

# **Robust electrical contacts in EV – Surfaces of importance**

**Presentation Cluster conference 2026-05-20**

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# **ELYFOG – Testing and development of longterm reliable electrical contacts in EV**

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# Testing and development of long-term reliable electrical contacts (ELYFOG)

## Project content and scope

- The project focuses on bolted joints and mechanical joining for connectors and connections for electric vehicles. This applies mainly to demountable fixed joints, but not switches.
- Goal is to develop relevant testing methods and solutions for electrical contacts in electric vehicles. That includes testing under combined loading, new surface treatment solutions, optimized assembly parameters fulfilling requirement specifications for electrical contacts.

## Project deliverables

- Analysis of application scenarios and relevant requirement specifications.
- Testing methods for combined loading and measurement of electrical contacts.
- Evaluated concepts for materials and surface treatment solutions for reliable contacts.
- Guidelines for fasteners, assembly, safety,...

## Project partners

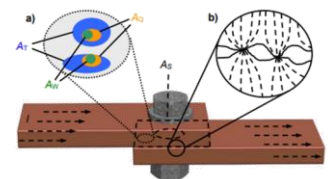
- RISE, Scania CV, Volvo AB, Volvo Cars, Northvolt, Micropowers, Provexa, Husqvarna, Stanley, Atlas Copco, Bulten, Harting, Elpress

## Needed competences:

- Mechanical joining, electrical engineering, mechanical and environmental durability, material and surface treatment for electrical applications, education and information, standardization

## Project details

- Apply for FFI Circularity ([28 March 2023](#)). Project start: Q3 2023. Project duration: 3 years. Project budget: >10 MSEK (50% in-kind)



Source: [1]



**Potential applications**

- Busbar contacts
- Grounding contacts

**Potential accelerated testing**

- Mechanical loads
- Environmental loads
  - Thermal loads
- Sequential vs. combined

**Potential evaluation**

- Contact resistance
- Oxidation and deformation
  - Clamping force
- Surface degeneration

**WP1  
Concepts, specimens and requirement specifications**

- Definition of application cases
- Definition of requirement specification for selected cases

**WP2  
Testing methodologies**

- Measurement methods
- Development of test methods for combined loading
- Comparison with existing testing methods
- Validation of testing concept with field tests

**WP3  
Evaluation of selected concepts**

- Testing of selected assembly parameters, surface treatments, conductor materials
- Testing in standardized tests and new combined test method
- Evaluation and ranking according to requirement specification and expected lifetime

**WP4  
Guidelines**

- Writing of documents for internal and external education
- Instructions for assembly of electrical contacts
- Derivation of best practices

**WP5  
Project management**

- Organise meetings and workshops
- Distribute results
- Report to VINNOVA
- Keep track of project budget
- WP leader: RISE

# Elyfog project

Testing and development of long-term reliable electrical contacts

**Goal:** To develop relevant testing methods and solutions for electrical contacts in electric vehicles. That includes testing under combined loading, new surface treatment solutions, optimized assembly parameters fulfilling requirement specifications for electrical contacts.

Program/Call: FFI Circularity

Project partners: Atlas Copco, Bulten, Elpress, Harting, Husqvarna, Micropower, Northvolt, Provexa, Scania CV, Stanley, Volvo AB and Volvo Cars

Project duration: sep 2023 – dec 2026



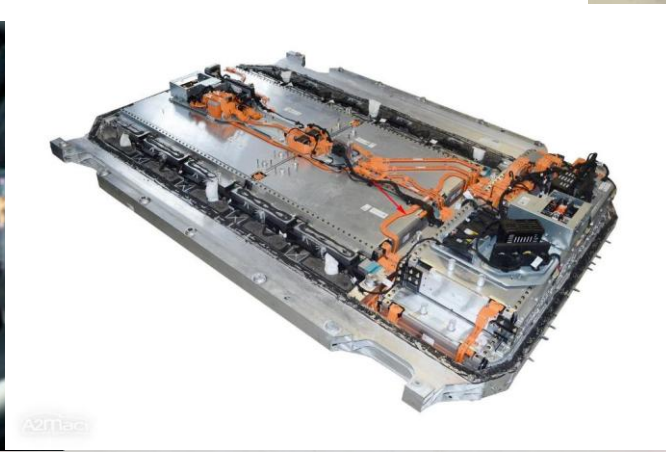
# Today's presentation

- **Background and basics: Contacts and conductivity**
- Resistance measurements
- Contact resistance vs climate
- Test Method development
- Combined testing: Climate and vibration

