Smart Materials für adaptive Oberflächen und deren Anwendungsmöglichkeiten

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10. VDI-Fachkonferenz - Automobiles Cockpit
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Center Smart Materials CeSMa Partner der Wirtschaft
Fraunhofer ISC

Outline

- Overview of Fraunhofer Gesellschaft and Fraunhofer ISC
- Overview of Center Smart Materials
- Definition of Smart Materials
  - Magnetorheological Materials
    - Elastomers (MRE)
    - Fluids (MRF)
  - Dielectric Elastomers
- Application examples for adaptive surfaces
- Conclusion & Cooperation possibilities

The Fraunhofer Gesellschaft at a glance

- Largest organization for applied research in Europe
- 72 research institutes in Germany
- Appr. 26,000 staff, in majority engineers and natural scientists
- Budget 2018:
- 2.6 Bill. € in total
- 2.2 Bill. € by contract research
- 70 % by industrial projects and publically founded projects
- 30 % basic financing by the federal state and federal countries (90 : 10)

Fraunhofer Institute for Silicate Research ISC
... Facts

379 employees (2019)

Locations:
Würzburg | Bayreuth | Bronnbach
with approx. 7 000 m² lab and technical space

Application Center Textile
Fiber Ceramics | Hof

EUR 34 million Budget (2018 – incl. Fraunhofer-Projectgroup IWKS):

8,6	Contract venue (industry)
12,5	Project funding (nat. | internat.)
9,1	Public funding

In million EUR

SUBJECT: MATERIALS MEET …

… ENERGY

… CLIMATE | RESOURCES

… BIOMEDICINE

… CLEAN ENVIRONMENT

… ADAPTIVE SYSTEMS

Fraunhofer Institute for Silicate Research ISC
... Future

MATERIALS MEET…

…ENERGY

- More efficiency in thermal processing
- Safe and high-performance energy storage
- More efficiency in energy conversion

…CLIMATE | RESOURCES

- Efficient use of renewables
- Biobased | biocompatible biodegradable materials
- Power-2-X
- Smart resourcing to emit less CO2

…BIOMEDICINE

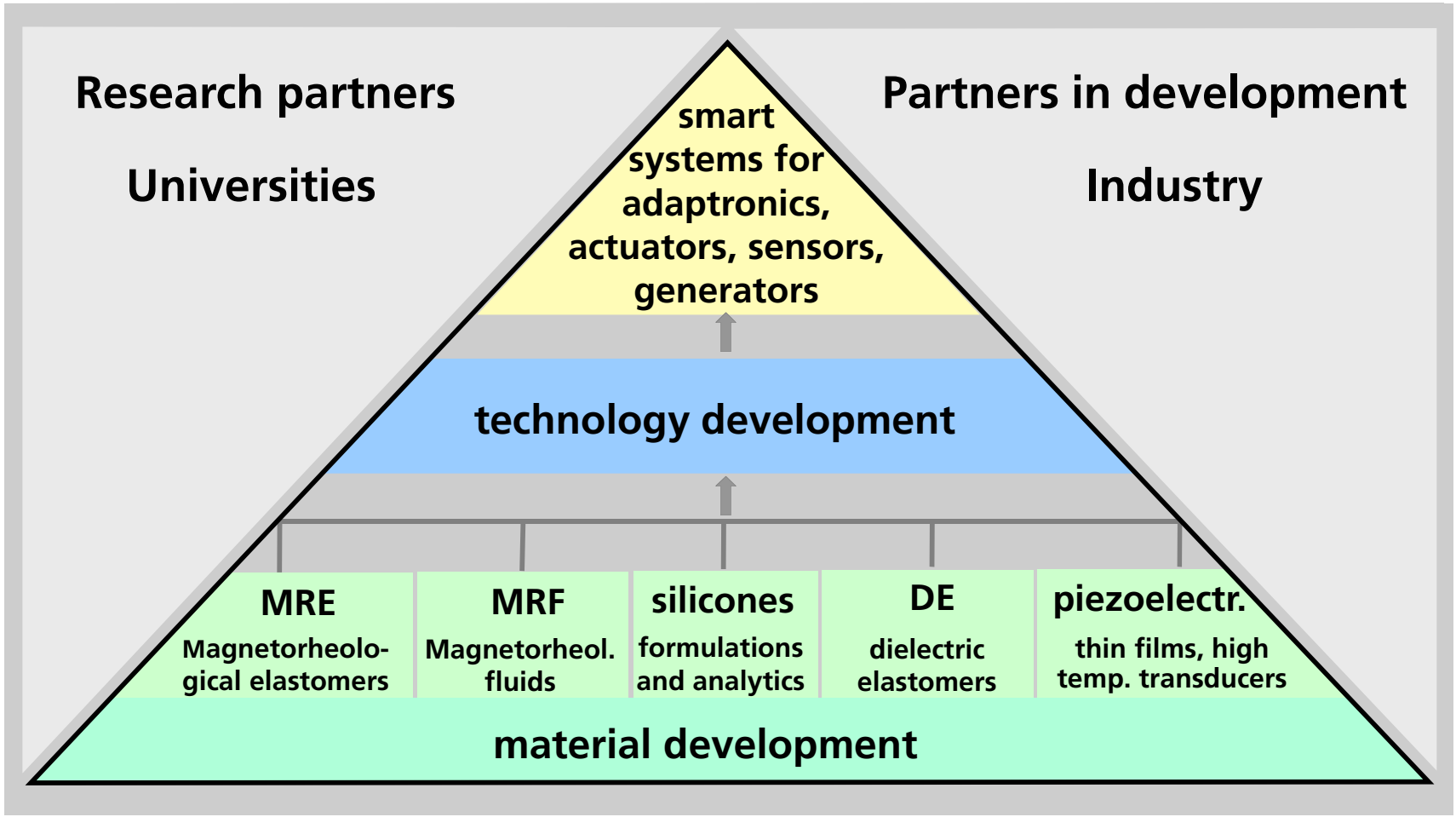
- Regenerative therapies
- Tissue based modelling
- Process automation
- Stem cell processing

…ADAPTIVE SYSTEMS

- Smart sensors and actuators
- Electrochromic systems
- Display Technology
- µ-Optics and µ-electronics

Center Smart Materials

How does CeSMa work?



