

Research Training Group DFG RTG 2430 – IFRC

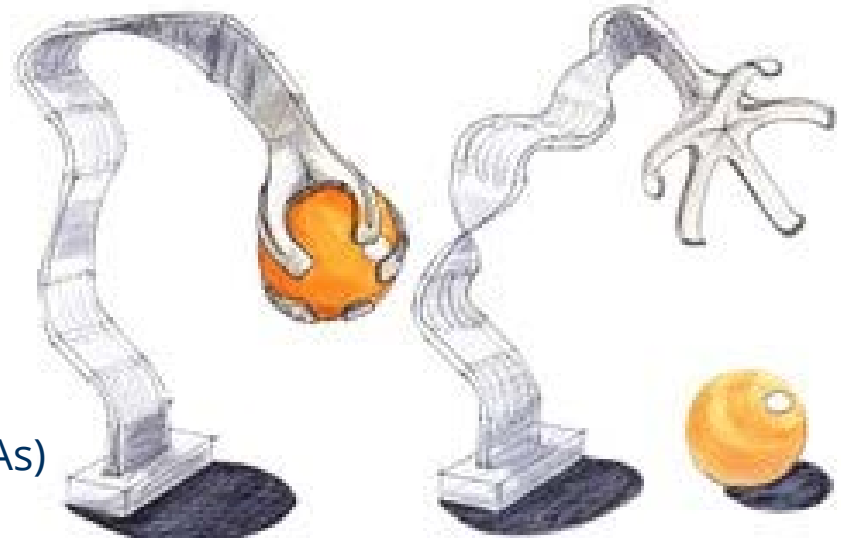
# Manufacturing of a helical, self-coiling dielectric polymer actuator

1st International Electronic Conference on Actuator Technology: Materials, Devices and Applications

Online | November 24<sup>th</sup> 2020

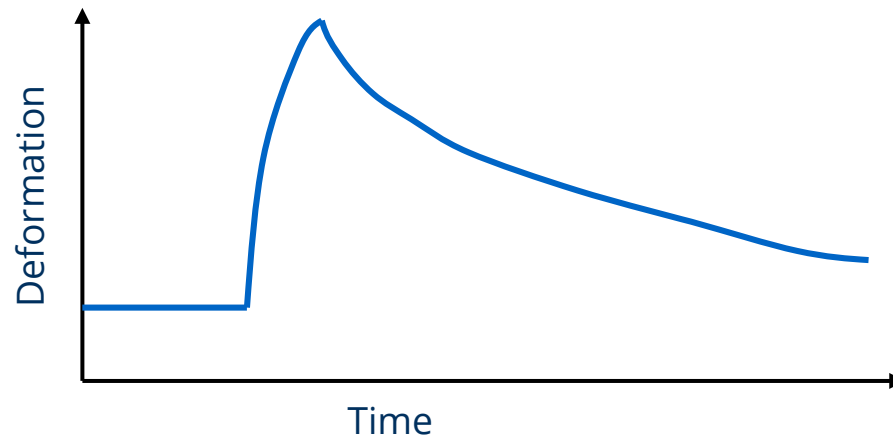
# Motivation

- Novel actuator materials required for new soft robotic applications
  - Strong
  - Fast
  - Robust
  - Self-Healing
  - Light
- Frequently used materials include:
  - Shape memory alloys/polymers (SMAs)
  - Pneumatics
  - Twisted coiled polymer actuators (TCPAs)
  - Dielectric elastomer actuators (DEAs)



