Strategic Focus Area
Advanced Manufacturing

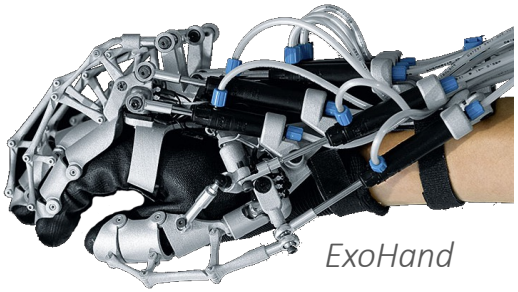
SFA Annual Review Meeting
14 Feb 2024

MANUFHAPTICS
Manufacturing of Actuators Integrated in Active Exoskeletons

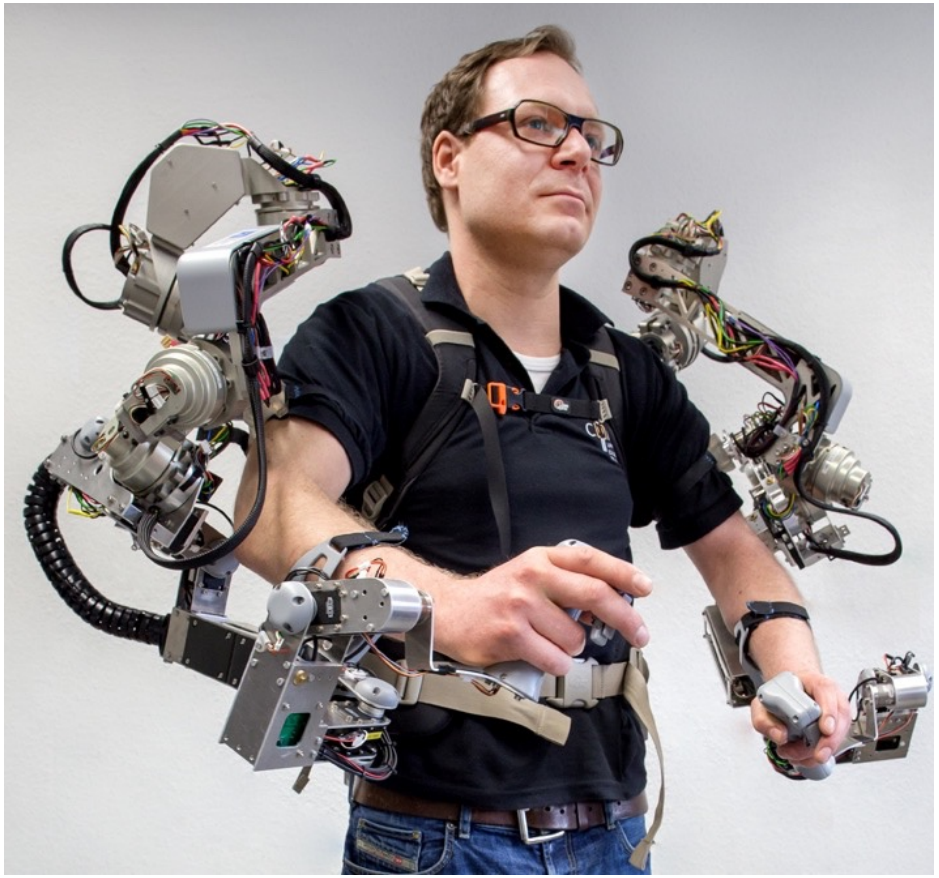
Presented by Prof. Herbert Shea
on behalf of the consortium

ETH zürich EPFL Empa

Dexmo



ExoHand



Capio exoskeleton

MANUFHAPTICS

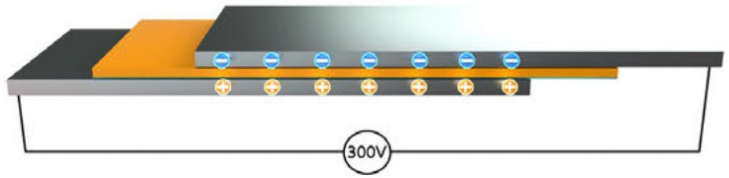
We develop AM techniques to build customized **soft** actuators for wearable soft exoskeletons

