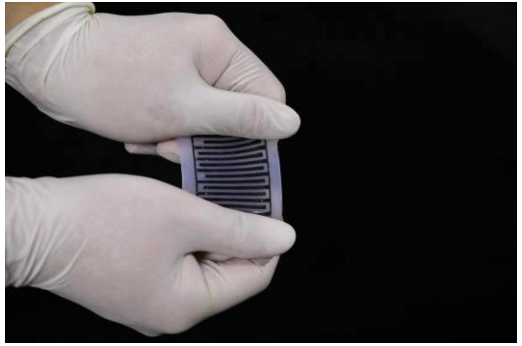 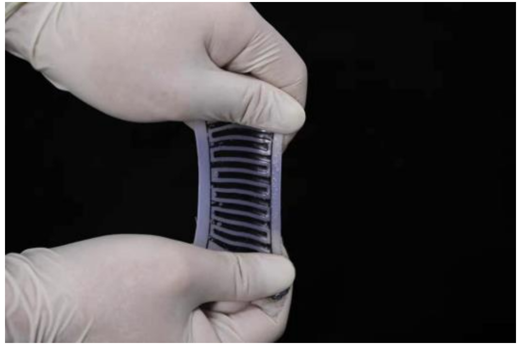 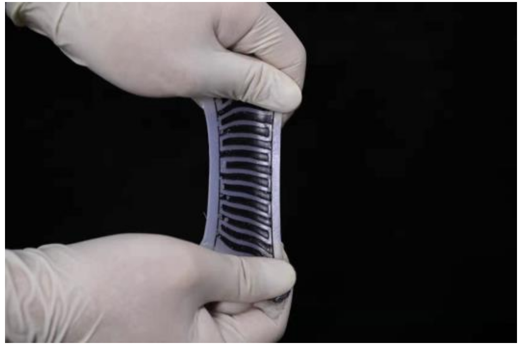 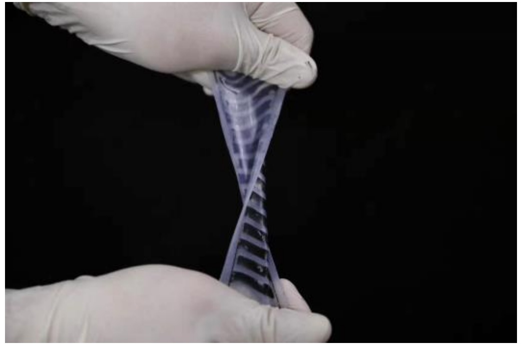

A Soft and Robust Electroadhesive Device

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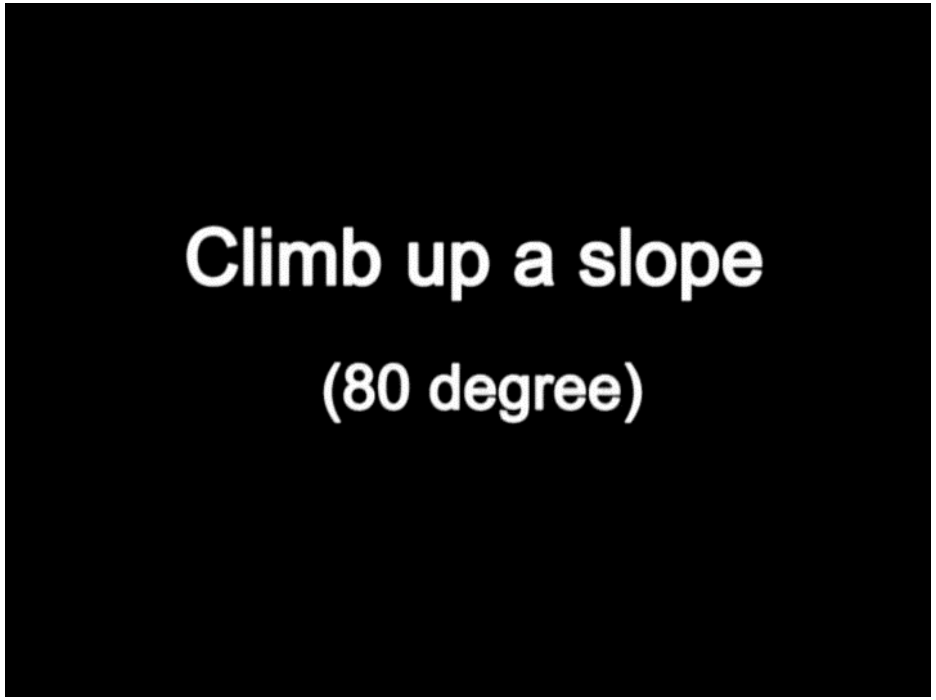
Advanced Actuators & Robotics Lab

Motivation

[GRABIT]



[Advanced Actuators &Robotics Lab, SUSTech]

Extensive applications:

- **grippers**
- **wall climbing robots**
- **clutches**

Motivation

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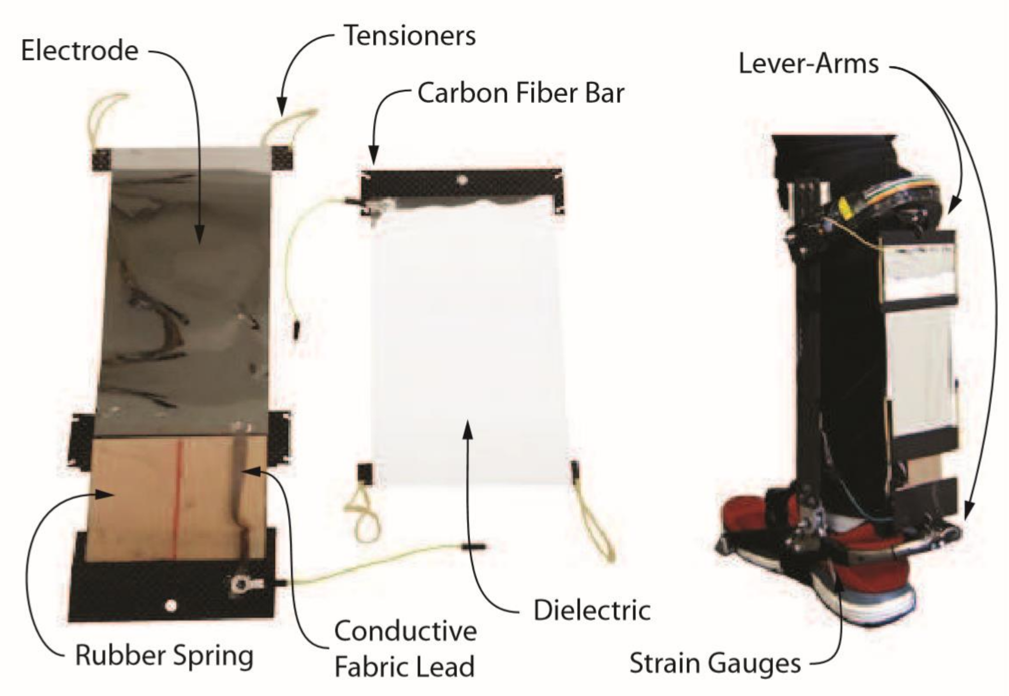
Extensive applications:

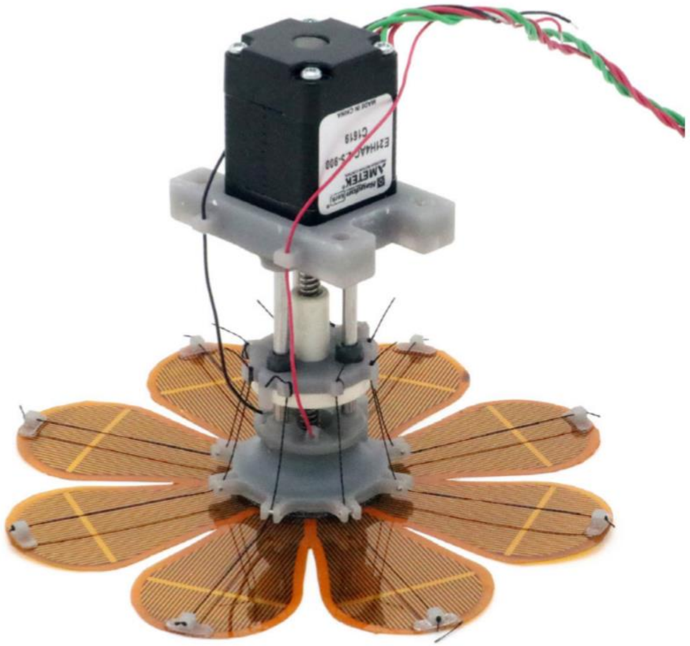
- suction grippers
- wall climbing robots
- clutches

Advantages:

✓ light weight
✓ strong force
✓ quick response



[Stuart Diller, ICRA, 2016.]



