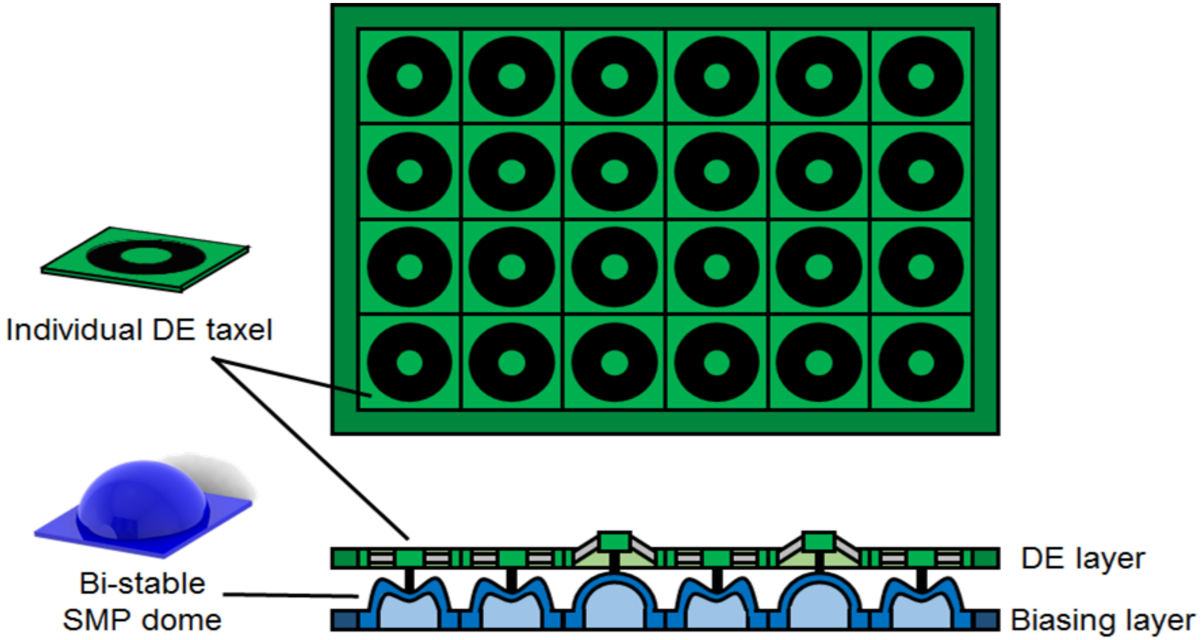
DECMAS - Project - Influence of residual stresses of sputtered thin film electrodes for dielectric elastomer applications



Prof. Dr. rer. nat. Günter Schultes

Prof. Dr.-Ing. Stefan Seelecke

Jun.-Prof. Dr. Gianluca Rizzello

Jonas Hubertus, M.Sc.

Julian Neu, M.Sc.

Sipontina Croce, M.Sc.

jonas.hubertus@htwsaar.de

KOMMMA A DFG PRIORITY PROGRAMME

intelligent Material Systems Lab

htw saar

UNIVERSITÄT DES SAARLANDES

Content

- DECMAS Project
- Compliant electrode
- Evaluation of the electromechanical results
- Conclusion

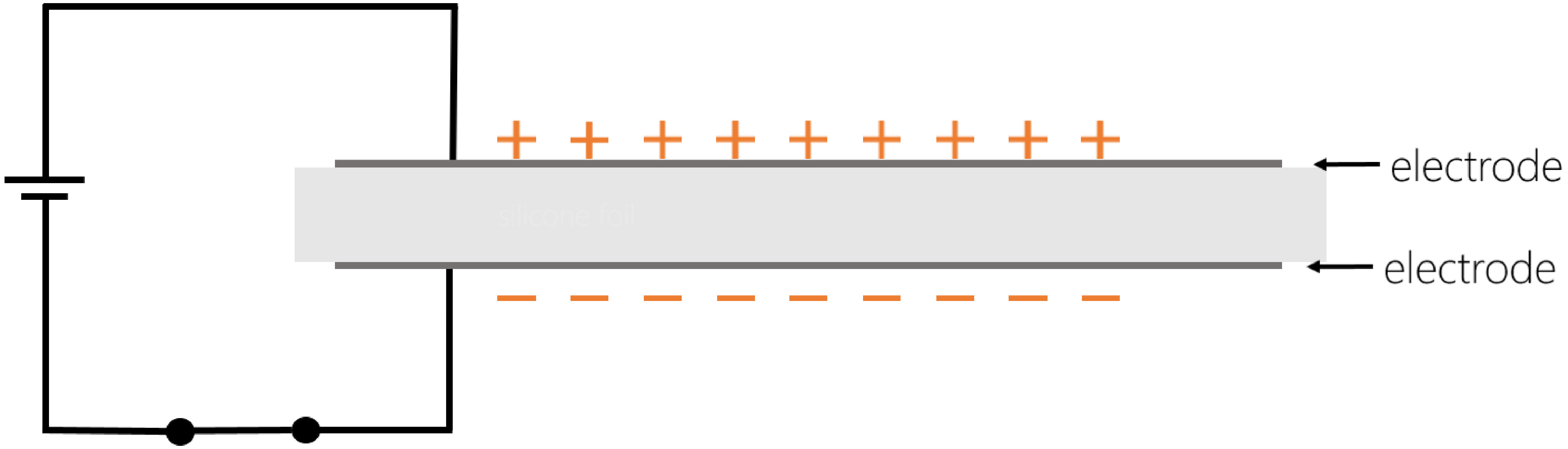
DECMAS

- DECMAS - Dielectric Elastomer Membranes for Cooperative Micro-Actuator/Sensor Concepts

flexible capacitor

DECMAS

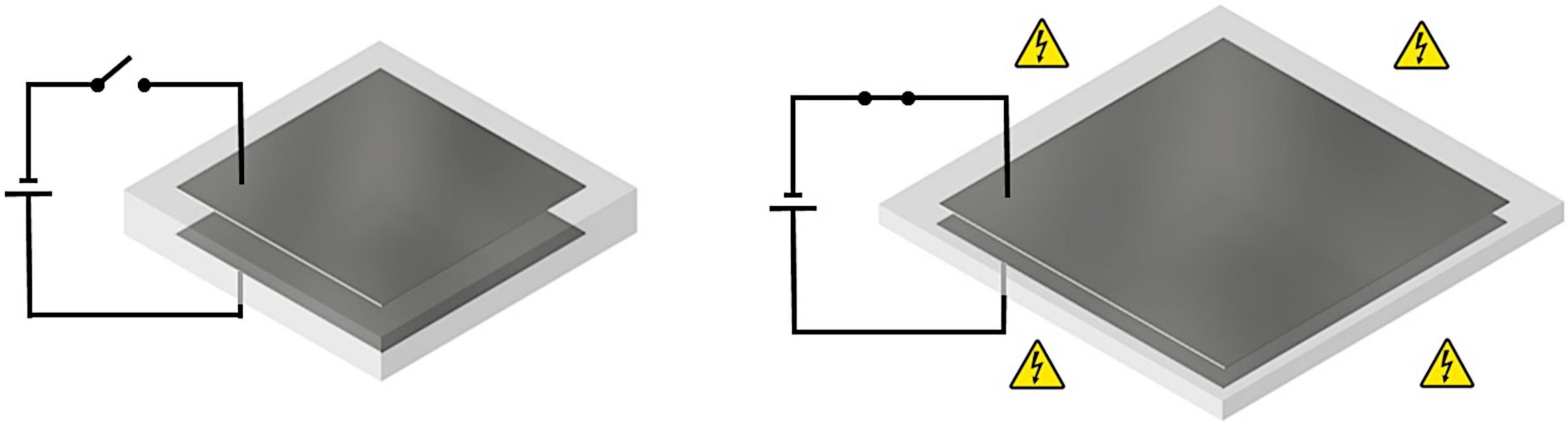
- DECMAS - Dielectric Elastomer Membranes for Cooperative Micro-Actuator/Sensor Concepts



Attraction of the charged electrodes due to the Maxwell-stress and in-plane expansion of the silicone membrane

DECMAS

- DECMAS - Dielectric Elastomer Membranes for Cooperative Micro-Actuator/Sensor Concepts



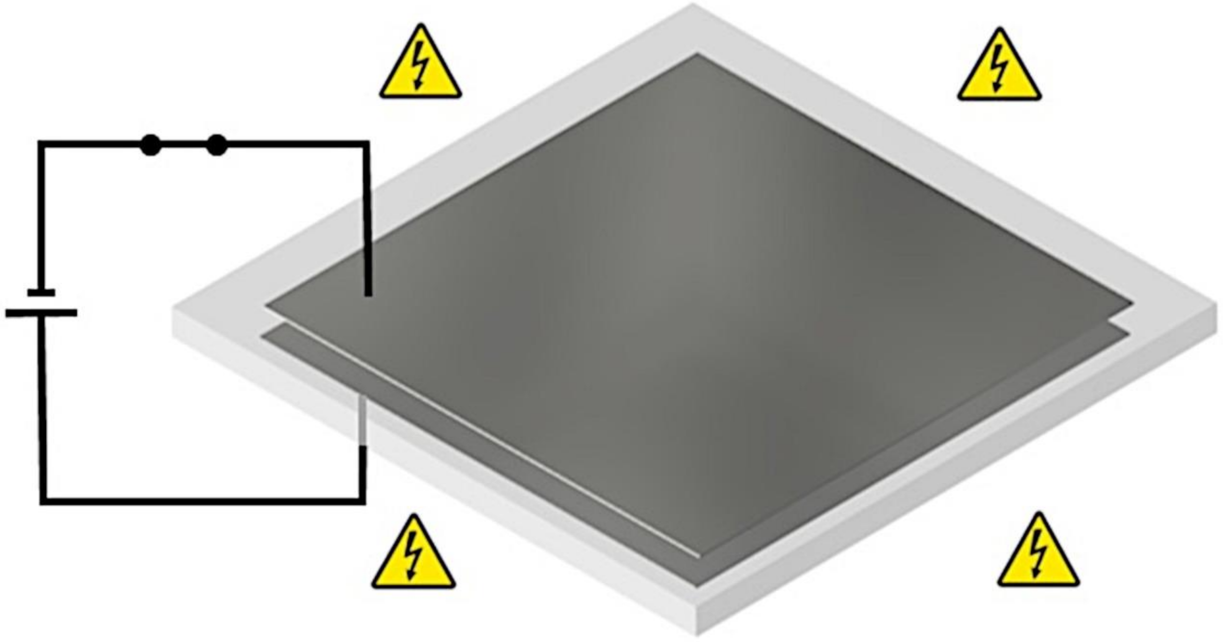
Attraction of the charged electrodes due to the Maxwell-stress and in-plane expansion of the silicone membrane

DECMAS

- DECMAS - Dielectric Elastomer Membranes for Cooperative Micro-Actuator/Sensor Concepts