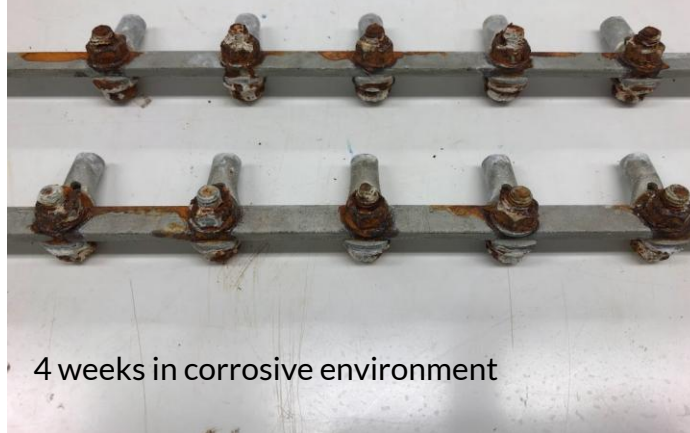
# Sometimes the knowledge is lacking



Automotive conditions can be very varying and demanding



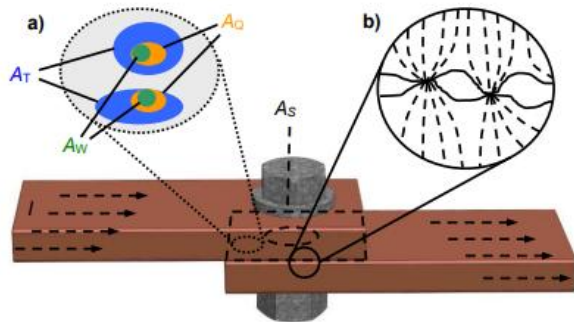
One winter in Norway



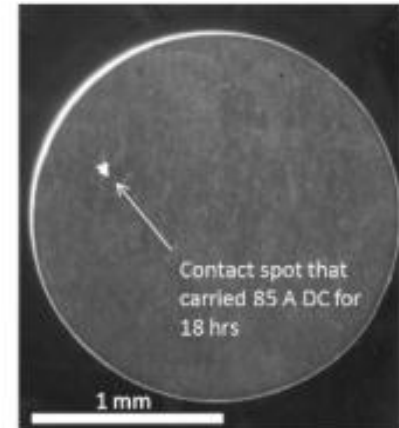
4 weeks in corrosive environment

# Basics, electrical screw joints

- Metal to metal contact
- Micro roughness in contact area
- **Nominal contact area** > Load bearing area > Electrical contact area
- Only small spots "a-spots" carries the current



Both elastic and plastic deformation



Polished aluminium  
DOI: [10.1109/HOLM.2019.8923842](https://doi.org/10.1109/HOLM.2019.8923842)

# Copper and aluminium are the common materials for electrical contacts (busbars, pole shoes, etc)

Property	Copper	Aluminium
Conductivity	Very high	Lower (~60 % of Cu)
Weight	Heavy	Lighter (~60 % of Cu)
Cost	Higher	Lower (~30-40 % of Cu)
Thermal expansion	Low	Higher
Oxide	<b>Conductive (relatively)</b>	<b>Isolating</b>
Robustness	High	Lower
Mechanical strength	High	Lower