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Magnetorheological materials

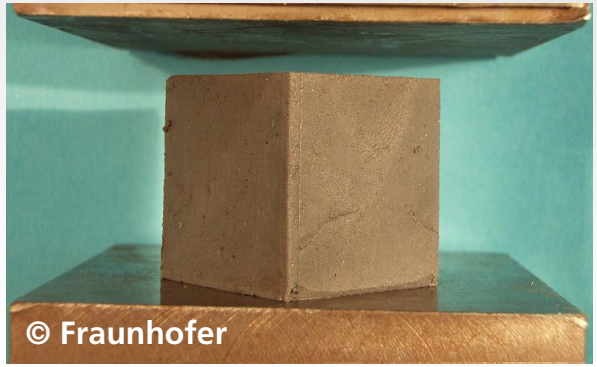
- **Magnetorheological materials:**
  Change of (rheological) properties by applying a magnetic field

MRF: Magnetorheological fluid

→ Change of viscosity

MRE: Magnetorheological elastomer

→ Change of hardness and shape

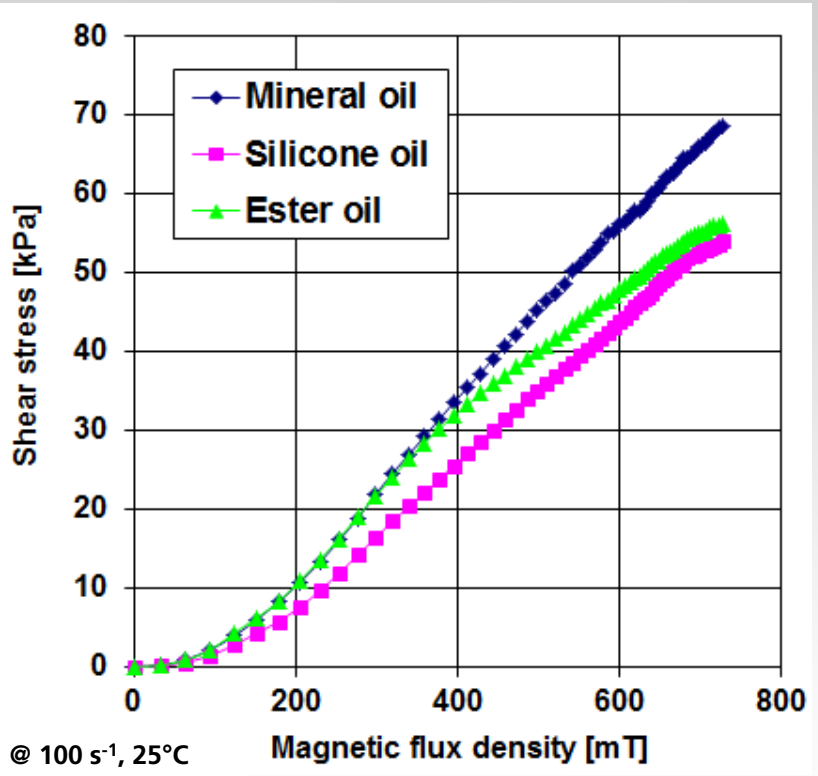


Magnetorheological fluid: MRF

- Suspension of magnetic polarizable particles in carrier fluid (size of the particles: few µm)
- Chain formation of the particles by interaction between the dipoles when applying the magnetic field
  → increase in stiffness / viscosity
- Speed of the stiffening: few milliseconds

Magnetorheological fluid: MRF

- Shear stress increases with rising magnetic flux density
- Parameters influencing the increase in shear stress:
  - Type of particles and carrier fluid
  - Particle size, filler content
  - Magnetic field design
- Preventing sedimentation by surface-modified particles and additional additives



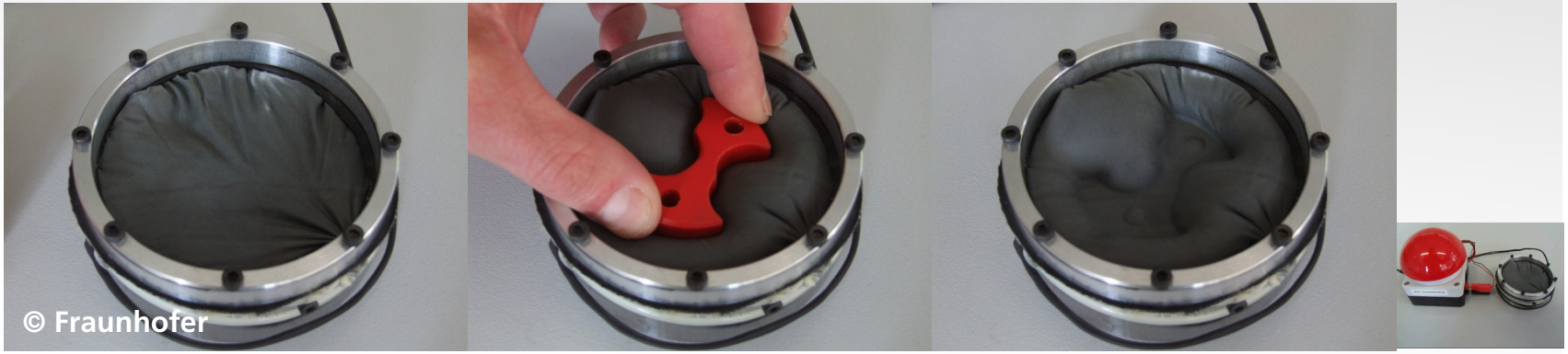
Application examples: Magnetorheological fluid