[Ethan W. Schaler ,IROS, 2017.]

Principle

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high voltage on electrode

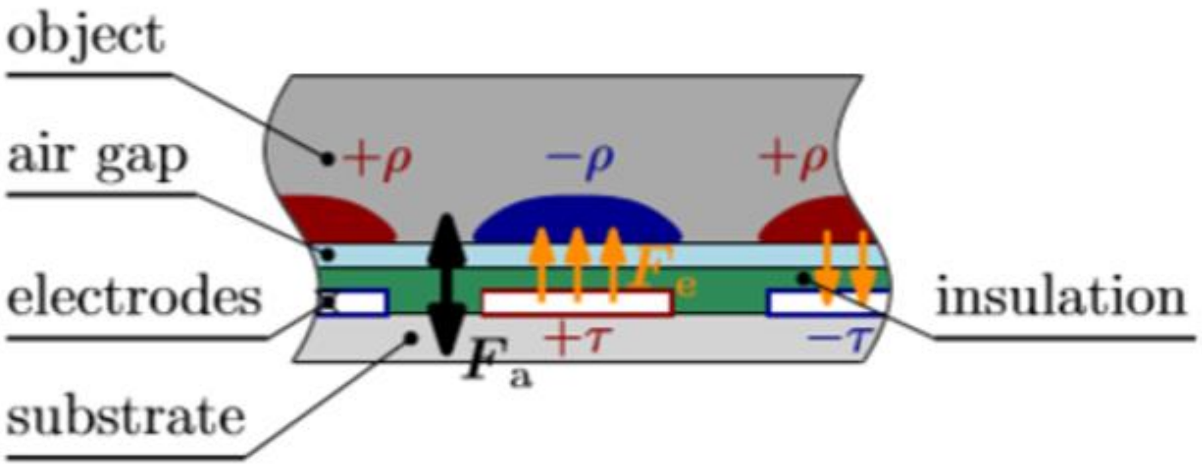
↓

attract free charges in conductors

↓

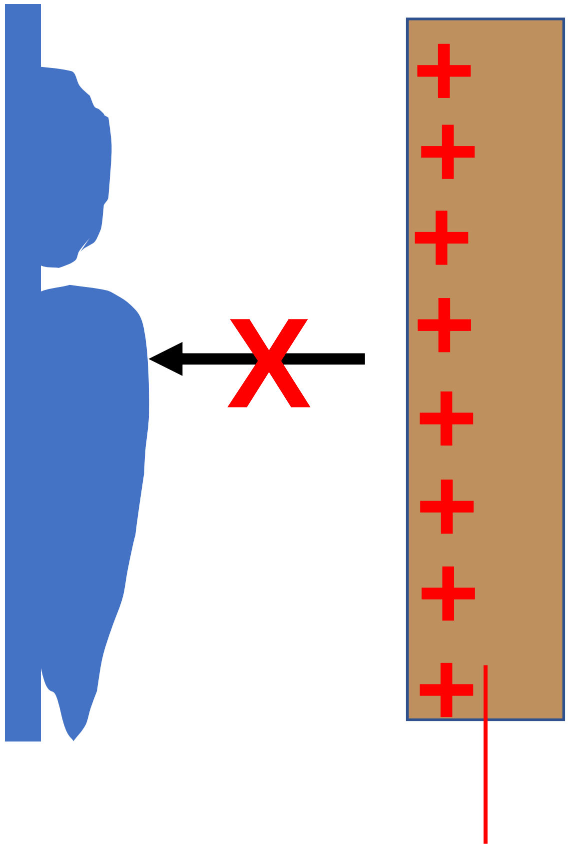
polarization in insulating objects

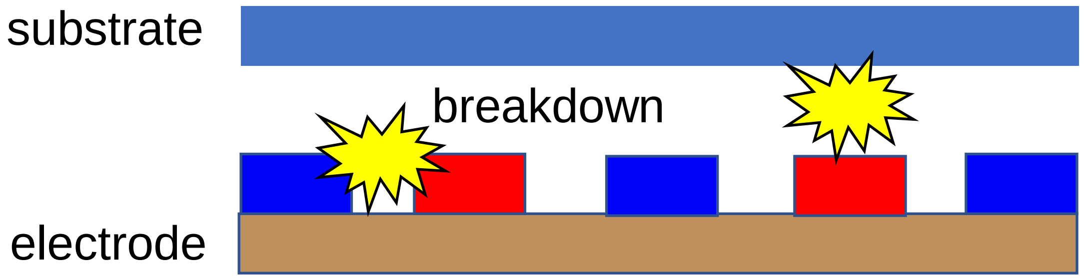
→ **induced and polarized charges**



[Fessl, *Open Physics*, 2018]

Challenges





- thin metal foils
- insulation cover layers

Disadvantages:

χ can not adhere to complex shapes

χ susceptible to electrical breakdown

Proposal

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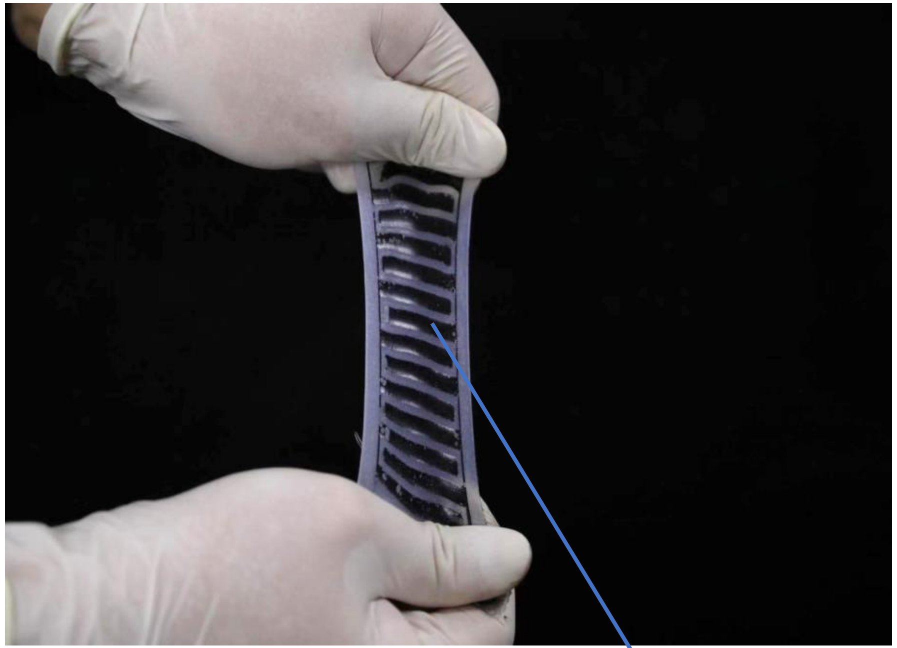
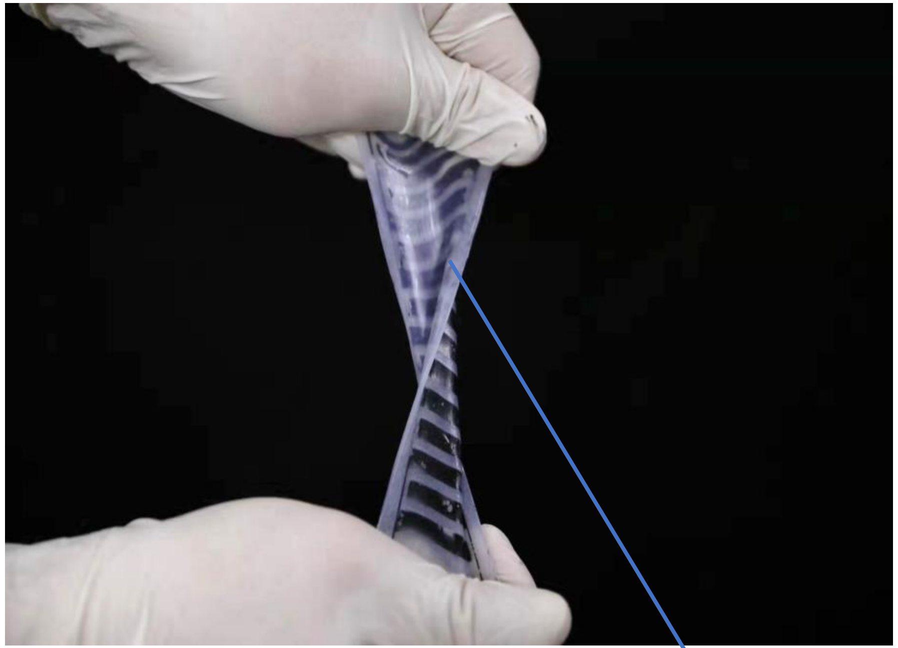