Both copper and aluminium connectors need protective coatings

# Coatings for electrical connections

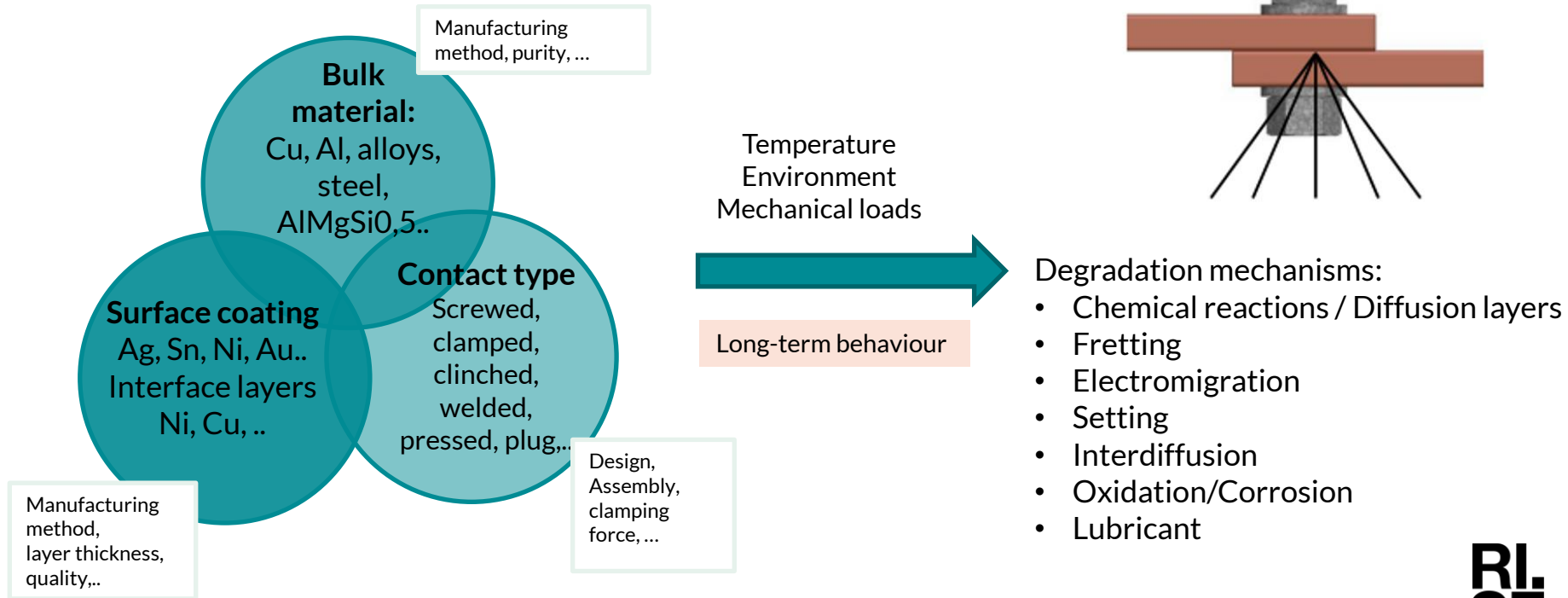
- **Tin (Sn)**
  - + common and cost efficient
  - + good solderability
  - oxidation and fretting
- **Nickel (Ni)** (there are many different variants...)
  - + barrier layer
  - + good wear and corrosion resistance
- **Silver (Ag)**
  - + best conductivity of all metals
  - + high currents
  - tarnishing (silveroxide/-sulphide)
- **Gold (Au)**
  - + high and stable conductivity
  - + no oxidation
  - + signal currents/voltages
  - expensive
- **Palladium/Palladium-Nickel and Rhodium**
  - + alternative to gold (often with goldflash on top, < 0,1  $\mu\text{m}$ )
  - + high wear- and corrosion resistance
  - + extreme requirements
  - expensive

**Alloys, like white bronze:**  
Cu, Sn, and Zn  
Zn, Cu, Al, and Mg

Interesting coatings are:

- **Cheap and available**
- **Stable deposition process**
- **Good conductors**
- Non insulating oxides
- Mechanically stable
- Good adhesion
- ”

# Long-term stability of a contact



# Insulation of busbars and connectors



Insulation of busbars and contacts prevent short circuits, enhances safety, and allows for more compact designs:

Common insulation methods and materials:

- **Heat-shrink tubing:** Polyolefin tubing that shrinks when heated (110 °C). Easy application, offering excellent dielectric strength, UV resistance, and flame retardancy.
- **Epoxy powder coating:** Fluidized bed process, where heated busbars are coated with epoxy, creating a durable uniform layer. Ideal for complex shapes and high voltage applications.
- **Insulating film/tapes:** The material (Mylar (PET), Nomex, or Kapton) is wrapped around the busbars / contacts for high dielectric performance in constrained spaces.
- **Solid insulated systems:** Epoxy coated or moulded systems.



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# Resistance measurement on conductive coatings

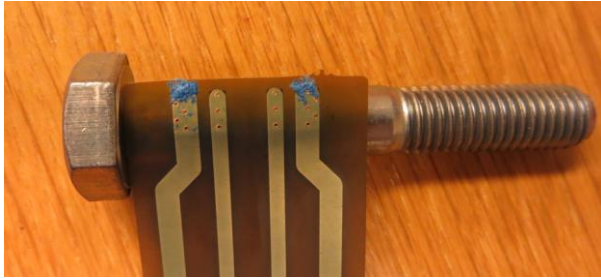
- Multimeter is not possible to use: the probes contact resistance will drown the results
- 4-point measurement with a relatively high current can measure down to  $\mu\Omega$



