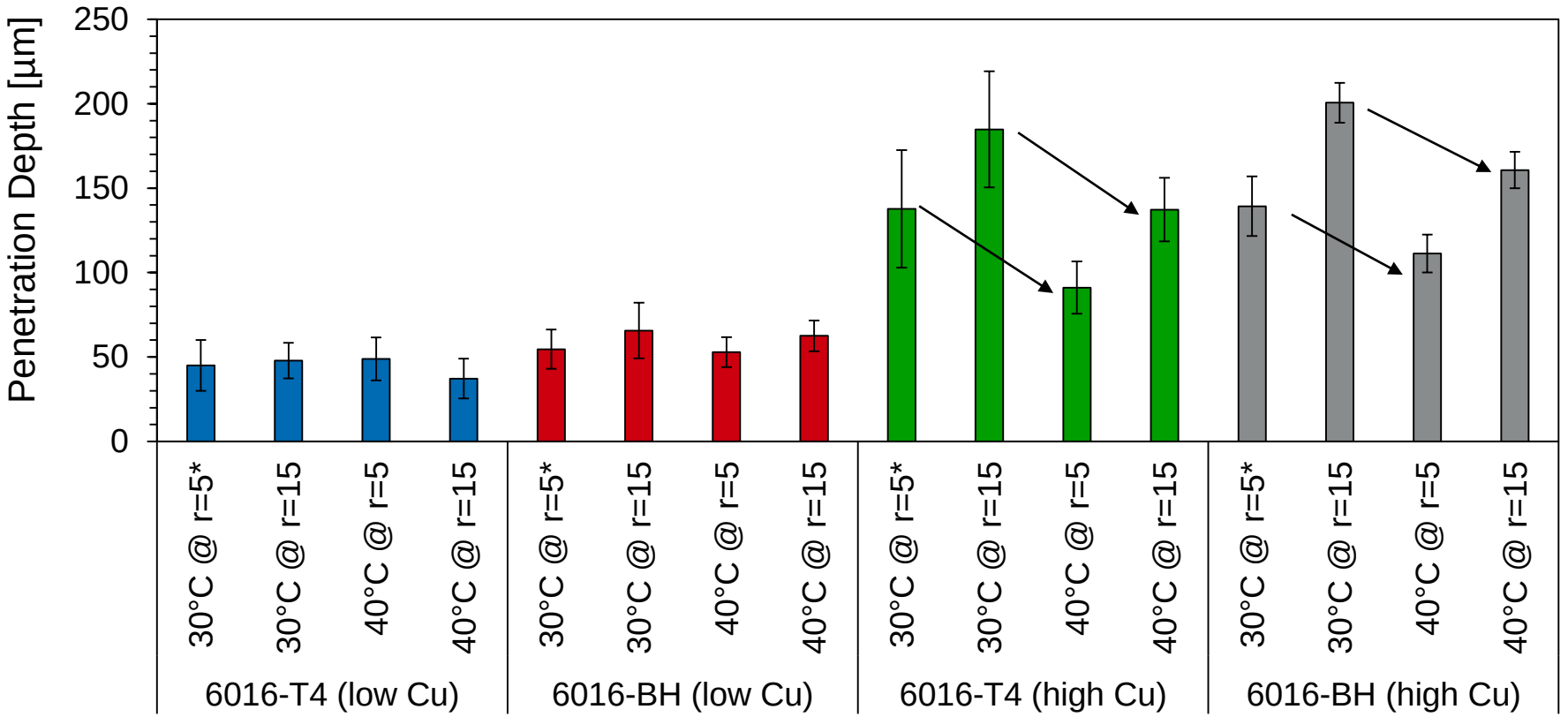
Results: WP 1.3 Surface Treatments



The surface treatment can significantly influence the test results!

Cathodic Si-rich particles on the surface resist alkaline pickling!