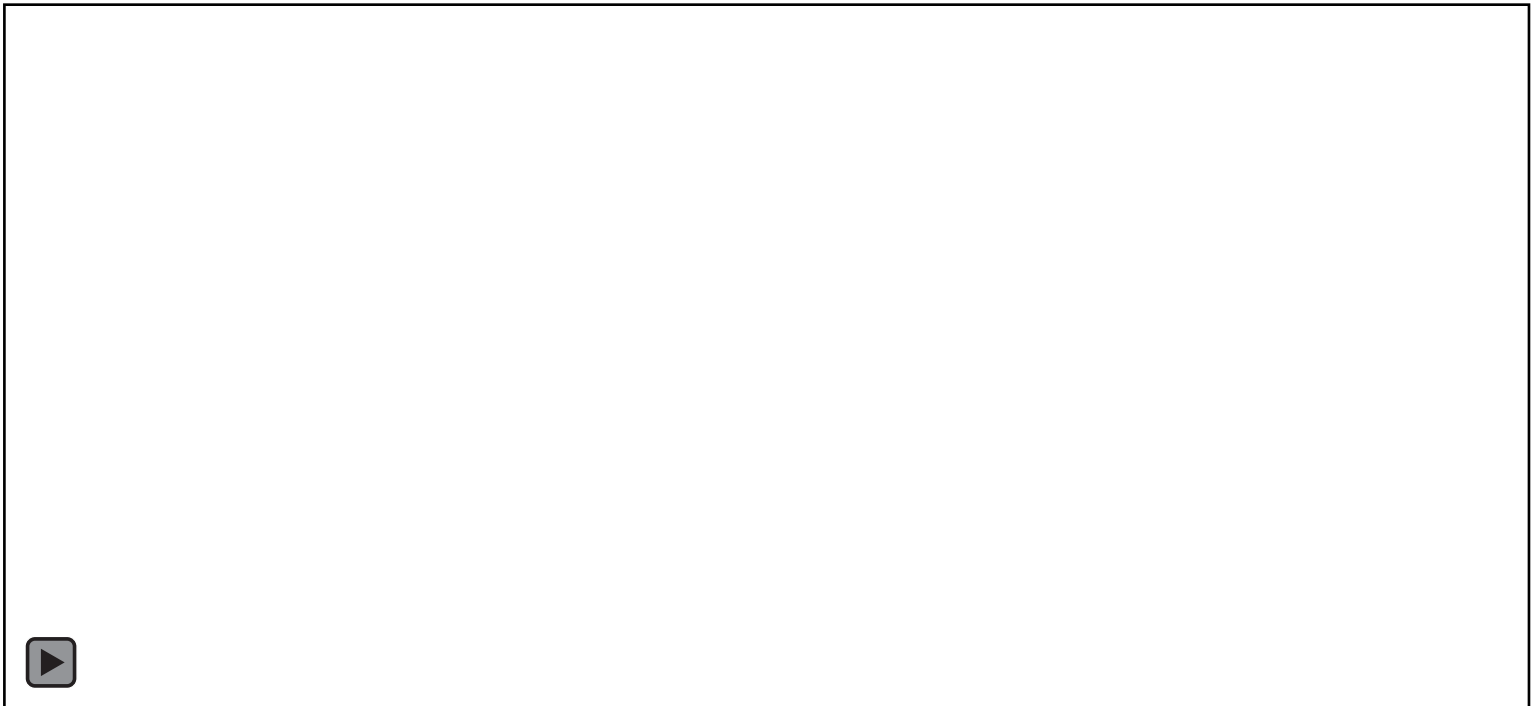
# Motivation

- SMAs offer high stress and work density but show hysteresis
- TCPAs have near to no hysteresis
- Operating frequency is low because heat needs to be dissipated
- Problem is worse if bundled up similar to natural muscle
- Active cooling is costly and leads to bulky systems