Fixation of objects

Fixation of objects in the dashboard:
MRF encapsulated by rubber film = MRF pad

- **Liquid state: Shape is pressed into the liquid**
- **Fluid stiffens by applying magnetic field**
- **Adaptive tray, e.g. smartphone, tablet, glasses**

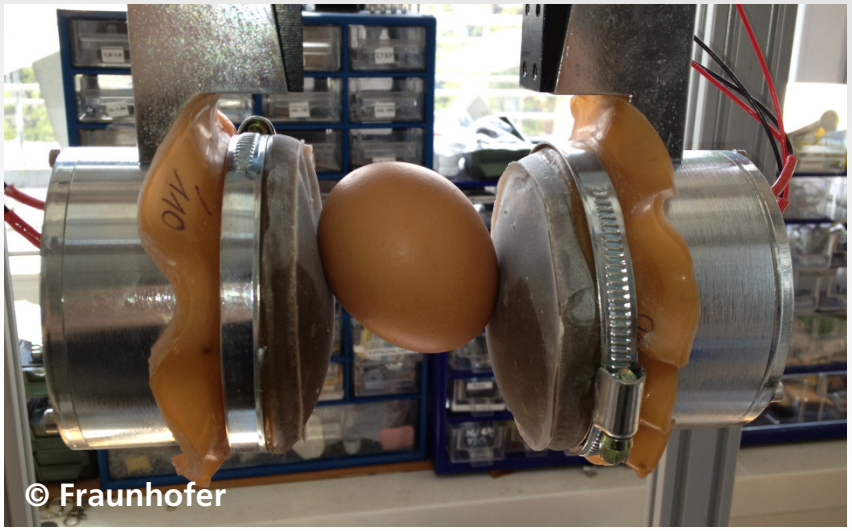
→ Reversibility of the fixation process



Application examples: Magnetorheological fluid
Gripping tool

Adaptive gripping tool for automation technology or robotics

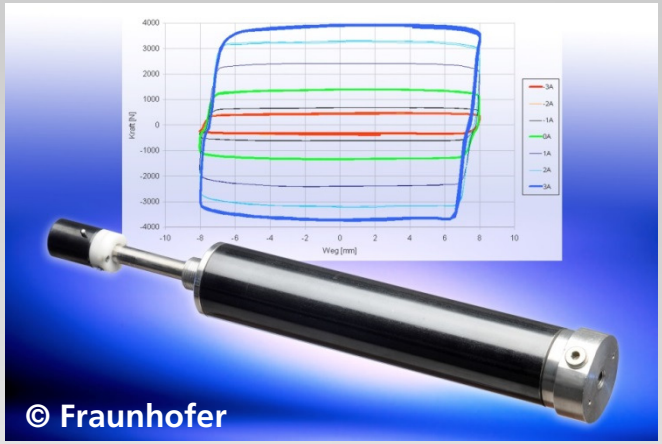
- **MRF-pad adapts to the shape of the object → magnetic field stiffens the fluid**
- **Advantage: Handling of sensitive objects with complex geometry**

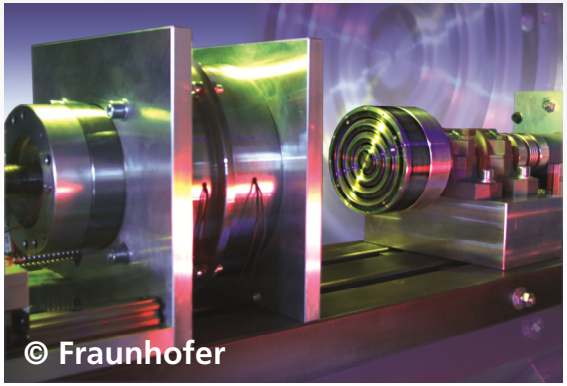


→ Adaptive Cup holder

Application examples: Magnetorheological fluid

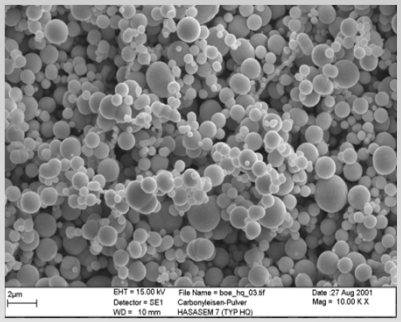
- Adaptive tray or cup holder
- Flexible gripping tool for robotics
- Adaptive damper
- Active vibration absorber
- Controllable clutch
- Controllable brakes
- Haptic control elements





Magnetorheological elastomer: MRE

- Elastomer filled with magnetizable particles (for example iron powder, particle size approx. > 5 µm)
- Magnetic field generates dipoles inside the particles → changing stiffness and shape of the material
- Reversible actuator by elastic force of the rubber
- Parameters influencing the actuation:
  - Particle size, filler content
  - Shore hardness of the rubber
  - Magnetic field design
- Speed of the actuator: up to 10 Hz
- Actuator force: single-digit Newton
- Individual sample manufacturing by molding