- In-plane expansion
- Change in dimensions and geometry

→ can be used for actuation with the appropriate biasing systems



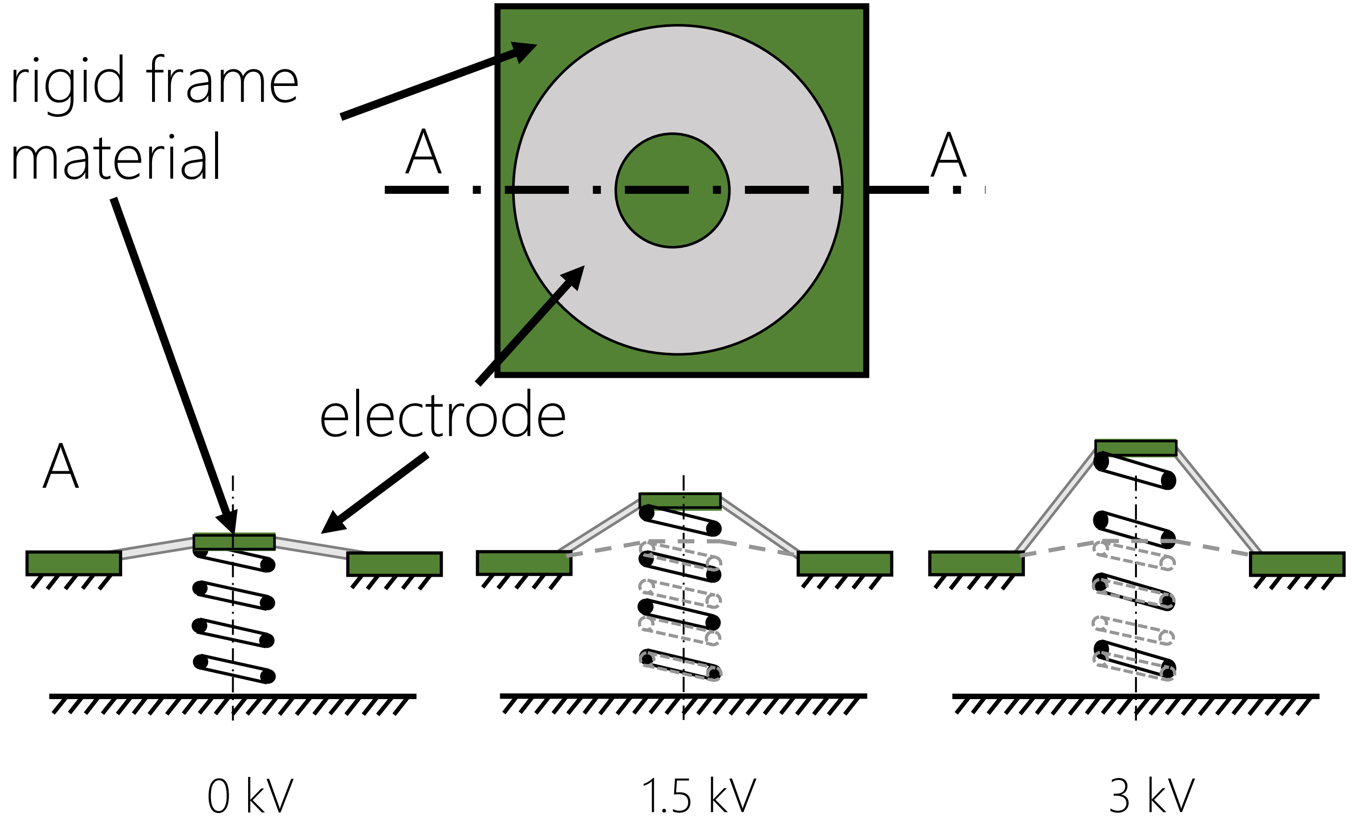
- Approach of the electrodes and increase of the electrode area

→increase of the capacitance

→Actuator and sensor in one element

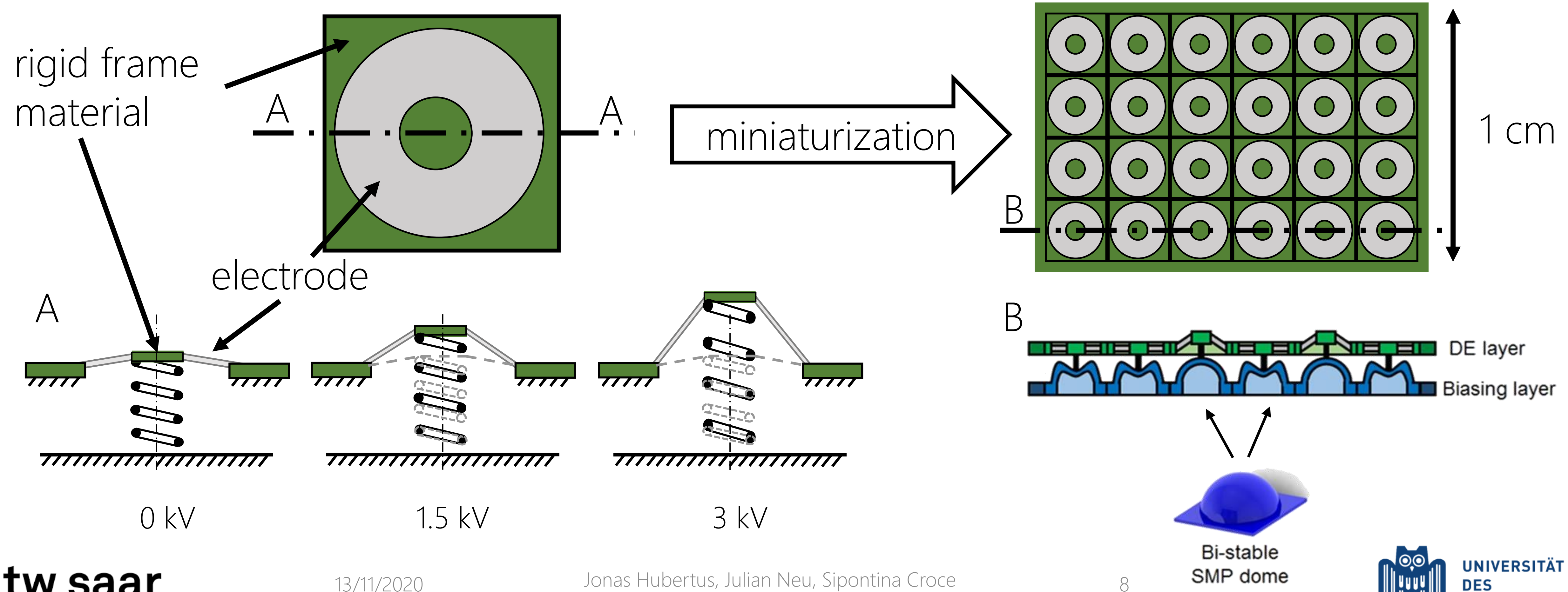
KOMMMA

- DECMAS - Dielectric Elastomer Membranes for Cooperative Micro-Actuator/Sensor Concepts

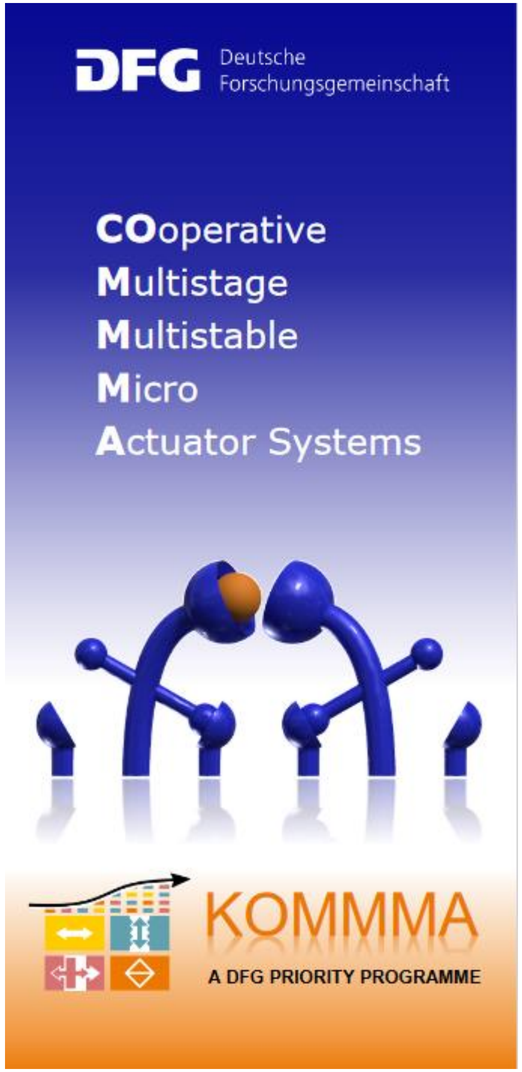


KOMMMA

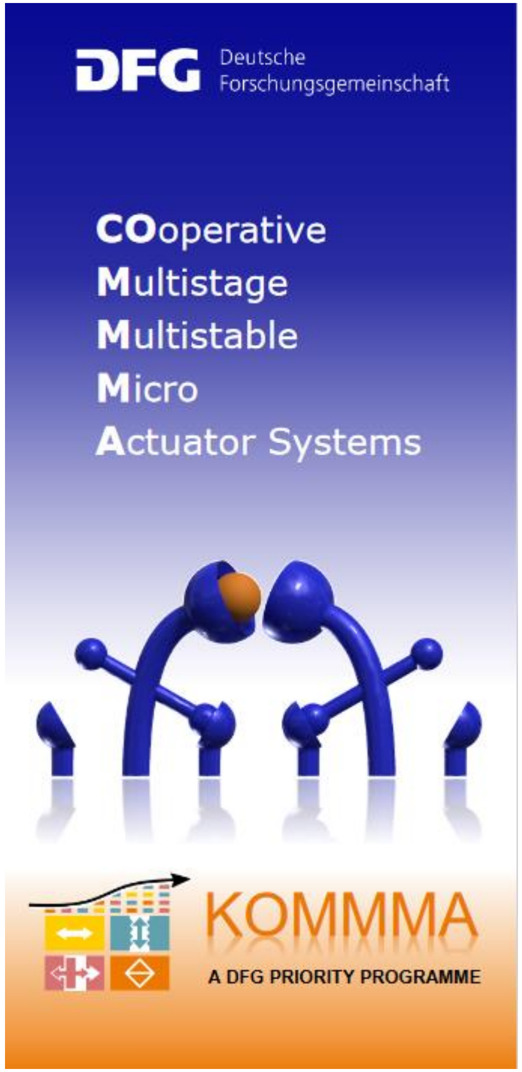
- DECMAS - Dielectric Elastomer Membranes for Cooperative Micro-Actuator/Sensor Concepts