# Motivation

- DEAs offer high strain rates
- Low force
- Not robust



# Motivation

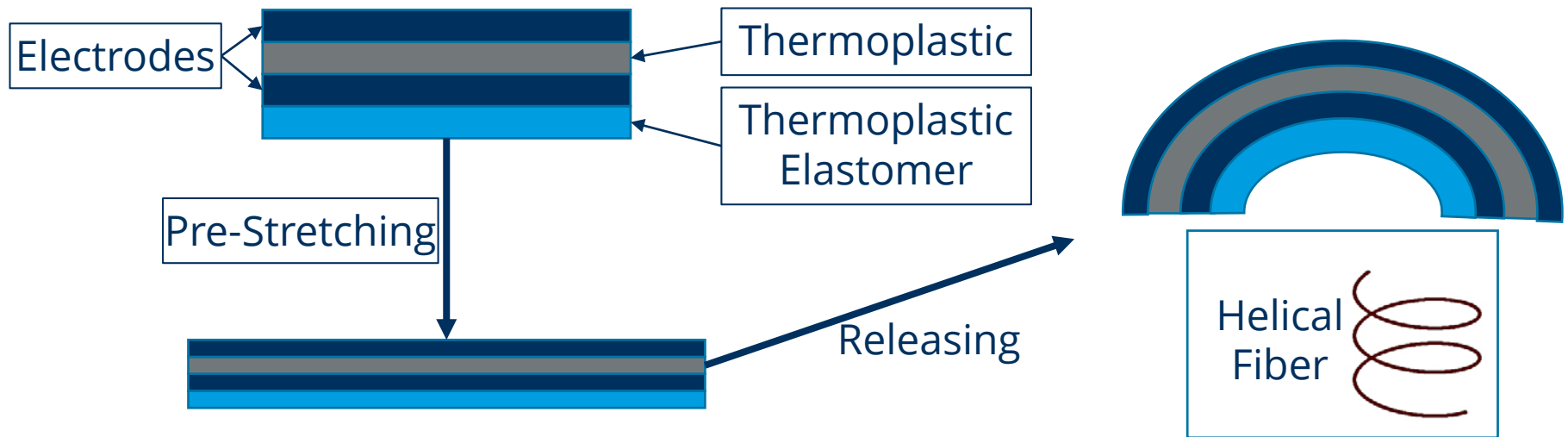
- DEAs offer high strain and strain rates
- Low force, needs pre-stretching device
- Low robustness

$$p_{eq} = \varepsilon_0 \varepsilon_r \frac{U^2}{t^2} \quad s_z = \frac{p_{eq}}{Y}$$


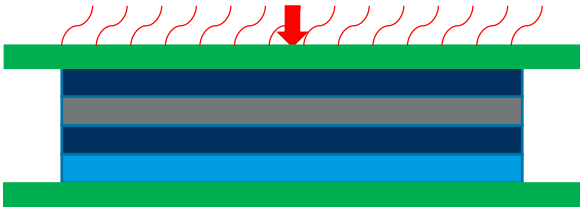
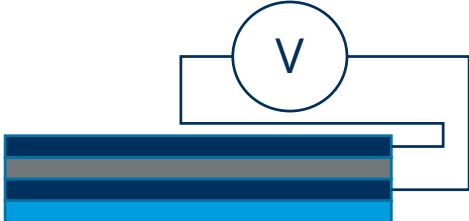
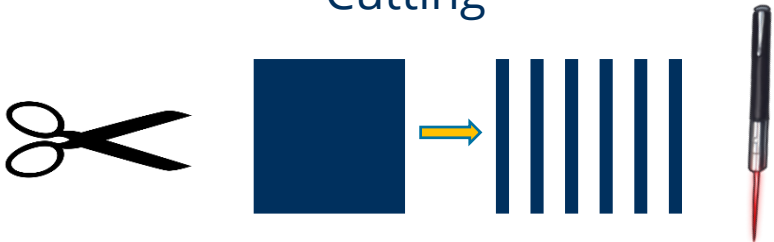

- Increase in  $\varepsilon$  or  $U$  disadvantageous
- Decrease in  $t$  leads to exceedingly thin films that are prone to tear and difficult to handle
  
- → Use of more robust thermoplastic materials
- → Strain gets negligible small

# Theoretical concept


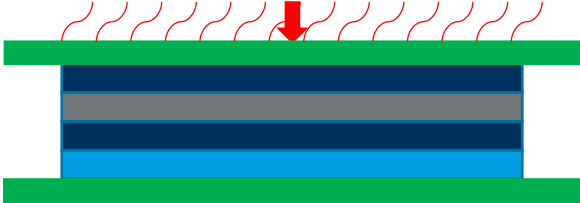
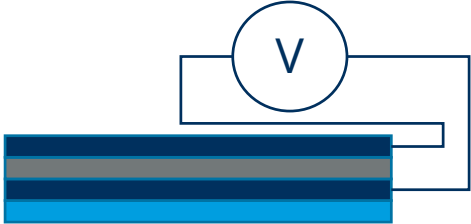