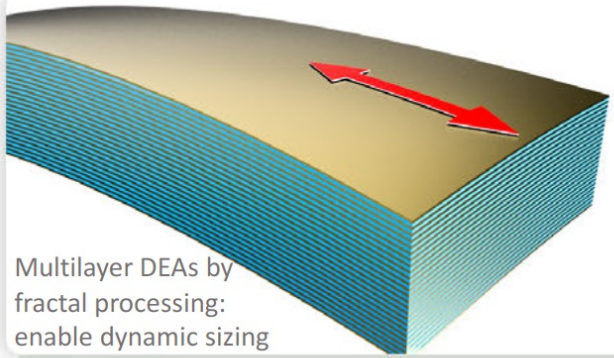
MANUFHAPTICS

We are developing AM techniques to build **soft** actuators in elastomer exoskeletons

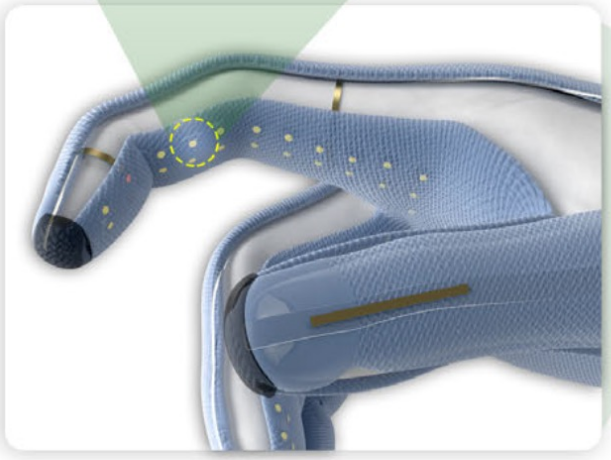
"zipping" cutaneous actuators:
provide a sense of touch and texture

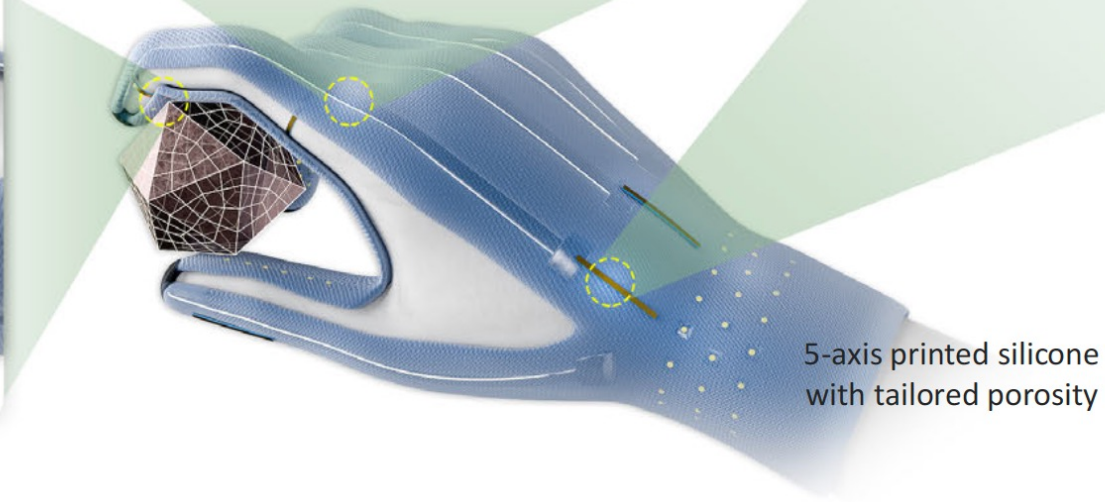
Flexible electrostatic brake with high-k dielectrics:
makes virtual objects feel solid





