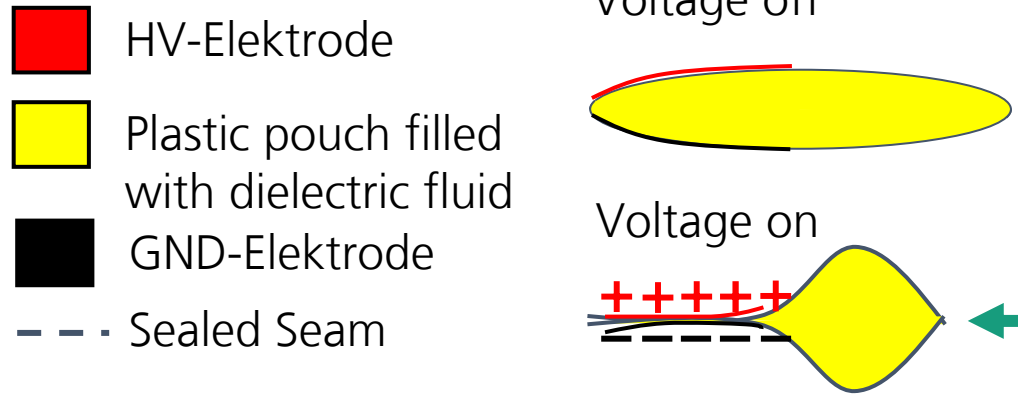**4Smarts Conference - Darmstadt, 14-15. November 2024**

# HASEL actuators in soft structures for robot gripping applications

Johannes Ehrlich; Peter Löschke, Marie Richard-Lacroix, Thomas Gerlach, Gerhard Domann and Holger Böse

Hydraulic amplified self healing actuators (HASEL)
Working principle

HV-Elektrode

Plastic pouch filled with dielectric fluid

GND-Elektrode

- - - Sealed Seam

Voltage off

Voltage on

+ + + + +

Video: 5kV applied to PEDOT electrodes, TPU pouch bag

- Various polymer pouch material possible (PP, OPP, BOPP, TPU, PET etc…)-> also biodegradable foils

- **Electrode material:** PEDOT (transparent) or carbon black

- Dielectric Fluid (PAO; silicone oil; Bio-based Oil)

- Various geometries with large actuations

- **Advantage:** high performance, simple, cheap;

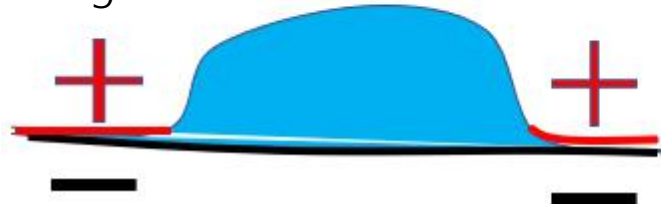- **Disadvantage:** liquid system

Video: 5kV 1 – 10Hz applied to carbon electrodes – PET pouch bag

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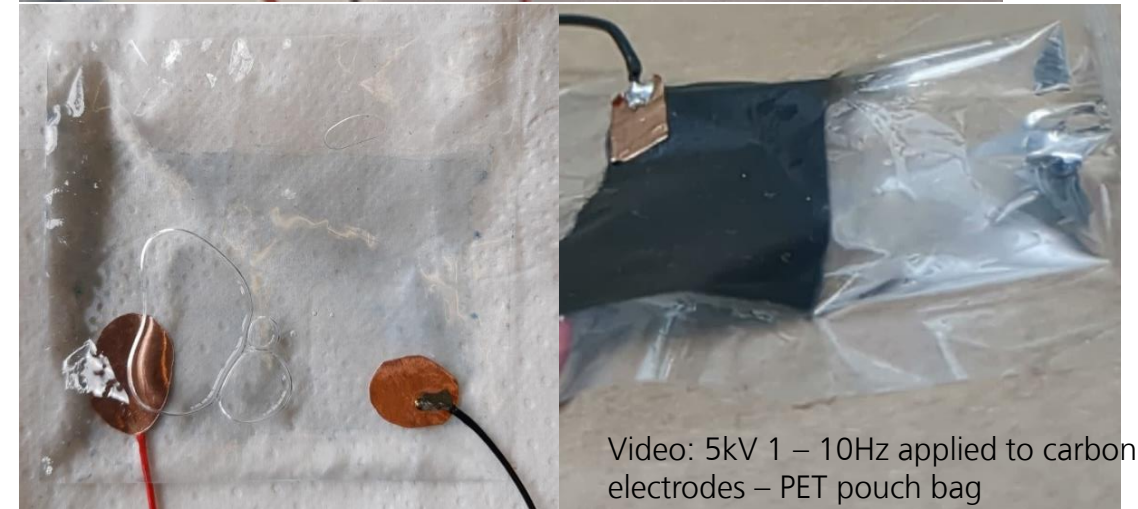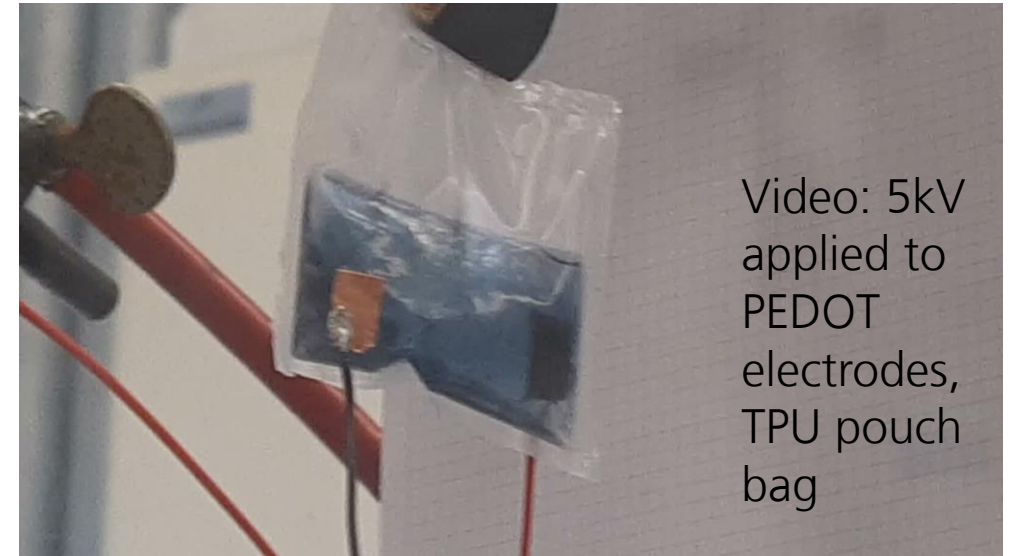
Hydraulic amplified self healing actuators (HASEL)
Working principle