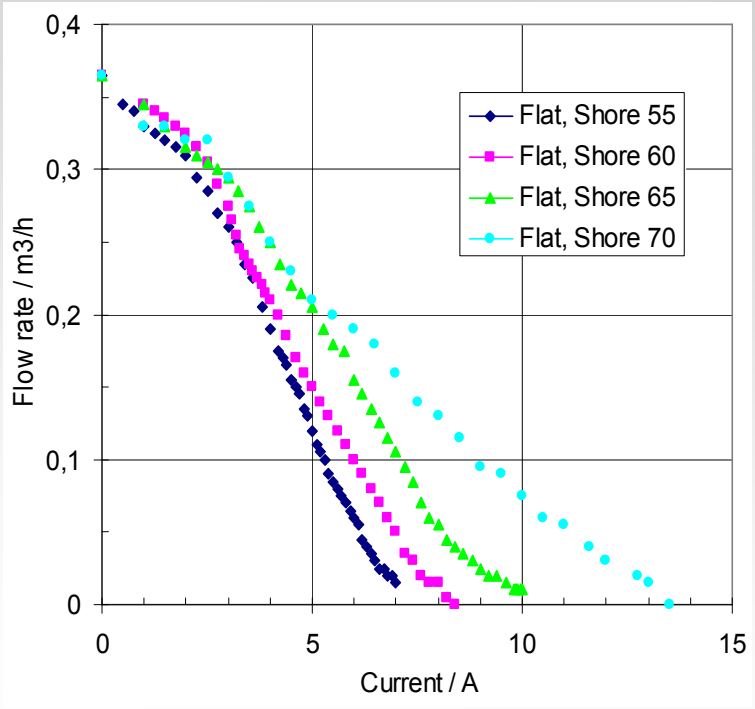


Application examples: Magnetorheological elastomer

MRE Valve

- Valve with complex actuator technology: radial actuation
  - Media: gases, liquids
  - Continuous adjustment of the gap
  - Variable material hardness

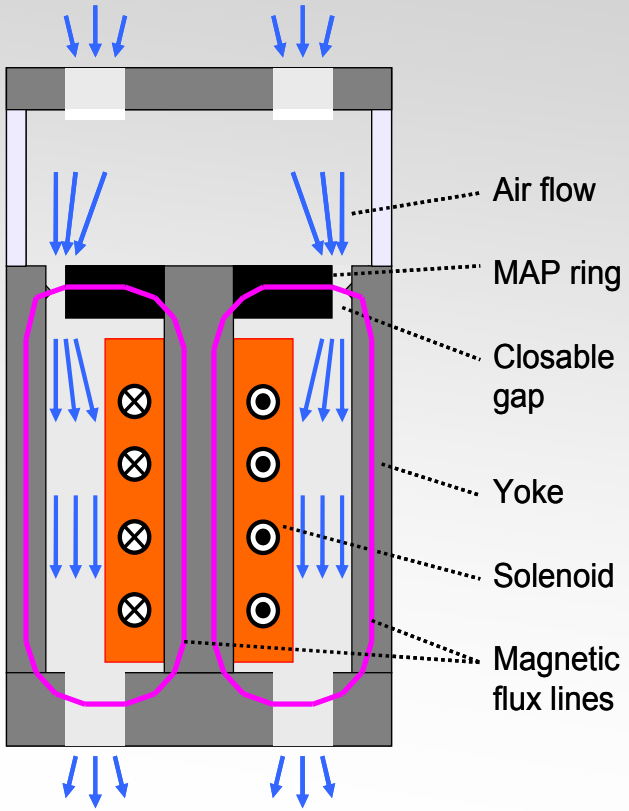
→ adjustable flow rate and clamping force

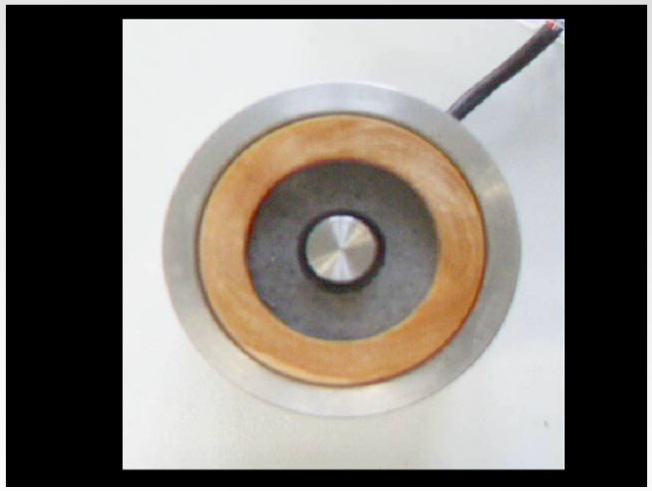


Application examples: Magnetorheological elastomer

MRE Valve

- Valve with complex actuator technology: radial actuation



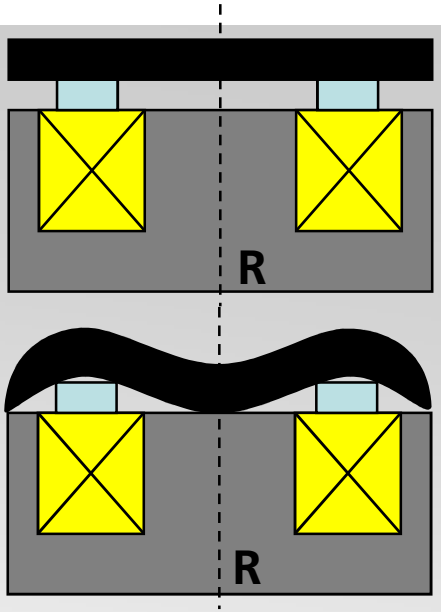


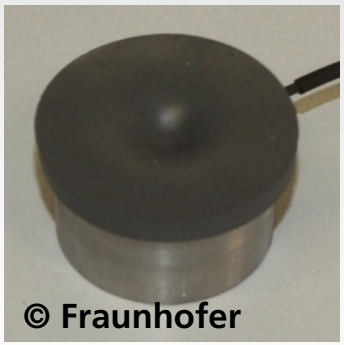
Application examples: Magnetorheological elastomer

Haptic Actuator

- "Morphing surface" as user interface (HMI)
- Smooth, soft and seamless surface
- Change of hardness and shape by applying magnetic field
- Response time: approx. 100 ms
- Soft actuation: no hard end stop
- Quiet actuation

→ changing surface and haptic feedback





Application examples: Magnetorheological elastomer

User interface with integrated sensor and actuator

- Multifunctional demonstrator: center console in cars
- “Morphing surface” via magnetorheological elastomer MRE
- Proximity sensor: Approaching finger visualizes piezoelectric switch
- Top switch starts music / Side switch activates light