Megger mikroohm measurement unit with 2 voltage probes and 2 current probes

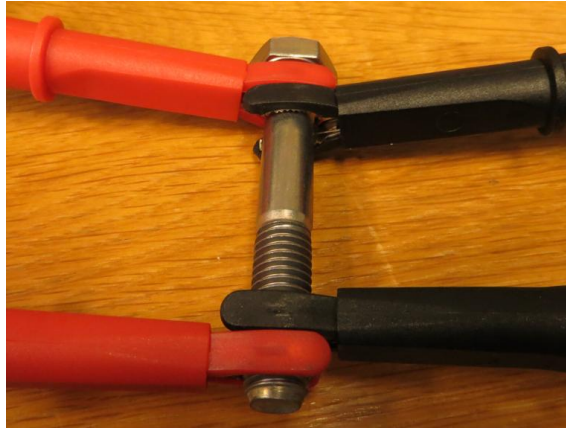
# Resistance measurement of coated parts

4-point square resistance



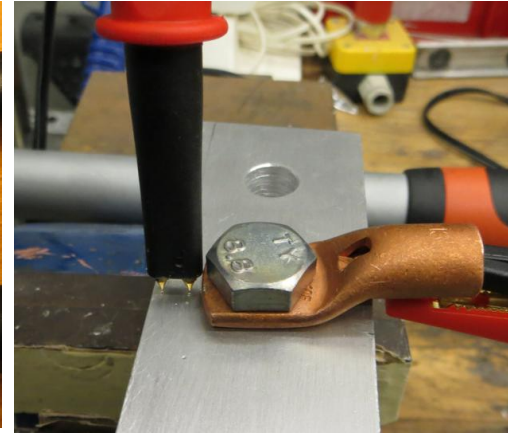
Soft contact probes  
No penetration of soft coatings,  
like passivation layers or oxides

4-point sharp probes



Probes penetrating to metal

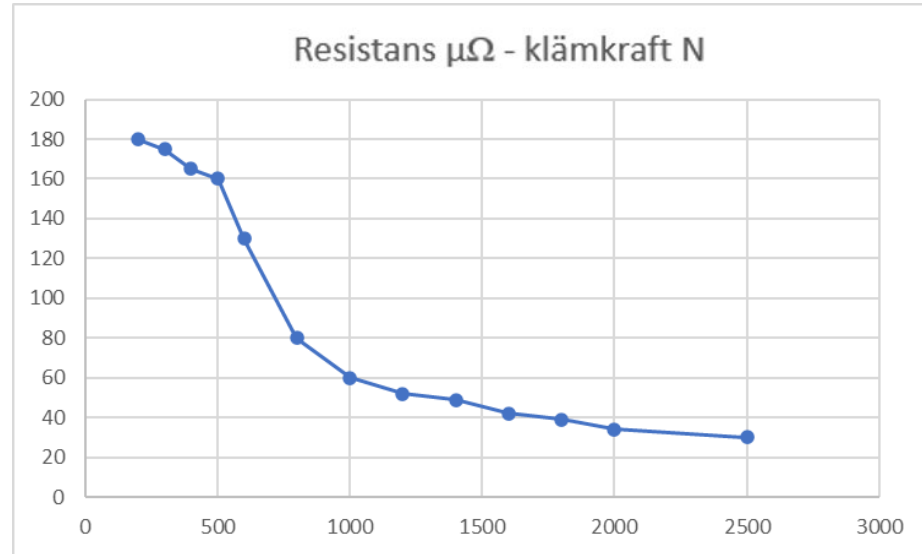
4-point sharp probes  
clamped contact surfaces



Probes penetrating to metal  
but clamped contact surfaces  
have intact coatings or oxide  
layers