Voltage off

Voltage on

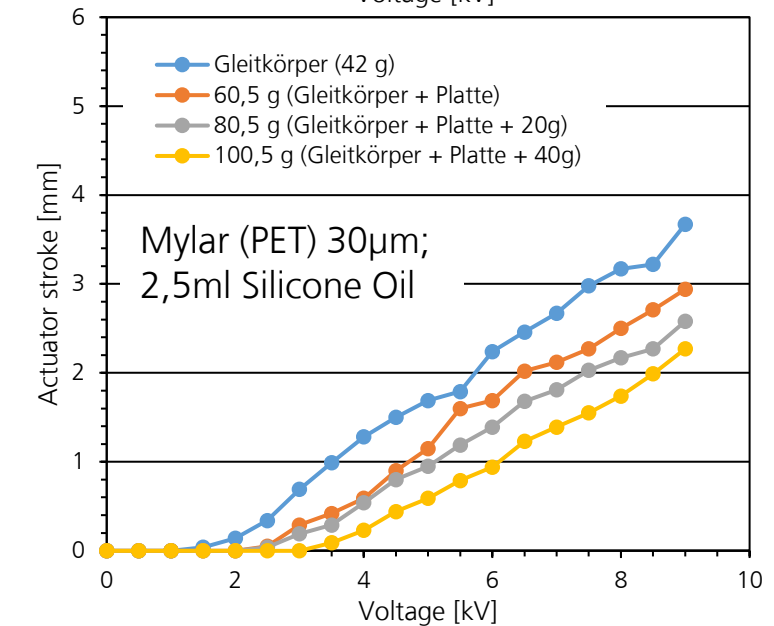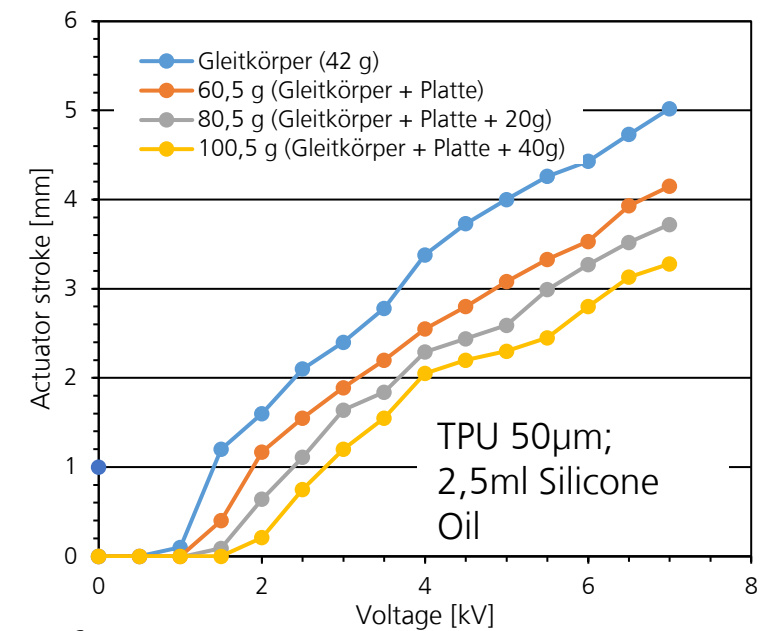- ▇ (red) HV-Elektrode
- ▇ (blue) Plastic pouch filled with dielectric fluid
- ▇ (black) GND-Elektrode
- - - - Sealed Seam

25 mm

50 mm

- Direct mechanical lifting of weight
- Mathematical model available, continous refinemend

Legend:
- Gleitkörper (42 g)
- 60,5 g (Gleitkörper + Platte)
- 80,5 g (Gleitkörper + Platte + 20g)
- 100,5 g (Gleitkörper + Platte + 40g)

TPU 50µm; 2,5ml Silicone Oil

Actuator stroke [mm] vs Voltage [kV]

Legend:
- Gleitkörper (42 g)
- 60,5 g (Gleitkörper + Platte)
- 80,5 g (Gleitkörper + Platte + 20g)
- 100,5 g (Gleitkörper + Platte + 40g)

Mylar (PET) 30µm; 2,5ml Silicone Oil

Actuator stroke [mm] vs Voltage [kV]

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Hydraulic amplified self healing actuators (HASEL)
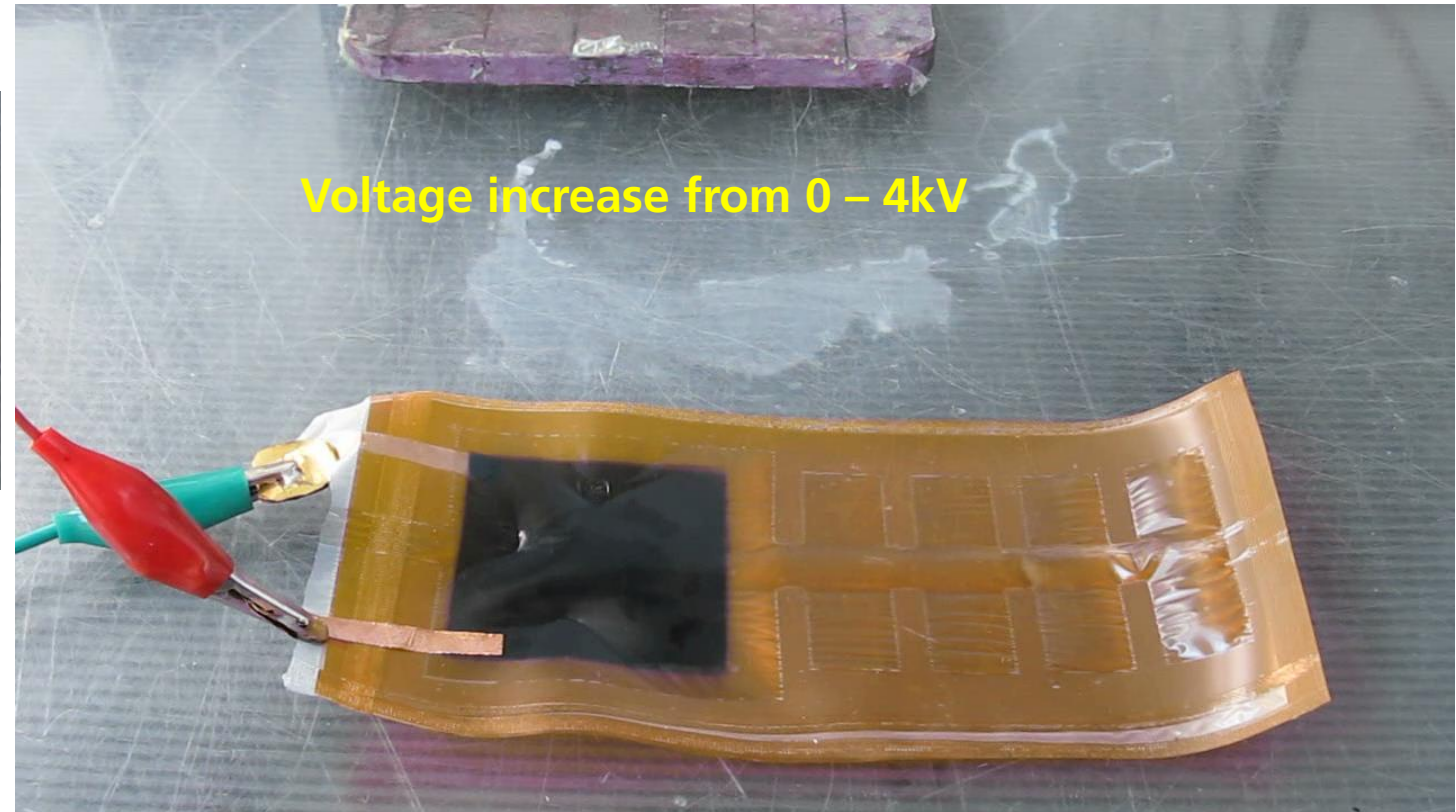## Working principle

