ENGINEERING HONORS PROGRAM
UNIVERSITY OF MICHIGAN

# Honors Capstone: Electroadhesive Technologies for Prosthesis Applications

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## Motivation

- Prosthesis currently on the market and described in literature have struggled to match human muscle performance. This is due to a variety of factors including torque density, weight, and speed capabilities [1].
- Electroadhesive devices provide a light weight, low power, modulated actuation solution for a variety of applications to improve the performace of prostheses.
- Due to their configurability in size and shape, electroadhesives can be readily implemented in many different prosthesis architectures.

## State of the Art

- Electroadhesives are currently used in a variety of applications, including haptics, tactile displays, and grippers.
- The best performing electroadhesive in terms of force density [3]:

i. Shear force density: 210kPa
ii. Operating voltage: 300V
iii. Parallel plate configuration.

- Another notable configuration is the interdigitated electrode geometry [4]:

i. Shear force density: 33kPa
ii. Operating voltage: 1kV

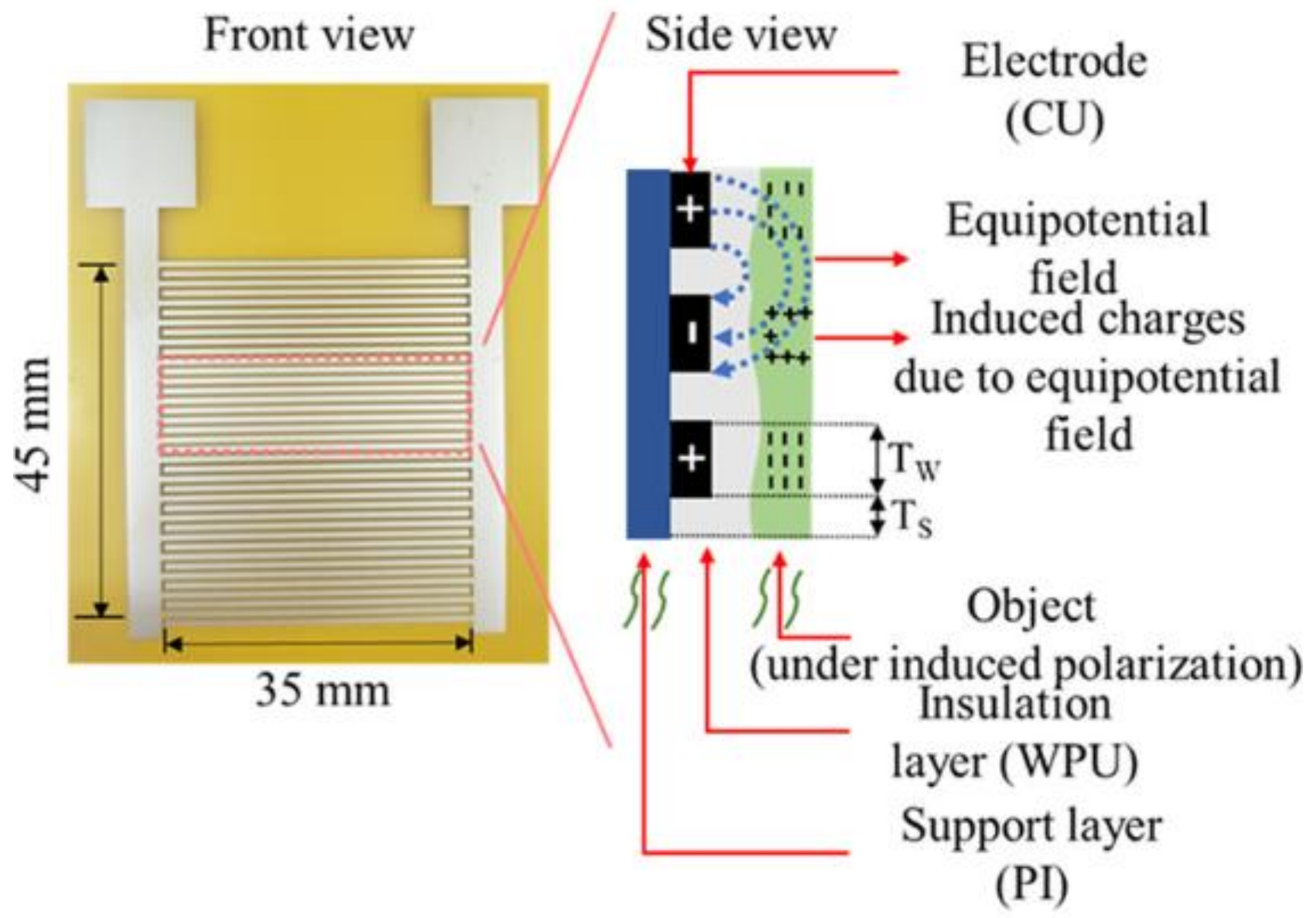

**Figure 1:** Top performing interdigitated electroadhesive[4].

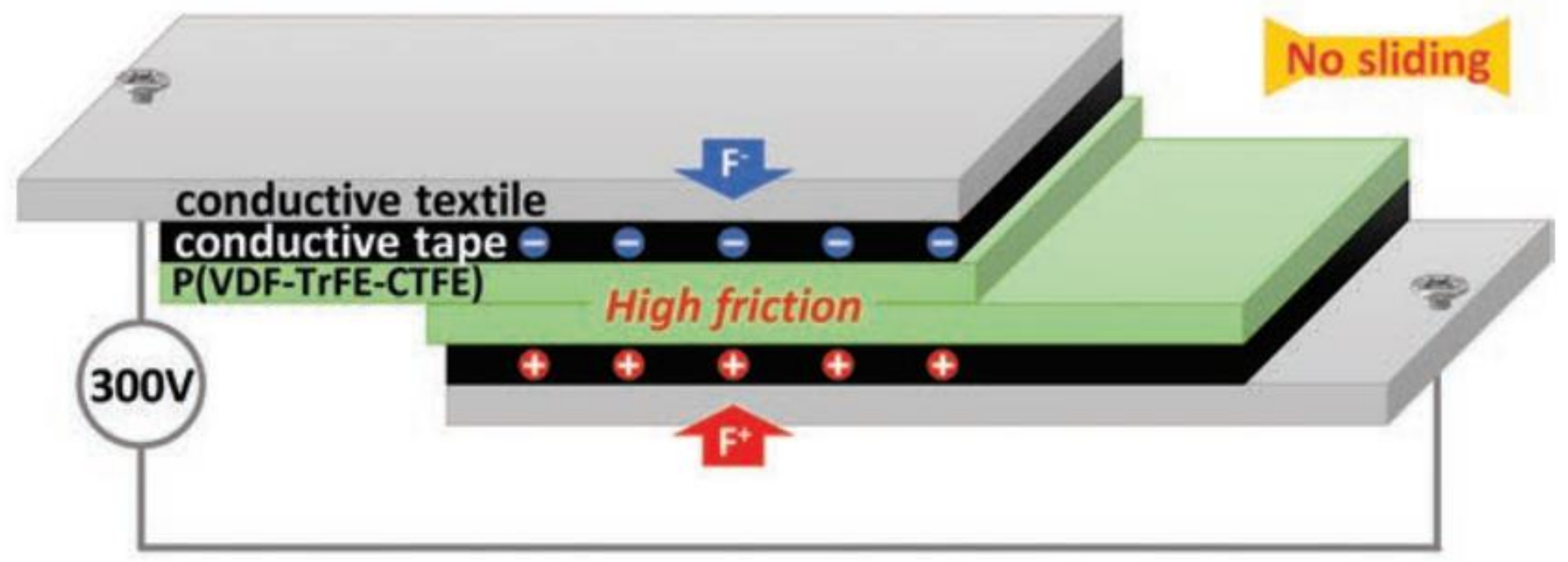

**Figure 2:** Top performing parallel plate electroadhesive[3].

## Objective

- Certain disadvantages of electroadhesives make implementation difficult in prostheses.

i. Parallel electrode geometry requies grounding of one side.
ii. Most interdigitated electrode designs are too weak for many applications in prostheses.

- Leverage characteristics of state of the art electroadhesive designs to accommodate prosthesis applications, i.e. high force density, small profile, and flexibility.