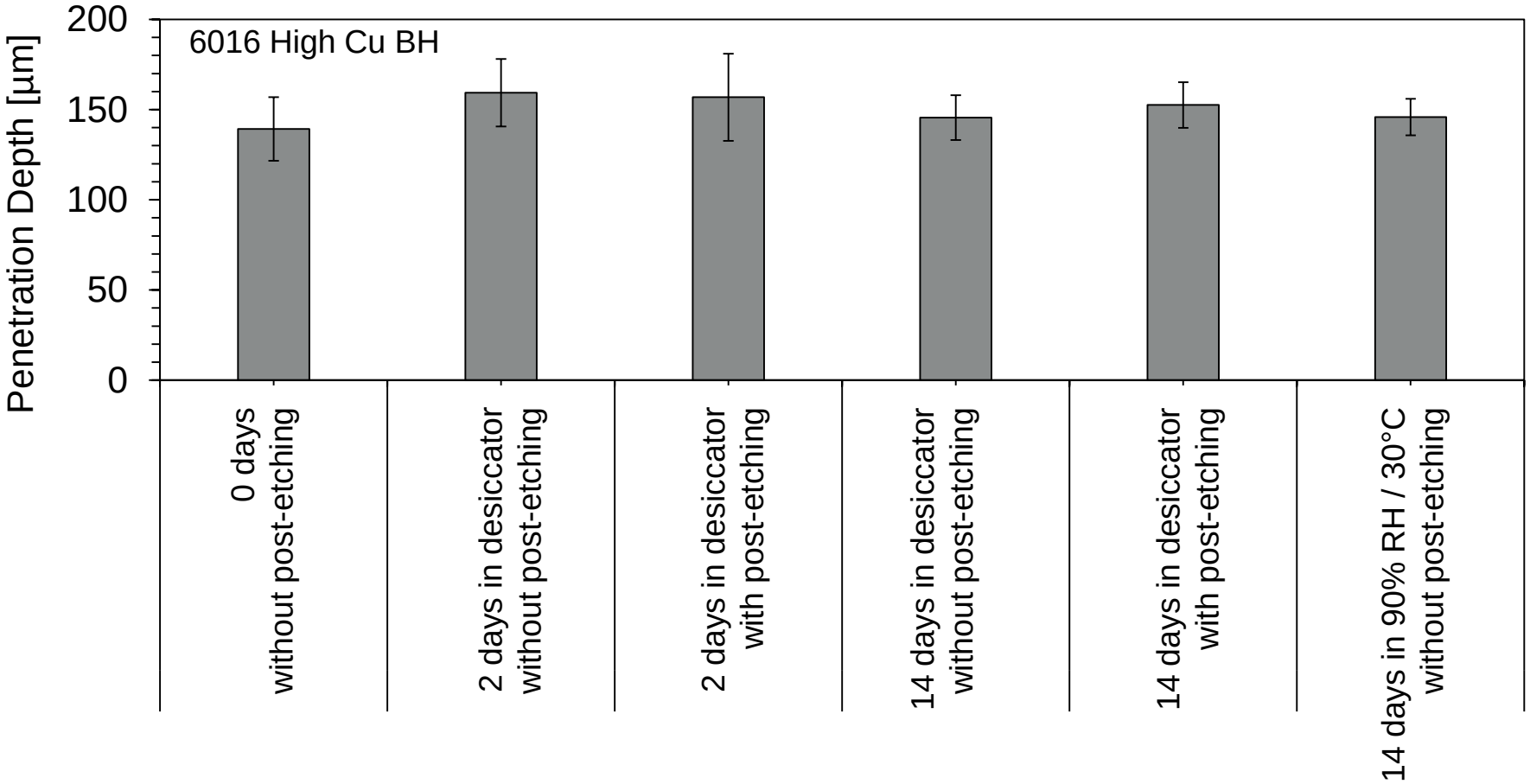
Results: WP 1.4 Solution Temperature



The solution temperature can significantly influence the test results!

Currently not clear/possible further research topic

Results: WP 1.5 Post-etching / Storage Time



The test results are independent of post-etching and storage time!