Passive System: 45 mm x 14 mm

Active Electrode: 45 mm x 45 mm

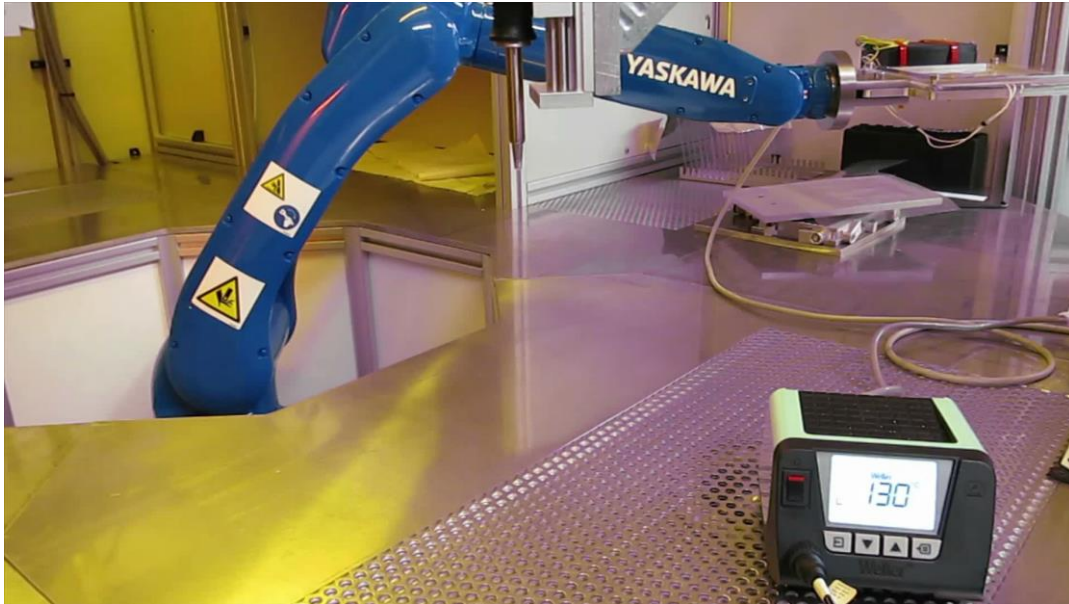- Oil transport from active to passive system
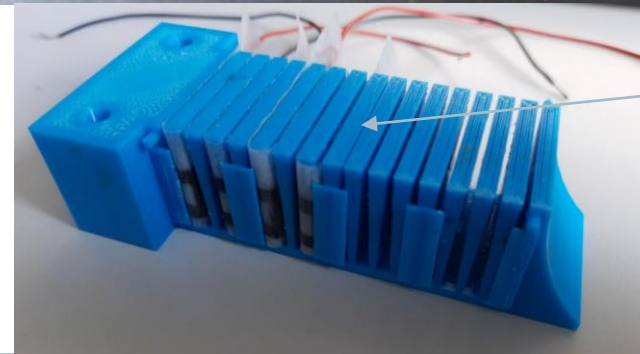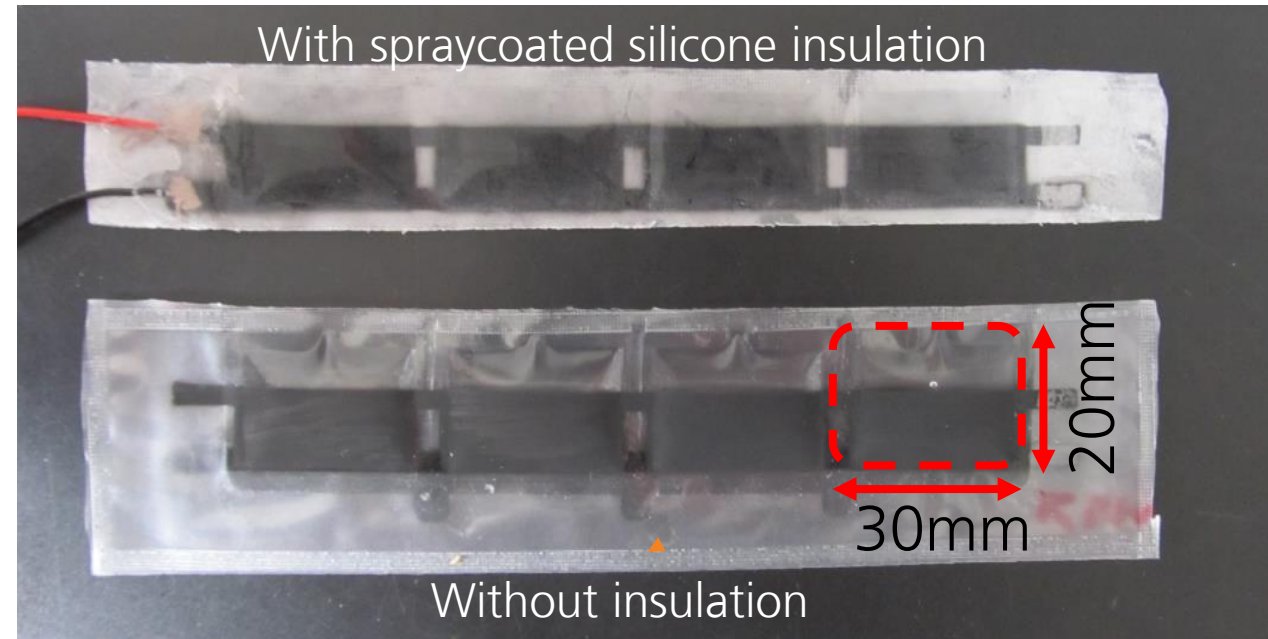- Passive stiffener necessary for large bends

Voltage increase from 0 – 4kV

Video: 4kV applied to PEDOT electrodes

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Hydraulic amplified self healing actuators (HASEL)
Manufacturing of HASEL actuators

With spraycoated silicone insulation

20mm

30mm

Without insulation

HASEL actuators folded into a passive and flexible 3D printed support structure

- Semi-automated sealing of HASEL pouches with MARAPRINT robot system (300 – 800 mm sealable area pending)
- Coating of processed HASEL actuators with silicone for high voltage insulation
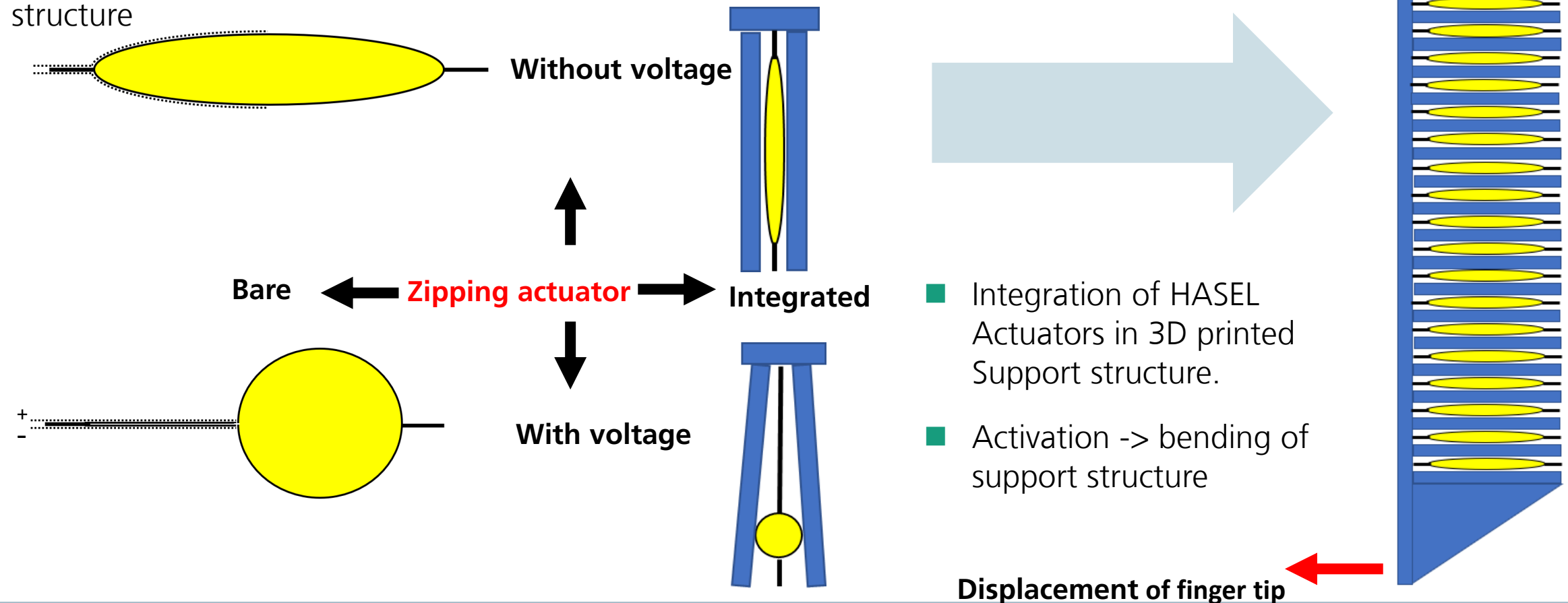- Use of HASEL chain in 3D printed structure.