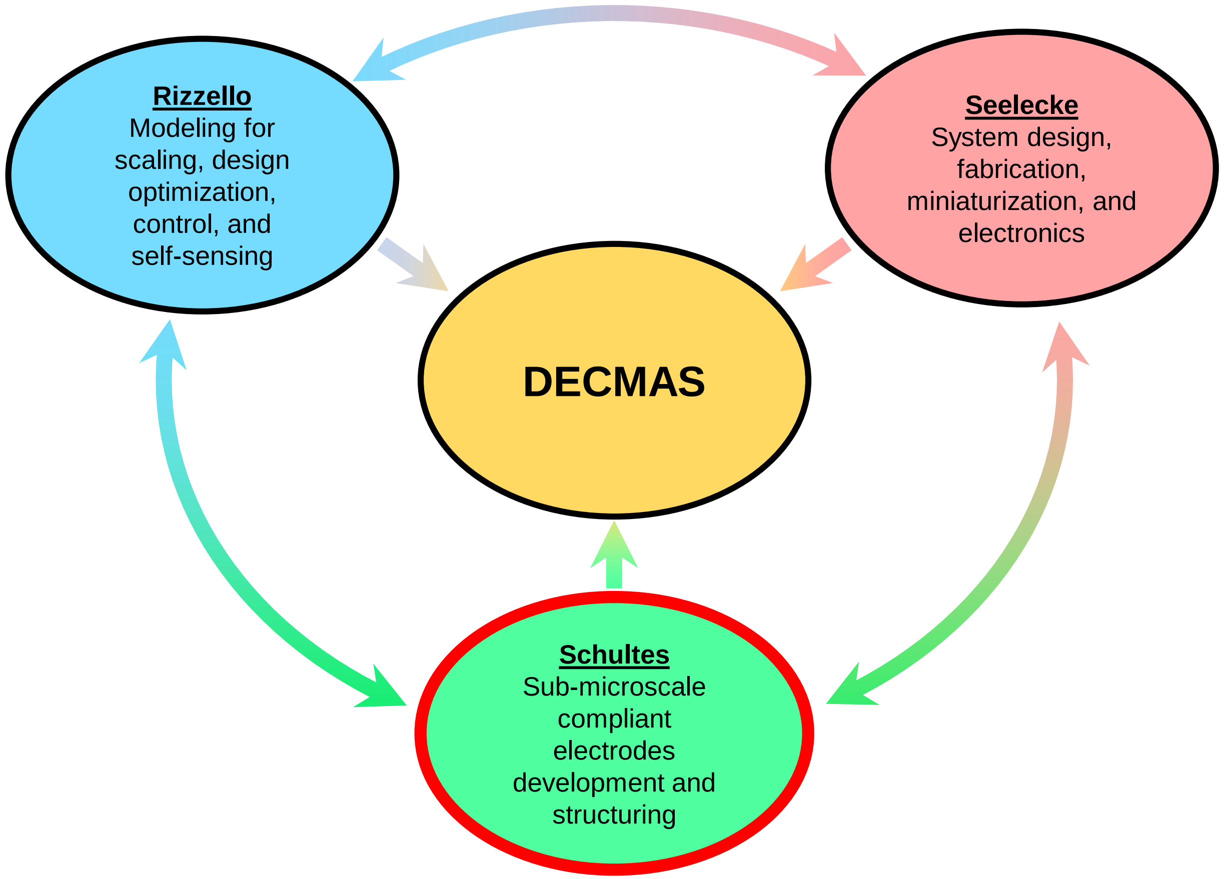


DECMAS project - Project structure



DECMAS project - Project structure

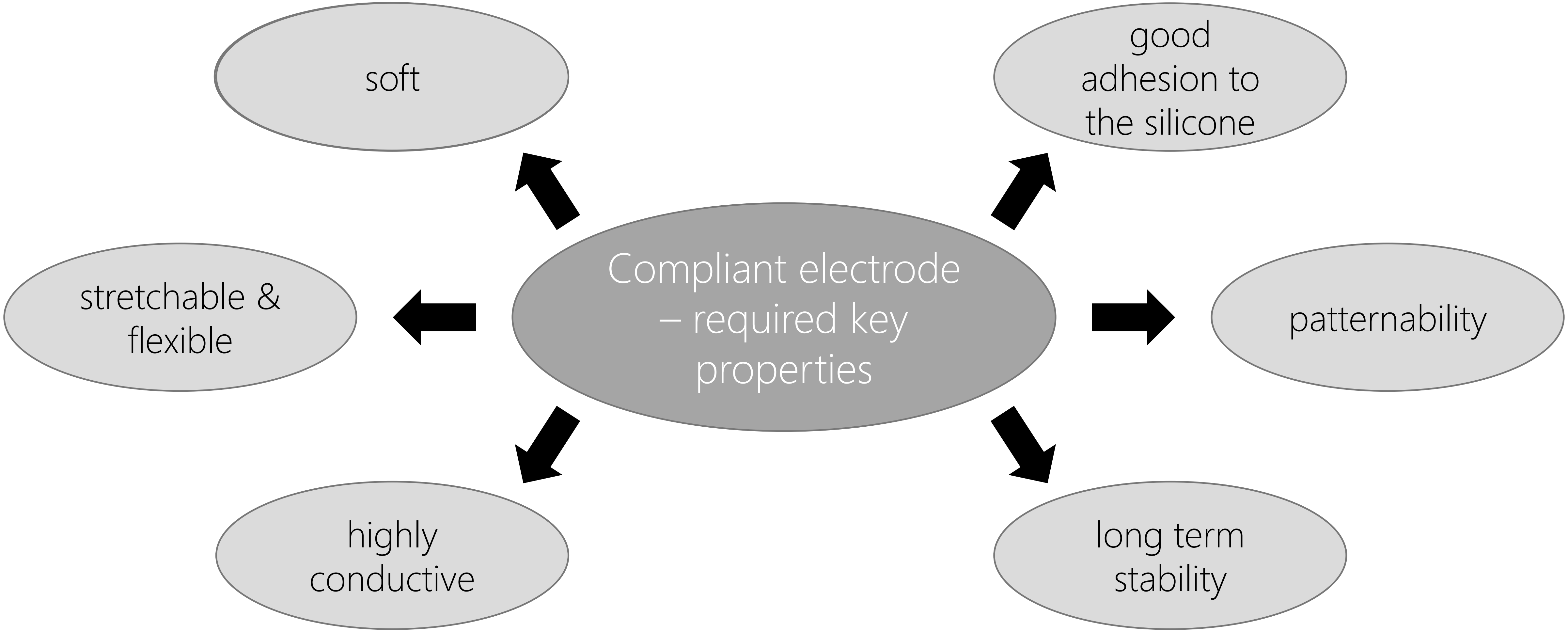




Content

- DECMAS Project
- Compliant electrode
- Evaluation of the electromechanical results
- Conclusion

Compliant electrode – general properties



Compliant electrode – general properties

Carbon black electrode	Properties of both electrode types	Metallic electrode
	good adhesion to the silicone	patternability
soft	long term stability	highly conductive
	stretchable & flexible	thin

Compliant electrode – general properties

Carbon black electrode	Properties of both electrode types	Metallic electrode
	good adhesion to the silicone	patternability
soft	long term stability	highly conductive
	stretchable & flexible	thin

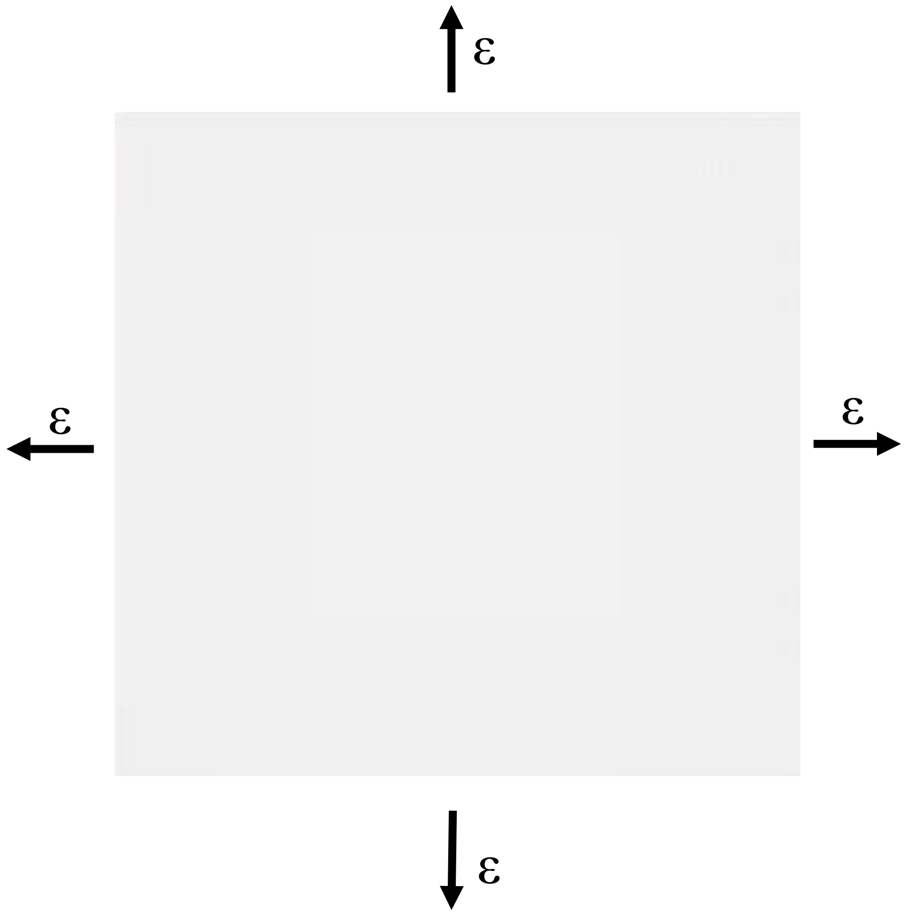
?