Multilayer DEAs by
fractal processing:
enable dynamic sizing





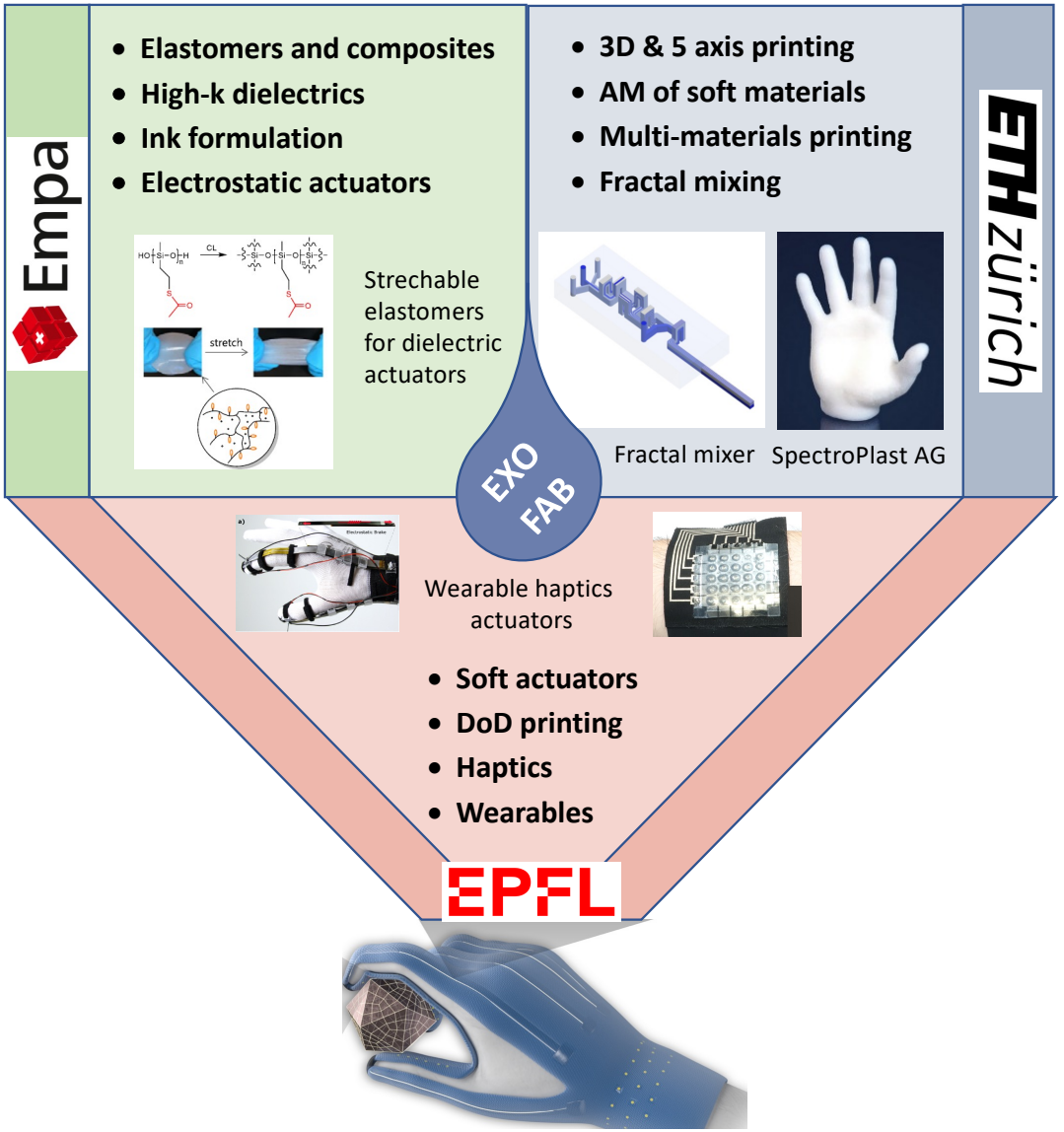
5-axis printed silicone
with tailored porosity

We develop an additively-manufactured glove with printed actuators for both kinesthetic and cutaneous haptics

Tasks

- New inks & materials
- Multimaterial Printing methods
- Design of electrostatic actuator
- Integration process and sizing.

