Applikationsbezogene Gefügeoptimierung von magnetischen Formgedächtnisaktoren

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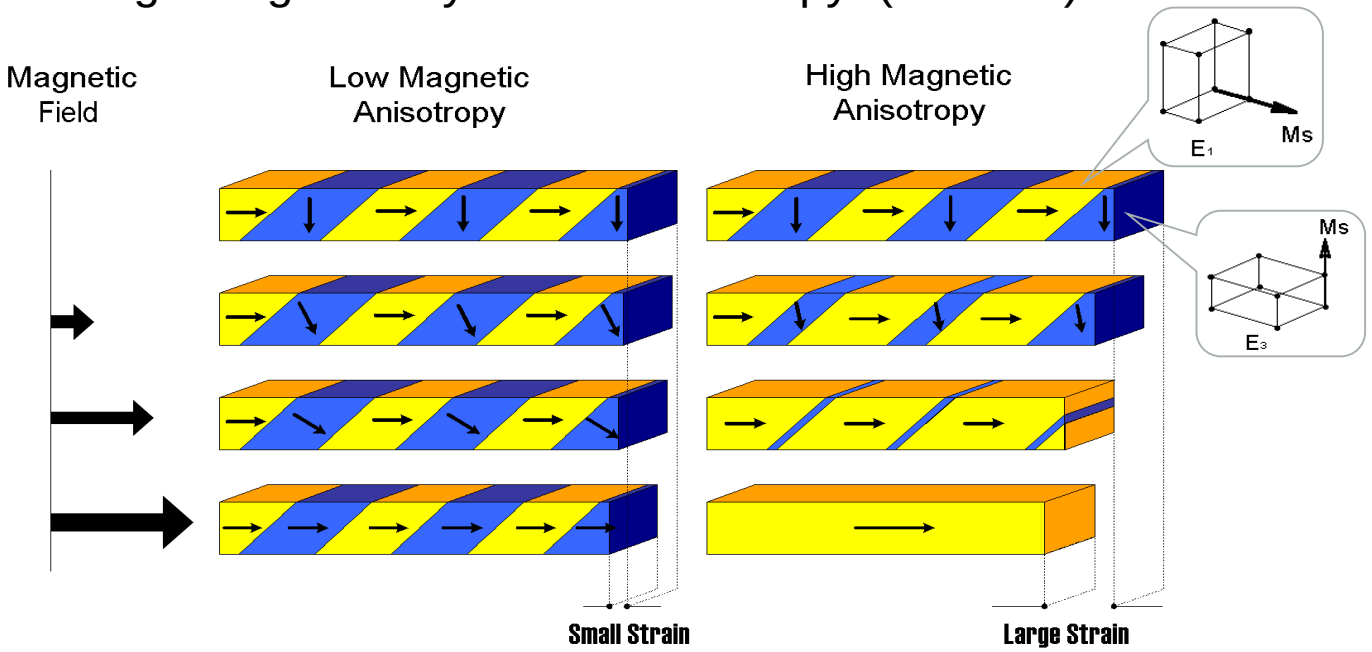
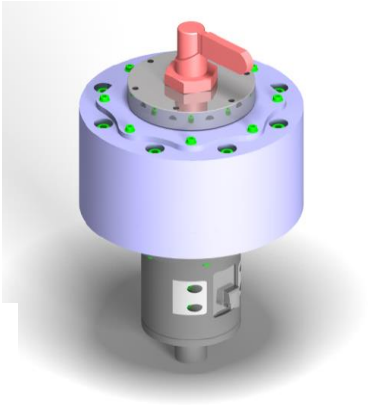
Motivation - Ferromagnetic Shape Memory Alloys