- Thermoplastic as dielectric layer (standard plastic wrap, 12 or 23  $\mu\text{m}$  thick)
- Self-coiling fiber to magnify strain



# Manufacturing process - Overview

<p style="text-align: center;">Stacking</p> 	<p style="text-align: center;">Pressing</p> 	<p style="text-align: center;">Contacting</p> 
<ul style="list-style-type: none"> <li>- Conductive particles</li> <li>- Polymer materials</li> <li>- Film thickness</li> </ul>	<ul style="list-style-type: none"> <li>- Temperature</li> <li>- Pressure / Vacuum</li> <li>- Time</li> </ul>	<ul style="list-style-type: none"> <li>- Material</li> <li>- Location</li> </ul>
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# Manufacturing process - Stacking

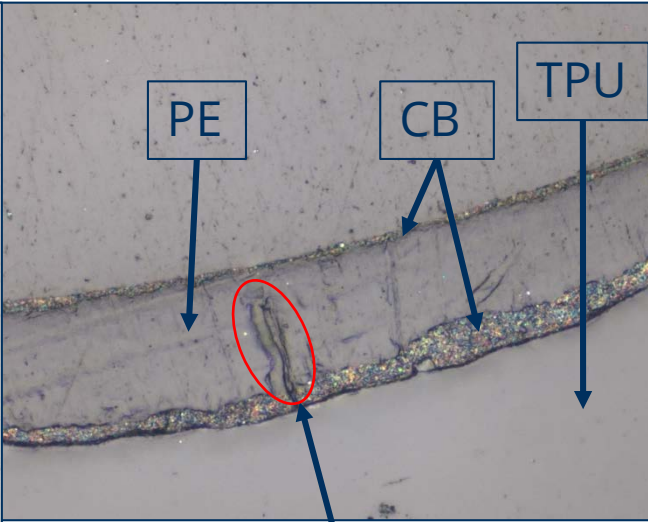
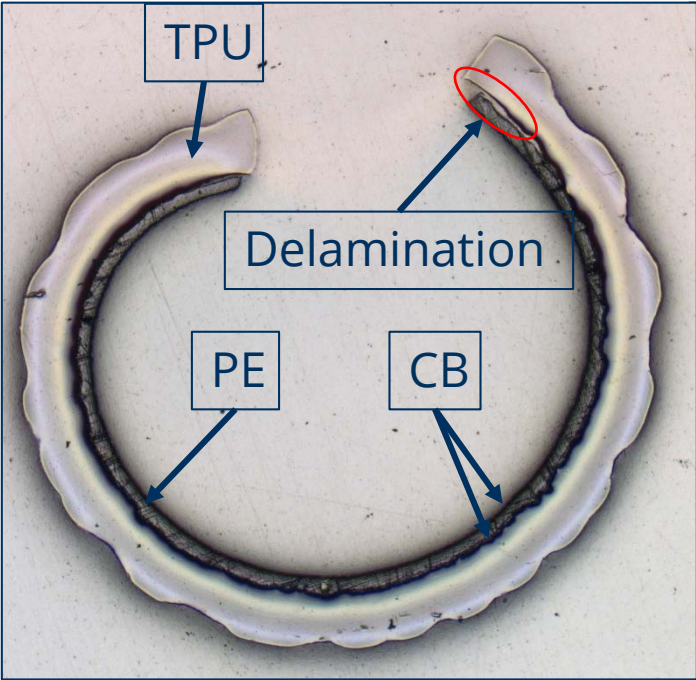
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# Manufacturing process - Stacking