Confidential – not for public use

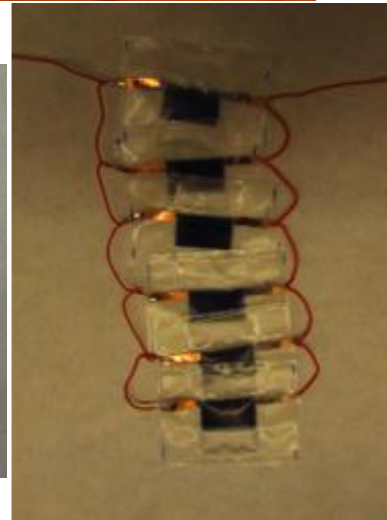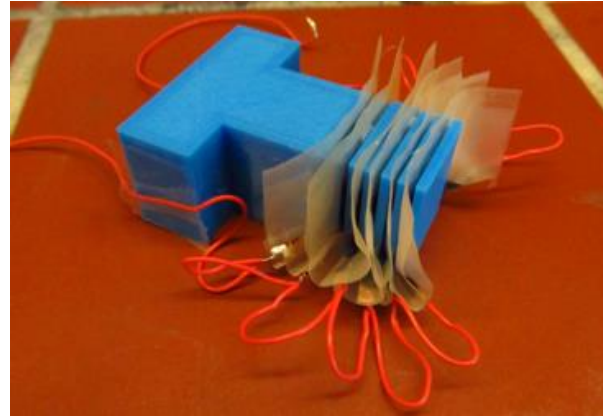# Hydraulic amplified self healing actuators (HASEL)
Working principle – steps to soft-robot finger

Single HASEL actuator
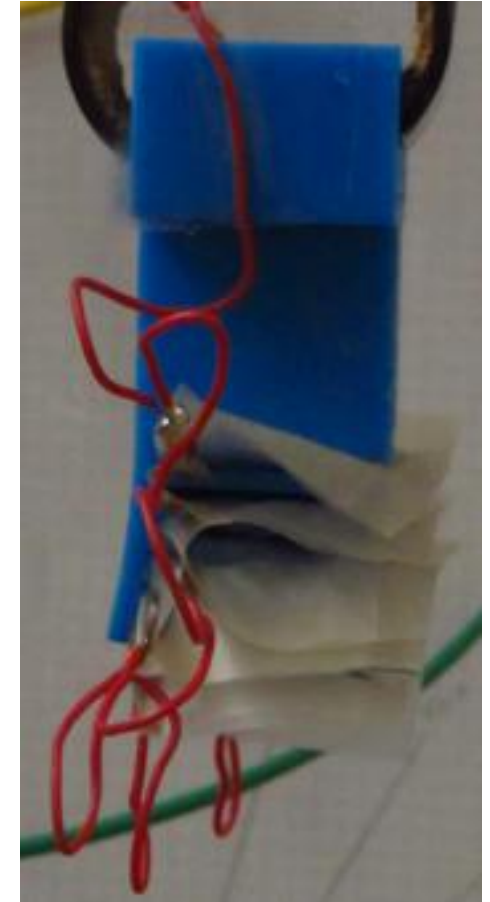Polymer pouch with electrodes and filled with oil and confinement in gap of finger structure

Without voltage

Bare ← **Zipping actuator** → **Integrated**

With voltage

- Integration of HASEL Actuators in 3D printed Support structure.

- Activation -> bending of support structure

Displacement of finger tip

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Hydraulic amplified self healing actuators (HASEL)
Working principle – steps to soft-robot finger

0 kV

4 kV

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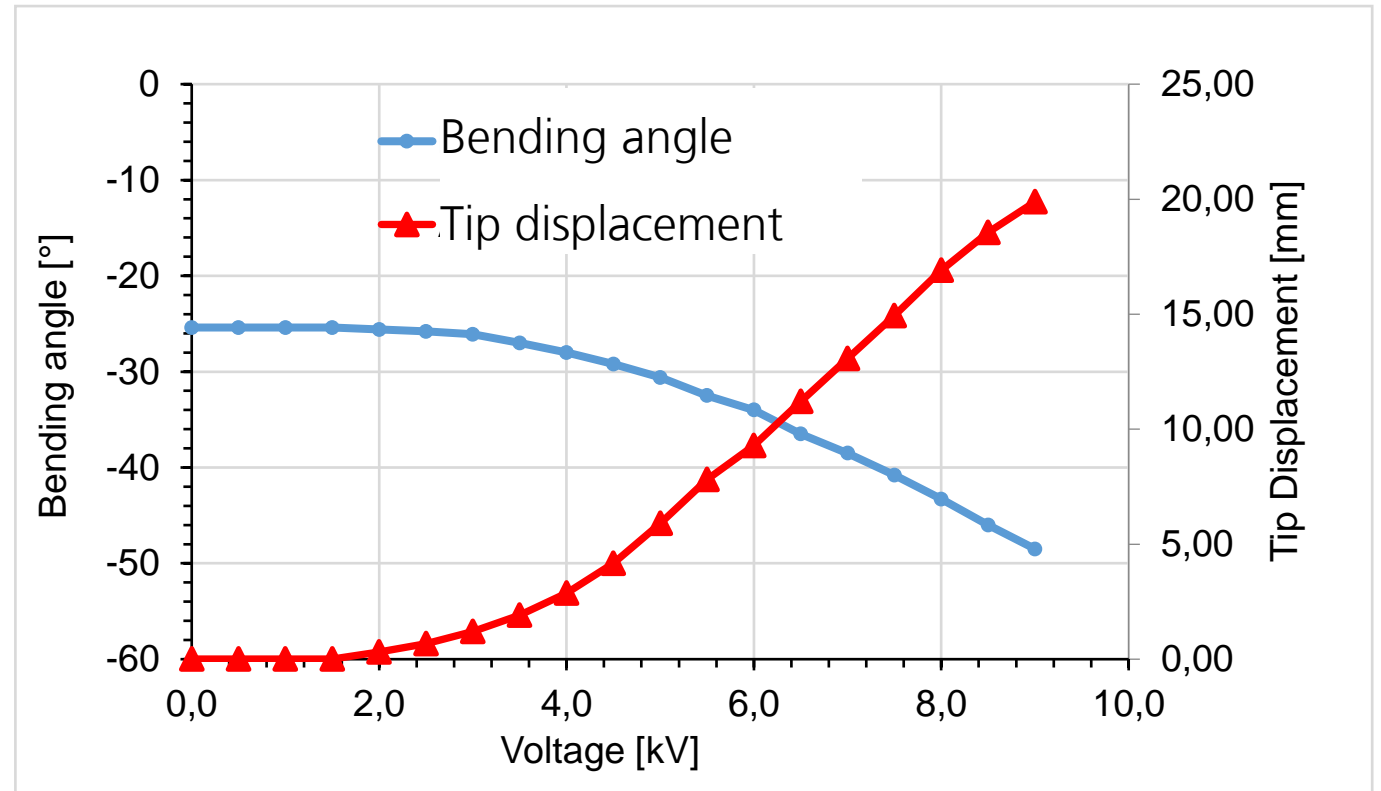HASEL actuators in soft structures for robot gripping applications