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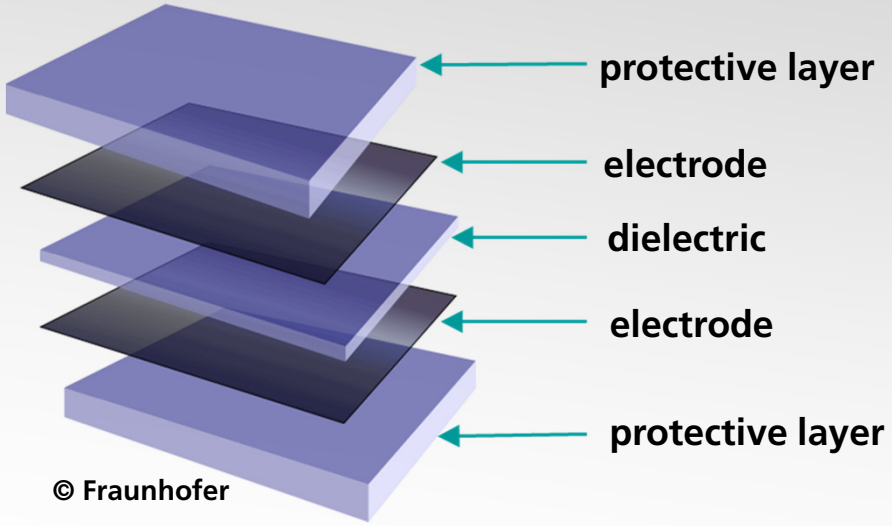
Dielectric elastomers

- Dielectric elastomers consist of a very stretchable elastomer film (silicone, polyurethane), coated on both sides with highly flexible and stretchable electrodes (silicone rubber filled with carbon black, graphite, metal particles)
- Highly stretchable (up to 100 % elongation)
- Soft and flexible characteristic is the basis for the integration into woven or knitted textile fabrics



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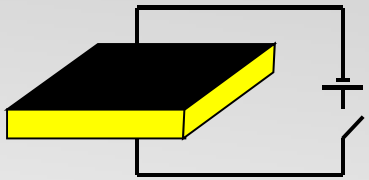
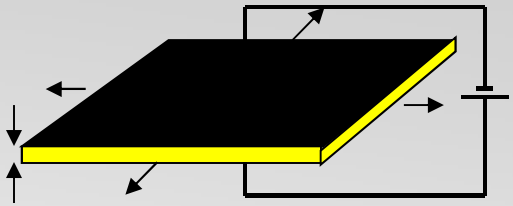
Dielectric elastomers as actuators (DEA)

- Applying electric voltage: Electrostatic attraction between electrode layers compresses the soft dielectric layer
  → reduction in thickness and increase of surface area

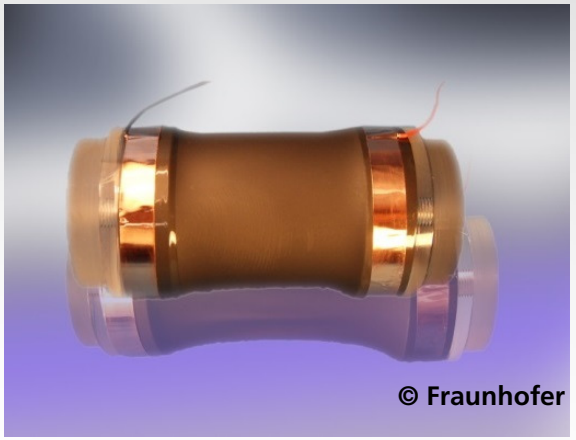




Technical data of DEA:

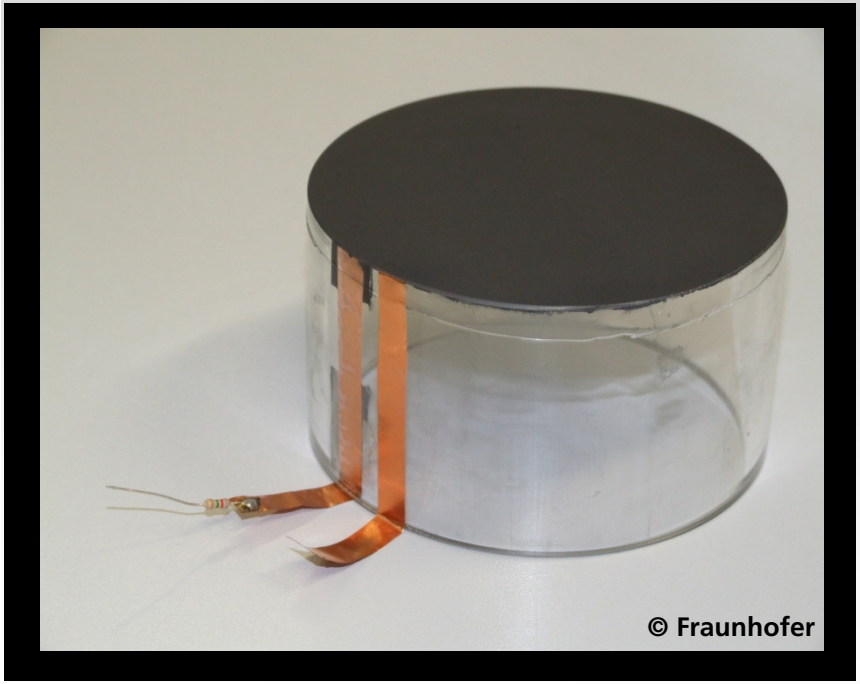
- Linear actuation of approx. 10 % (extreme situation up to 100 %)
- Actuator force: single digit Newton
- Frequency > 1 kHz at low amplitude
- Advantages:
  Lightweight, noiseless, thin, high design diversity