# Measurements –

tinplated copper contact pressed by M10 screw against nickelplated copper bar

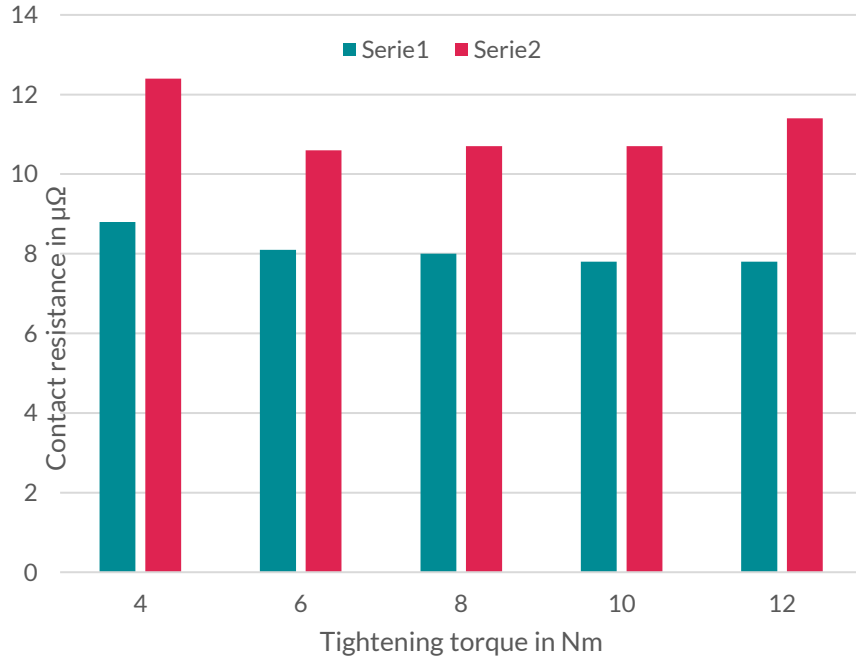


- Resistance has reached steady-state at about 2,5 kN
- At this clamping force, less than 1/10 of the M10 screw strength is utilised

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# Contact resistance vs. Climate



- Serie 1: busbar-cable shoe
- Serie 2: busbar-cable lug after 2 weeks climate chamber

Impact of climate not torque

Same resistance with a tightening torque of 4-12 Nm (!)

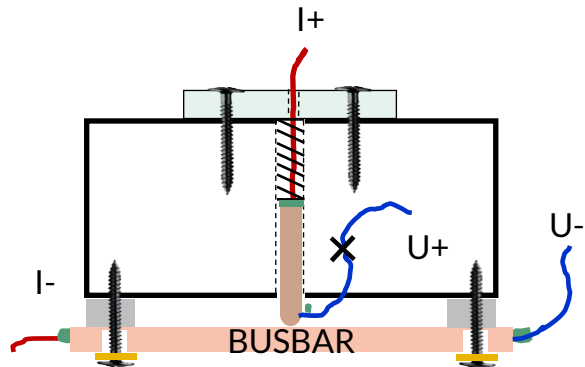
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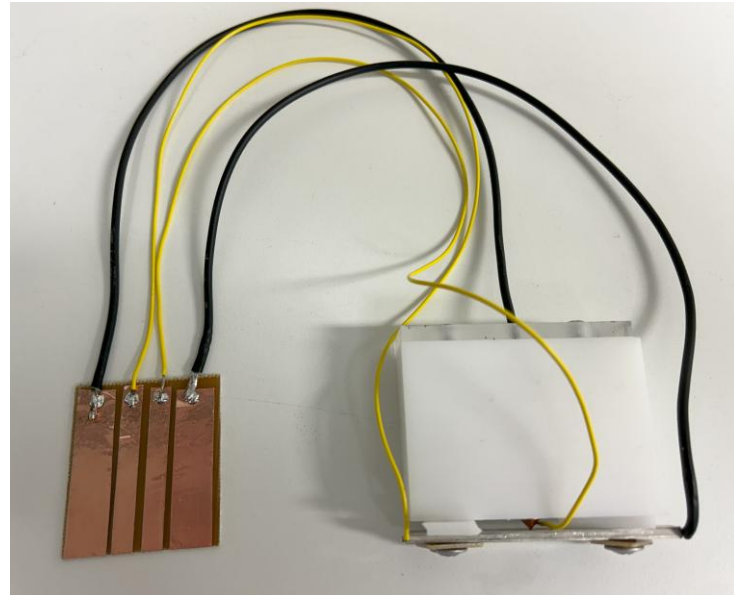
# WP2, Method development