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Hydraulic amplified self healing actuators (HASEL)

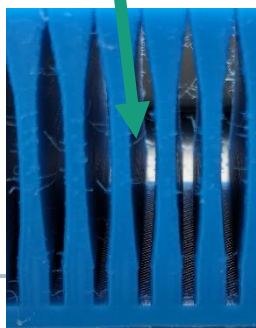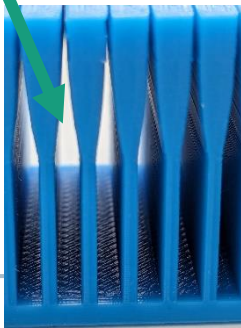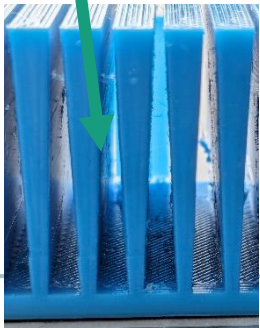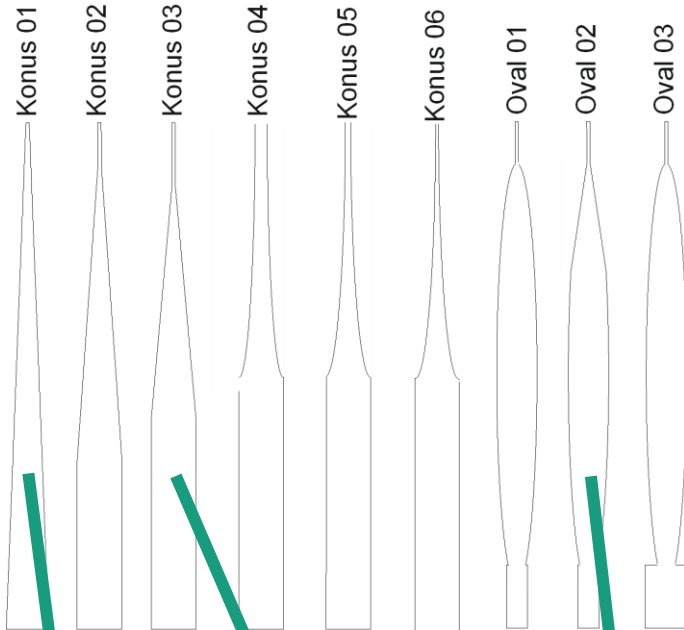## Working principle – Soft-robot finger

- 5 x 4 HASEL chain with 50µm TPU foil and silicone oil in 3D printed support structure (TPU shore **A 95**)
- Individual adressable actuator chains – finger joints possible
- TIP displacement of approx. 20mm and bending angle of about 25° possible – **but large pre-bending!**
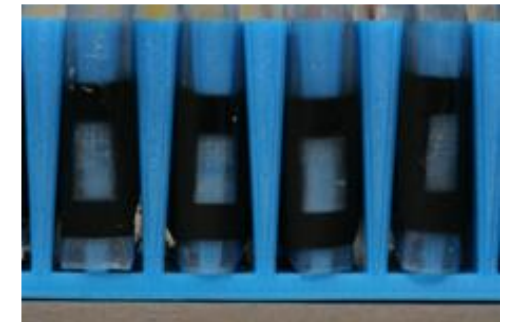
Hydraulic amplified self healing actuators (HASEL)
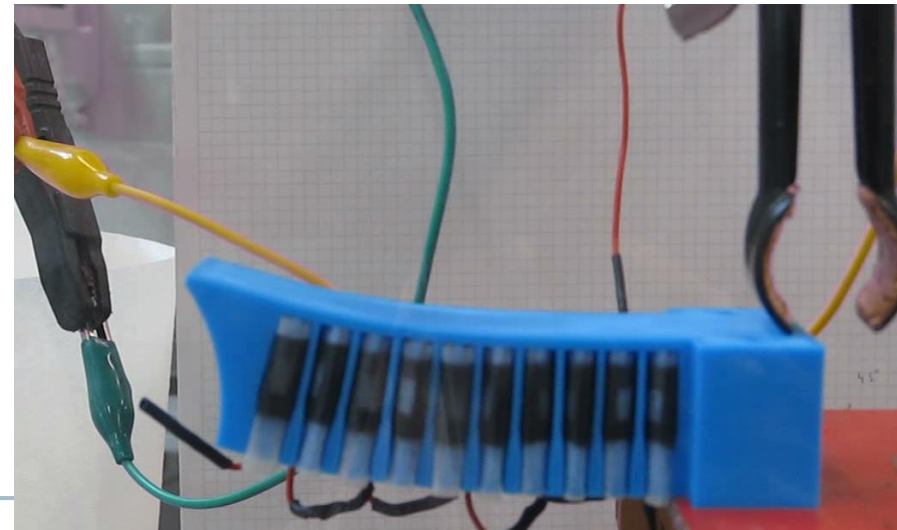## Working principle – Soft-robot finger

Support structures with various HASEL gap shapes have been produced by 3D printing