- EPFL - Soft Transducers Lab (H. Shea)
- ETHZ - Complex Materials Lab (A. Studart)
- ETHZ - Soft Materials Lab (J. Vermant)
- Empa – Lab for Functional Polymers (D. Opris)



Glove overall Design

- A fully personalised glove, precisely conforming to the wearer's unique anatomy.
- Emphasis placed on:
  - i) ease of donning ,
  - ii) modularity to easily replace any part,
  - iii) force transmission

- A multi-axis multi-material 3D printer was built specifically for this task

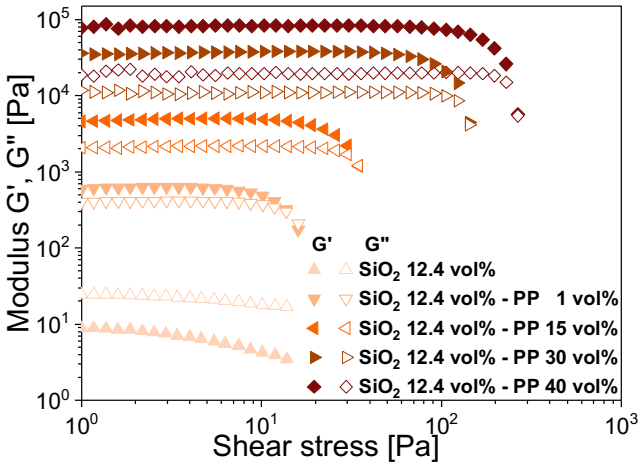
- We developed several types of Linear Actuators
  - DEA stack
  - DEA fiber
  - Sliding electrostatic actuator