Improve understanding and screening of parameters

To evaluate different **coatings** and different **exposures**



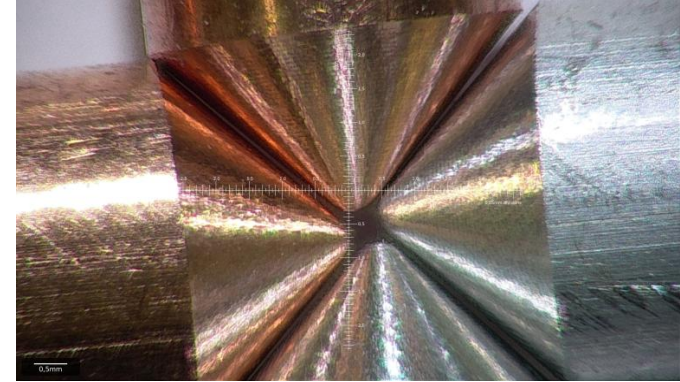
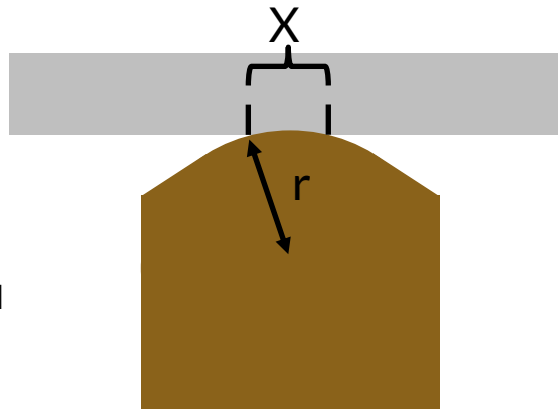
- Defined contact point for analysis
- Constant **force**
- Four-point **resistance measurements**



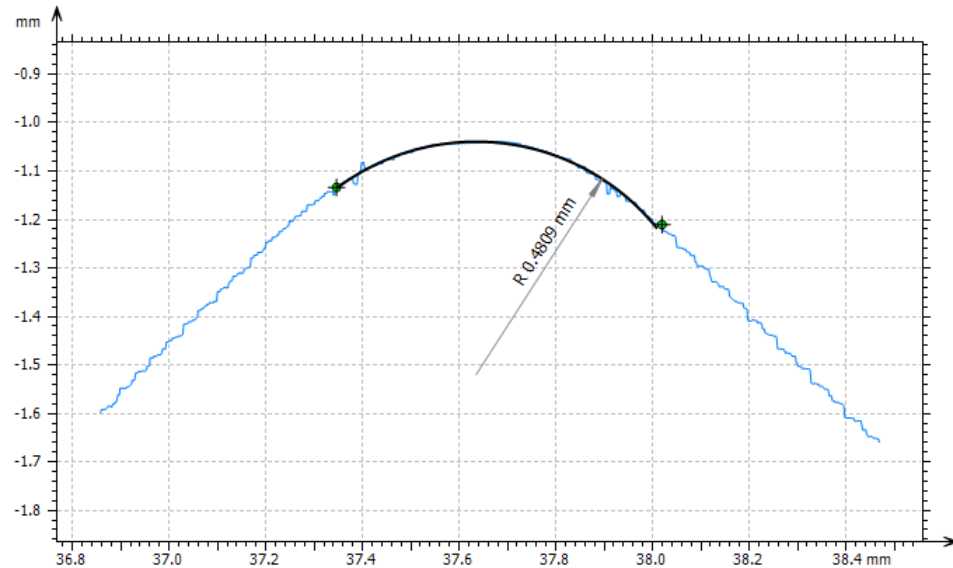
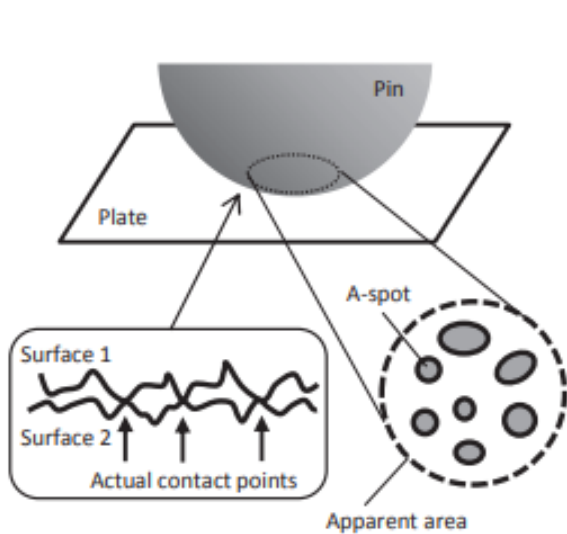
# Contact tip