Compliant metallic electrode (CME) - manufacturing

PDMS film

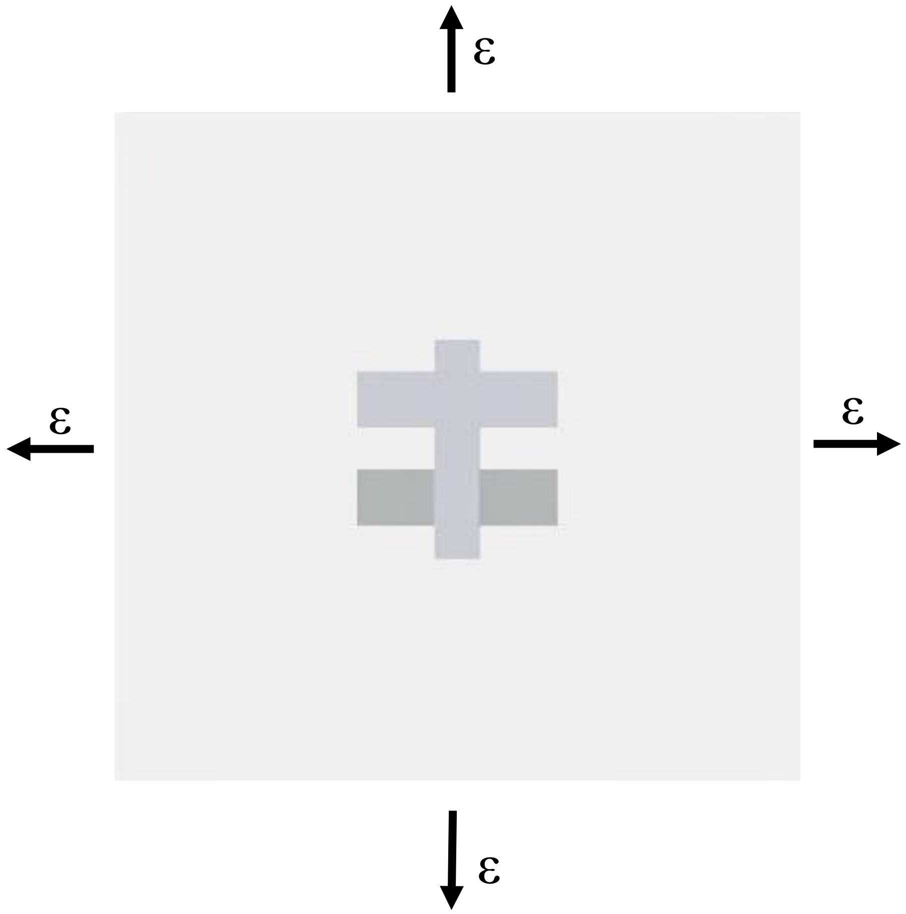
Compliant metallic electrode (CME) - manufacturing

- PDMS film is pre-stretched



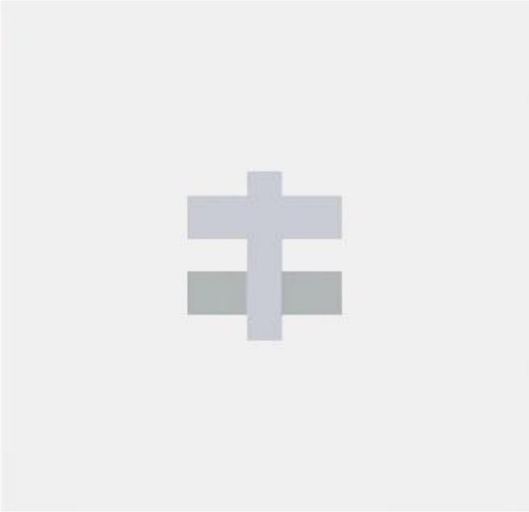
Compliant metallic electrode (CME) - manufacturing

- PDMS film is pre-stretched
- DC magnetron sputter coated on both sides
- 10nm Ni or 20nm Ni + carbon sandwich



Compliant metallic electrode (CME) - manufacturing

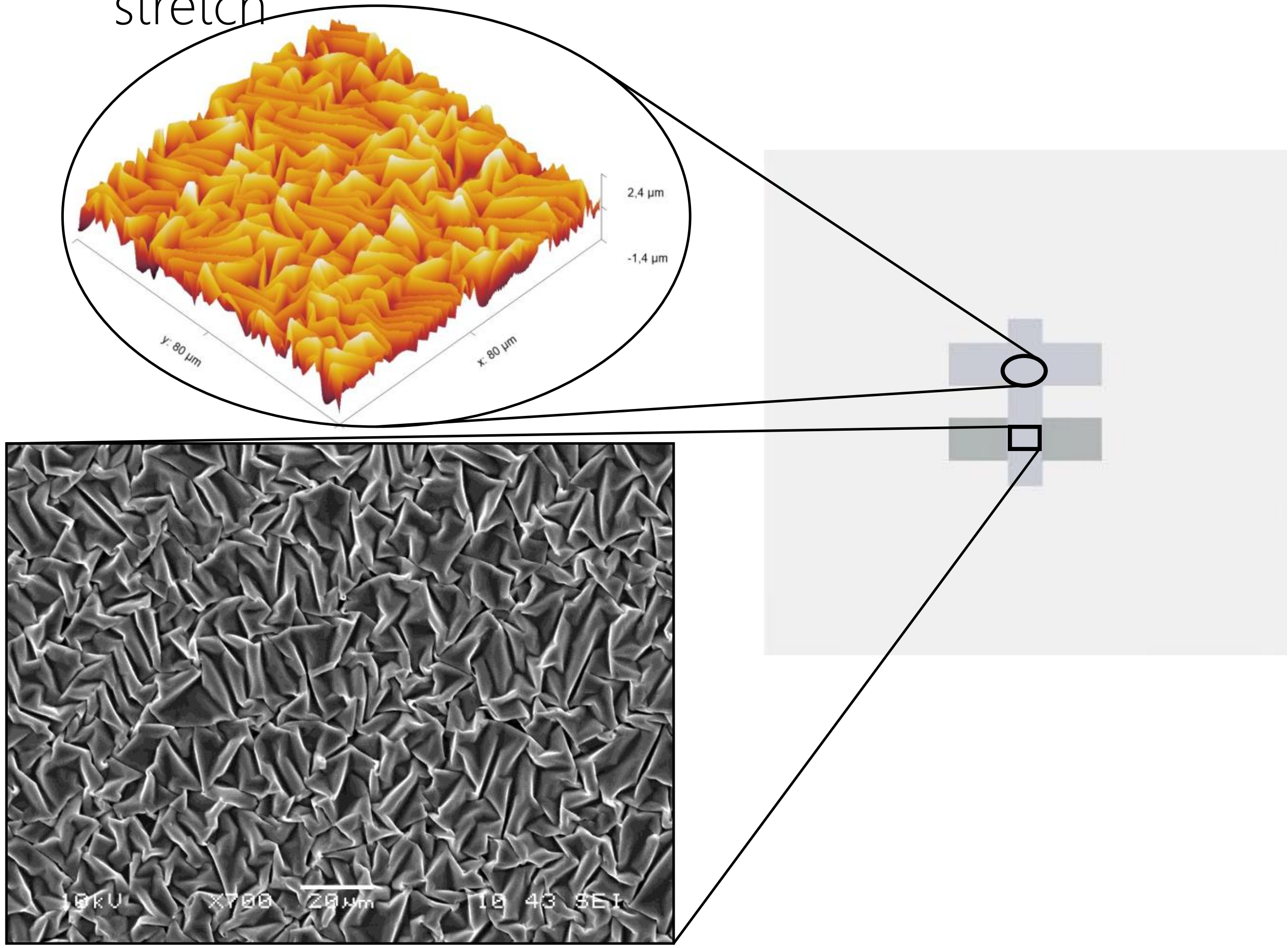
- PDMS film is pre-stretched
- DC magnetron sputter coated on both sides
- 10nm Ni or 20nm Ni + carbon sandwich
- Pre-stretch is released



CME- structure

- PDMS film is pre-stretched
- DC magnetron sputter coated on both sides
- 10nm Ni or 20nm Ni + carbon sandwich
- Pre-stretch is released
- Wrinkled metallic surface is obtained

biaxial pre-stretch



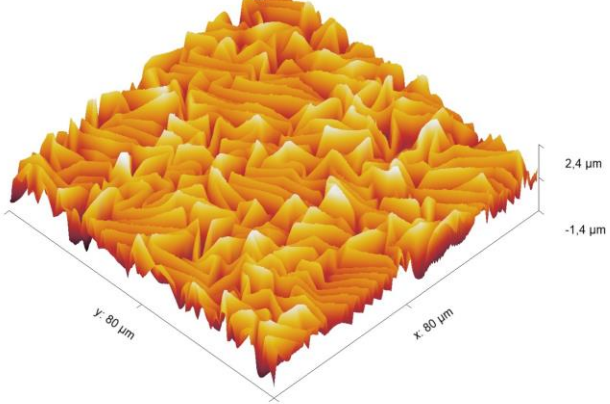
KOMMMA
A DFG PRIORITY PROGRAMME

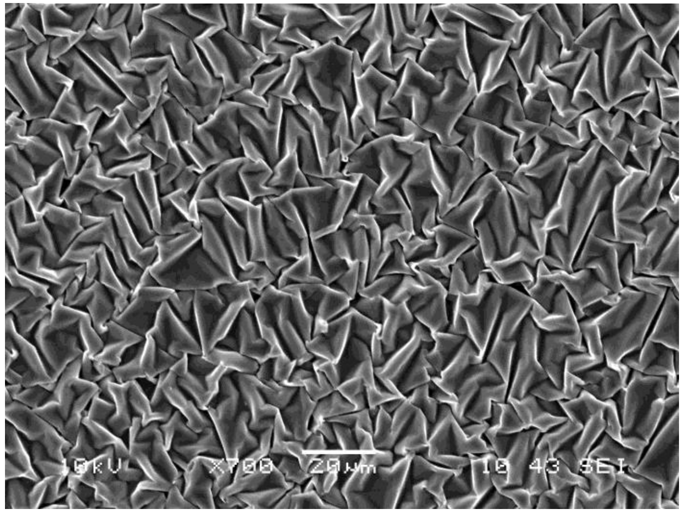
CME- structure

intelligent Material Systems Lab

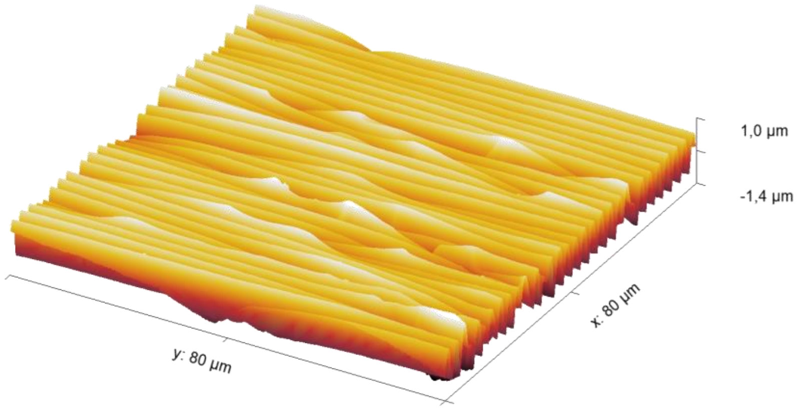
- PDMS film is pre-stretched
- DC magnetron sputter coated on both sides
- 10nm Ni or 20nm Ni + carbon sandwich
- Pre-stretch is released
- Wrinkled metallic surface is obtained
- Wrinkles act as mechanical buffer during actuation