(previous) metal foils → **conductive fluid**
(carbon nanotube suspension)

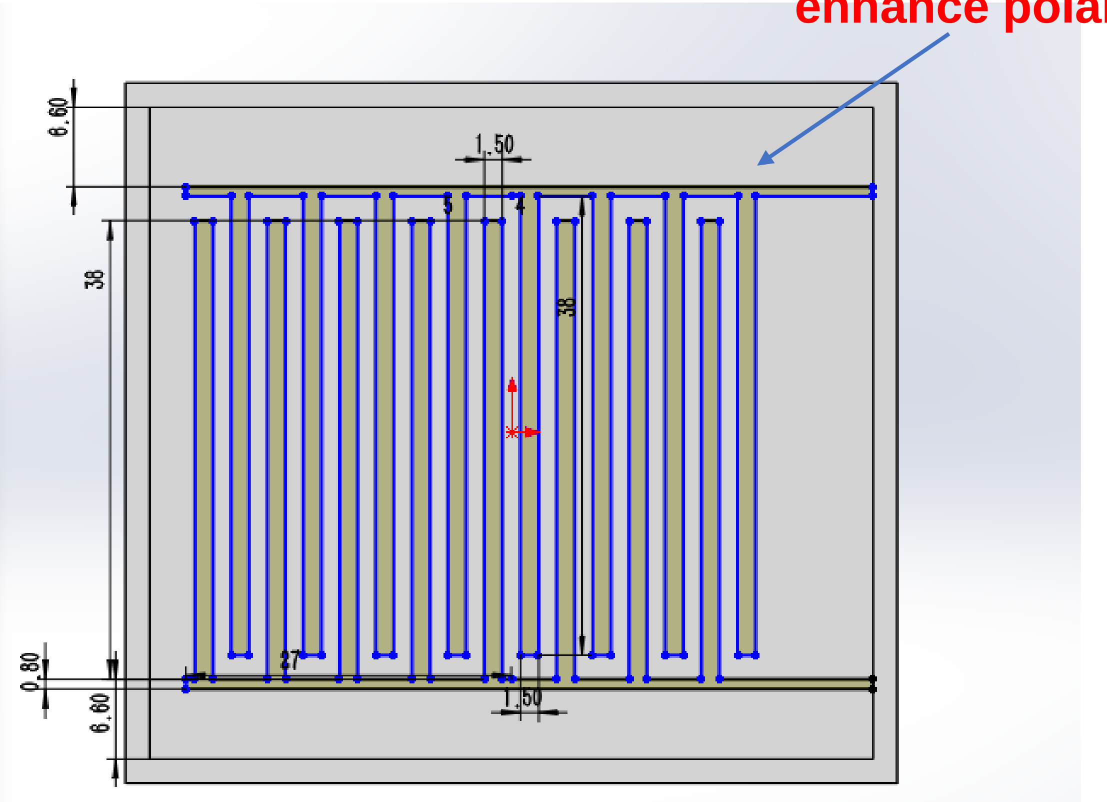
(previous)
stiff plastics → **soft elastomer**
(Ecoflex 00-30, Smooth-On)

Advantages:

- ✓ **highly soft, deformable and adaptive**
- ✓ **self-healing of circuit, robust**

Fabrication method

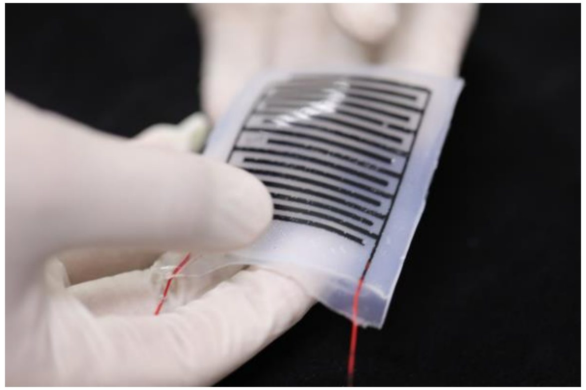
many boundaries to **enhance polarization**

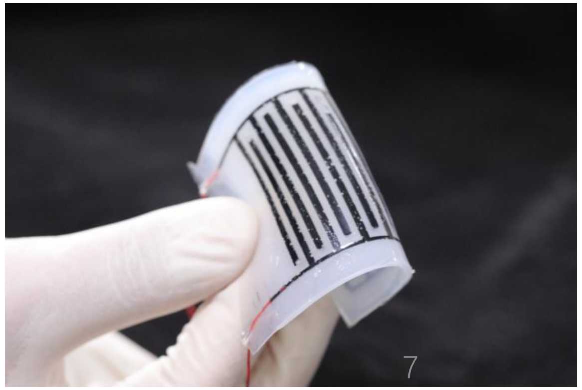


Standard Interdigitated Electrode Plate

length	38 mm
width	1.5 mm
height	0.5 mm
spacing	1.5 mm

Effective electrostatic adhesion area is 9 cm^2.





Fabrication method

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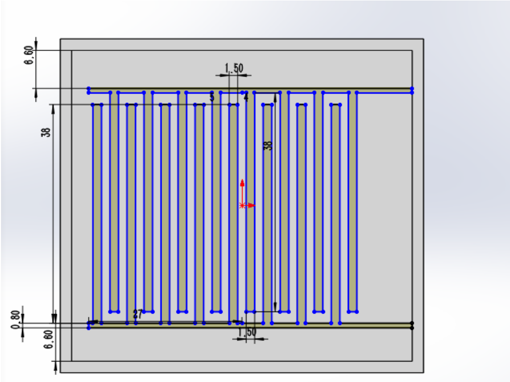
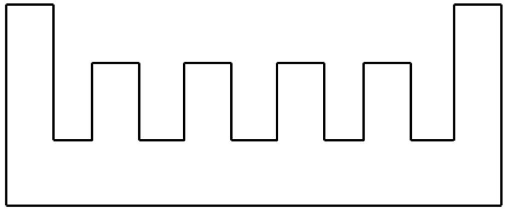
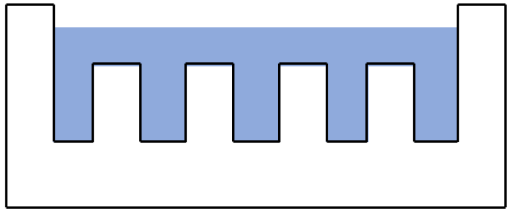
3D printing technology