These devices require new materials for performance and for printability

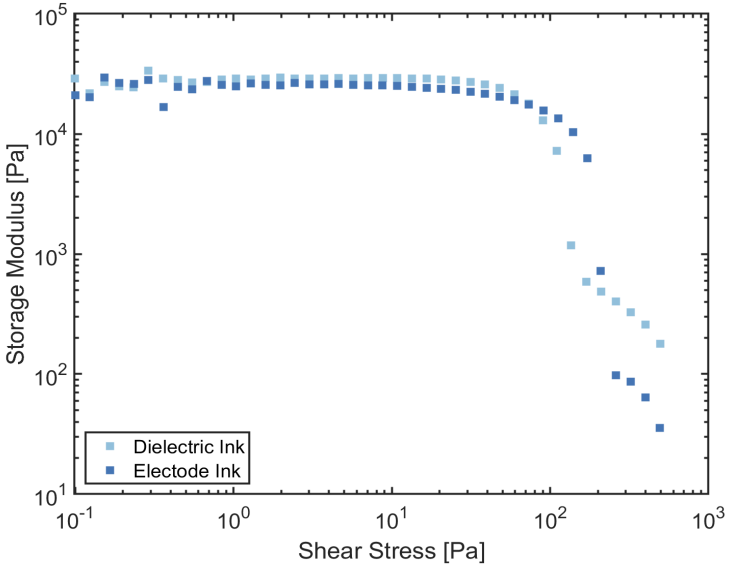
Synthesis of inks for printing DEAs

tunable thixotropic and shear-thinning materials

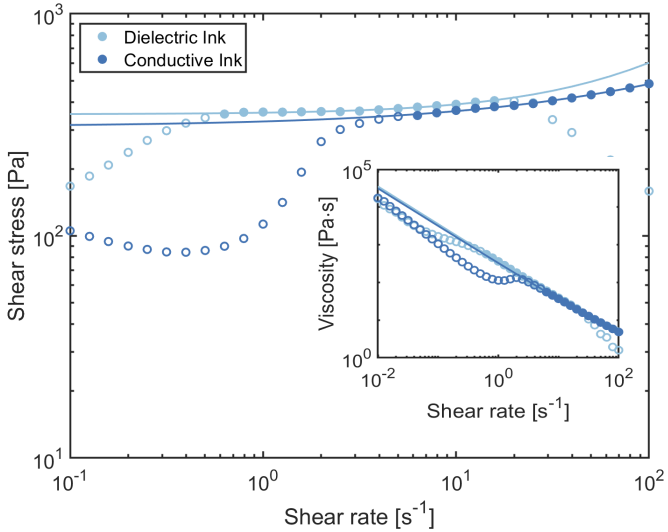
High permittivity dielectrics



Elastic and viscous response of dielectric and conductors are matched:



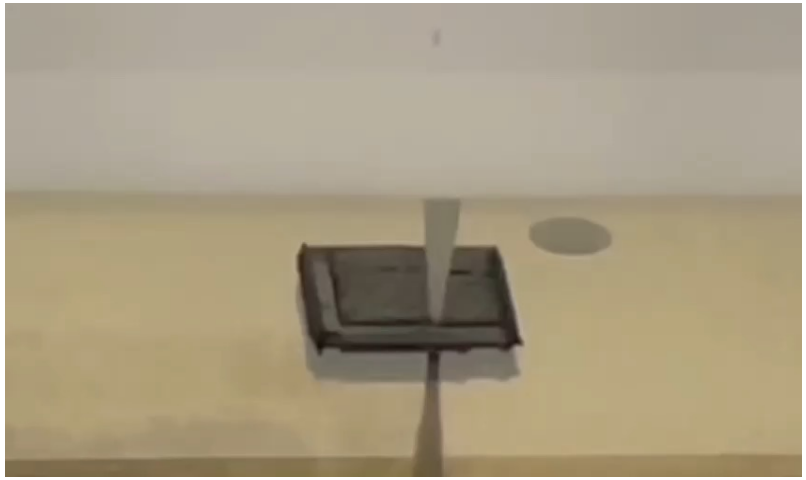
Flow behaviour:

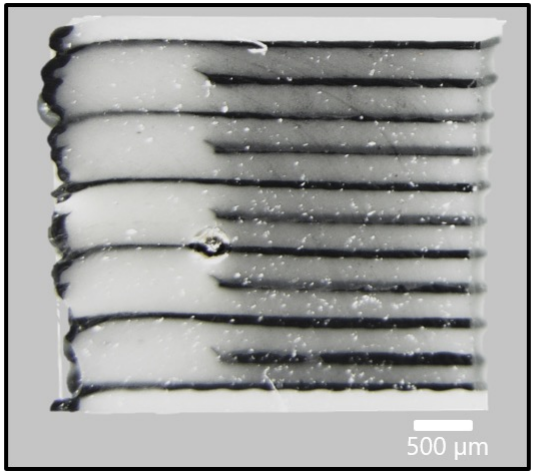


- Tuneability of inks' flow behaviour
- Matched yield stress
- **Matched** degree of shear thinning
- Similar wall slip behaviour