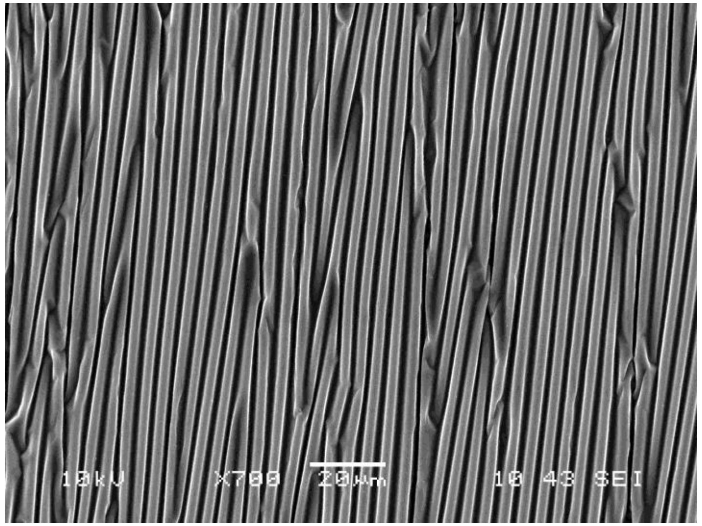
biaxial pre-stretch





pure-shear pre-stretch



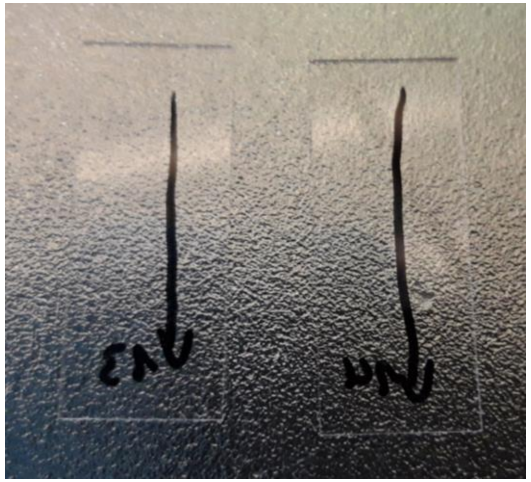


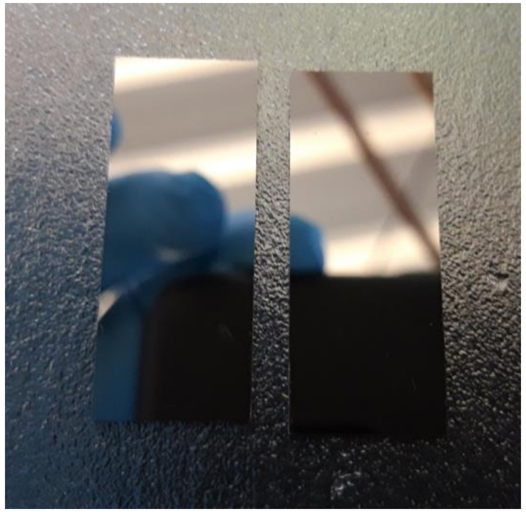
Content

- DECMAS Project
- Compliant electrode
- Evaluation of the electromechanical results
- Conclusion

Experimental: residual stress

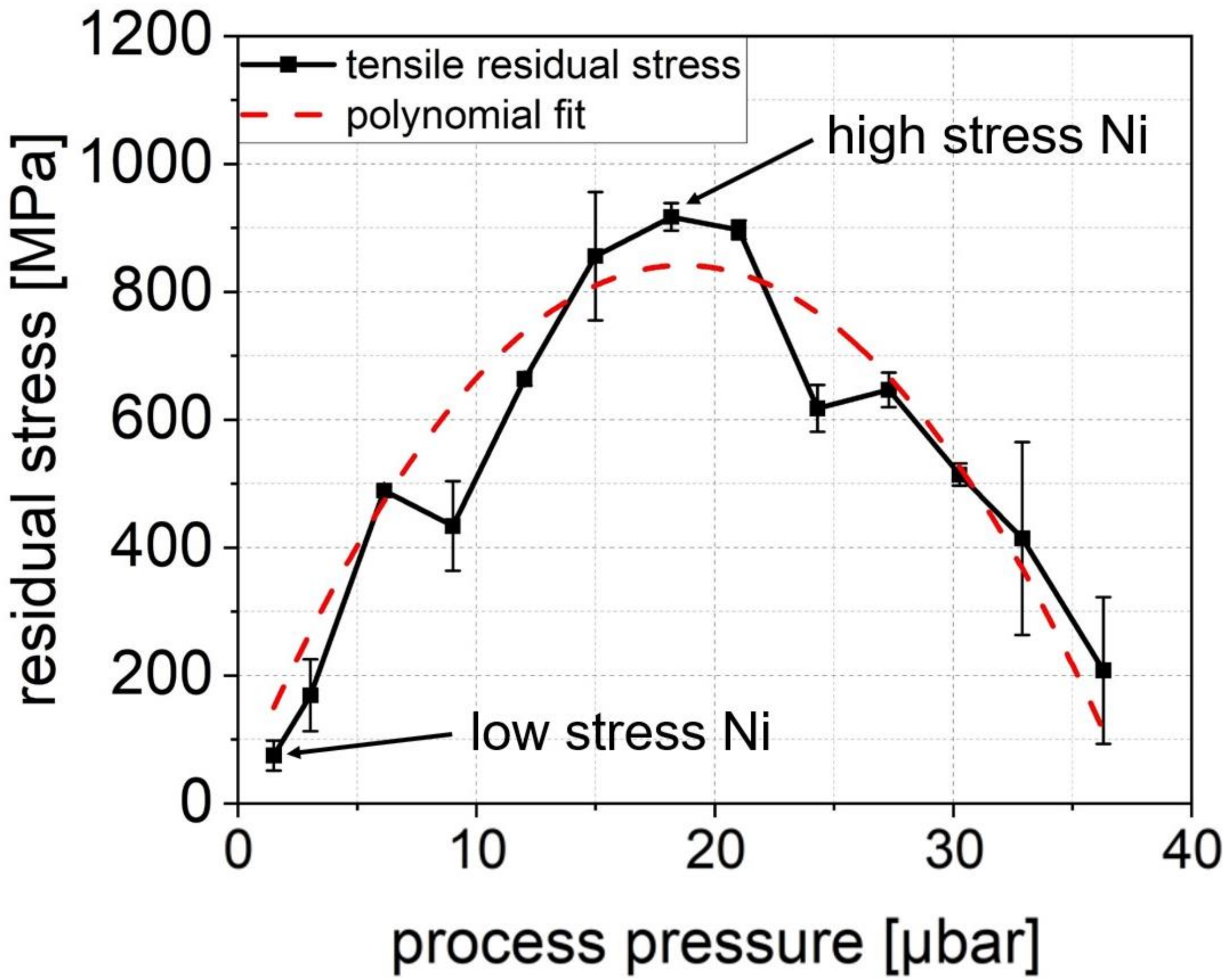
- Deposition of pure nickel (115 nm) onto glass slides
- Application of 13 different process pressures
- Measurement of the residual stress of the thin film by means of
- Stoney –Equation: $$\sigma_R = \frac{E_s}{6 * (1 - v_s)} \frac{h_s^2}{h_f} \left(\frac{1}{R} - \frac{1}{R_0} \right)$$





Results: residual stress

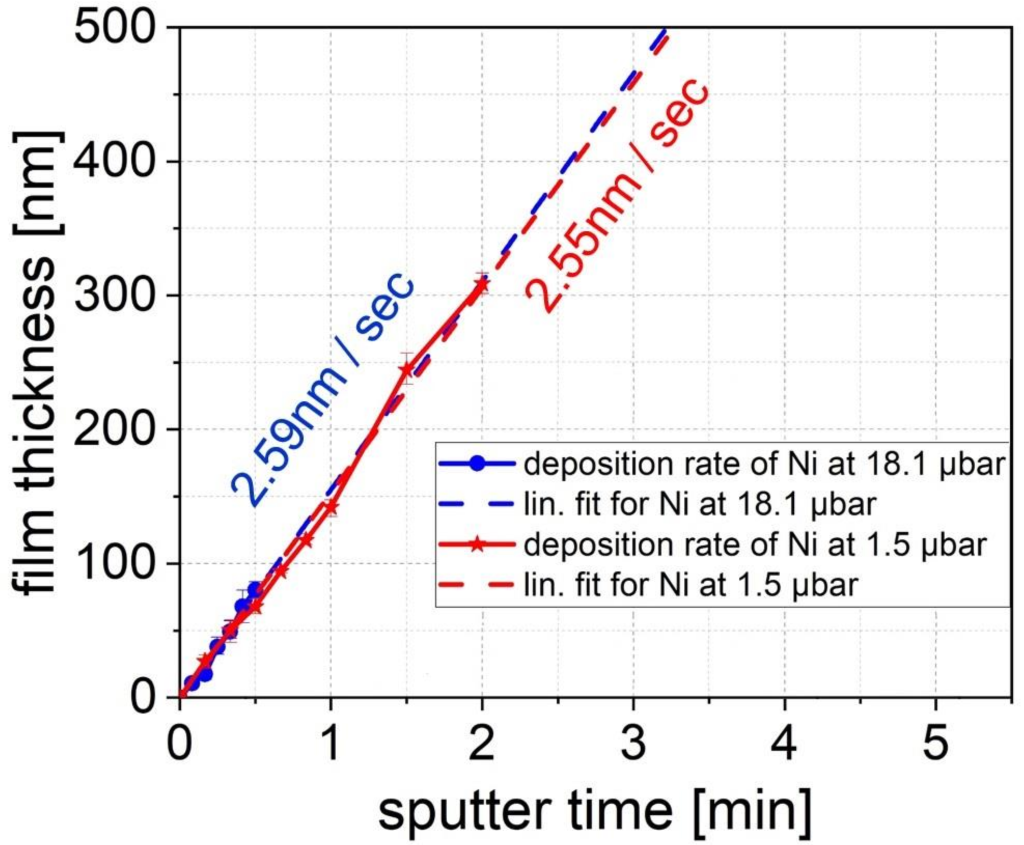
- Minimum value of approx. 95MPa at 1.5µbar
- Maximum value of approx. 920MPa 18µbar
- Fit similar to inverted parabola
- In the following: thin film electrodes with high stress nickel are compared to thin film electrodes containing low stress nickel