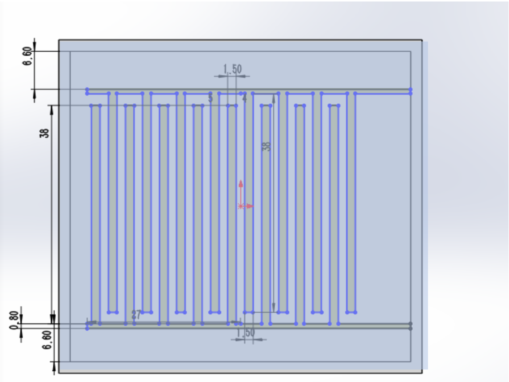


two-row positive and negative **interdigital** electrode template



pure rubber (Ecoflex 00-30) was poured on the template





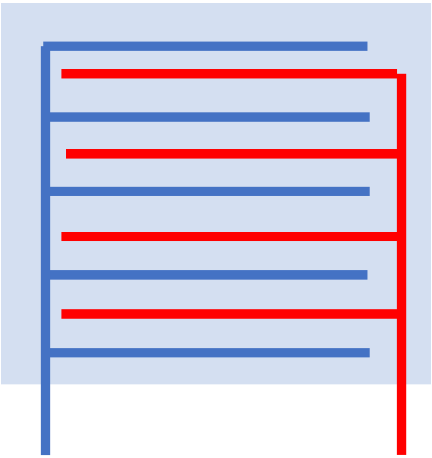
curing 3 hours at room temperature

thickness is nearly about 1.5 mm

different spin speed

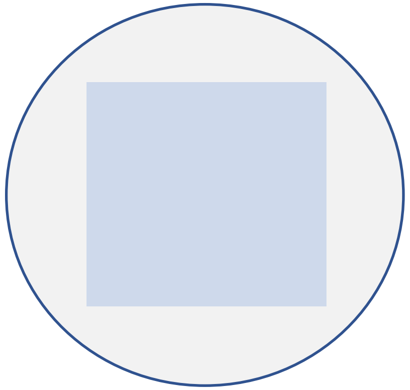
spin coater

Ecoflex 00-30



demolded silica gel

+



thin layer of rubber

Fabrication method

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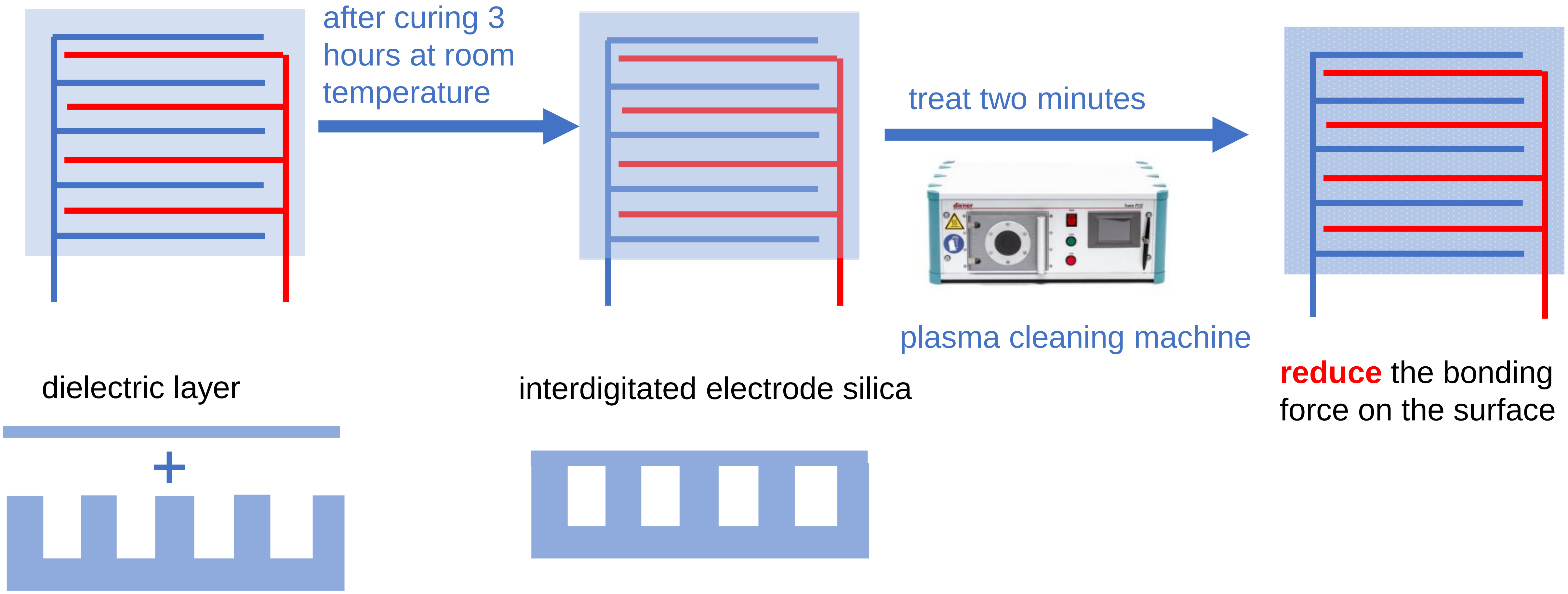
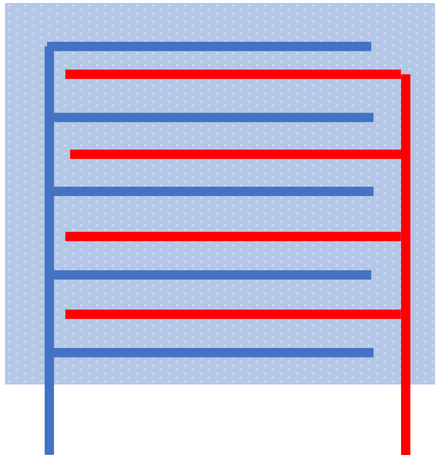


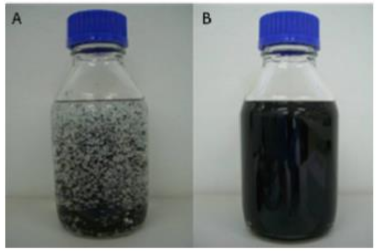
Fabrication method

after curing 3 hours at room temperature

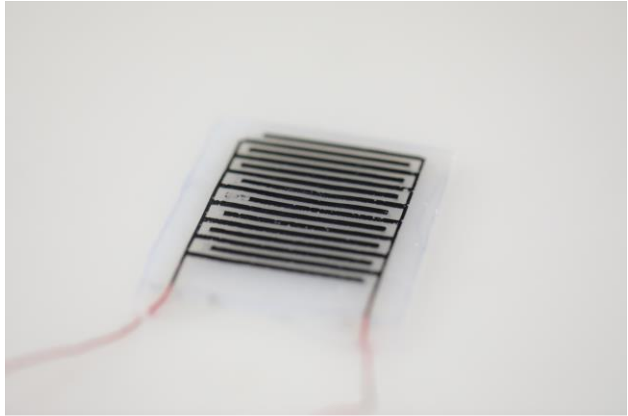


well bonded

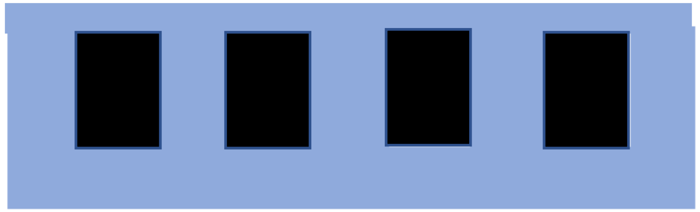
injected into the interdigitated electrode **microchannel**