Summary Main Goal 1: ISO11846 Method B

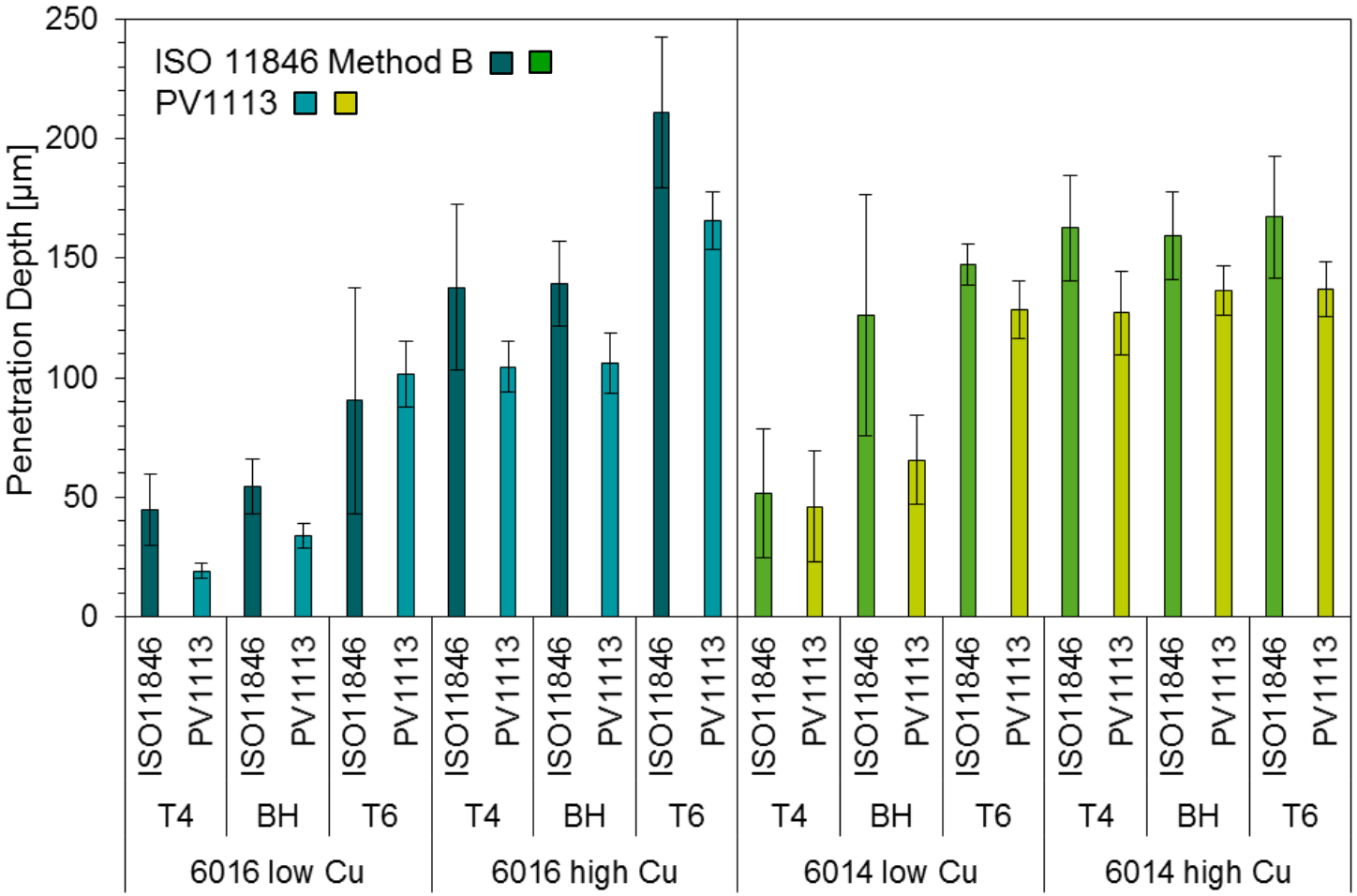
Main Findings

- **Cu** has dominant **detrimental effect** on IGC
- The **test results** according to ISO 11846 Method B are **highly dependent on** the used **parameters**
- A **narrower specification** of the test parameters is required in order to obtain more reliable and comparable test results