Results: residual stress

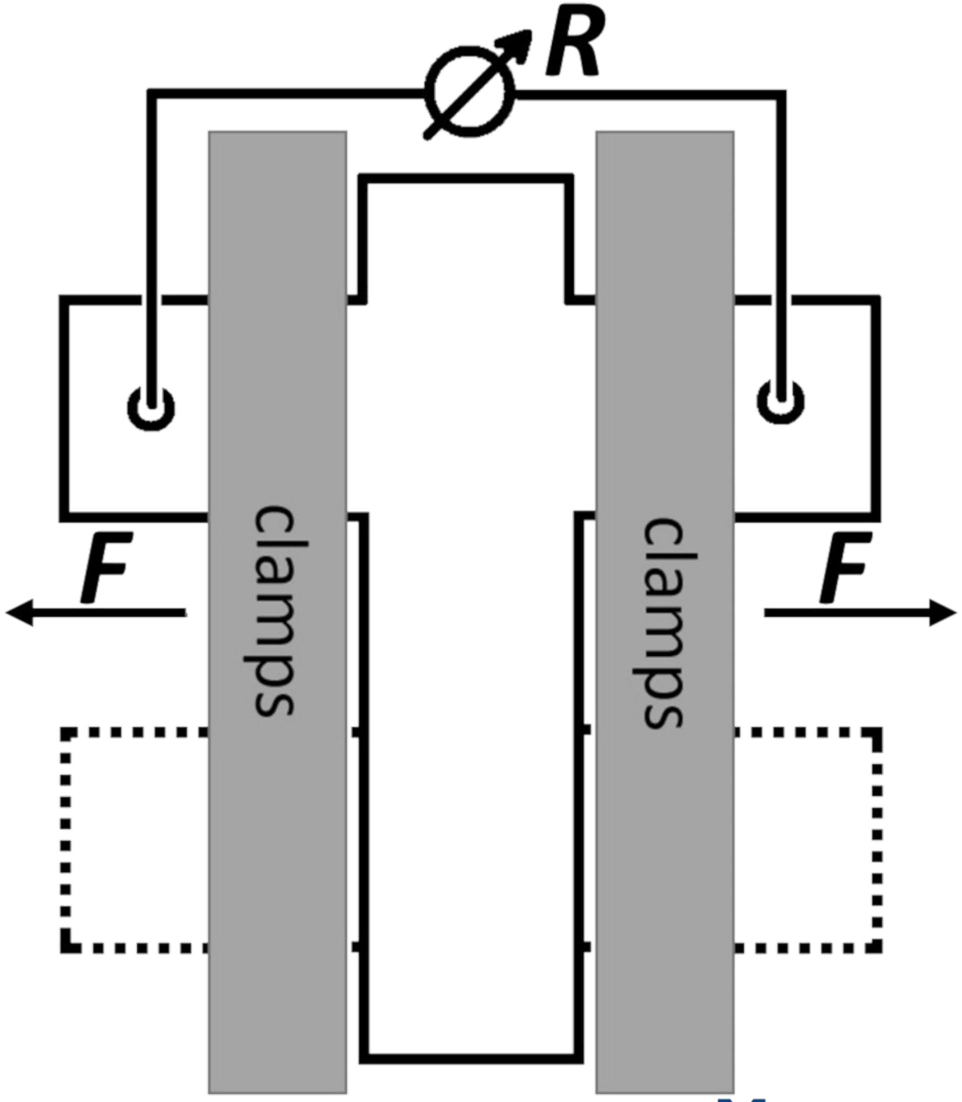
- Comparable deposition rate for low stress nickel and for high stress nickel

- No contribution to residual stress state due to different layer thicknesses



Experimental: resistance versus strain

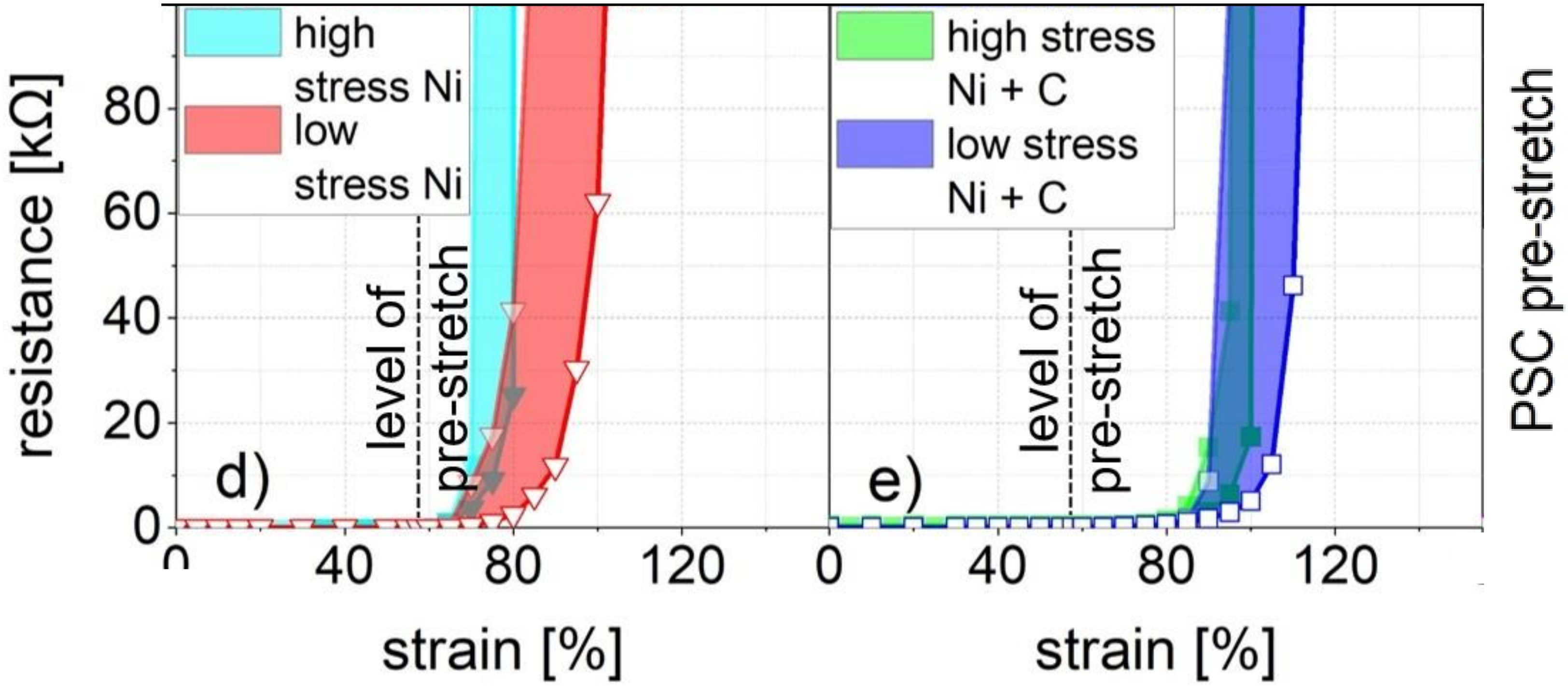
- Biaxially or pure shear pre-stretched silicone membranes
- Deposition of cross-shaped electrodes onto pre-stretched membranes
- Pure nickel thin film (10 nm)
- Sandwich thin film: Ni+C (20 nm) and C+Ni (20 nm)
- High and low residual stress nickel thin films
- Pure shear tensile test
- Measurement of the resistance versus strain



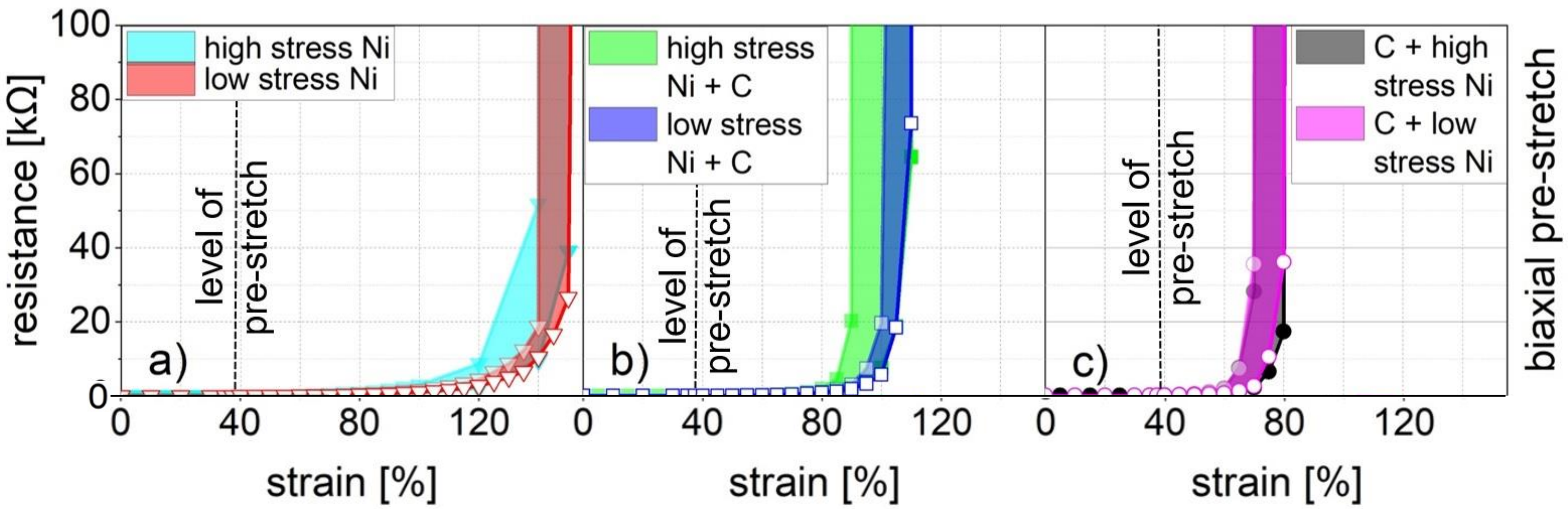
Results: resistance versus strain

For PSC pre-stretched membranes with Ni and Ni+C:

- Degradation of the nickel and the Ni+C electrode is shifted towards higher strain level
- Degradation of the electrode is dominated by residual stress state



Results: resistance versus strain



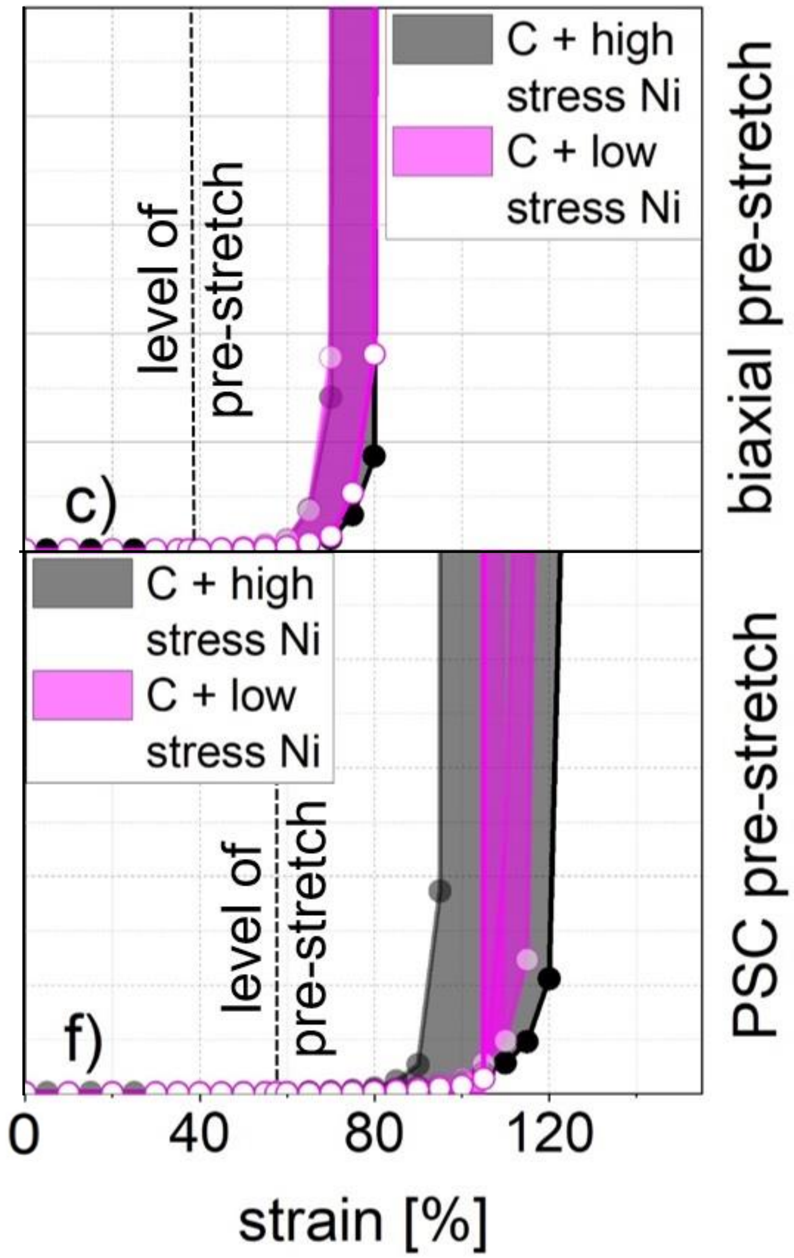
For biaxially pre-stretched membranes:

- No influence of the residual stress state on the electromechanical properties
- Degradation of the electrode is dominated by the failure mechanism of the electrode

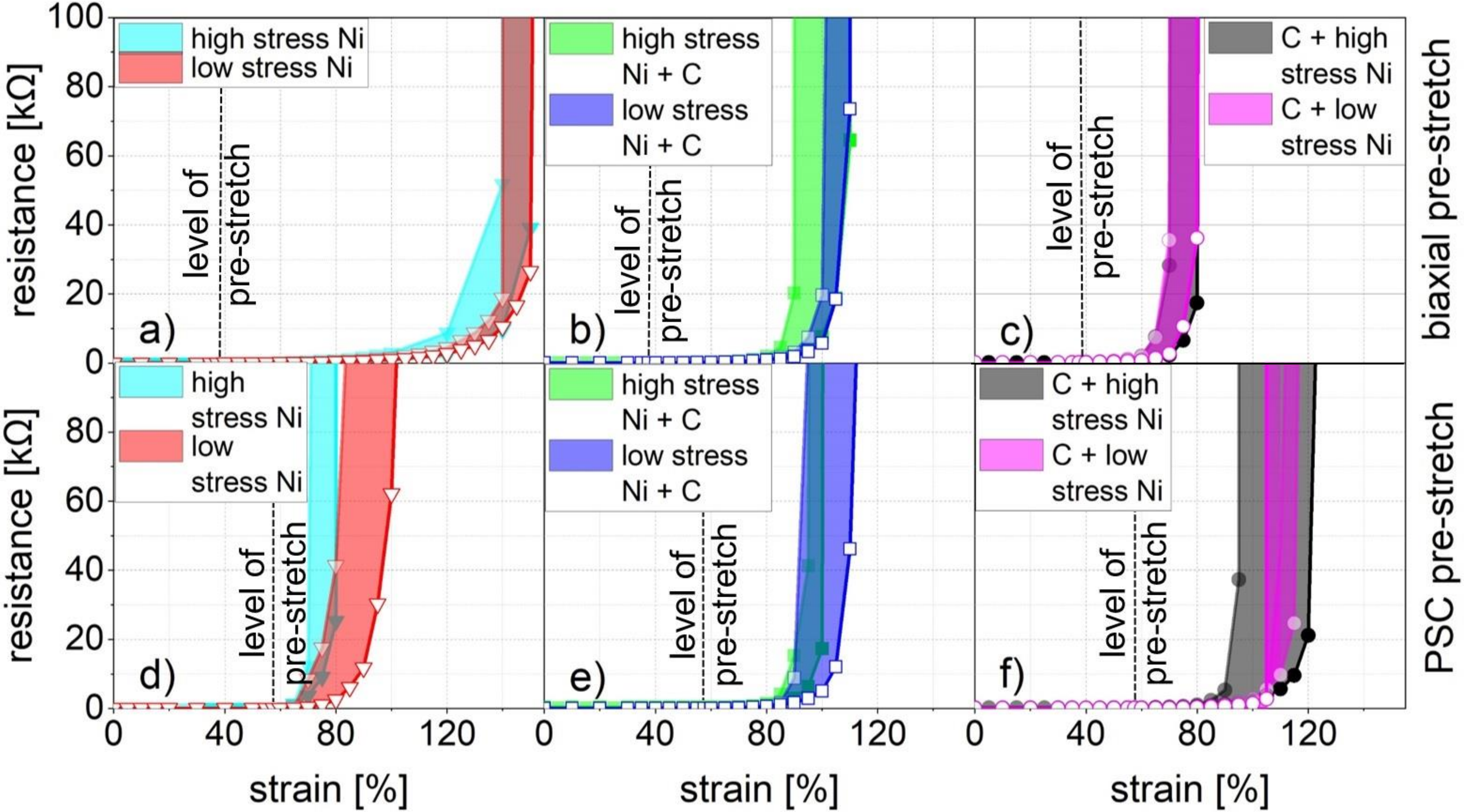
Results: resistance versus strain

For C+Ni thin film electrodes:

- No influence of the residual stress state on the electromechanical properties
- Carbon sub-layer absorbs the residual stresses of the top-layer



Results: resistance versus strain

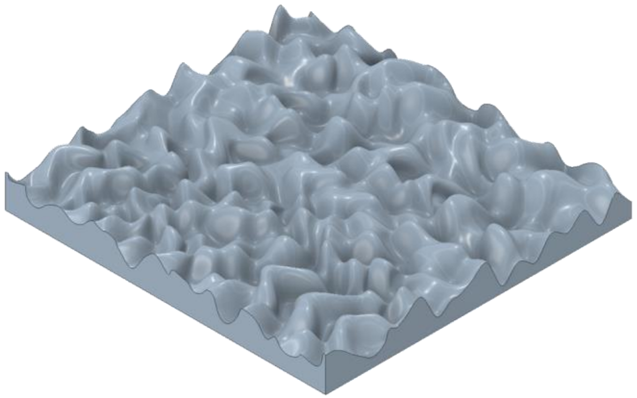


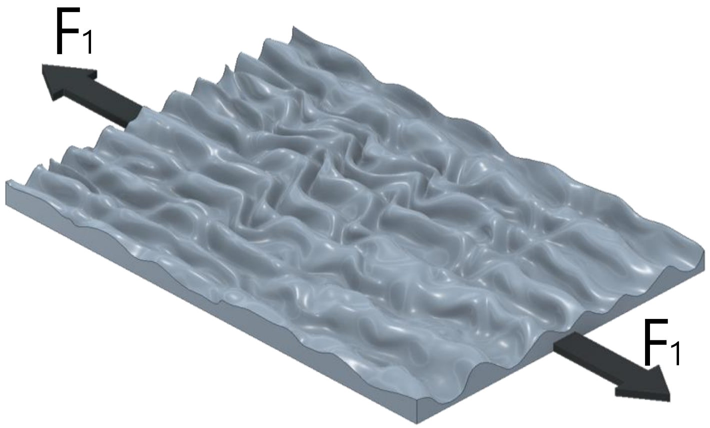
ht

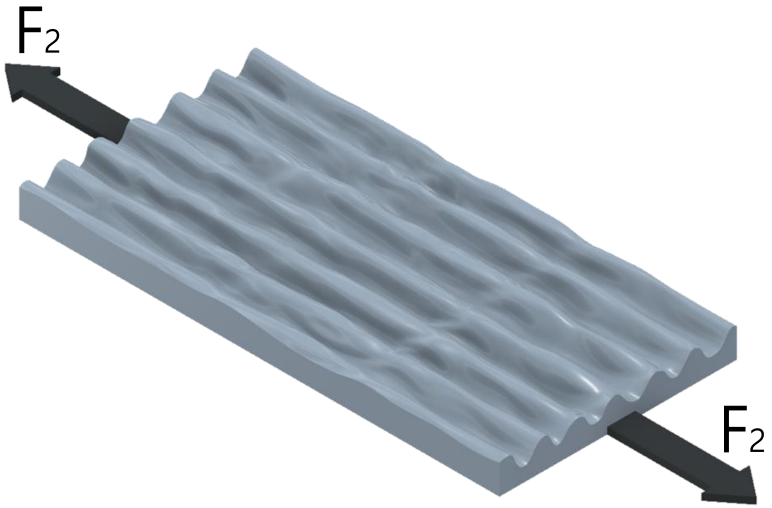
SITÄT

NDES

Biaxial failure mechanism







Initial state:

$\varepsilon = 0$

$F = 0$

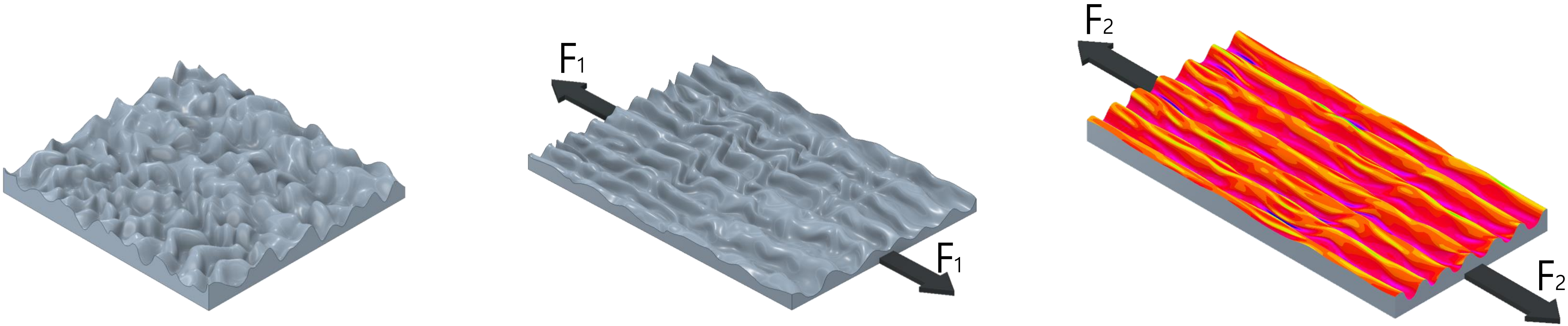
$\varepsilon < \varepsilon_{pre}$

$0 < F_1$

$\varepsilon = \varepsilon_{pre}$

$0 < F_1 < F_2$

Biaxial failure mechanism



Initial state:

$\varepsilon = 0$ | $\varepsilon < \varepsilon_{pre}$ | $\varepsilon = \varepsilon_{pre}$