carbon nanotube suspension



sealed after two wires are respectively connected



Experimental process

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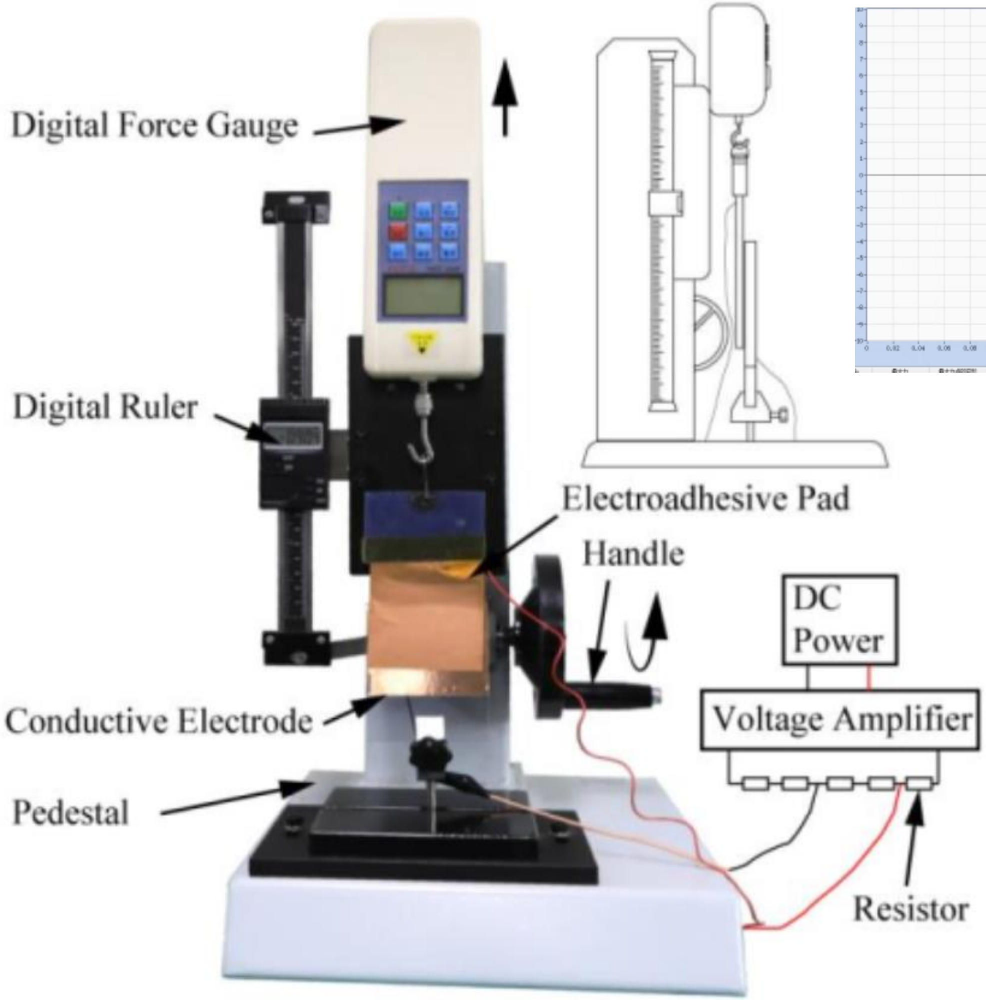

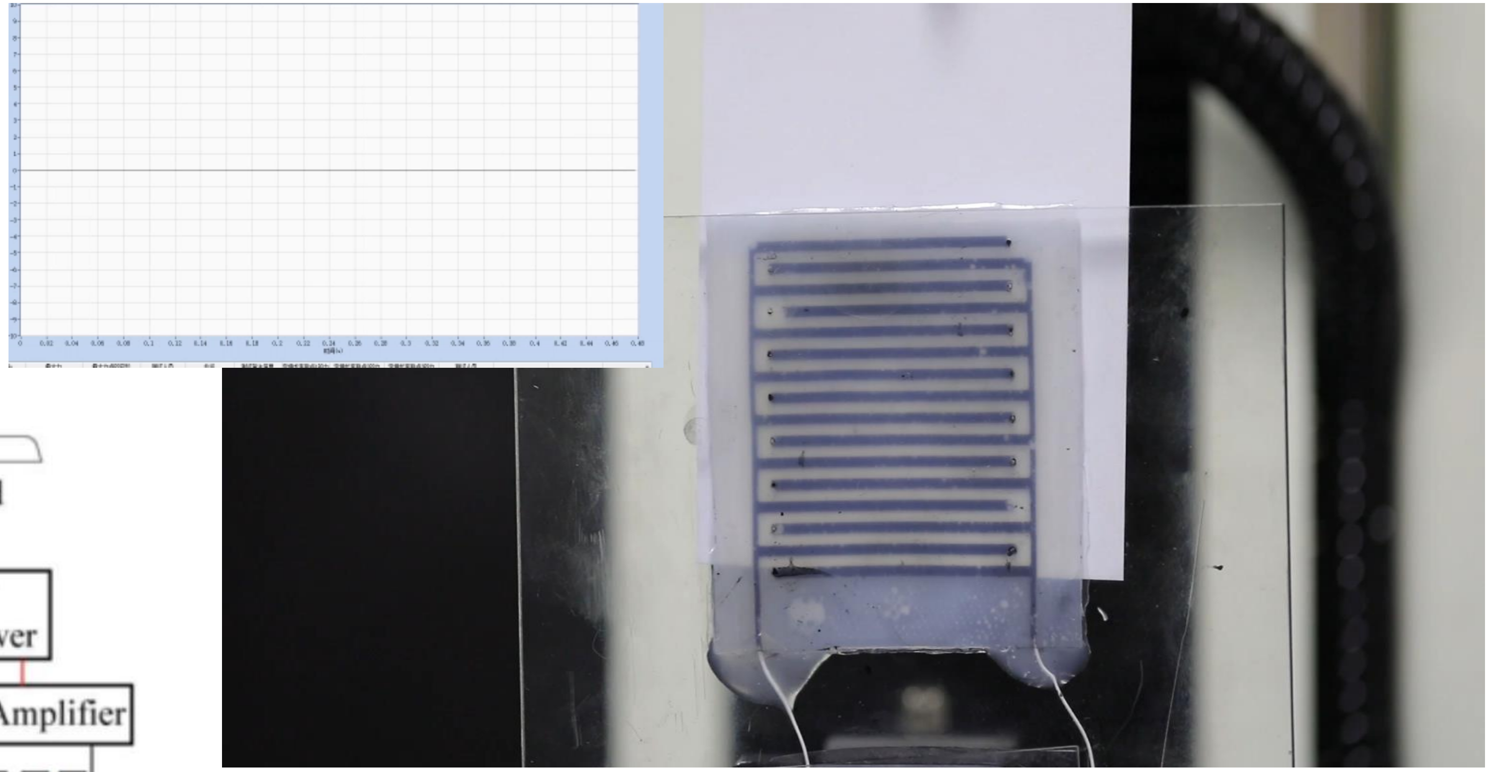

- Every result mentioned before is taken an average of six measurements
- Each test has half an hour interval
  (in order to **remove remnant polarized charges**).

Results

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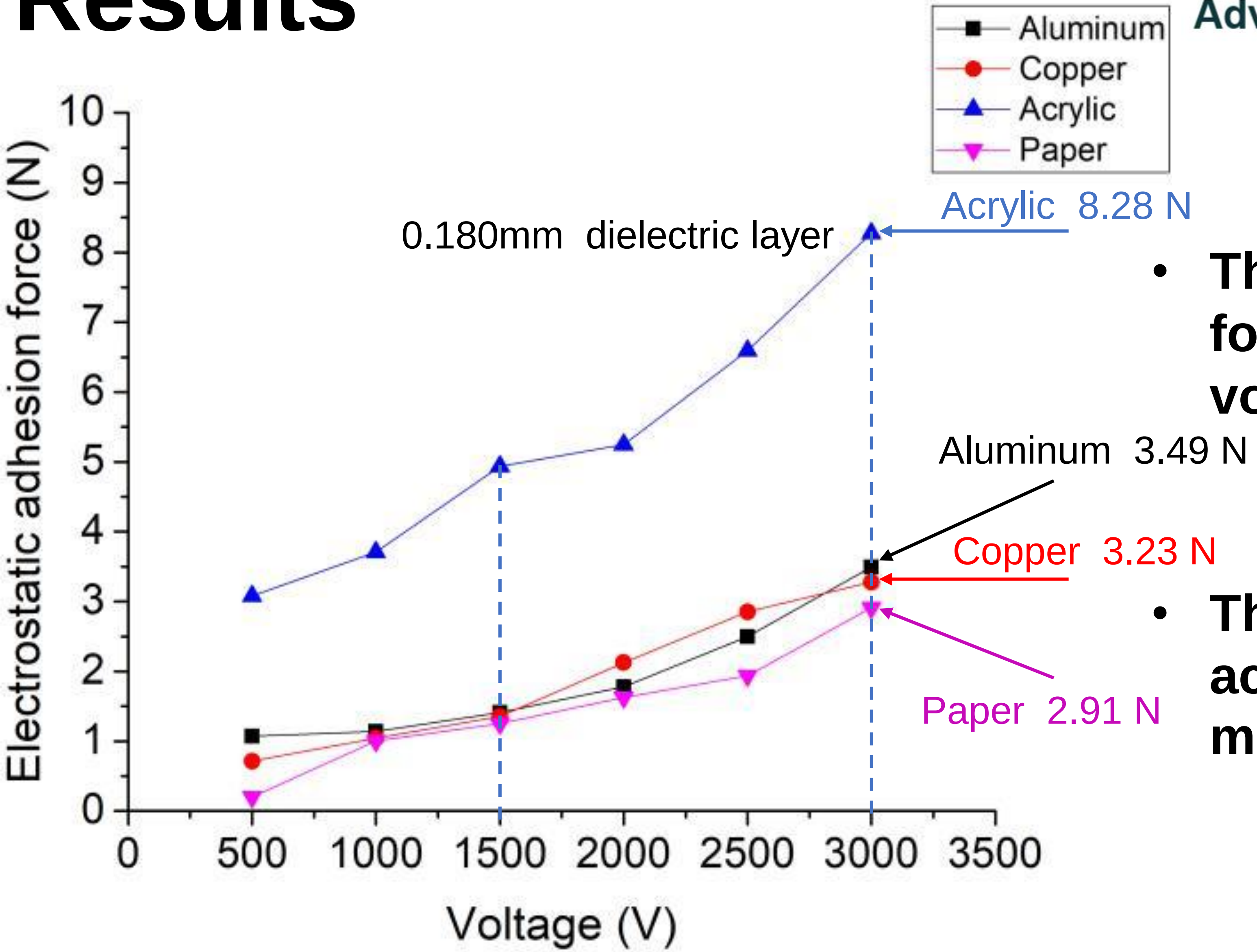