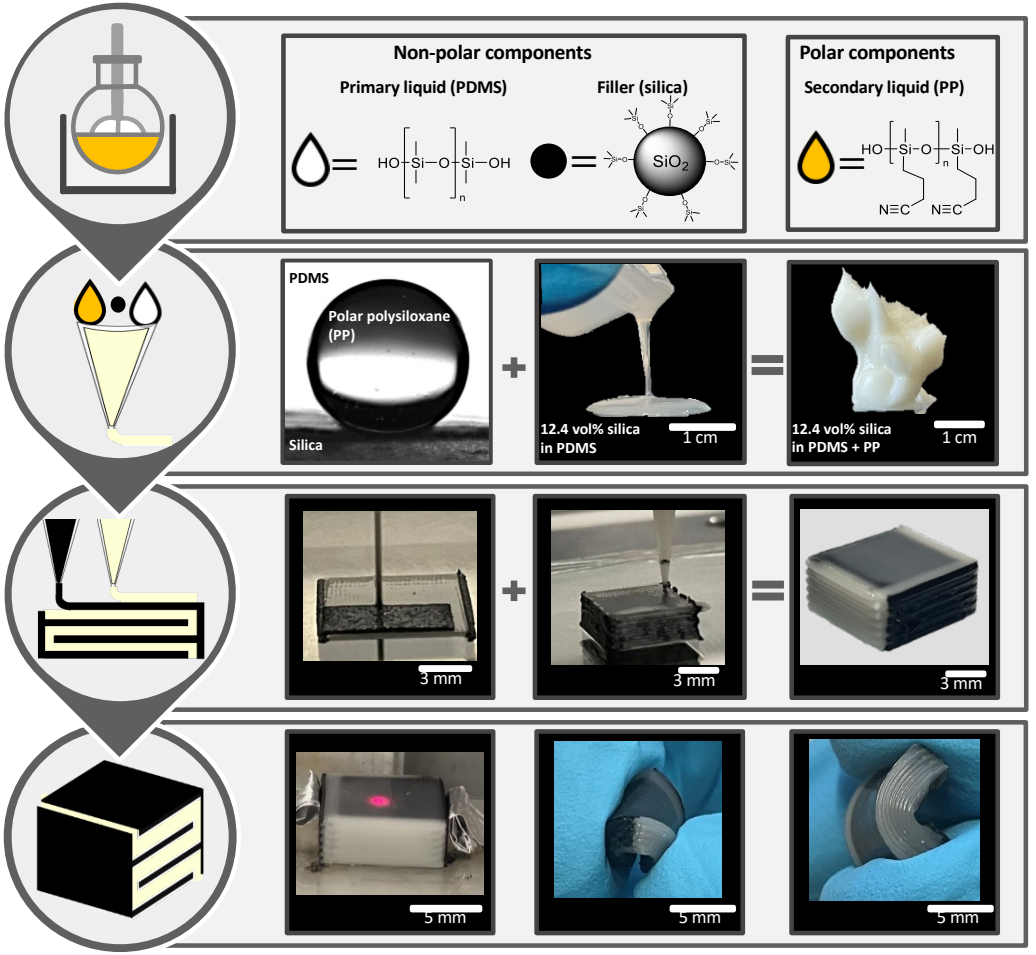
- P.M. Danner, T. Pleij, G. Siqueira, A.V. Bayles, T. Raman Venkatesan, J. Vermant, D.M. Opris, *Adv. Funct. Mater.* **2023**, *2313167*.
- P. Danner, et al. Patent, EP23161063, 2023.