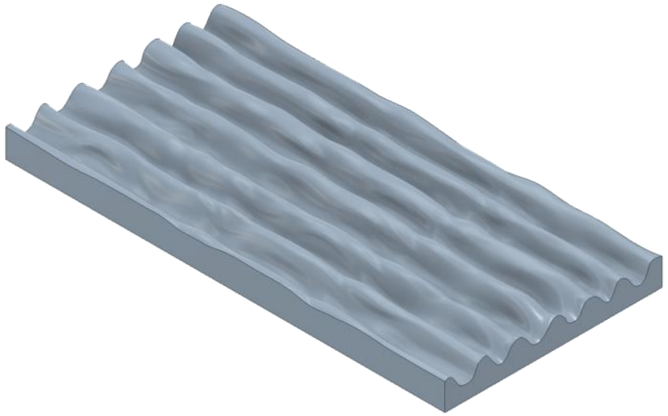
$F = 0$ | $0 < F_1$ | $0 < F_1 < F_2$

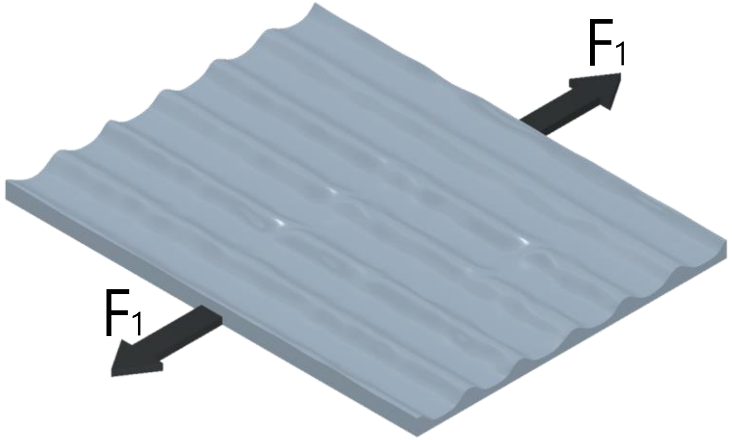
→ Inhomogeneous stress distribution on the wrinkled surface

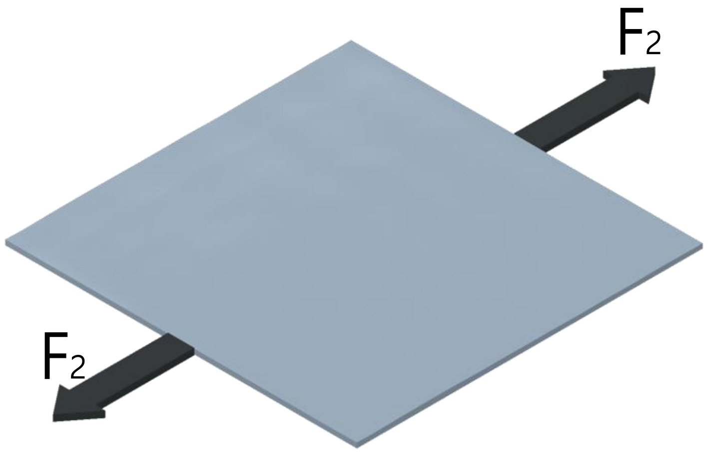
Biaxial failure mechanism

- Inhomogeneous stress distribution
- Crack propagation is hindered at wrinkles
- Huge number of small cracks

Pure shear failure mechanism







Initial state:

$\varepsilon = 0$

$F = 0$

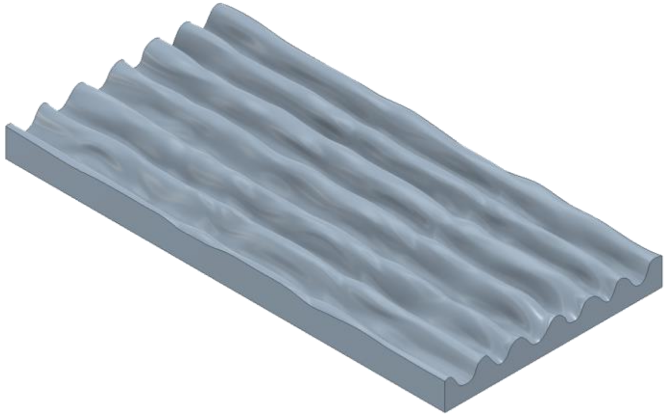
$\varepsilon < \varepsilon_{pre}$

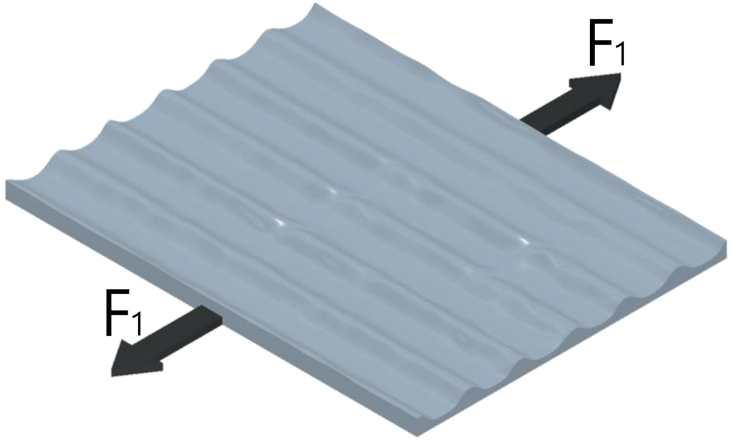
$0 < F_1$

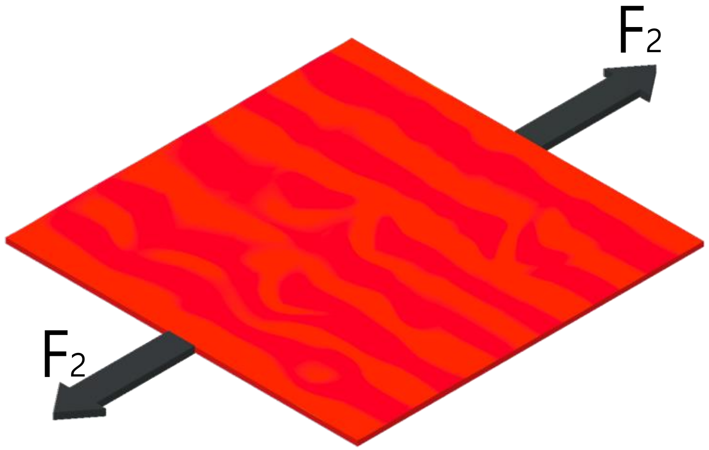
$\varepsilon = \varepsilon_{pre}$

$0 < F_1 < F_2$

Pure shear failure mechanism







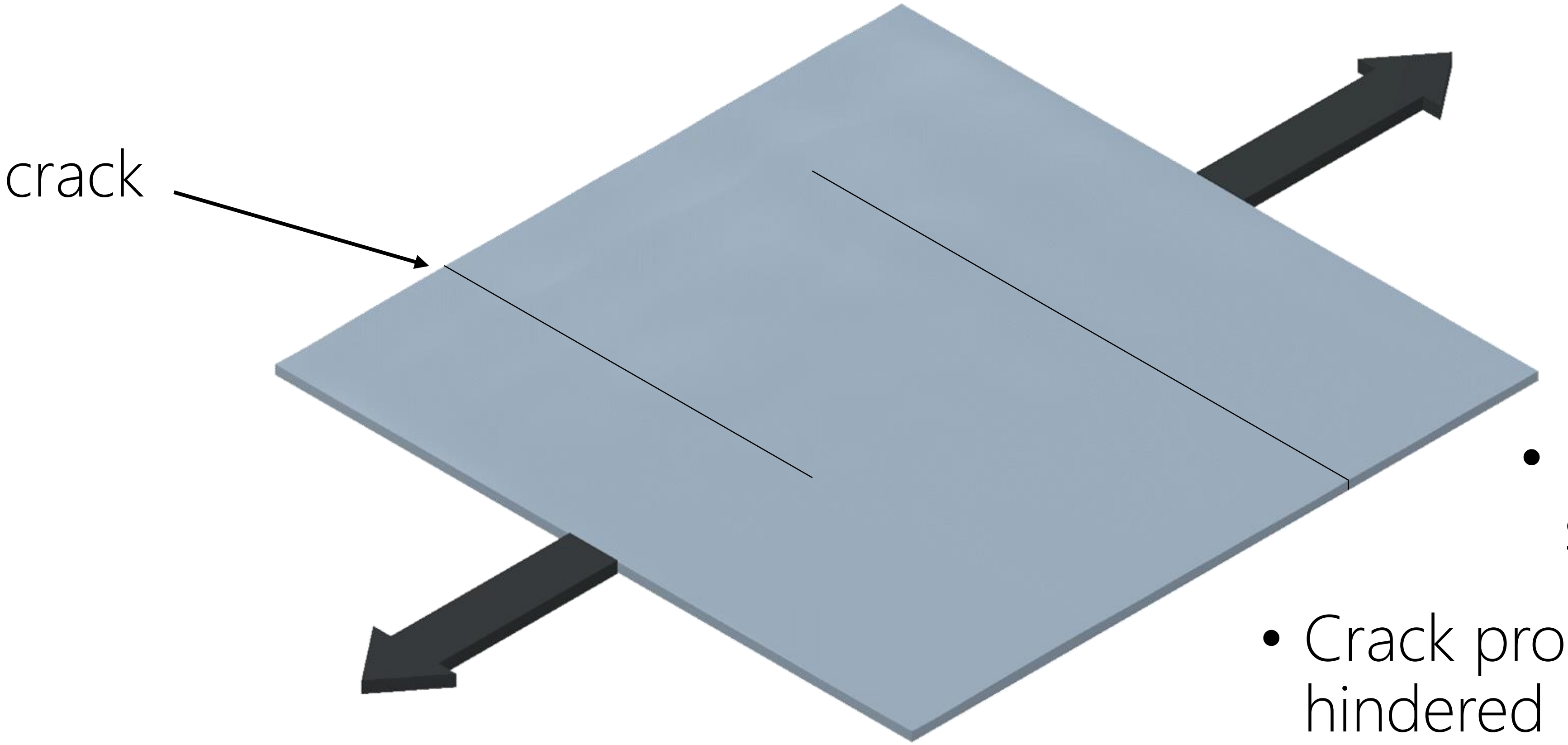
Initial state:

$\varepsilon = 0$ | $\varepsilon < \varepsilon_{pre}$ | $\varepsilon = \varepsilon_{pre}$

$F = 0$ | $0 < F_1$ | $0 < F_1 < F_2$

→ Homogeneous stress distribution on nearly flat surface

Pure shear failure mechanism



- Homogeneous stress distribution
- Crack propagation is not hindered
- Few, but large cracks

Content

- DECMAS Project
- Compliant electrode
- Evaluation of the electromechanical results
- Conclusion

Conclusion

Results:

- Reduction of residual stress has no drawbacks
- Using low stress nickel in the right combination offers advantages
- Highly recommend to use low stress thin films in all cases

Future work in the DECMAS project:

- Laser structuring

Acknowledgments

Thank you very much for your attention!

htw saar

DFG

KOMMMA
A DFG PRIORITY PROGRAMME

UNIVERSITÄT DES SAARLANDES

intelligent Material Systems Lab

Jonas Hubertus – jonas.hubertus@htwsaar.de

Thank you very much for your attention!

Jonas Hubertus – jonas.hubertus@htwsaar.de