Single crystals: Mechanism of MIR-effect relies on two facts

1. Mobile twinning ➔ preferential deformation mechanism
2. High magneto-crystalline anisotropy (c/a ratio)

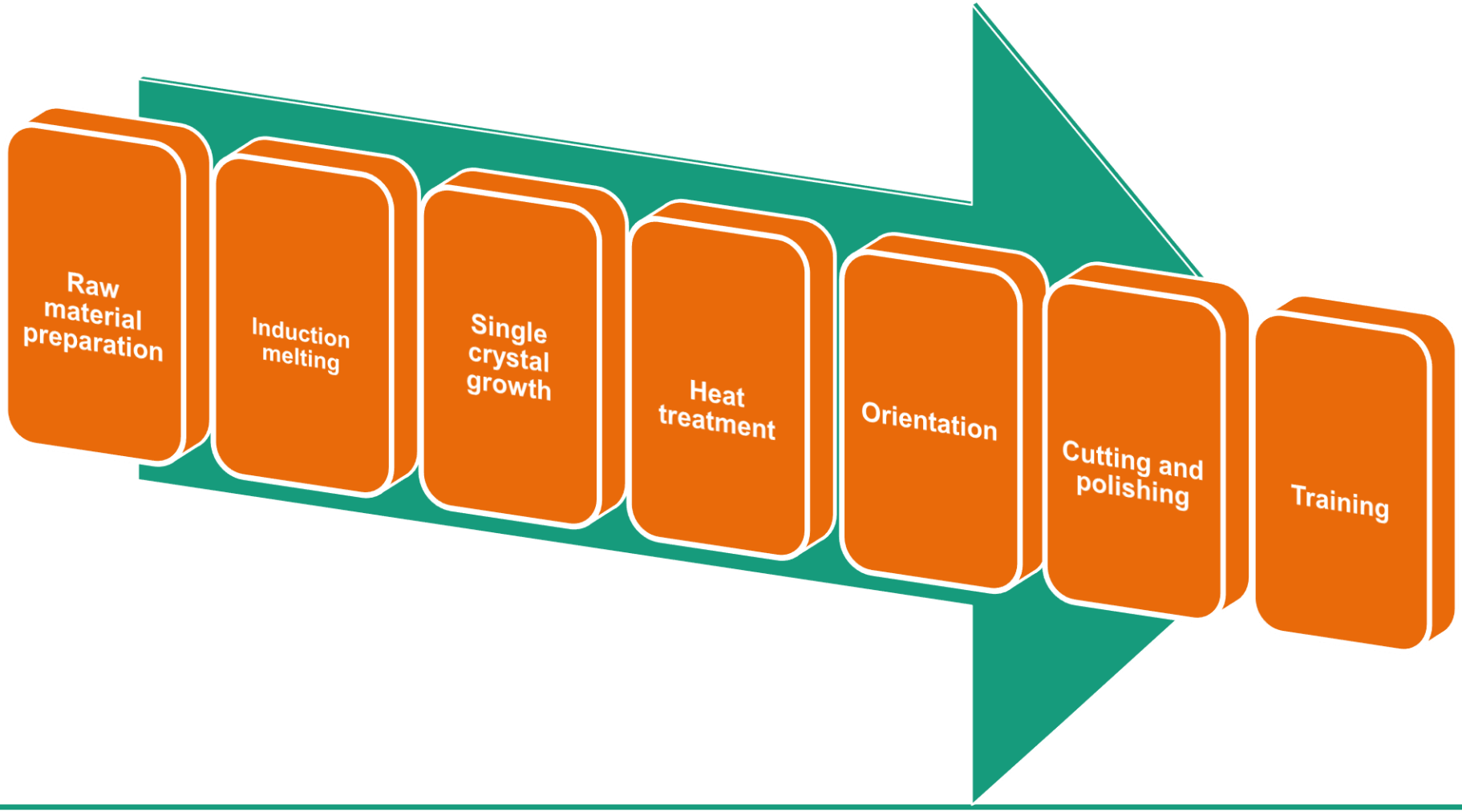




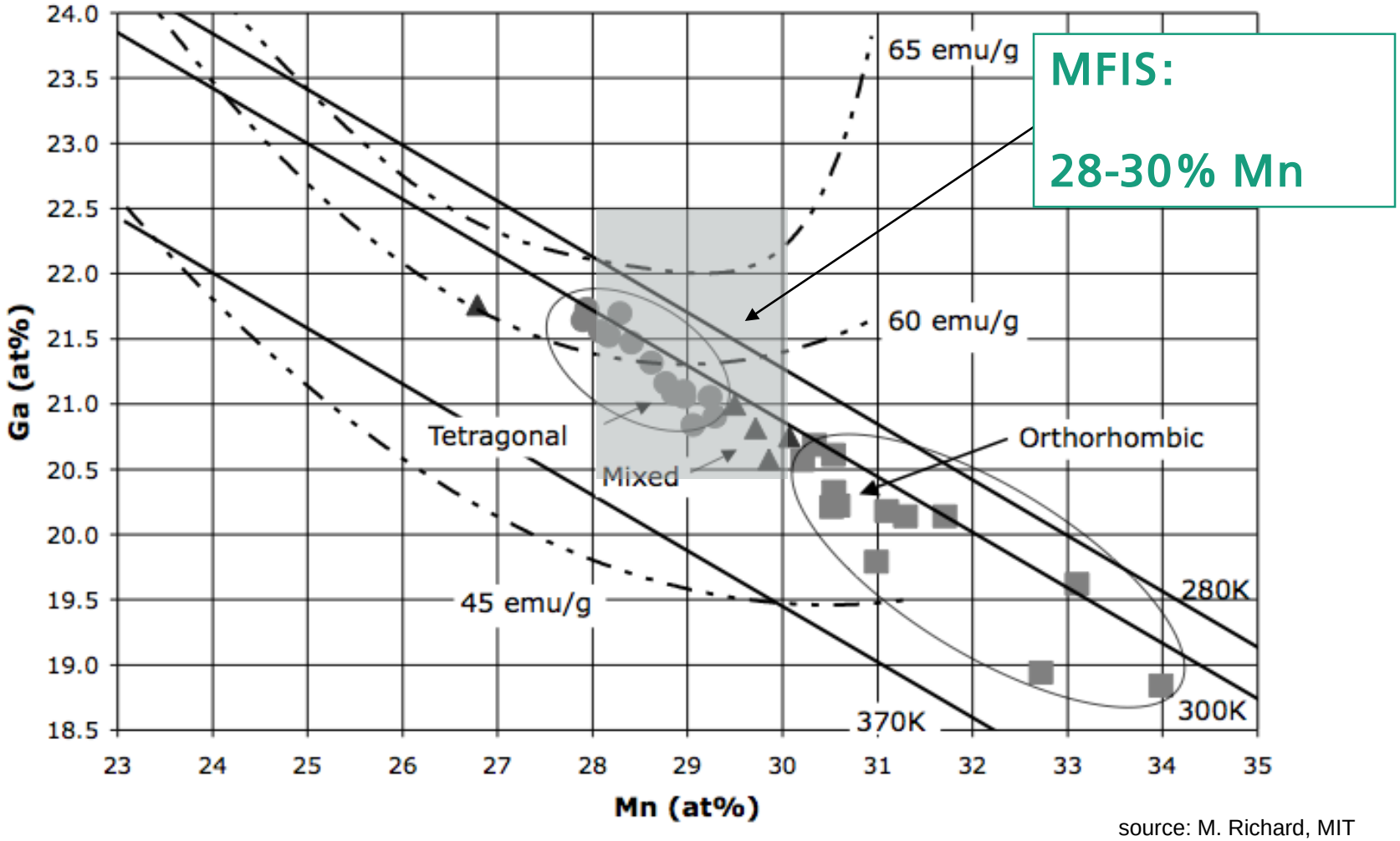
➔ **Application:** Development of actuator systems based on FSMA

Fabrication of Ni-Mn-Ga actuator sticks

Processing steps



Processing step 1: Raw material preparation
Chemical composition



source: M. Richard, MIT

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Processing steps 2 - 3:

Induction melting and Single crystal growth

Bridgman technology and Single crystalline MAGNETOSHAPE® material

source: Laufenberg, ETO MAGNETIC GmbH

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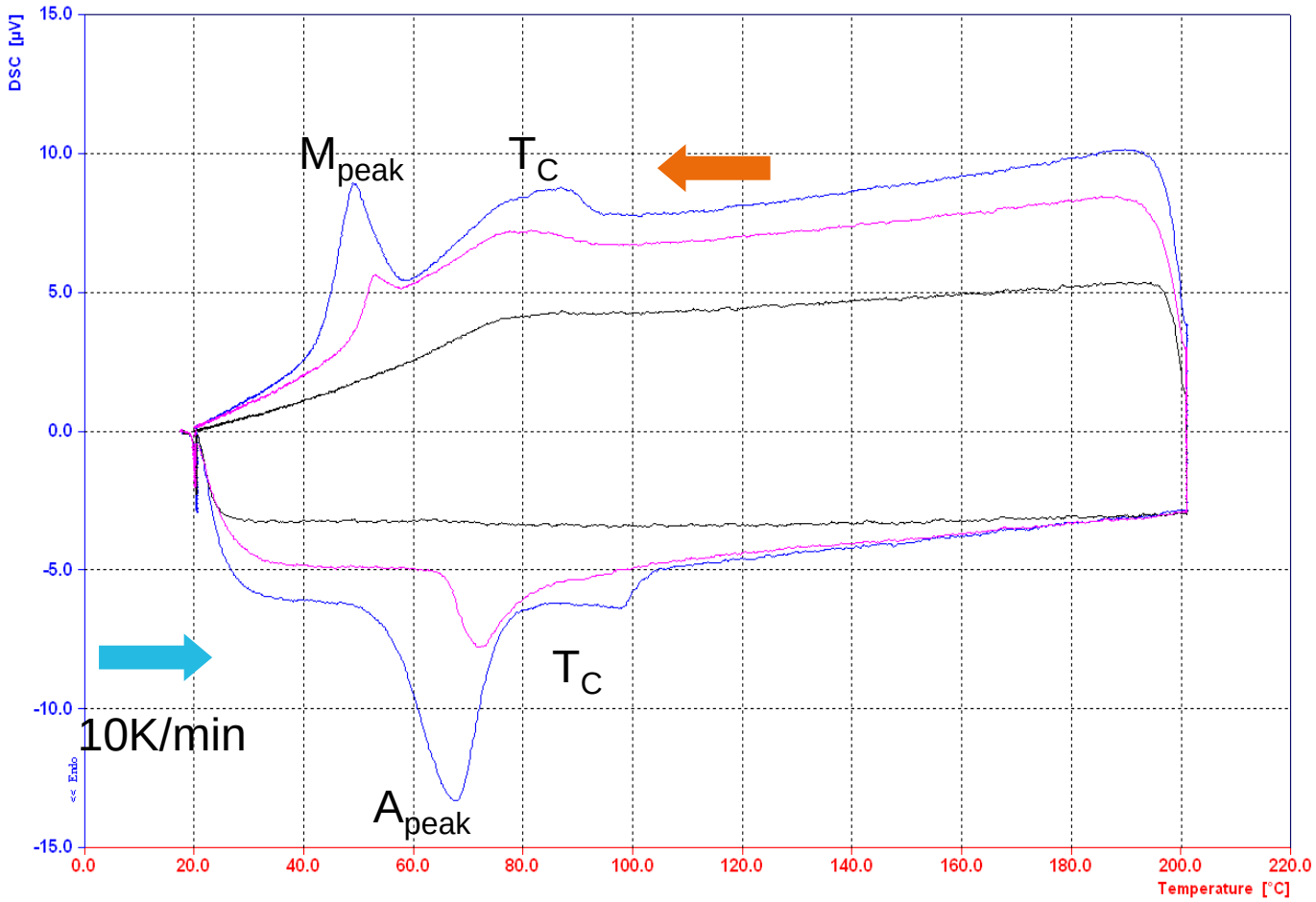
Processing step 4: Heat treatment for homogenization



after fabrication

+ heat-treatments

➔ Measurement of thermal properties using DSC

➔ Differences in phase transformation behaviour

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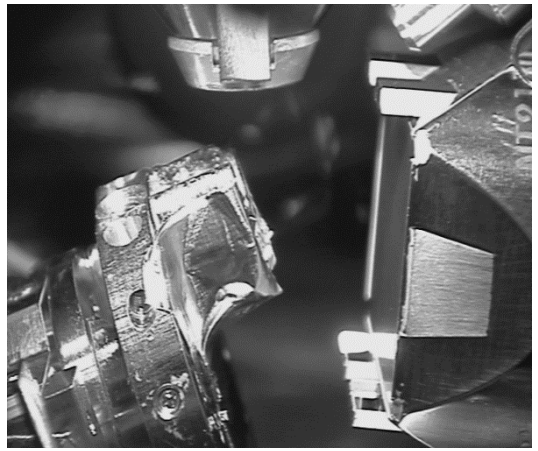
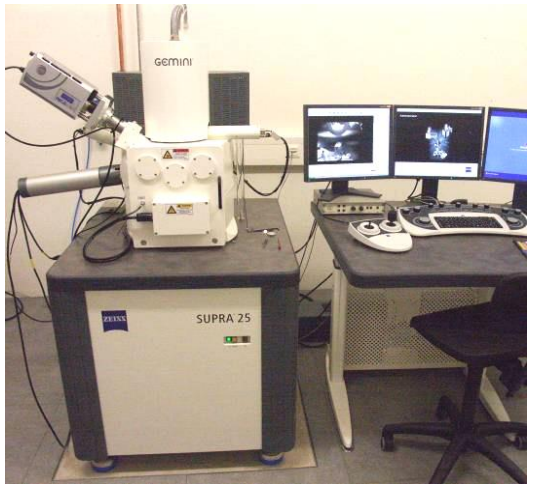
Processing step 5: Determination of orientation

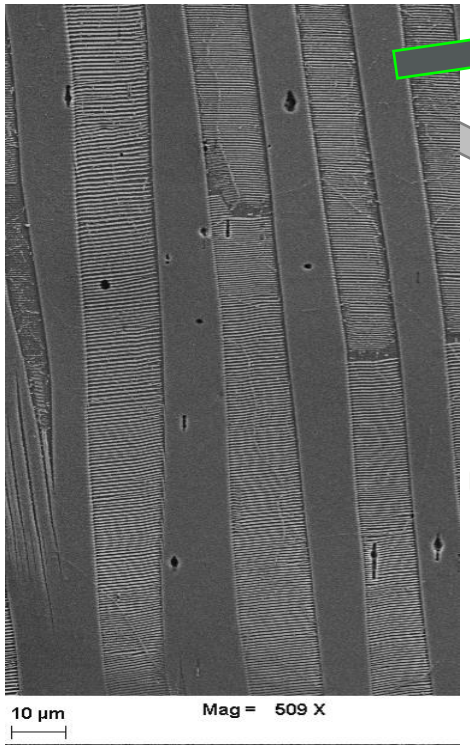
State of the art:



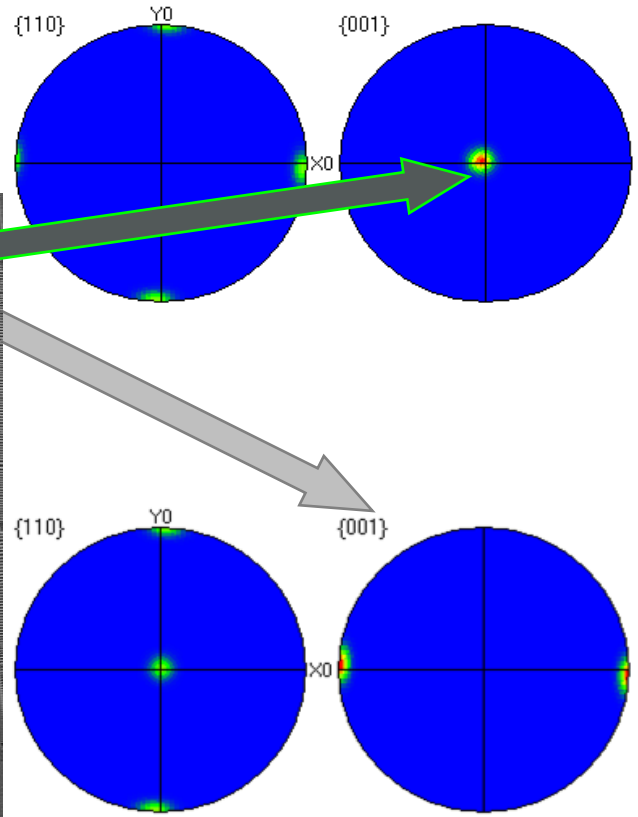


SEM with EBSD

SEM result



a-axes c-axis



Polfigures: Crystal orientation of macro twinning variants (10M)