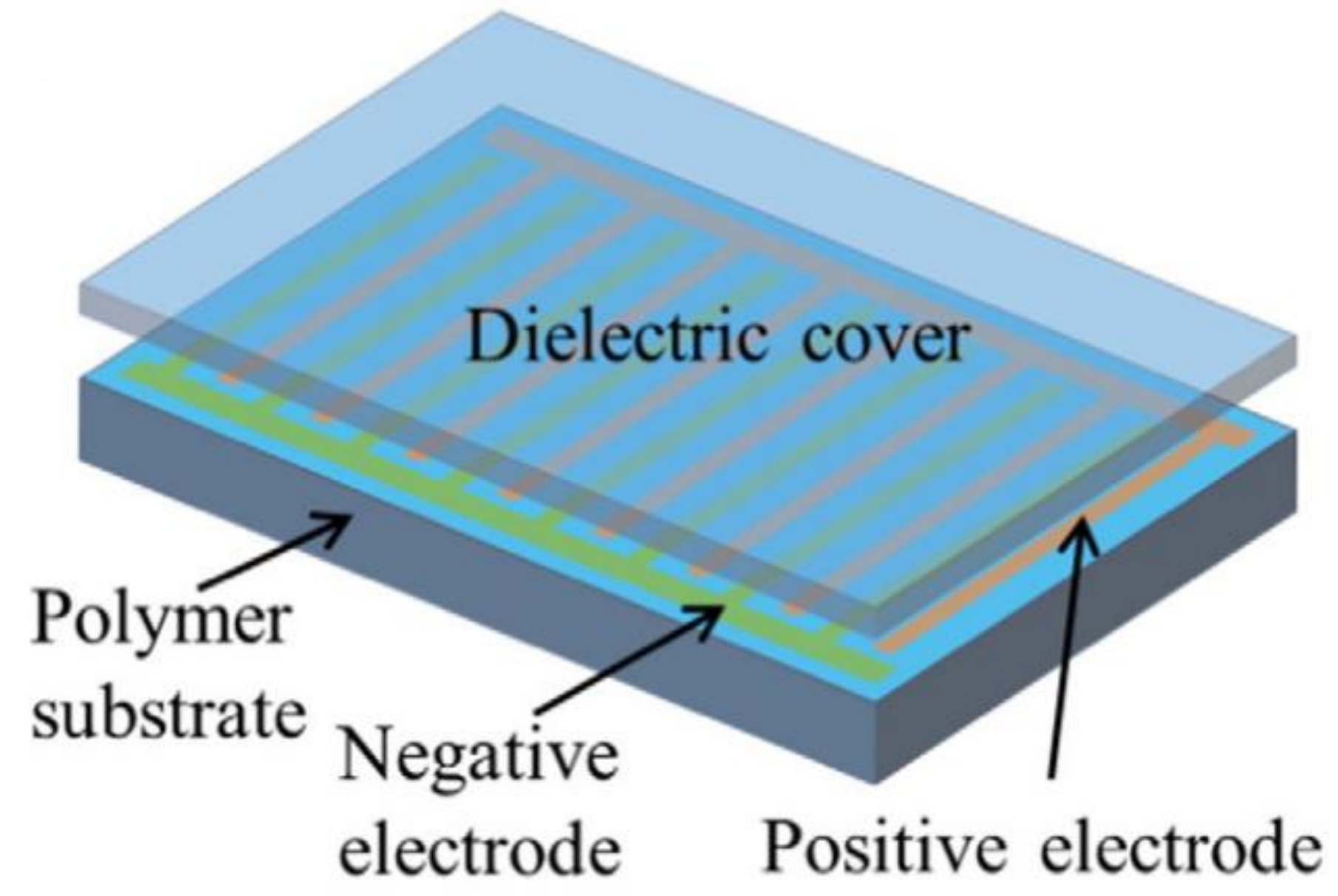

**Figure 3:** Electroadhesive architecture representative of the concept proposed for this work[2].

## Approach

**Materials Research**

- Force density is dependent on electrical properties of the dielectric.

i. Ability to withstand high operating voltages (breakdown voltage).
ii. Ability to permit electric field (electrical permittivity).

- Varying fabrication methods with dielectrics affect design feasibility.