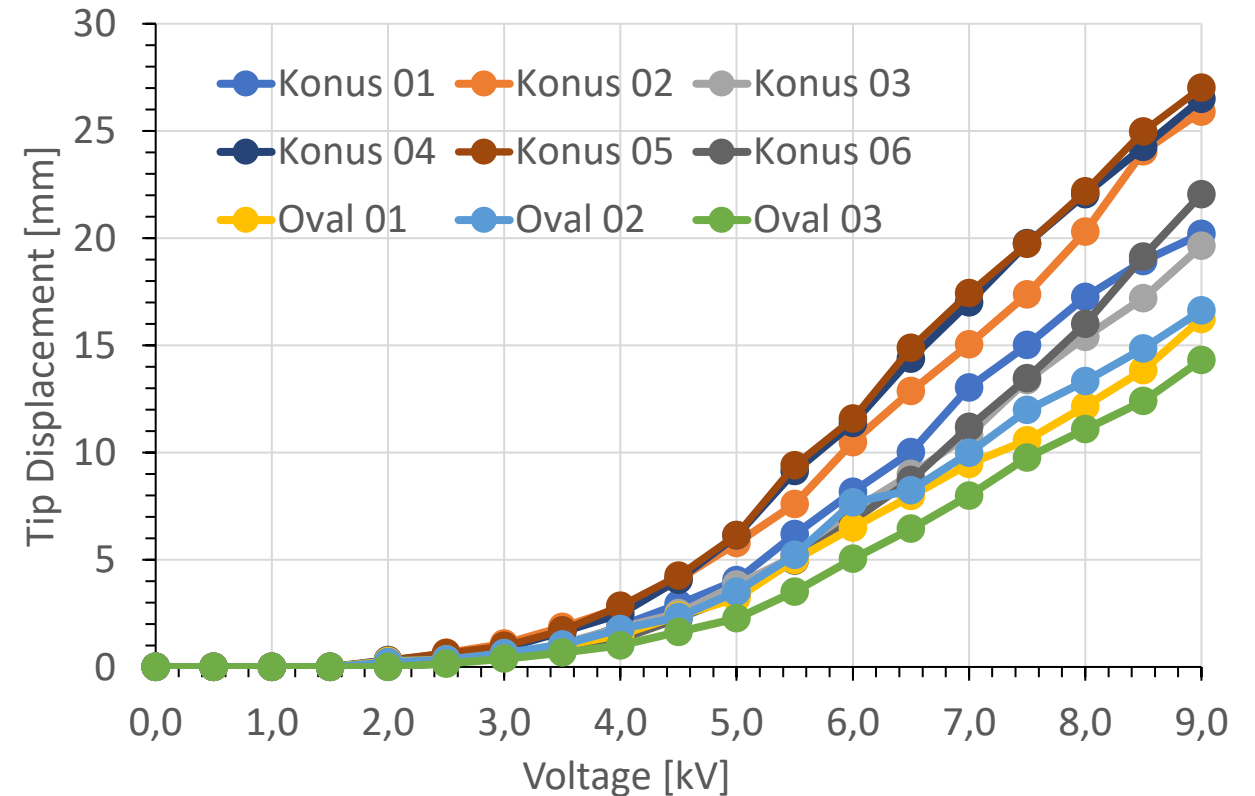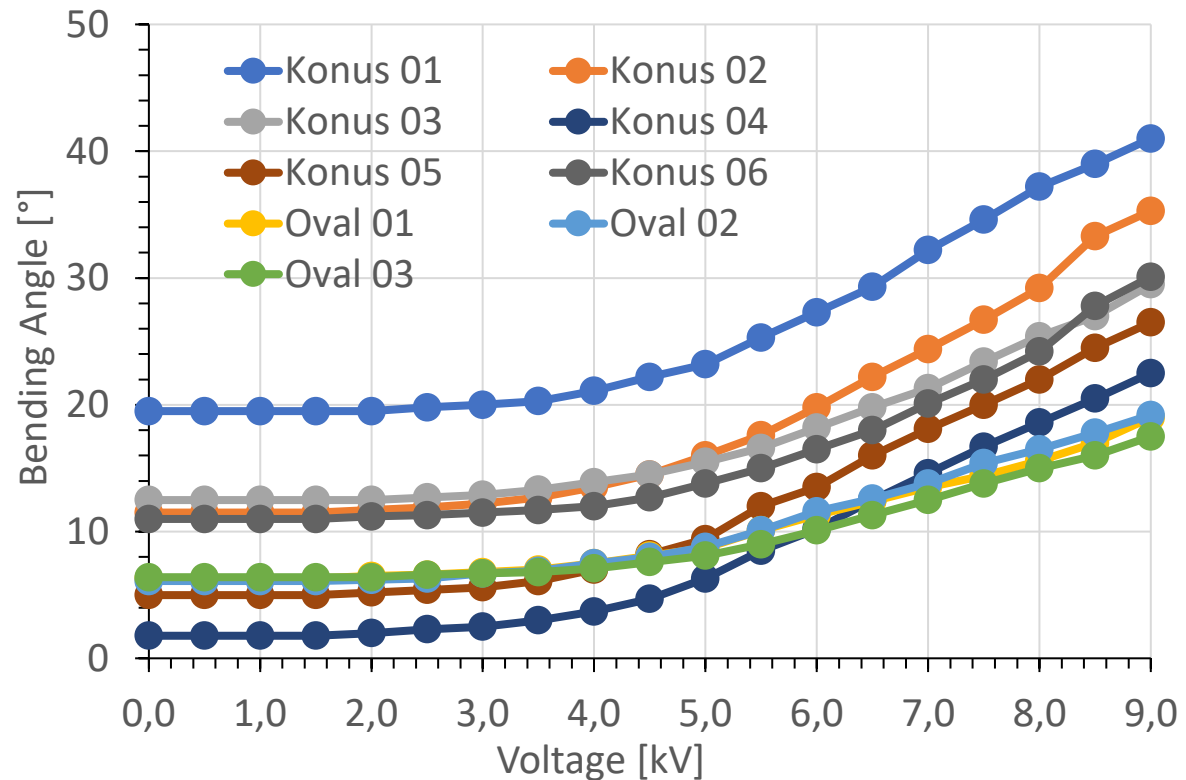Konus 01 Konus 02 Konus 03 Konus 04 Konus 05 Konus 06 Oval 01 Oval 02 Oval 03
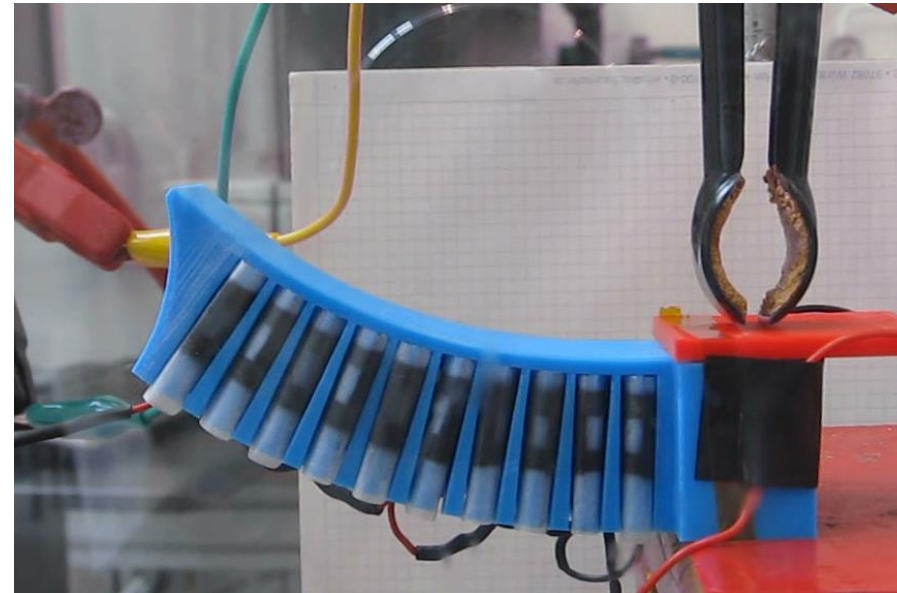
**Konus 01 structure
-> HIGH pre-bending**

**Konus 04 structure
-> LOW pre-bending**

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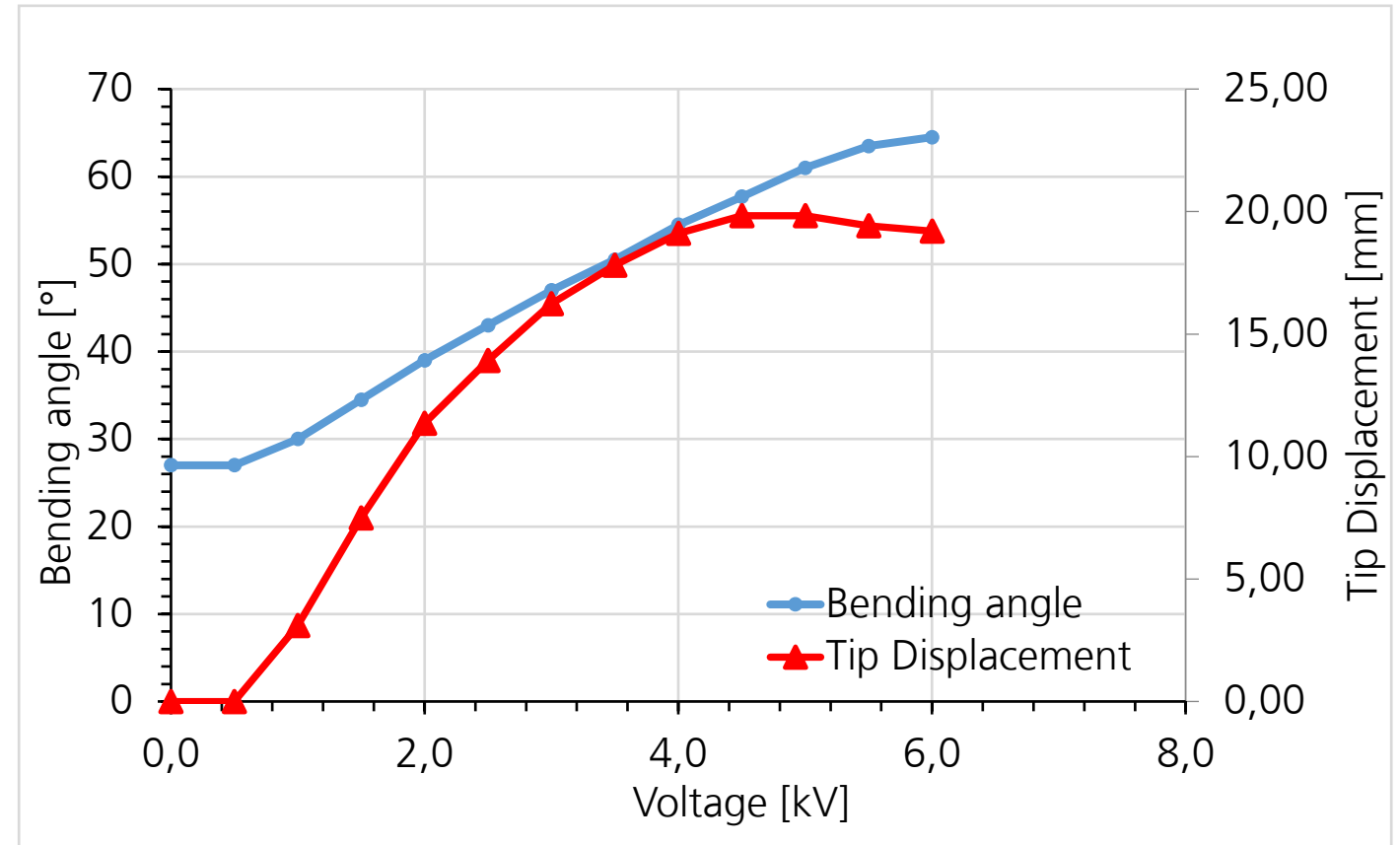# Hydraulic amplified self healing actuators (HASEL)
Working principle – Soft-robot finger