## Aim:

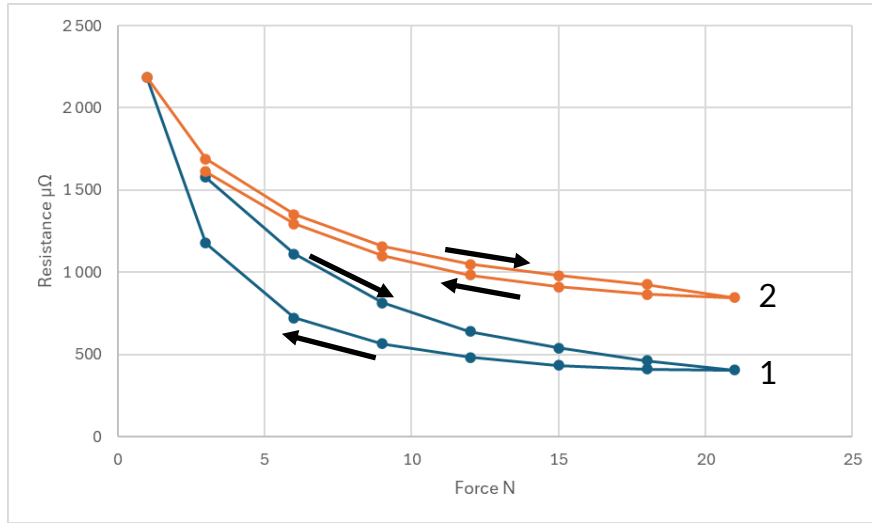
- Defined indent that can be analyzed
- Rather flat contact area
- No interlocking penetration
- Contact area = function of the surface roughness



CNC machining of 0,5 mm radius tips



# Oxide removal tests (etching)

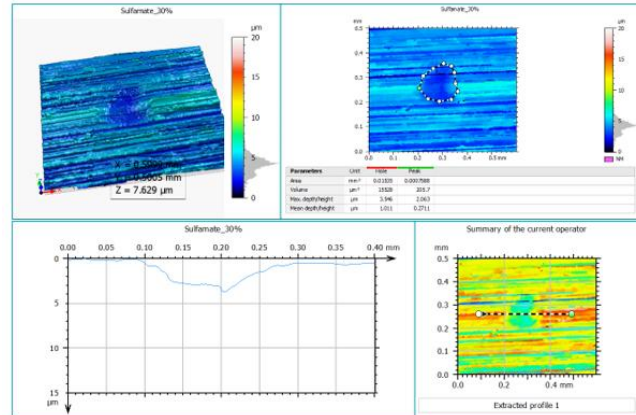
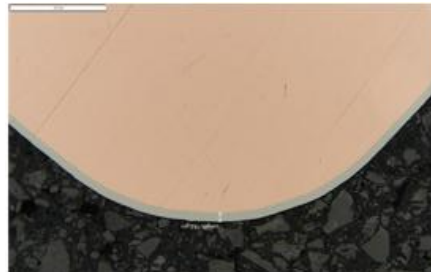


The blue curve is the first load cycle.

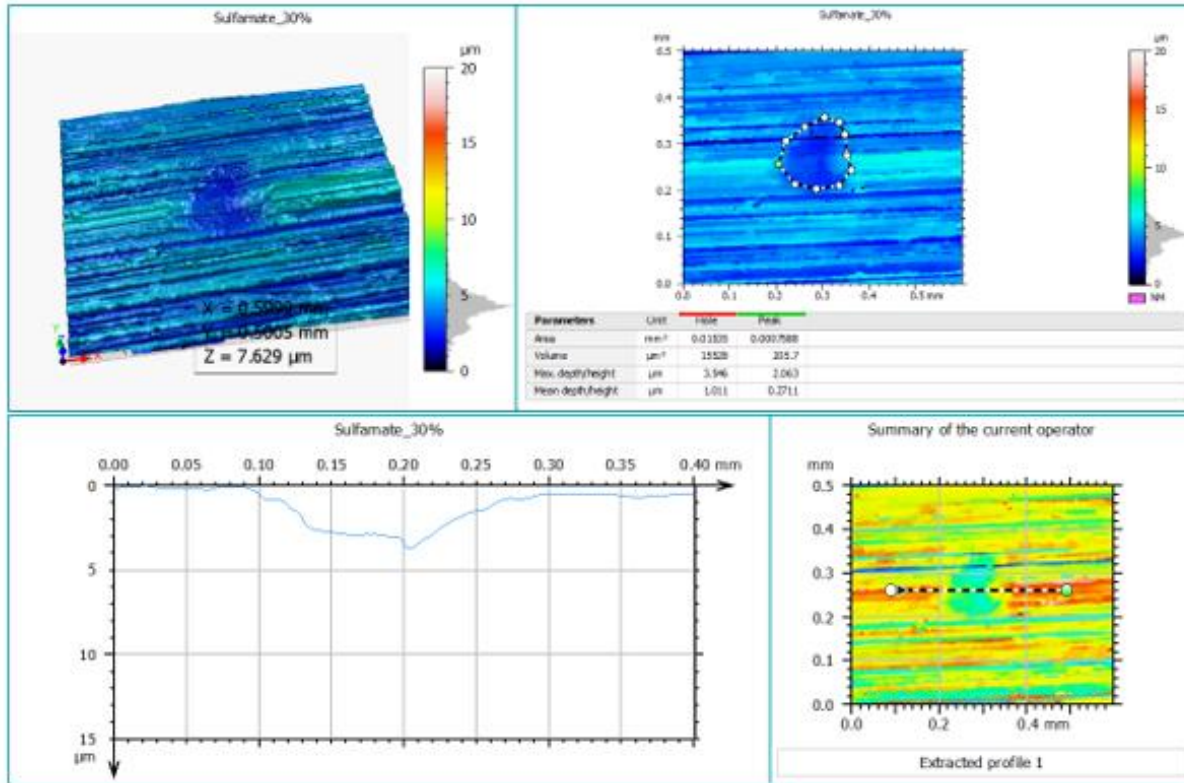
Resistance of HCl-etched (19 µm, 50 N) sulfamate nickel tip into etched sulfamate 5 m busbar at 21 N.