Spring-roll actuator

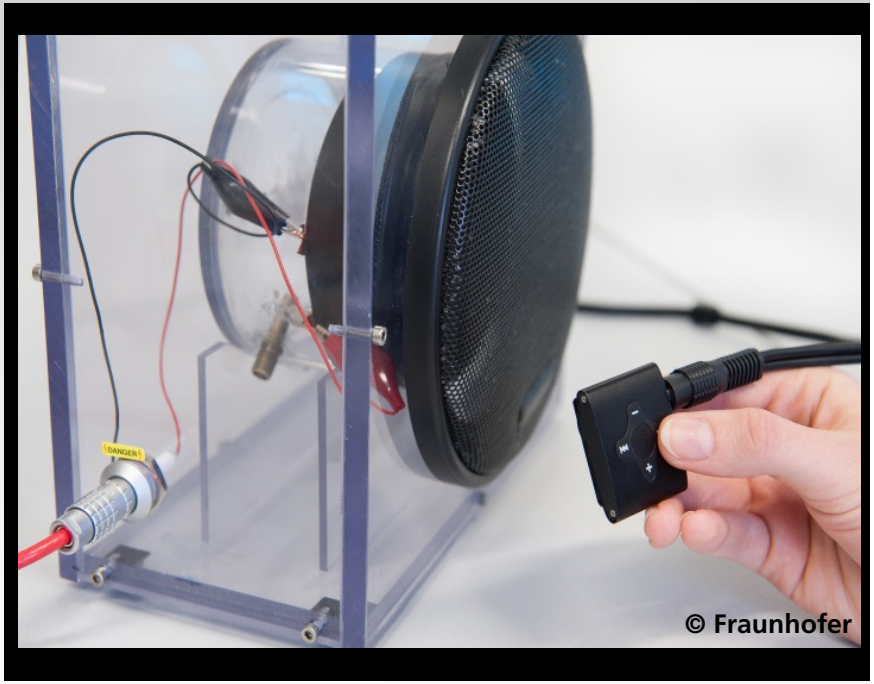


Application examples: Dielectric elastomer actuator (DEA)

Lift actuator by using Acrylic-/Silicone rubber



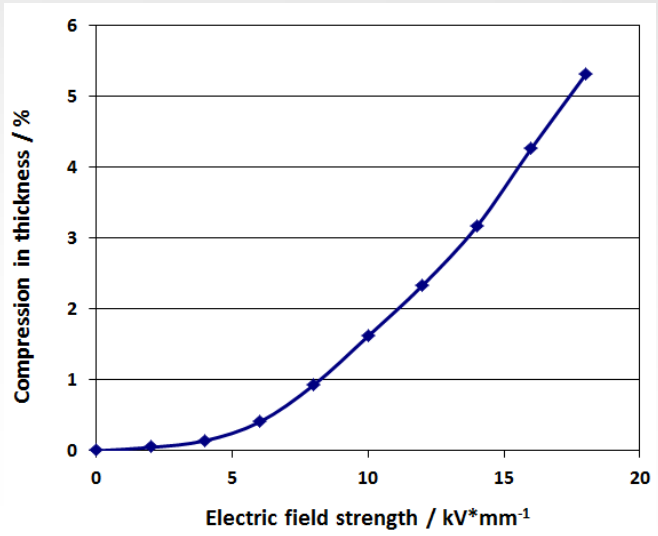
Loudspeaker: sound generation by high frequency actuation

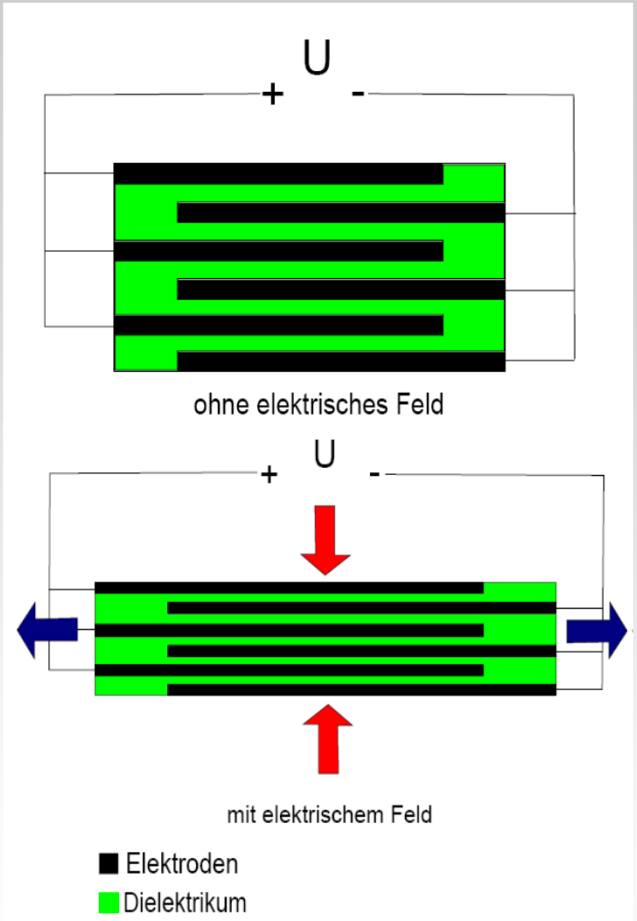


Application examples: Dielectric elastomer actuator (DEA)

Stack actuator

- **Stack actuator: up to 9 dielectric layers**
  → increase of actuation in thickness
  → absolute thickness reduction approx. 1 mm