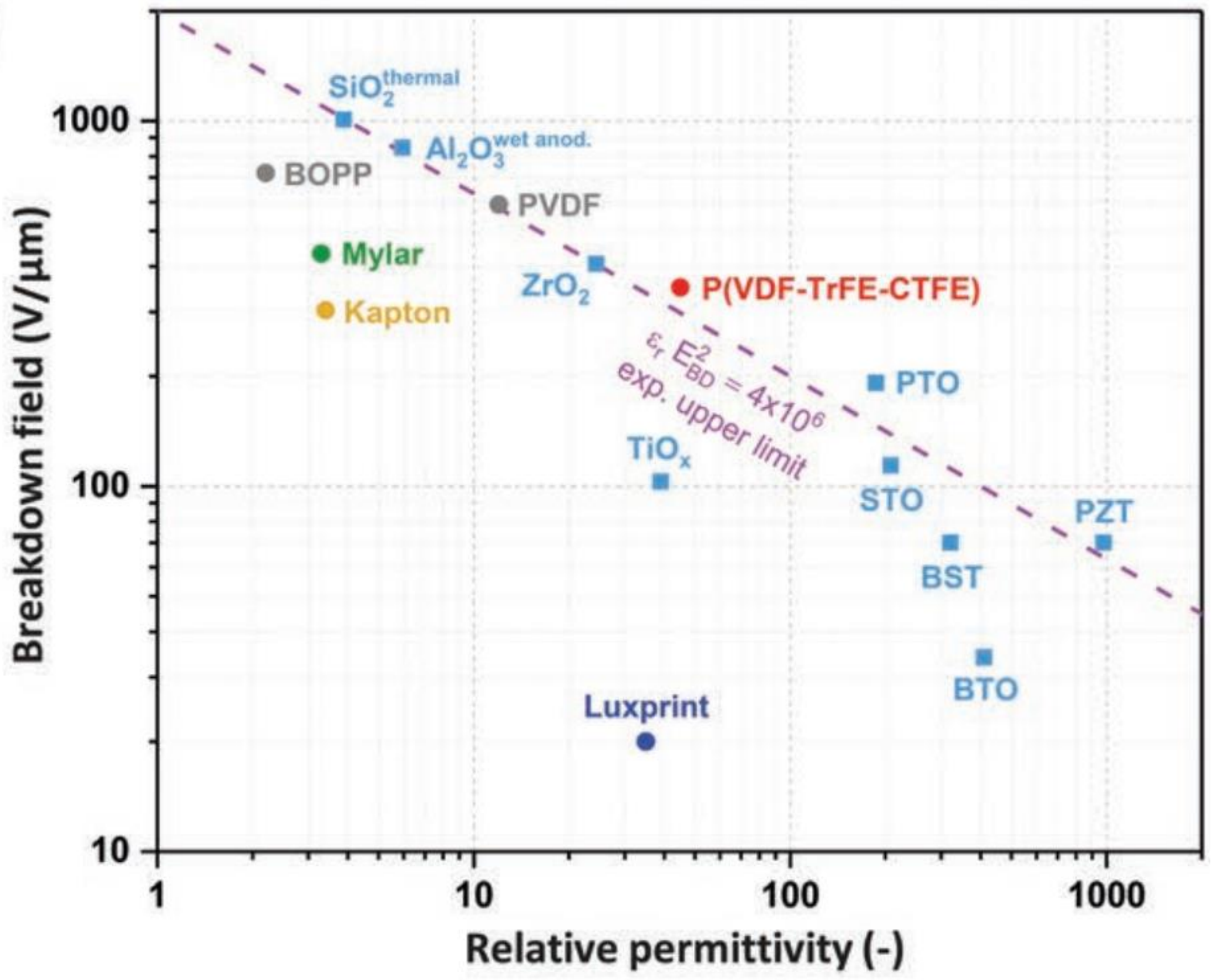

**Figure 4:** Dielectric performance of materials used in prior art[4].

**Electrode Geometry**

- Interdigitated electrode geometry provides easiest implementation for different applications.
- Force density directly related to electrode's width, spacing, and dielectric thickness[2].

## Initial Design Concept

**Materials Selection**

- 0.002" copper foil electrodes
- PiezoTech® P(VDF-TrFE-CTFE) RT-TS dielectric ($\kappa$ = 40)
- ⅛" Fabric-Reinforced High-Temperature Silicone Rubber Base
- DEVMO 8-32V to 45-390V DC-DC High Voltage Boost Converter
- LM317 voltage regulator

**Design Parameters**

- Supply voltage: 350V DC
- Electrode dimensions (width, spacing): 2mm, 0.5mm
- Dielectric thickness: 25µm
- Device profile (length, width): 3cm, 1.5cm
- Predicted Force Density: >25kPa