Main Goal 2: Comparison of established Testing Methods

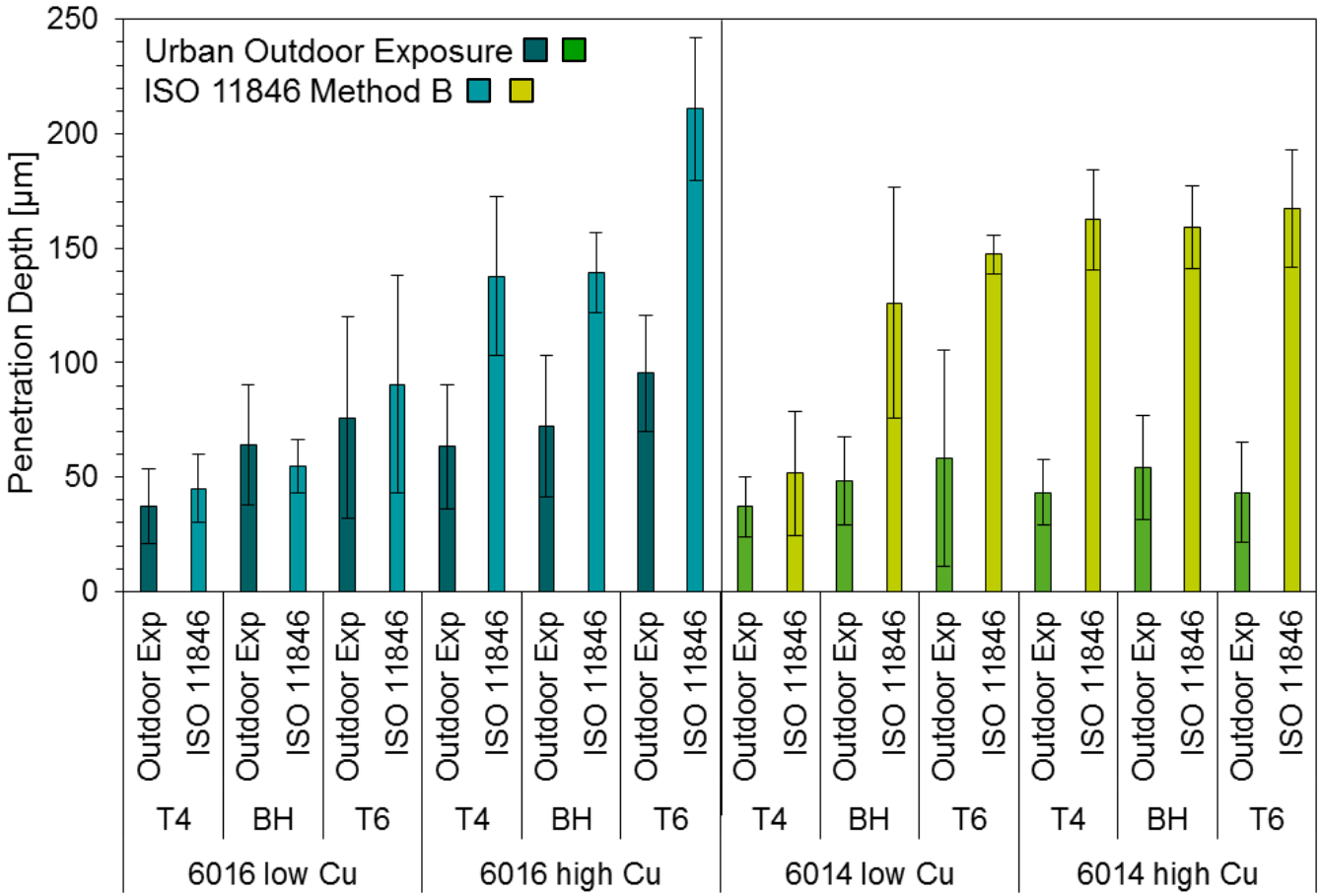
- **ISO11846 Method B → Reference**
- **PV1113**
- **VDA233-102**
- **VDA621-415**
- **ASTM G85**
- **Urban Outdoor Exposure**