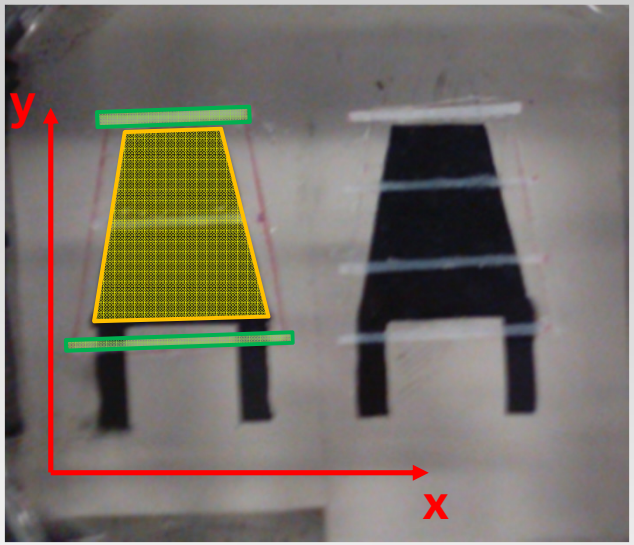




Application examples: Dielectric elastomer actuator (DEA)

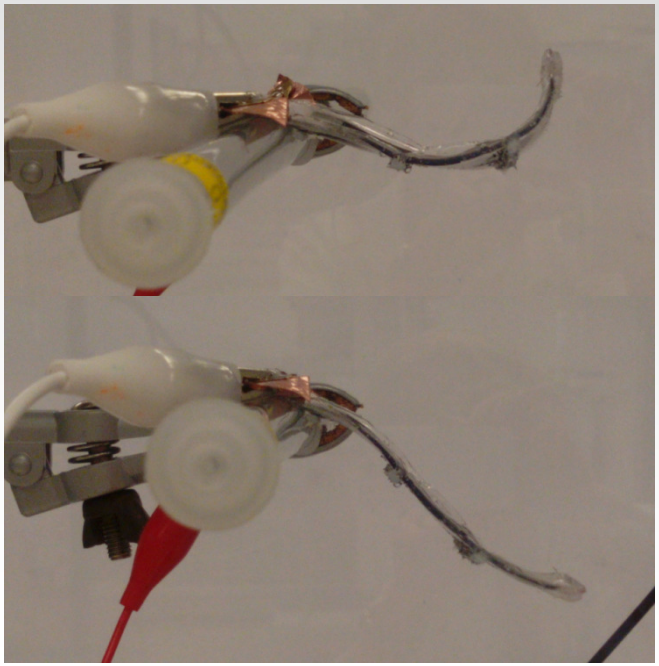
Bender actuator

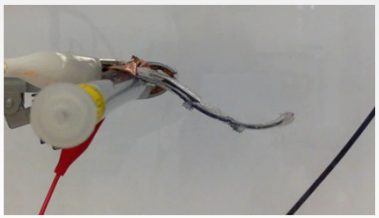
- Multilayer system consisting of active / passive layers and reinforcing structures
- Prestretched (2-dim.) DEA film
- Bending by expansion of the DEA



U > 1 kV

U = 0 V

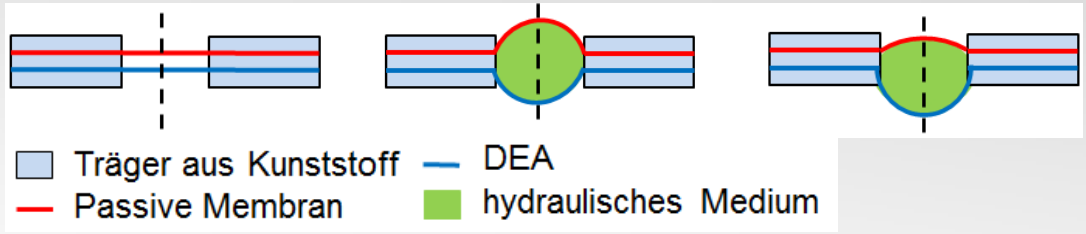


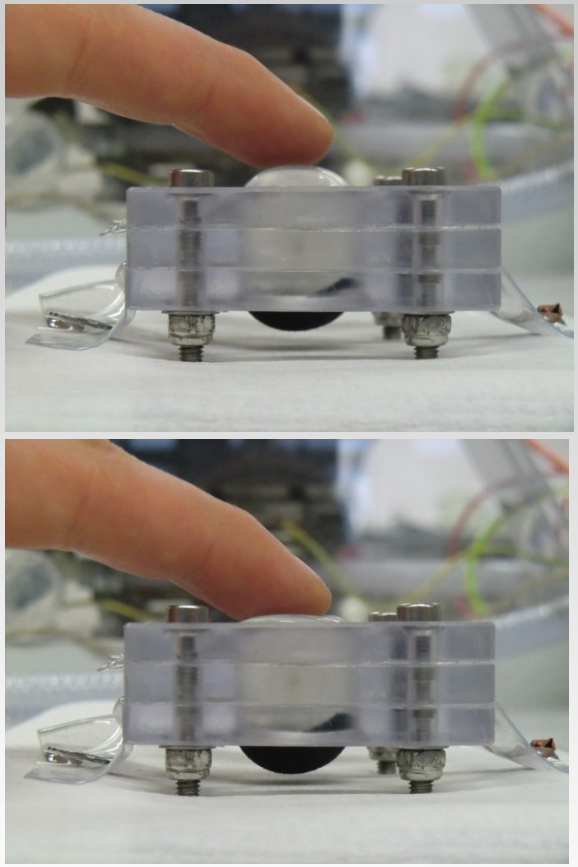


Application examples: Dielectric elastomer actuator (DEA)

Haptic actuator

- DEA with hydraulic force transfer
- Activated DEA enlarges, weight force of the fluid changes surface
- Lift up to 1 mm