- Varaiation of gap structure with a **Konus** and **Oval** structure
- Gap structure shape influence pre-bending and overall tip displacement angle
- Konus04 structure identified as best shot

Hydraulic amplified self healing actuators (HASEL)

Working principle – Soft-robot finger

- 5 x 4 HASEL chain with 50µm TPU foil and silicone oil in 3D printed support structure (TPU shore **A 60**)
- Individual adressable actuator chains – finger joints possible
- **Still pre-bending because of soft and not symmetric structure. Tip displacement 20mm.**

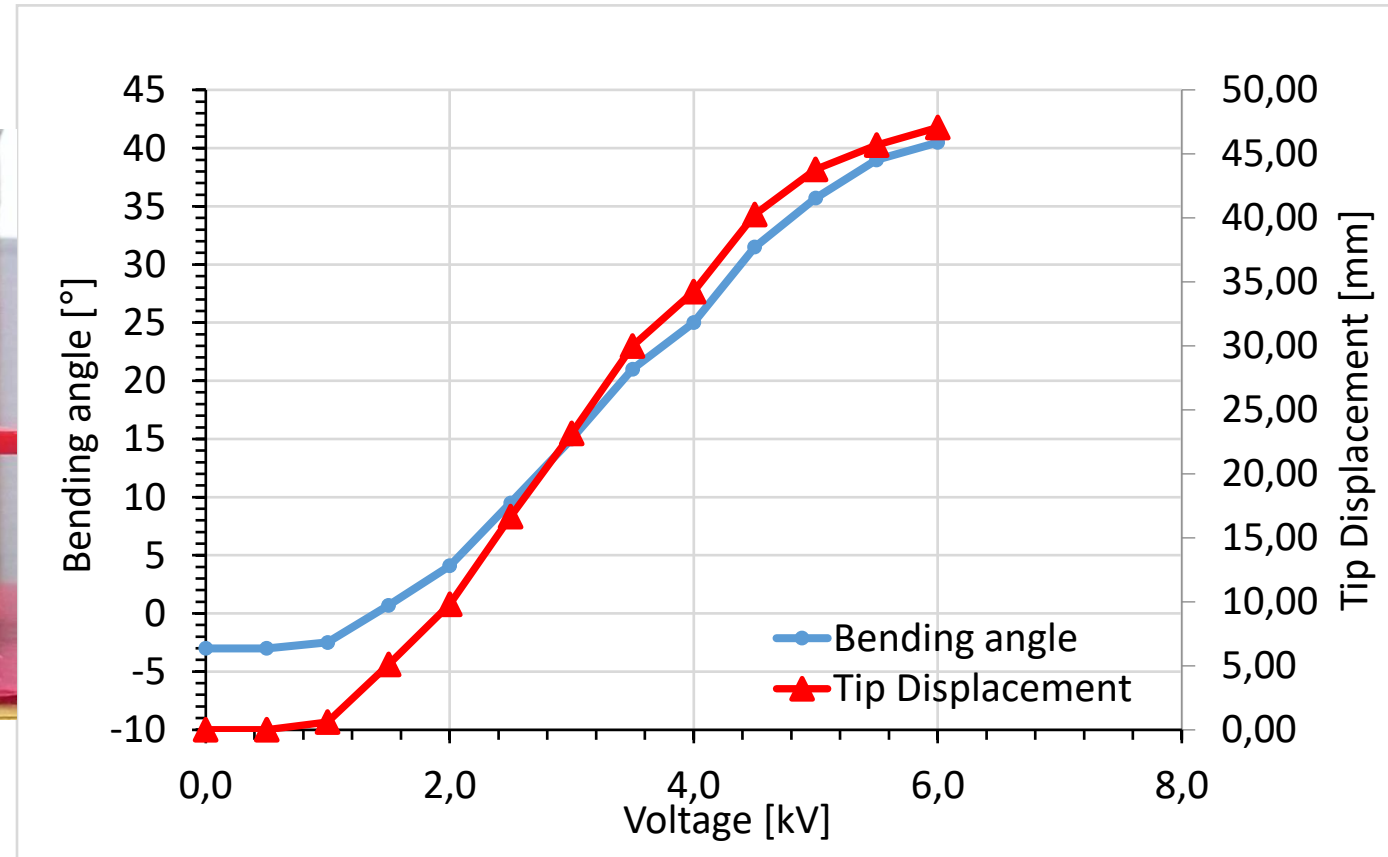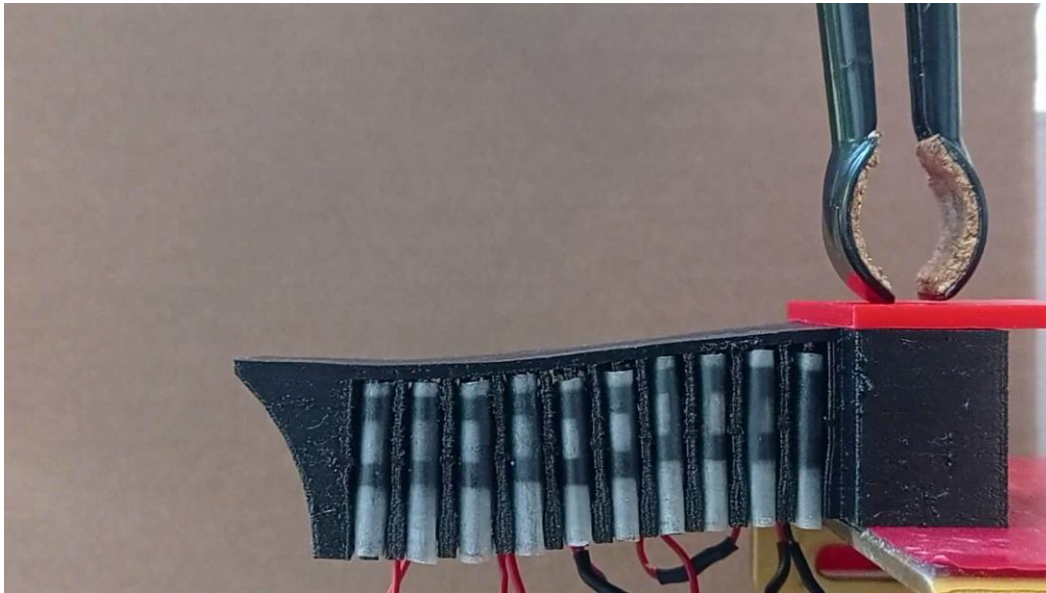# Hydraulic amplified self healing actuators (HASEL)
Working principle – Soft-robot finger