ISO11846 Method B vs PV1113



- **Systematical difference of 20 to 40 µm**
- **High comparability**

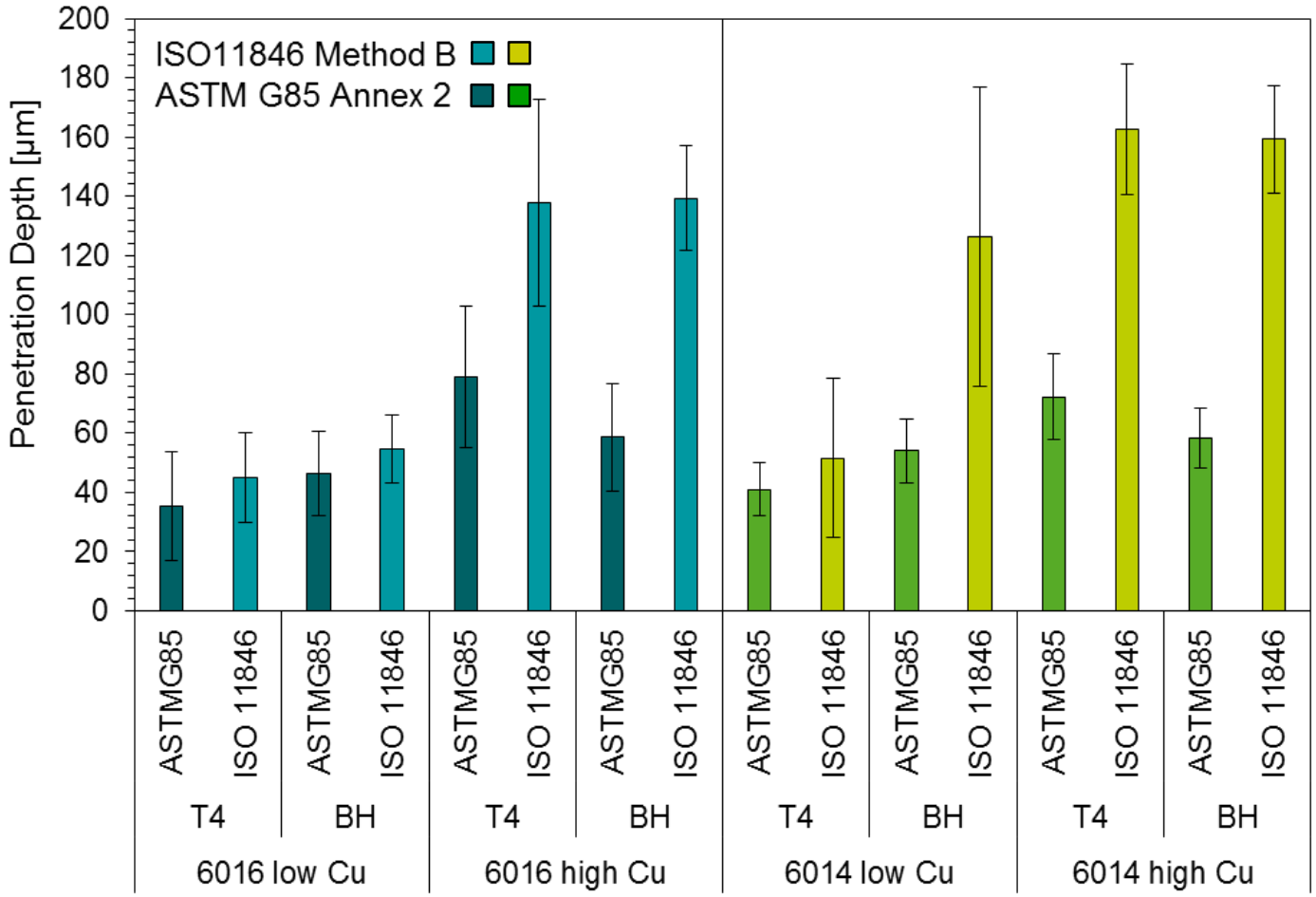
Urban Outdoor Exposure vs. ISO 11846 Method B



IGC susceptibility increases with increasing heat treatment

BUT: detrimental effect of Cu is less distinct!
→ Cu less critical for in-service conditions than usually assessed using immersion tests?

ASTM G85 Annex 2



Influence of heat treatment and Cu-content seems to be rather low (at least when compared with immersion tests)

Summary Main Goal 2: Testing Methods

• For all tests localized corrosion occurred **predominantly as intergranular corrosion**. ASTM G85 Annex 2 predominantly caused pitting corrosion on all materials.

• The highly accelerated lab tests, ISO11846 Method B and PV1113, showed a very **good correlation** with a systematic deviation ranging from 5 to 45 µm.

• ISO11846 Method B and PV1113 showed a distinct dependence between the penetration depth and the Cu content; the average penetration depth is significantly increased with **increasing Cu content**.

• ASTM G85 Annex 2, as well as the urban outdoor exposure, showed a less strong correlation between penetration depth and Cu content → the **detrimental effect of Cu** is likely to be less critical for in-service conditions than usually assessed using ISO11846 and PV1113.

• VDA233-102 and VDA621-415 are **not recommended** for the testing of blank aluminum sheets since the corrosion attack is very little even after a duration of 12 or 10 weeks, respectively.

•The **highest correlation** to accelerated outdoor exposure in terms of penetration depths was found for ASTM G85 A2

Project Goals

- Project aims fulfilled, various influence factors on IGC testing identified and differences between corrosion tests displayed ✓
- Project finished within proposed project timeframe ✓
- First AMAP research project with advisory board consisting of OEMs ✓
- Highly beneficial collaboration between industry partners, OEMs and the Chair of Corrosion and Corrosion Protection ✓
- Initiation of new VDA standard and round robin tests → Further analysis of influence factors ✓

➢ New successor project: AMAP P22 UnICorn – Understanding the Intergranular Corrosion of 6000-Aluminum Alloys

Outlook

Future Activities

- 1st publication of the ISO 11846 parameter study in *Materials&Corrosion* — Published
- 2nd publication about cyclic corrosion testing is in *Materials&Corrosion* — Accepted
- Presentation at EUROCORR´17 — Held
- Presentation at EUROCORR´18
- Development of a VDA standard in cooperation with AK Korrosionschemie — In Progress

Thank you very much for your attention!