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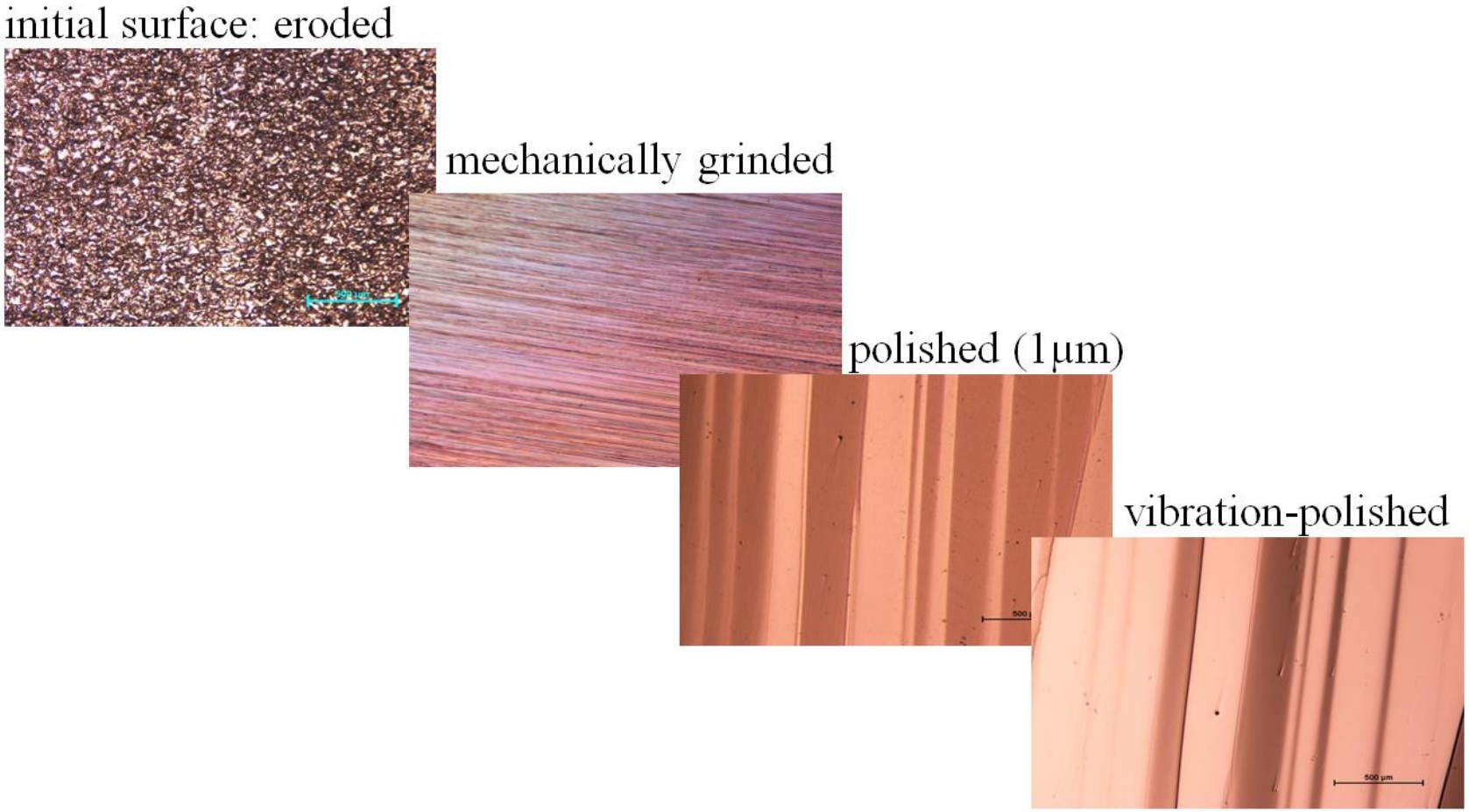
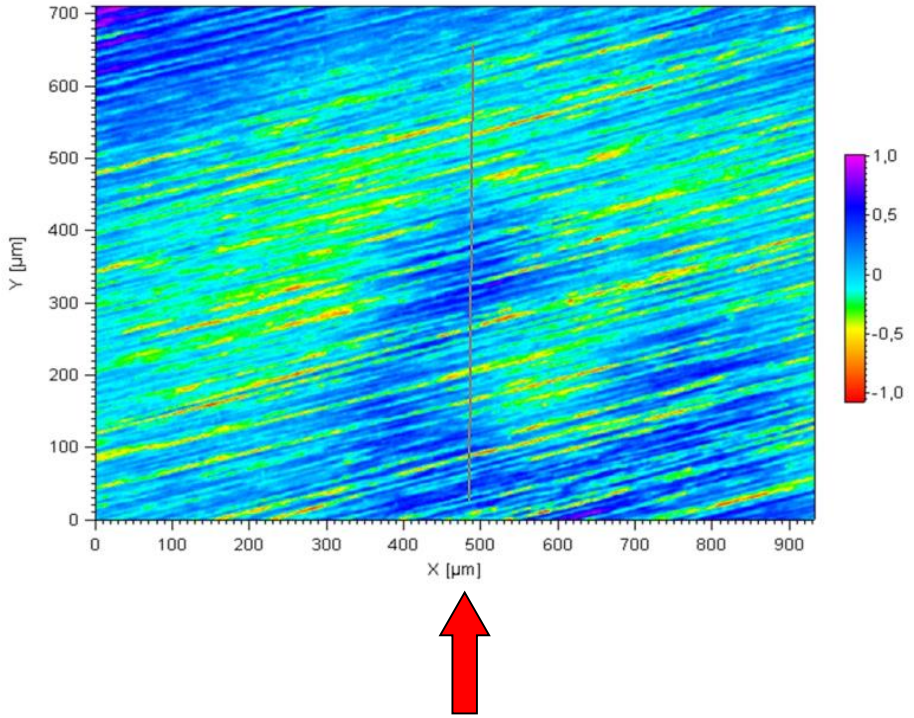
Processing step 6: Cutting and Polishing