- 5 x 4 HASEL chain with 50µm TPU foil and silicone oil in 3D printed support structure (TPU shore **A 60**)
- Flat characterisation results in over 40° of bending angle and 45 mm of Tip displacement
- **Best improvement of pre-bending**

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Hydraulic amplified self healing actuators (HASEL)
## Working principle – Soft-robot finger & gripper
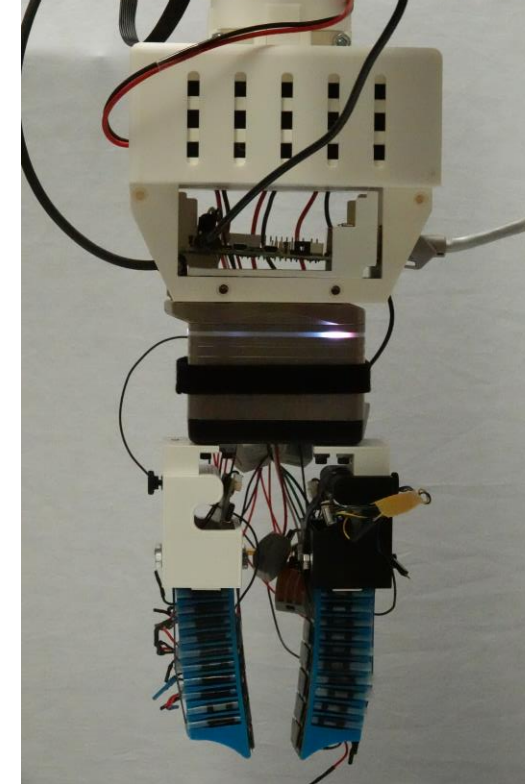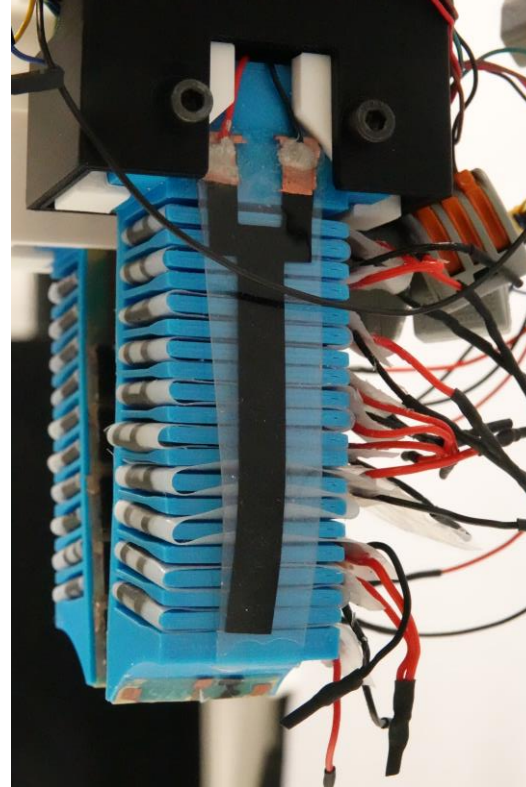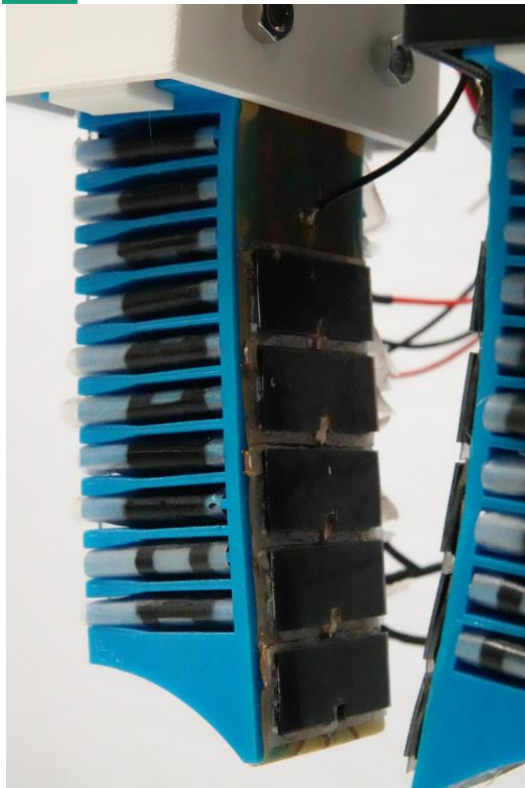
- Soft-gripper prototype @ Fraunhofer IPK. Individual control of HASEL-Chains with independend high voltage channels possible
- Including soft dielectric elastomer bending- and pressure sensors
- Gripping tests ongoing.

HASEL actuators in soft structures for robot gripping applications

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Electroadhesion – possible combination with HASEL – Robot Finger
Working principle - Electroadhesion

- Flexible interdigital structures on polymer or/and elastomeric substrate with 0.5 mm linespace

- Active size 25x45mm

- Voltage on electrodes up to 5kV DC

- **Use as sensor possible!**
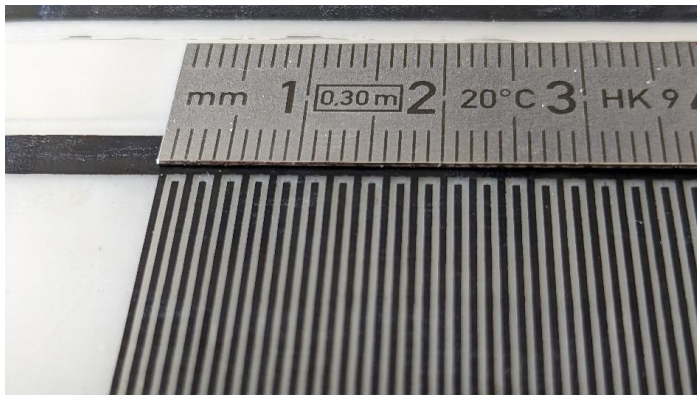
Cable drum: 65g

Apple: 125g

Power adapter: 164g

3M Adhesive Tape: 175g

Pumpkin: 625g

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Conclusion

Overall:

- HASEL actuators offer a high performance and extremely flexible actuator design with beeing simple and cheap
- Manufacturing of HASEL actuators can be automated for cheap and high volume manufacturing
- Insulating of high voltage electrodes is essential for use of HASEL actuators soft-robotics structures.
- Soft-robotics applications are possible with and without soft support structures.

Soft-robotics finger:

- High bending angles up to 43° are possible (over 60° with pre-bending)
- High Tip displacements up to 45 mm are possible
- Addressing of single HASEL units offer the possibility of realisation of finger joints.
- HASEL gap structure is essential to reduce pre-bending and to improve overall finger movement.

For the future:

- Combination of HASEL technology with sensing (DES - **d**ielectric **e**lastomer **s**ensors) and additional smart actuator devices like electroadhesion are possible and can increase the active holding force.
- Use of sustainable and bio-based materials for human like robots possible

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Thank you – Questions?

Kontakt

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