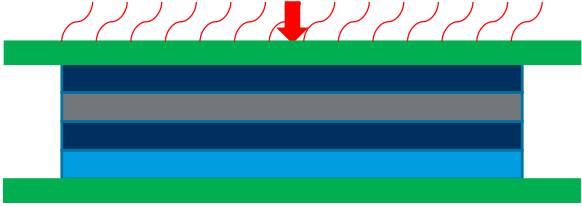
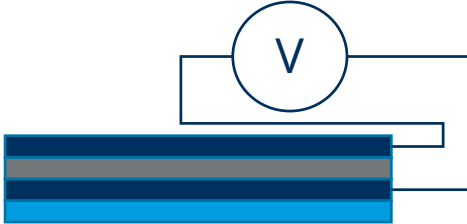
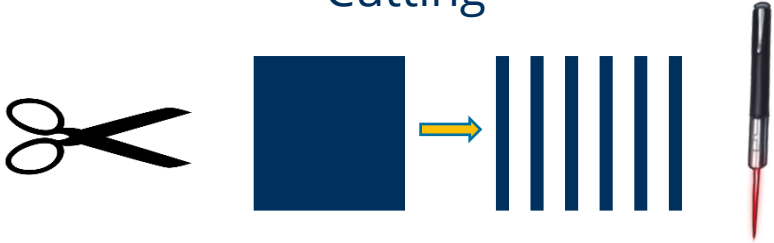



Agglomerated → Dispersed Excessive



Tear in the PE-film


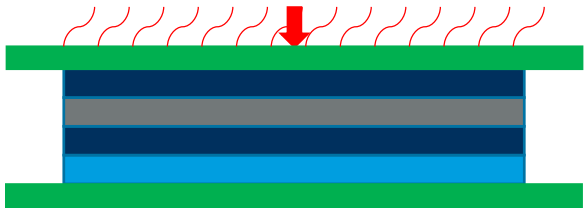
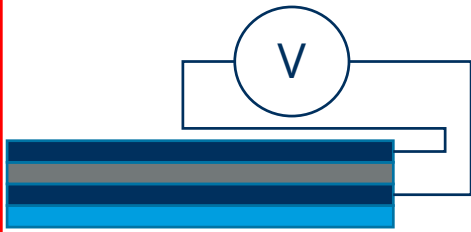
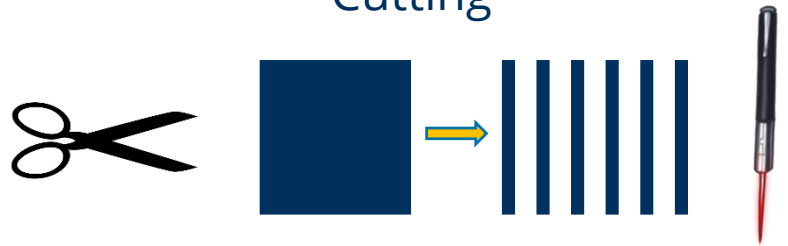

# Manufacturing process - Pressing

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# Manufacturing process - Pressing

- Vacuum to evacuate air bubbles between layers
- Temperature chosen accordingly to differential scanning calorimetry
- Temperature slightly over PE's melting point
- Pressure of 10 bar
- Pressure held up for two minutes after target temperature is reached

# Manufacturing process - Contacting

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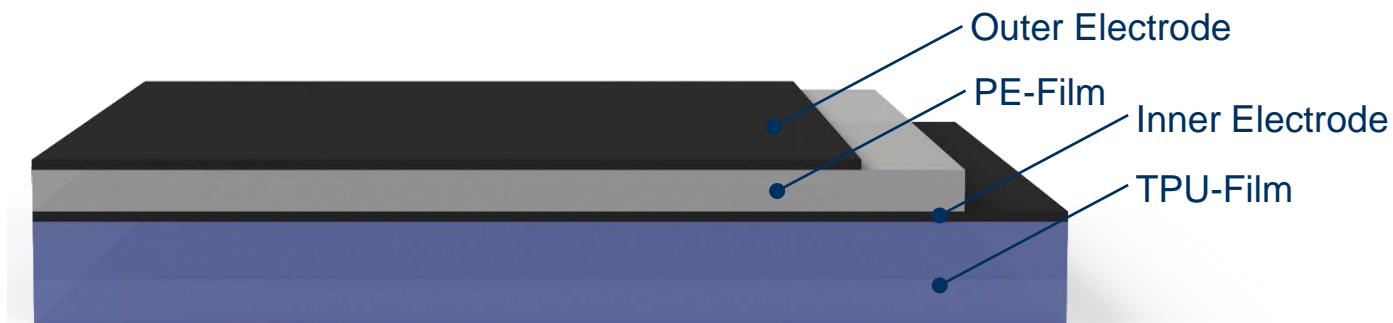
# Manufacturing process - Contacting