The second load curve has significantly higher resistance.

The explanation may be deformation of active metal surface followed by relaxation and oxide growth?



# Measurement of contact area



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# Combined climate and vibration tests

Tests performed at Micropower

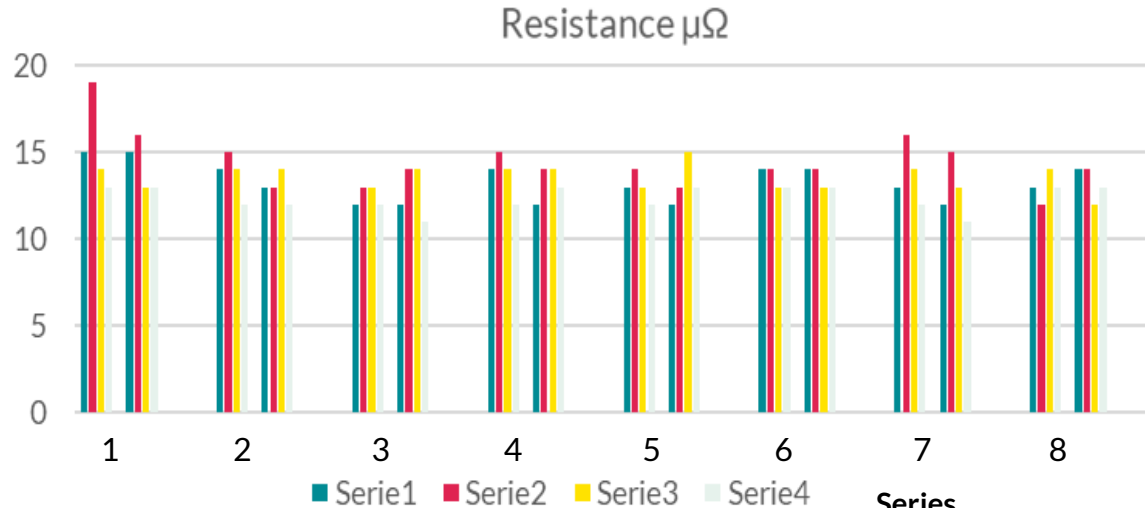


200 h with combined temperature cycling\* and vibration\*\*

\* - 40°C – + 72°C, 5°C/min, stop 20 min at extremes

\*\* Vibration: random 4 g RMS (Root mean square) in x direction

# Resistance cable shoe - busbar



## Contact type/assembly method

- 1 Washer 16 Nm
- 2 Washer 20 Nm
- 3 Washer 24 Nm
- 4 Washer+Belleville 16 Nm
- 5 Washer+Belleville 20 Nm
- 6 Washer+Belleville 24 Nm
- 7 Presscrew washer 16 Nm
- 8 Presscrew washer 20 Nm

## Series

- Green After assembly
- Red After vibration test
- Yellow After temperature cycling
- Grey After combined vibration and temperature cycling.

Summary: The contact resistance is very little affected by assembly method, vibration, and temperature cycling in these tests!?

# Assemblies after combined testing



# Assemblies after combined testing



# Summary



The **mechanical** long-term properties of the contacts are a prerequisite for the **electrical** long-term properties.



We need to continue to investigate the properties for connections/contacts – not only battery and battery cell prestanda



Use the developed test methods to evaluate coatings and climate cycling impact

**Questions?**