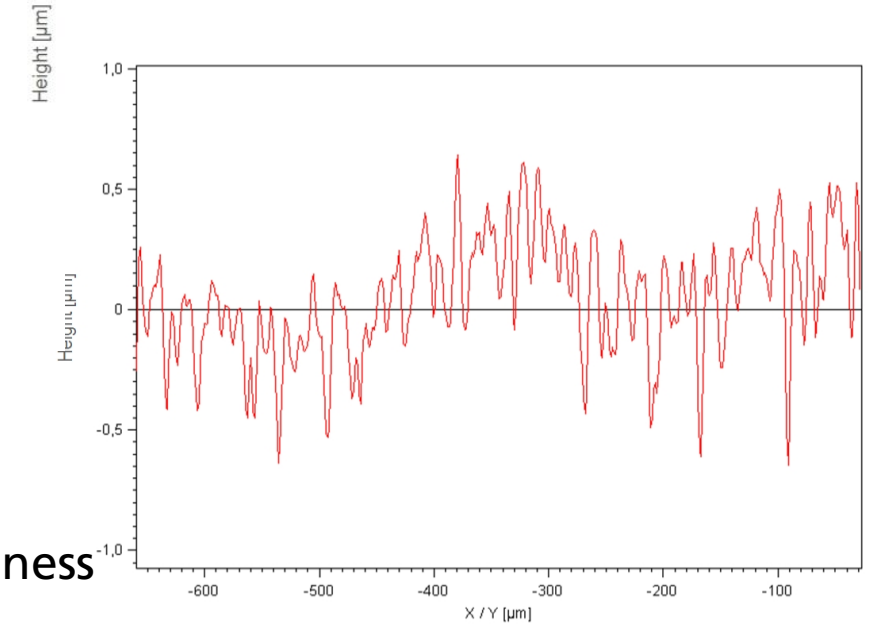


Metallographic investigations on the surface condition of an actuator stick produced by EDM process

Processing step 6: Cutting and Grinding



Results of surface roughness measurements after grinding process



left: area roughness; right: line roughness

➔ **Surface defects from wire eroding processing can be eliminated**

➔ **good surface qualities (S_a < 0.5 µm) were achieved**

➔ **No MFIS measurable**

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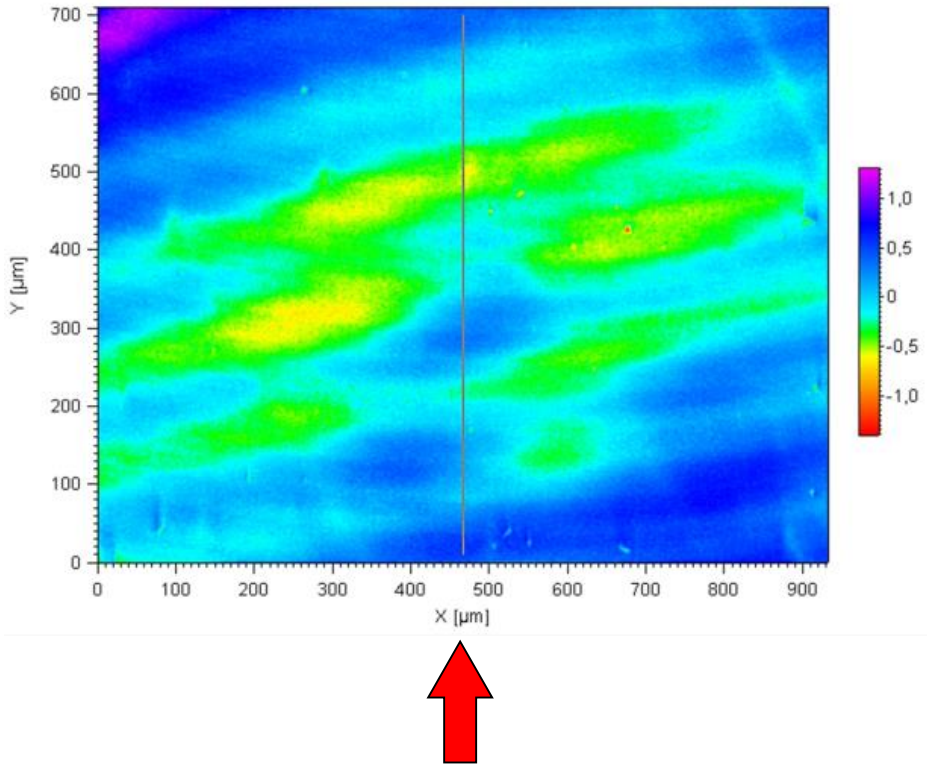
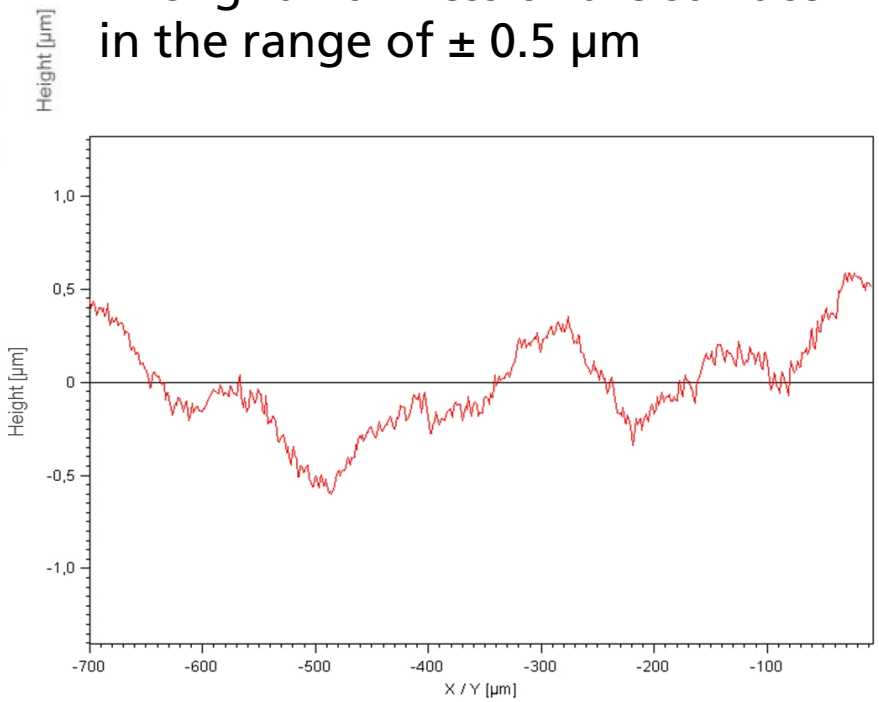
Processing step 6: Cutting and Polishing



left: area roughness; right: line roughness

Results of surface roughness measurements after grinding and polishing:

➔ Slight waviness of the surface in the range of ± 0.5 µm



➔ **Very good surface qualities, roughness value S_a is < 0.3 µm**

➔ **No MFIS measurable**

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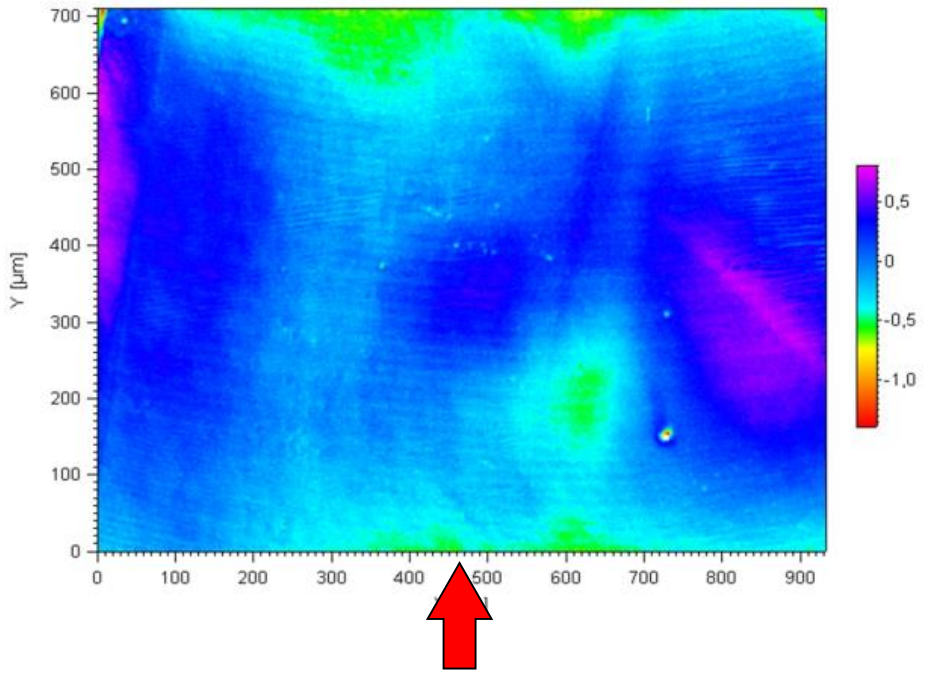
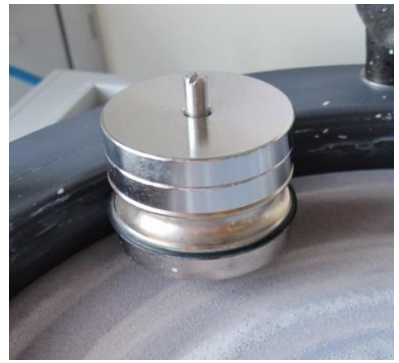
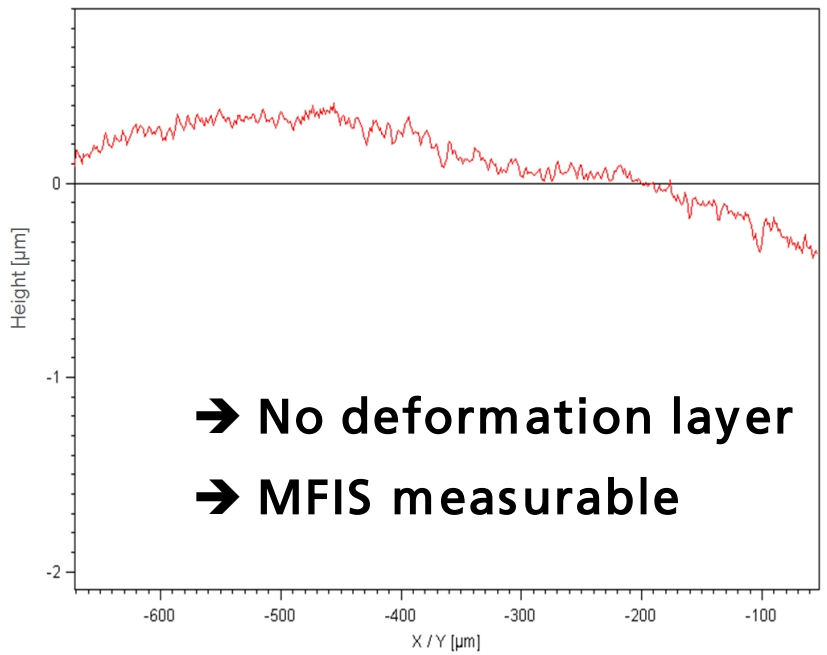
Processing step 6: Cutting and at last Vibration Polishing







Roughness value S_a lies in the range of 0.23 - 0.28 µm.

The sectional view has shown:

➔ Very homogenous surface, almost without impurities

➔ No traces of processing recognized

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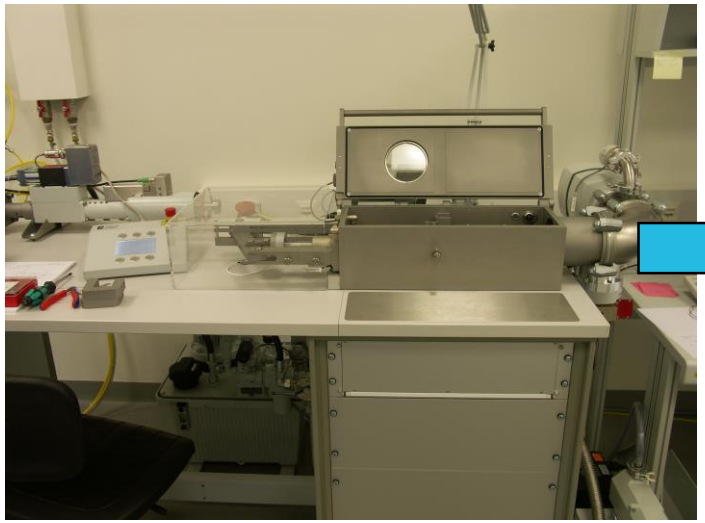
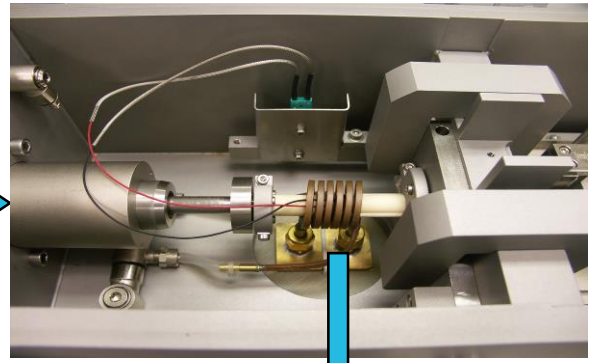
Processing step 7: Training

Special dilatometer: deformation and quenching dilatometer (TTT-diagrams)