- **The electrostatic adhesion force strengthens with the voltage increasing.**
- **The adhesion force on acrylic is better than metal.**

Results

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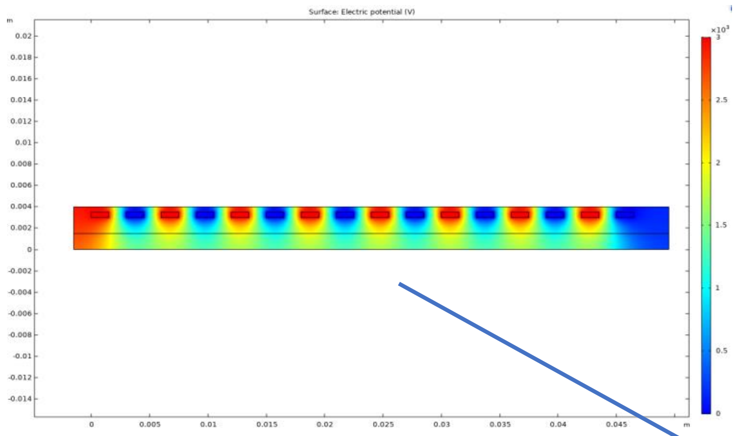
The bonding force (when voltage=2 kV→0, pressure=0)

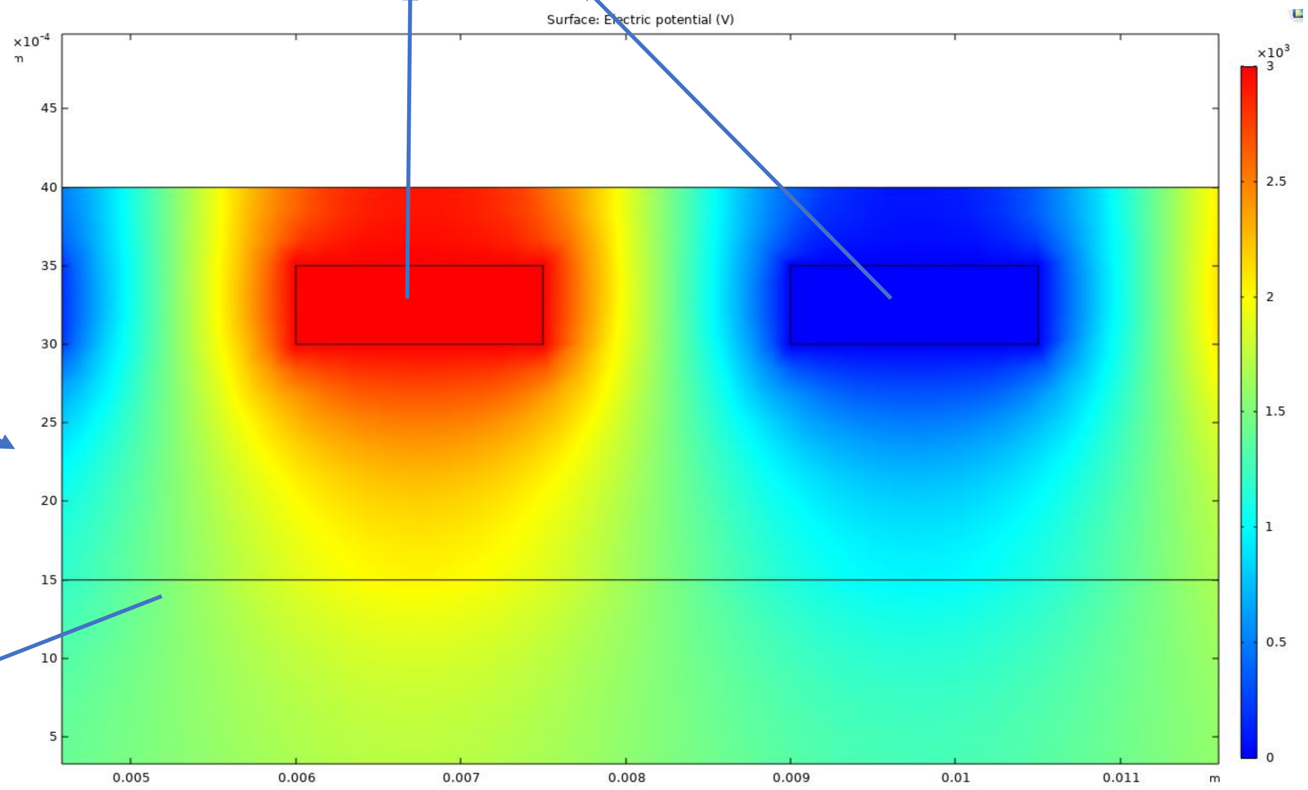
Substrates	Bonding Force
paper	0.67 N
acrylic	5.41 N
copper	0.79 N
aluminum	1.56 N

- **The final adhesion force = bonding force + electroadhesive force**
- Electroadhesive force can introduces more bonding force (pressure sensitive).

Analysis and Simulation



Electrode (CNT , 3000 V)



the distribution of scalar electric potential φ

Aluminum Plate
(1.50 mm thickness)