3D printed stack DEA actuators





5% actuation strain at 21 V/µm



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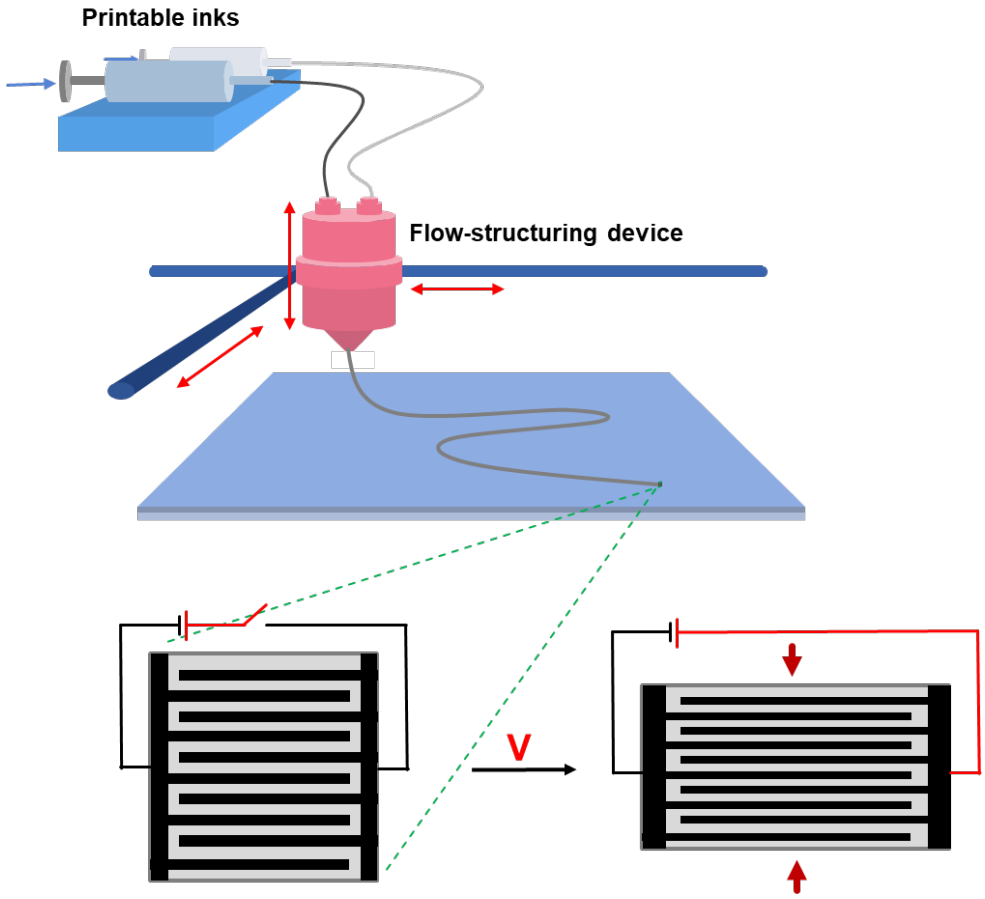
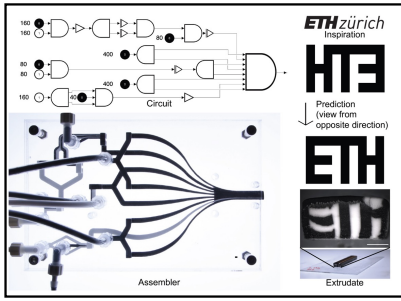
Printing Structured Multilayer DEA Filaments

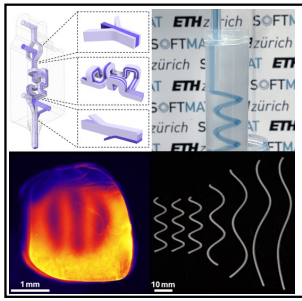
Flow-structuring approaches to print interdigitated, multi-layered, multi-material filaments





From Electronics to Extrusion: Adapting Boolean Logic to Model Fluid Flow and Design Material Assemblies.
A.V. Bayles, T.Pleij, et al. [submitted]

→ Engineering and predicting geometrically complex multi-material flow structures
→ Tool for advective assemblers' design



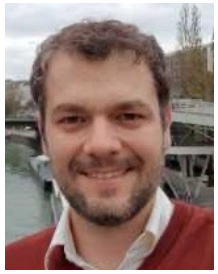
Advective Assembler-Enhanced Support Bath Rotational Direct Ink Writing.
T.Pleij, A.V.Bayles and J.Vermant [submitted]

→ Advective assemblers employed to print 3D multi-ink structures in sacrificial support bath
→ Hydrogel inks used to print differential-swelling helical actuators with multi-phase cross sections

Manufhaptics Objectives till June 2025

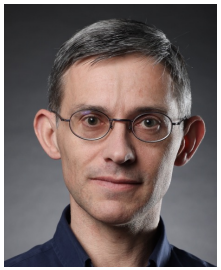
1. **Improve performance of fingertip and linear actuators**
2. **Mount actuators on the "core"** printed glove and validate user experience
3. Demonstrate **integration of the three types of printed high-force flexible electrostatic actuators in a glove** to enable force feedback






Partners

- EPFL - Soft Transducers Lab
- ETHZ - Complex Materials Lab
- ETHZ - Soft Materials Lab
- Empa – Lab for Functional Polymers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