- Several methods evaluated:
  - Aluminum foil
  - Copper wire
  - Silver-plated yarn
  - Open electrodes


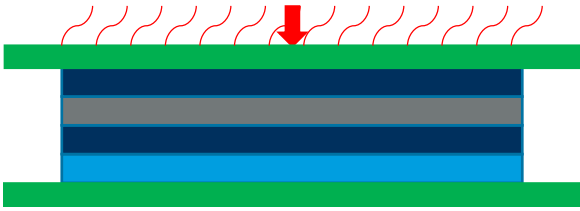
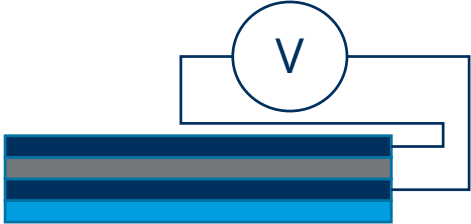
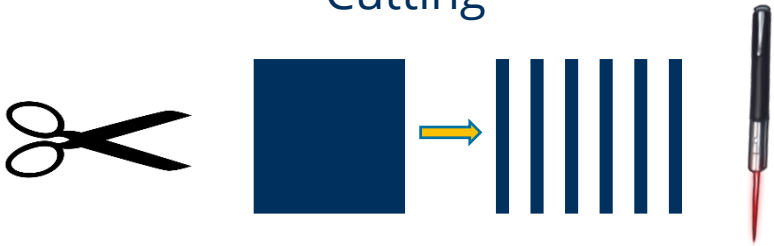



# Manufacturing process - Contacting

- Several methods evaluated:
  - Aluminum foil
  - Copper wire
  - Silver-plated yarn
  - **Open electrodes**



# Manufacturing process - Cutting

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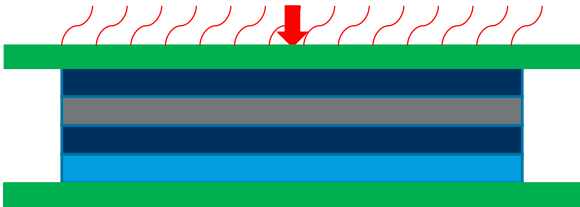
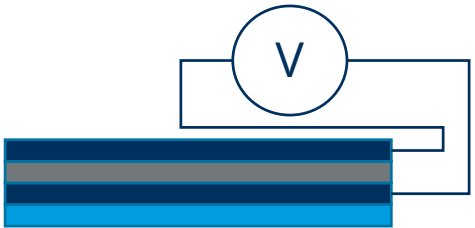


# Manufacturing process - Cutting

- Manual cutting:
  - Works but many samples have some kind of defect after pre-stretching
- Laser cutting:
  - Better reproducibility
  - Seals the edges and prevents short-circuit between electrode layers