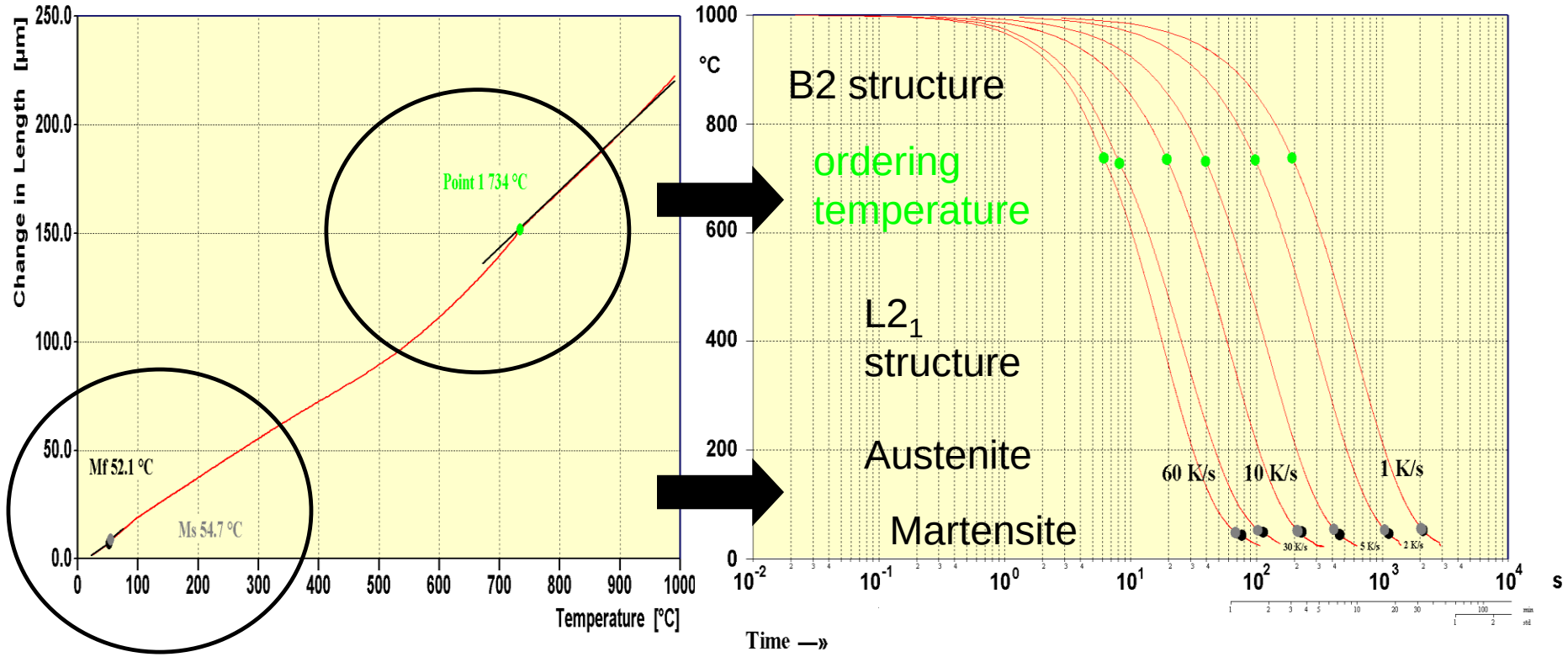
Heat treatments
without or with load

Temperatur range	**20 °C – 1500 °C**
Heating principle	**inductive**
Sample material	**electrically conductive solid body**
Atmosphere	**inert gas, vacuum, air**
Resolution Δl/°C	**0,05 µm / 0,05 °C**

➔Benefit:
Exactly temperature control (± 1K) with thermocouples on sample

Processing step 7: Training

Time-Temperature-Transformation diagram



Previous results: Ni-Mn-Ga samples with post-heat treatments

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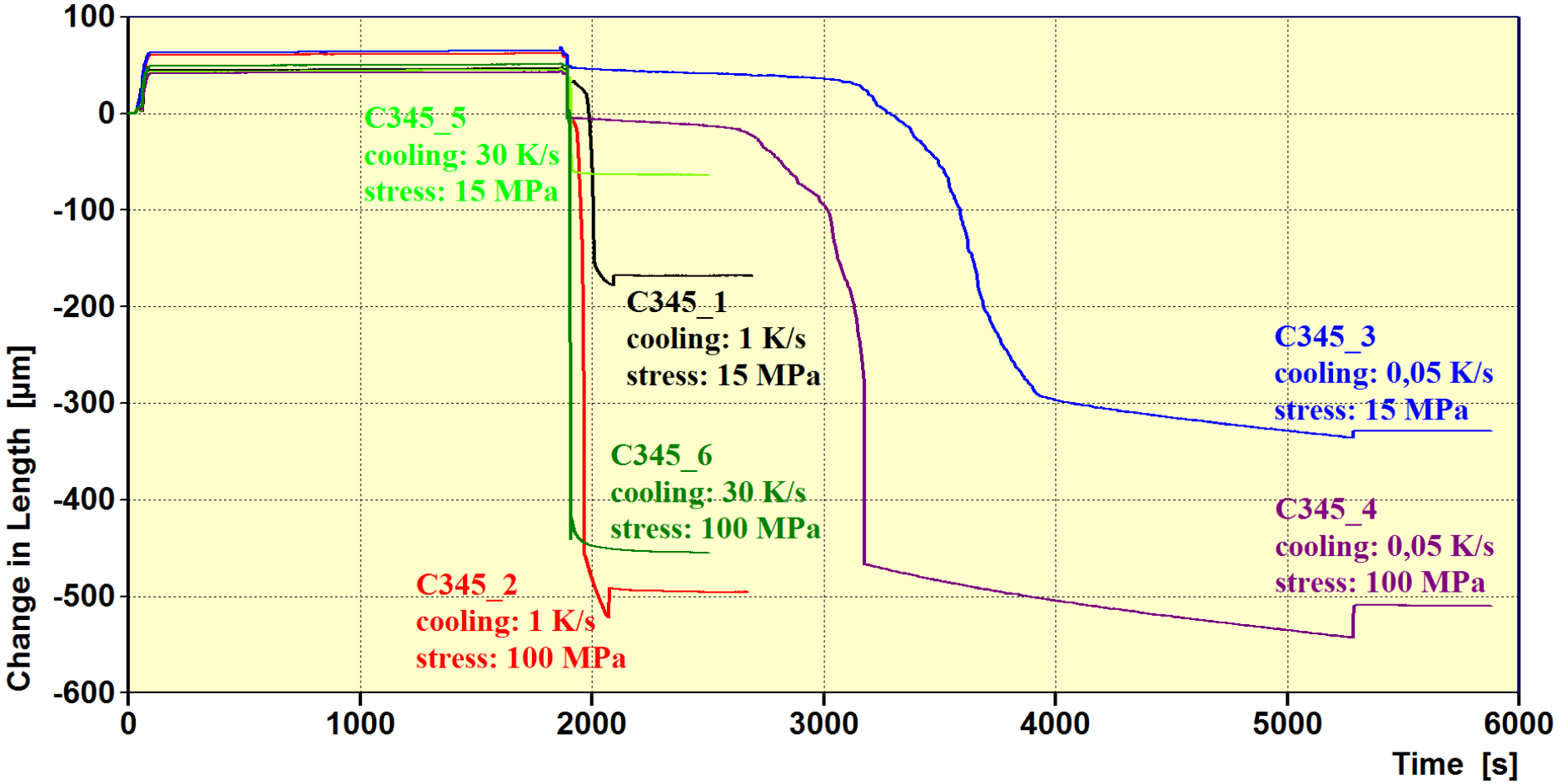
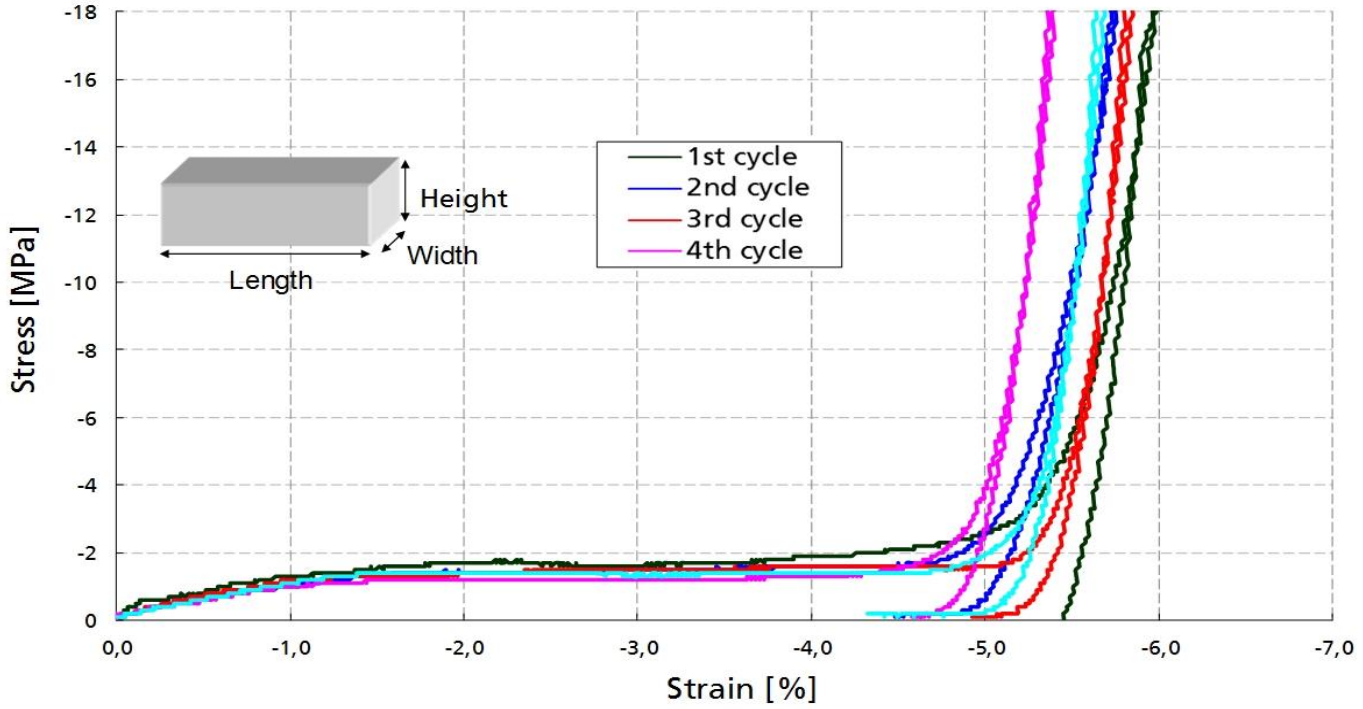
Processing step 7: Training
Results – comparison