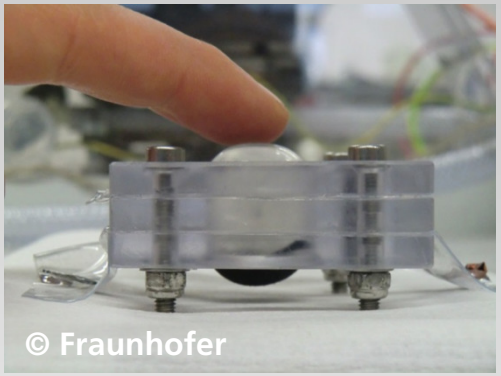


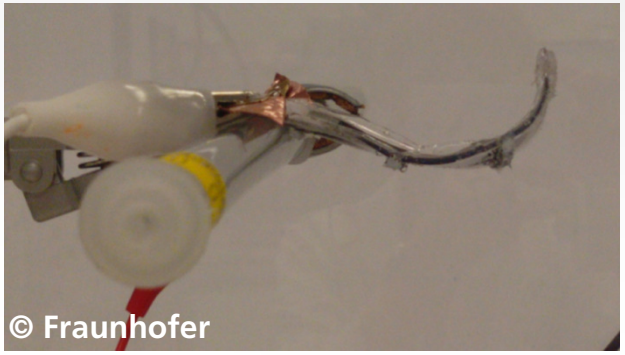
→ Haptic feedback

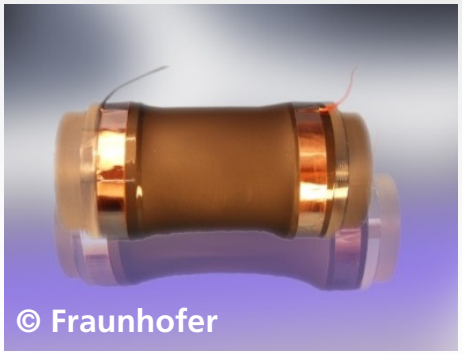
→ Continuous and fast change of lift

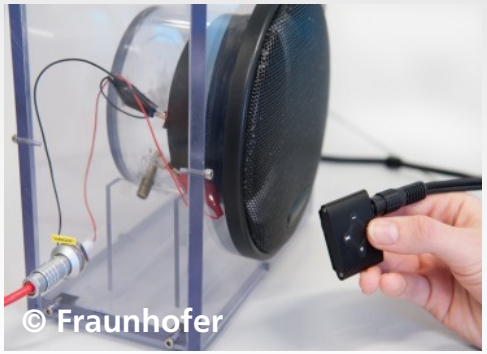
Application examples: Dielectric elastomer actuator (DEA)

- Haptic actuator
- Bender actuator
- Stack actuator
- Lift actuator
- Loudspeaker
- Ring actuator
- Linear actuator









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Conclusion

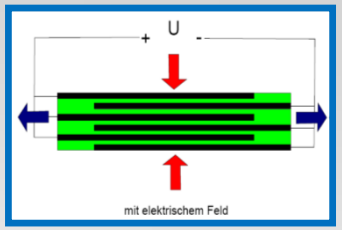
Smart Materials for Adaptive Surfaces

- Smart materials for adaptive surfaces:

  Magnetorheological Elastomer MRE

  Magnetorheological Fluid MRF

  Dielectric Elastomer Actuator DEA



Seamless and "morphing" surface

Combinable with technical textiles

High mech. durability

High design diversity

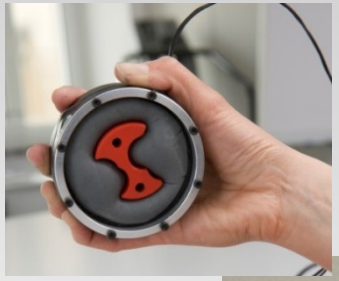
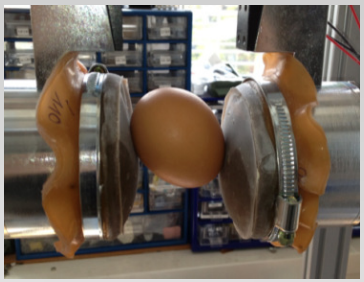
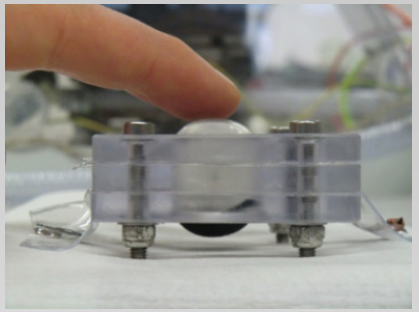
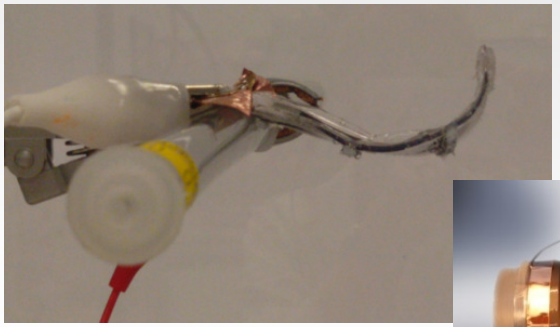
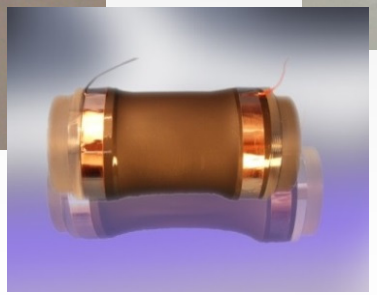
High temperature stability

Chemical stability

Conclusion

Smart Materials for Adaptive Surfaces

- **Application examples for adaptive surfaces:**


Cooperation possibilities
Center Smart Materials

- **Our offer:**
  - **Scientific knowledge on smart materials: various patents and publications**
  - **Material and technology development of smart materials**
  - **Design, construction and prototype fabrication of smart systems based on smart materials**
  - **Feasibility studies, sampling, technology transfer**

- **We are looking for:**
  - **New ideas and applications for smart materials**
  - **Partner for R&D projects (direct cooperation, publically funded projects)**


Fraunhofer
ISC
Center Smart Materials
CeSMa
Partner der Wirtschaft
Thank you for your attention!
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