# Manufacturing process - Stretching

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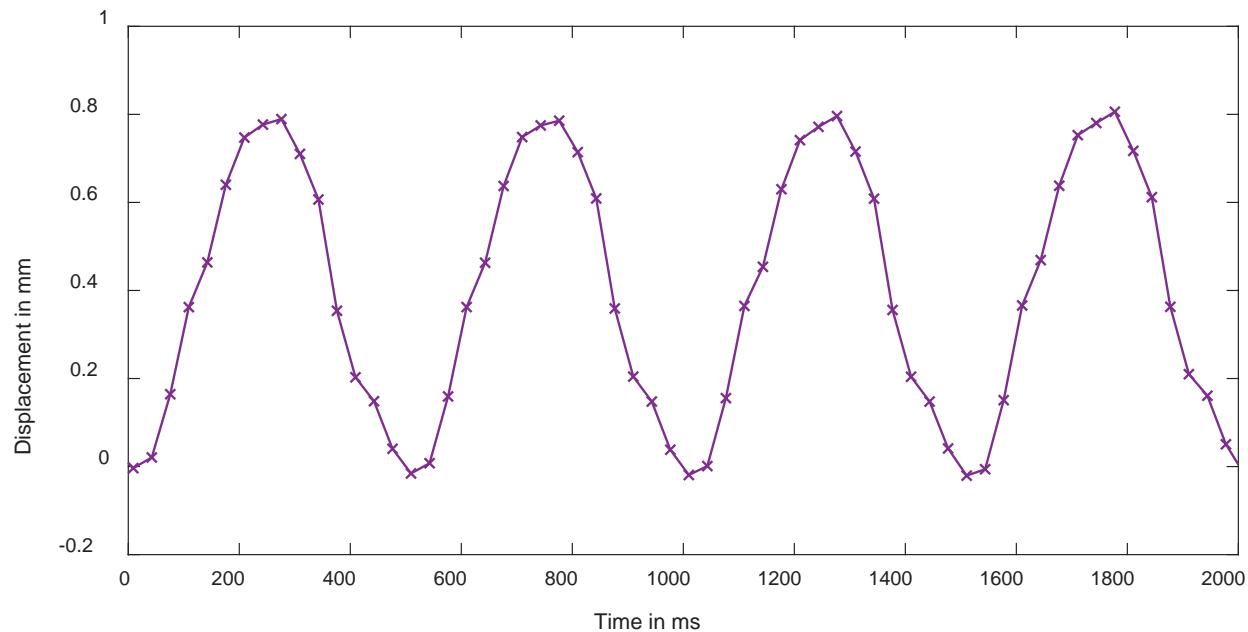
# Manufacturing process - Stretching

- Too little pre-stretch: No coil formation
- Too much pre-stretch: Defect sample



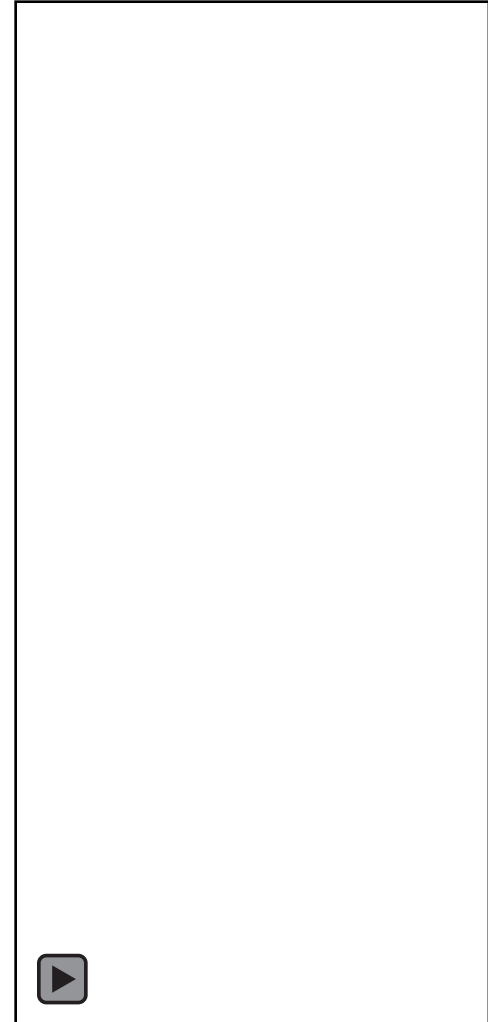
# Actuation

- Weight attached, which is six times the actuators own weight
- Voltage of 5 kV applied at 2 Hz
- → 0.8 mm Contraction equivalent to -2 % strain
- → Strain rate of 8 %/s



# Actuation

- New actuator material is:
  - Fiber-shaped
  - Electrically activated
  - High strain rate
  - Low strain
  - Robust
- Has potential for further optimization with regard to:
  - Material
  - Geometry
  - Manufacturing process



# Thank you for your attention!

Do you have any questions?

**Please contact me: [Johannes.Mersch@tu-dresden.de](mailto:Johannes.Mersch@tu-dresden.de)**