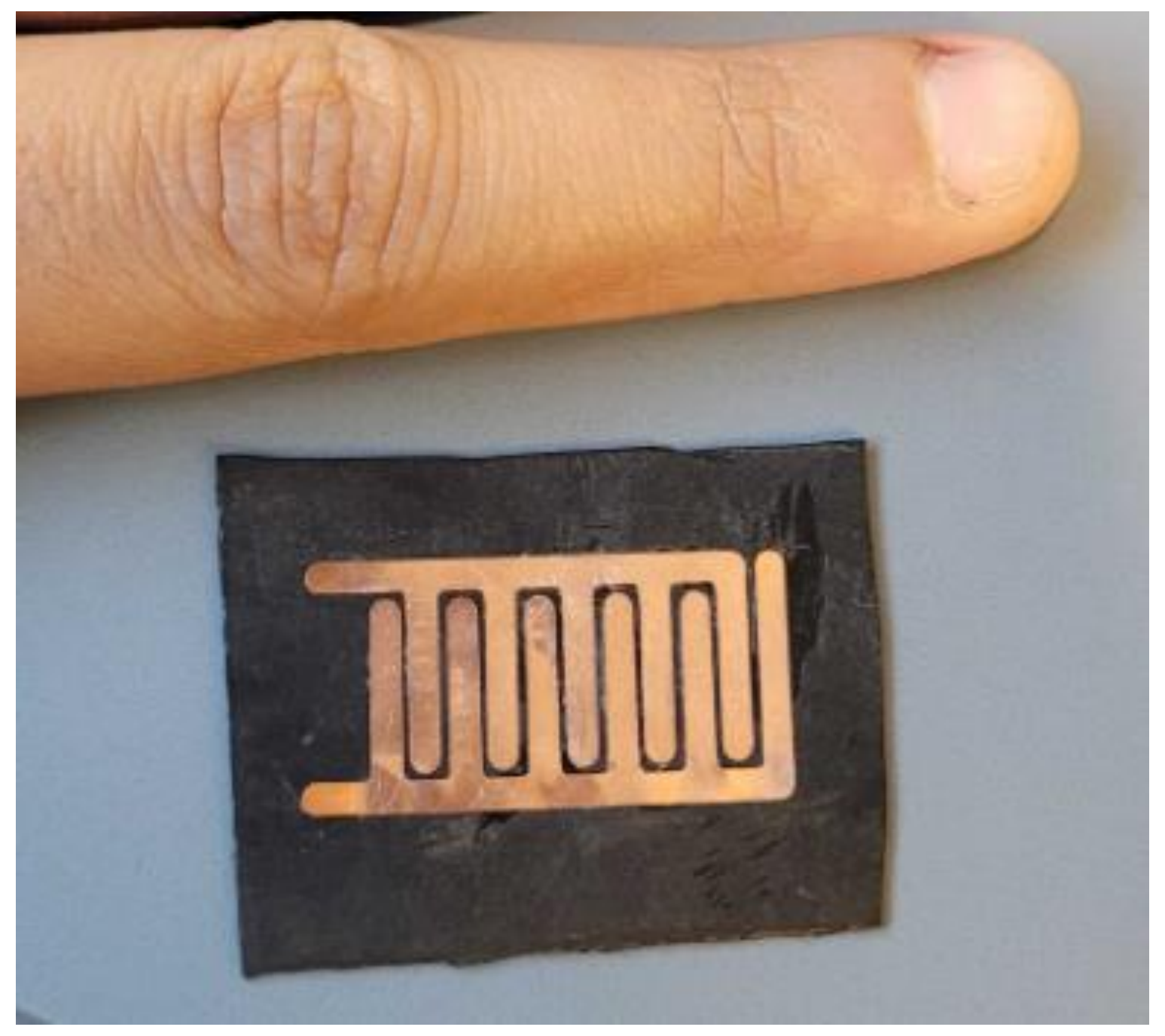

**Figure 5:** Fabrication test of electrodes on rubber substrate. Electrode width and spacing will be reduced to find the limitations of the current fabrication method.

## Future Work

- Determine electrode dimension limit of fabrication method
- Complete fabrication of functioning prototype
- Verification and characterization testing of prototype
- Implement H-bridge to actuate with AC
- Prosthesis implementation

## Acknowledgments

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## References

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[2] Cao, Changyong et. al, Theoretical model and design of electroadhesive pad with interdigitated electrodes, Materials and Design 89 (2016) 485-491
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