Analysis and Simulation

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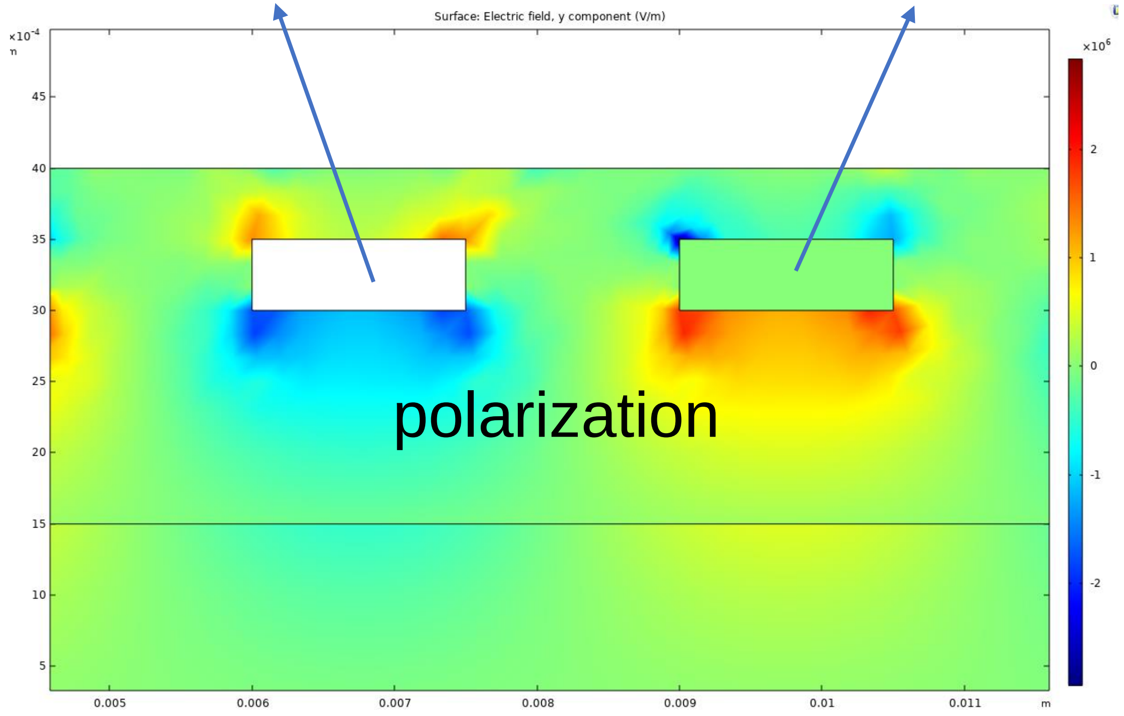
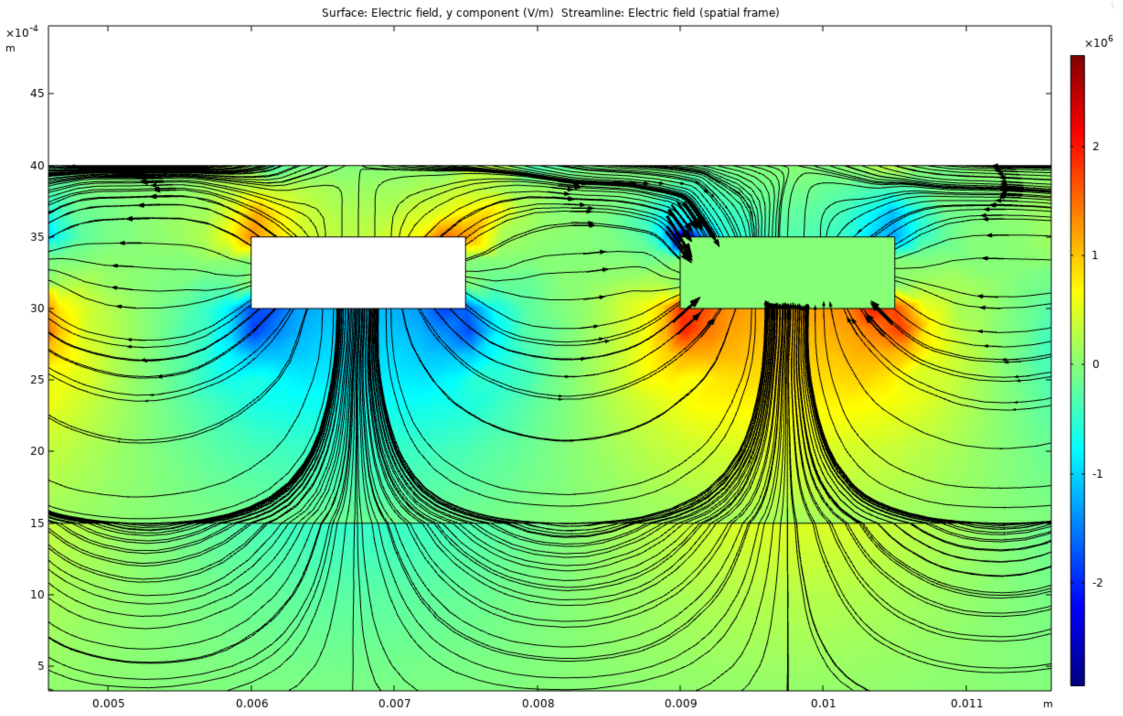
positive electrode   negative electrode





the distribution of electric field E in the definition area
(with & without electric field line)