Measurement results for heat treatment of single crystalline Ni-Mn-Ga+X samples

Processing step 7: Training

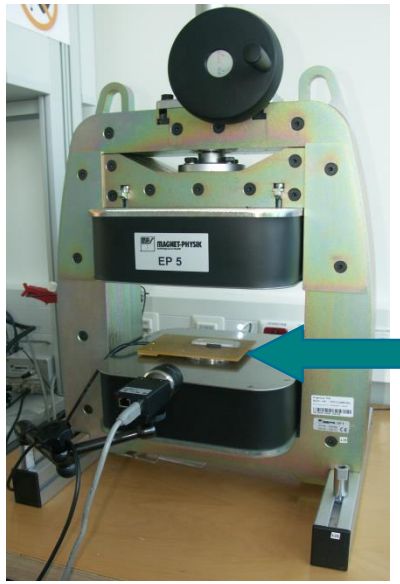
Functional tests of the prepared actuator sticks for application



- compression load along two directions
- Stress-strain curves of a vibration-polished Ni-Mn-Ga actuator stick as a function of the number of cycles (training)

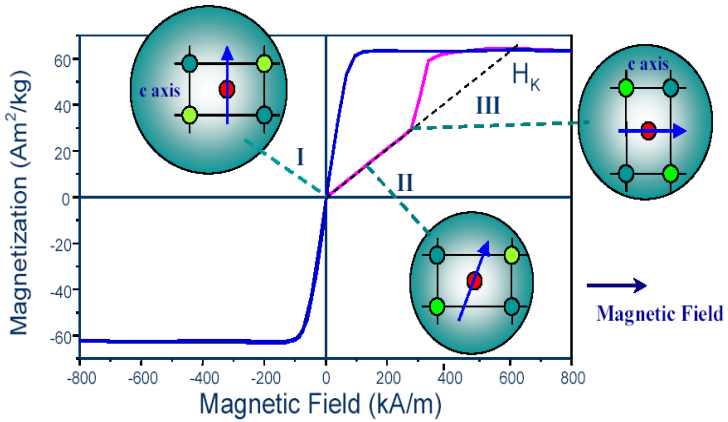
Processing step 7: Training

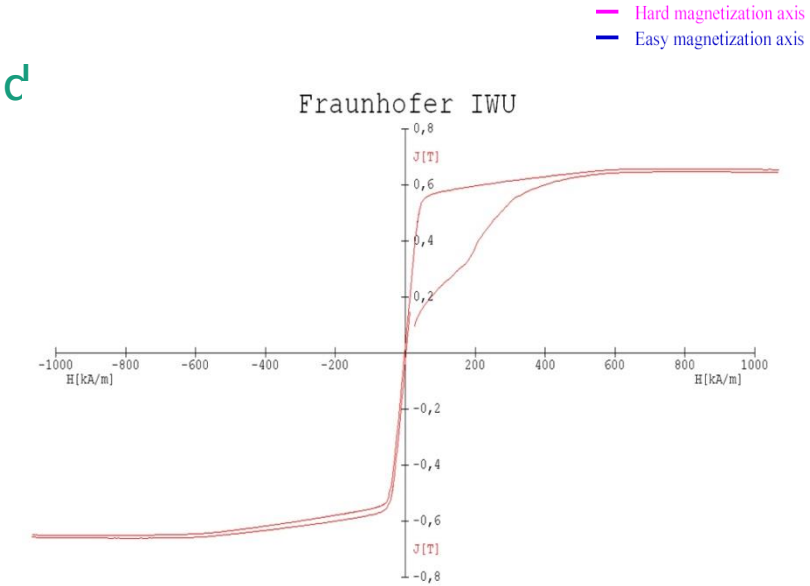
MFIS measurements



Permagraph:

Static magnetic field up to 3 T





➔ MFIS measurements on a vibration-polished Ni-Mn-Ga actuator stick

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