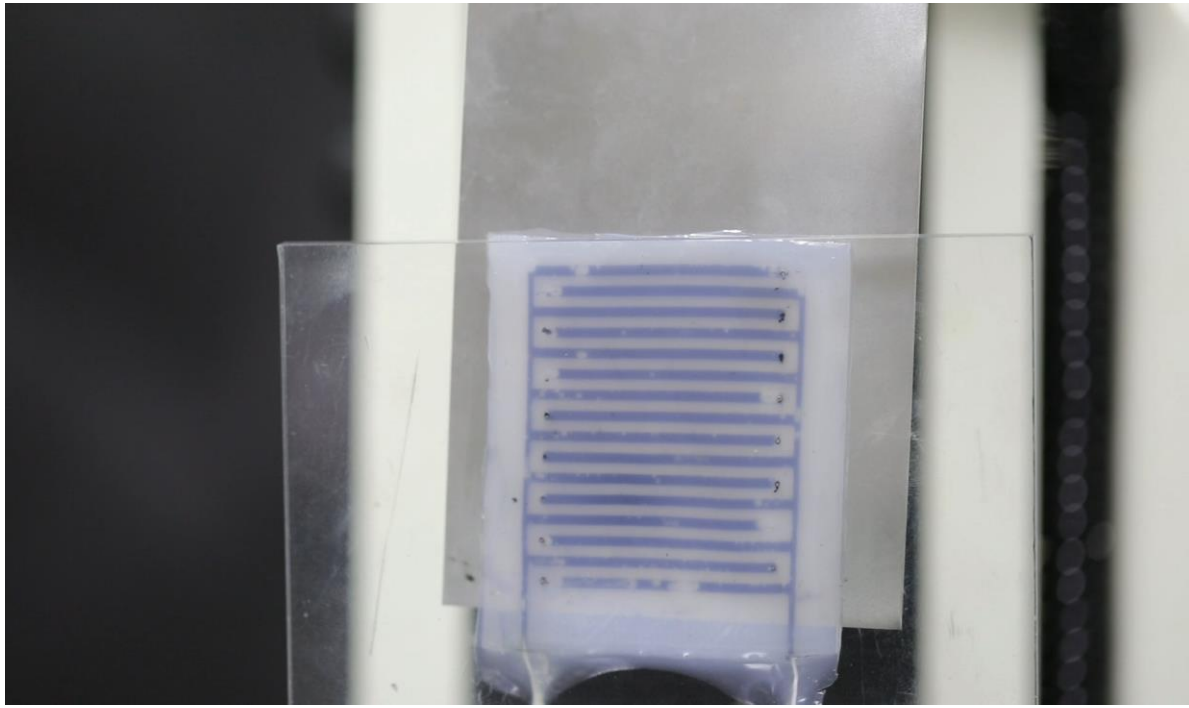
By simulation,

$F_{\mathrm{sim}} = 1.216\ N$

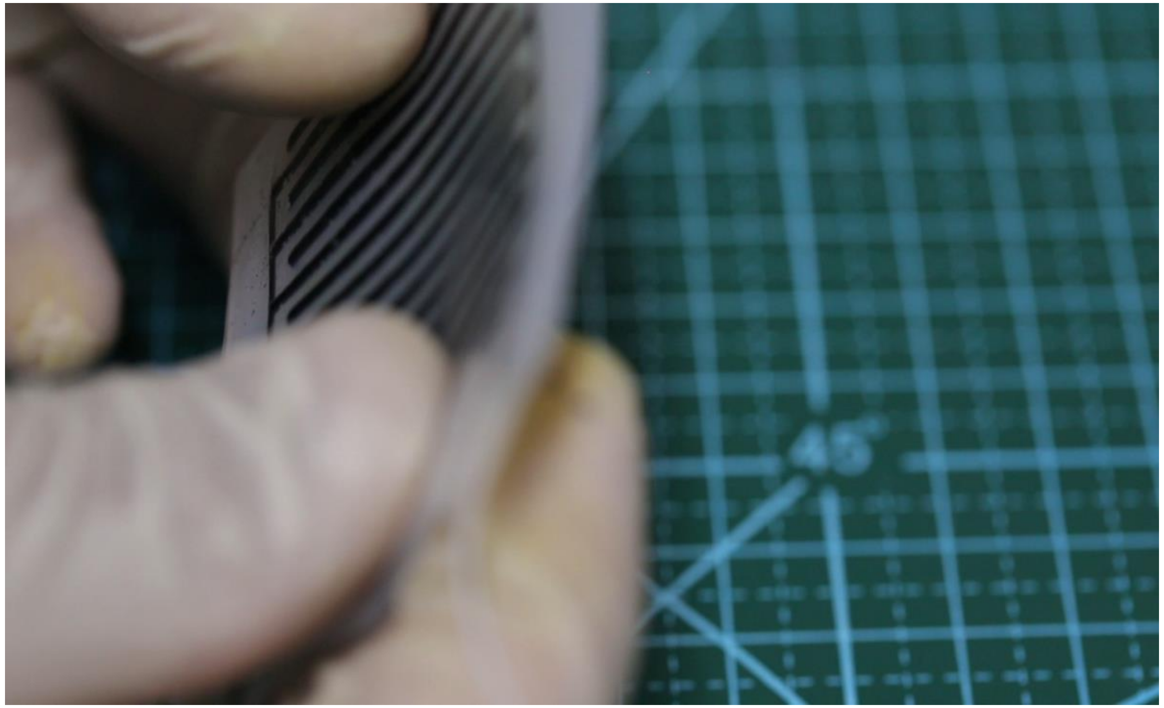
By experiment,

$F_{exp} = 3.49 - 1.56 = 1.93\ N$

Self-healing



electrical breakdown



physically penetration

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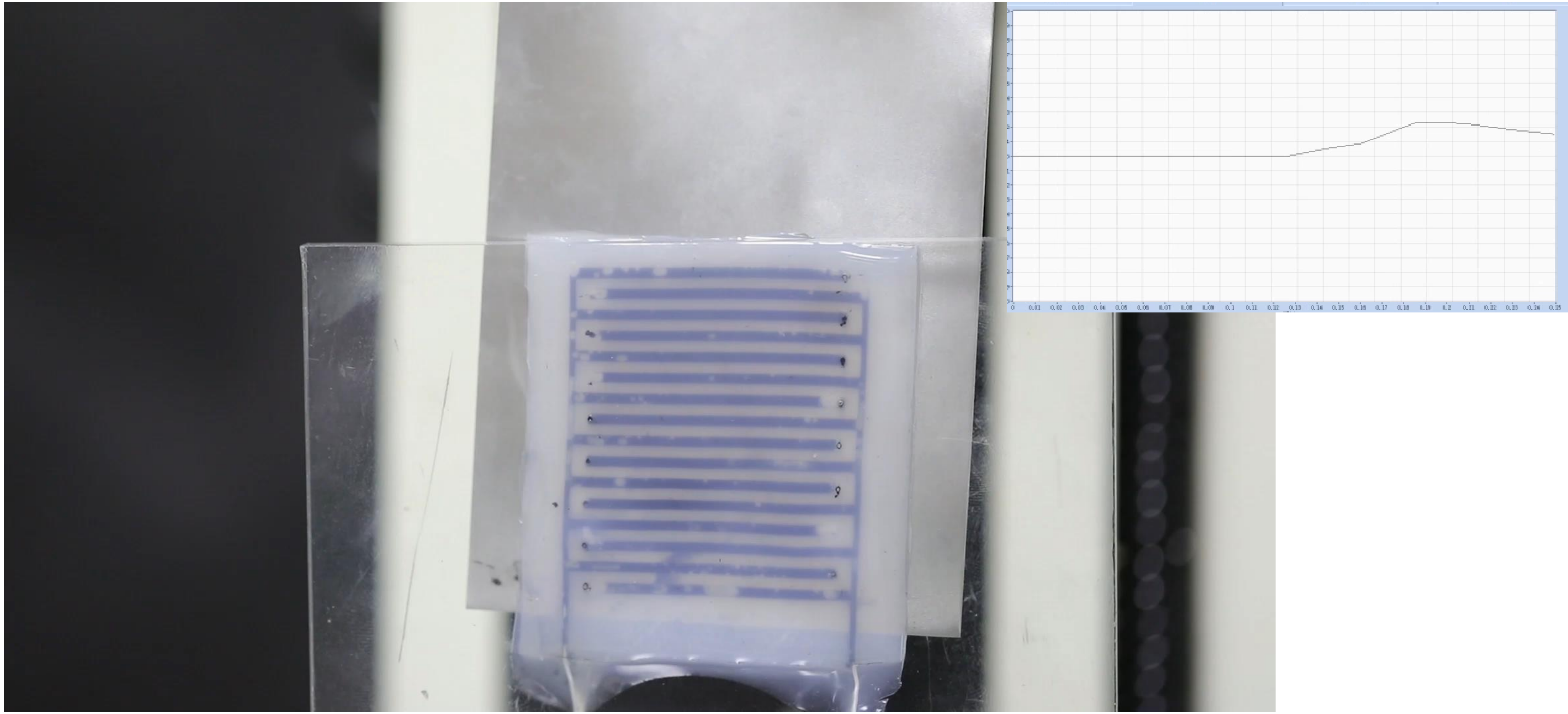
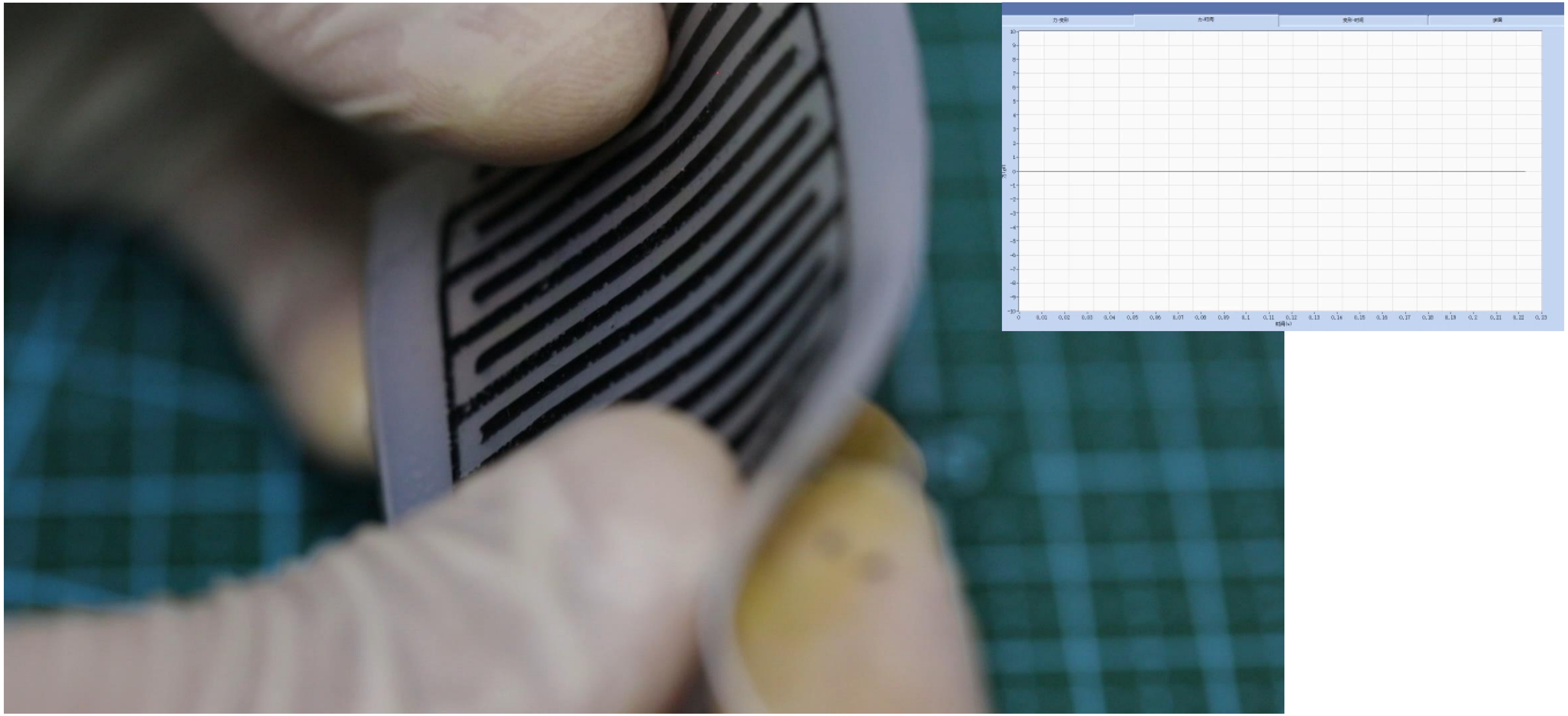
Self-healing



The adhesive pad can recover back and still work after the **electrical breakdown** （2500 - 3500 V ） .

Self-healing



The adhesive pad can recover back and still work after the **physically penetration.**

Self-healing

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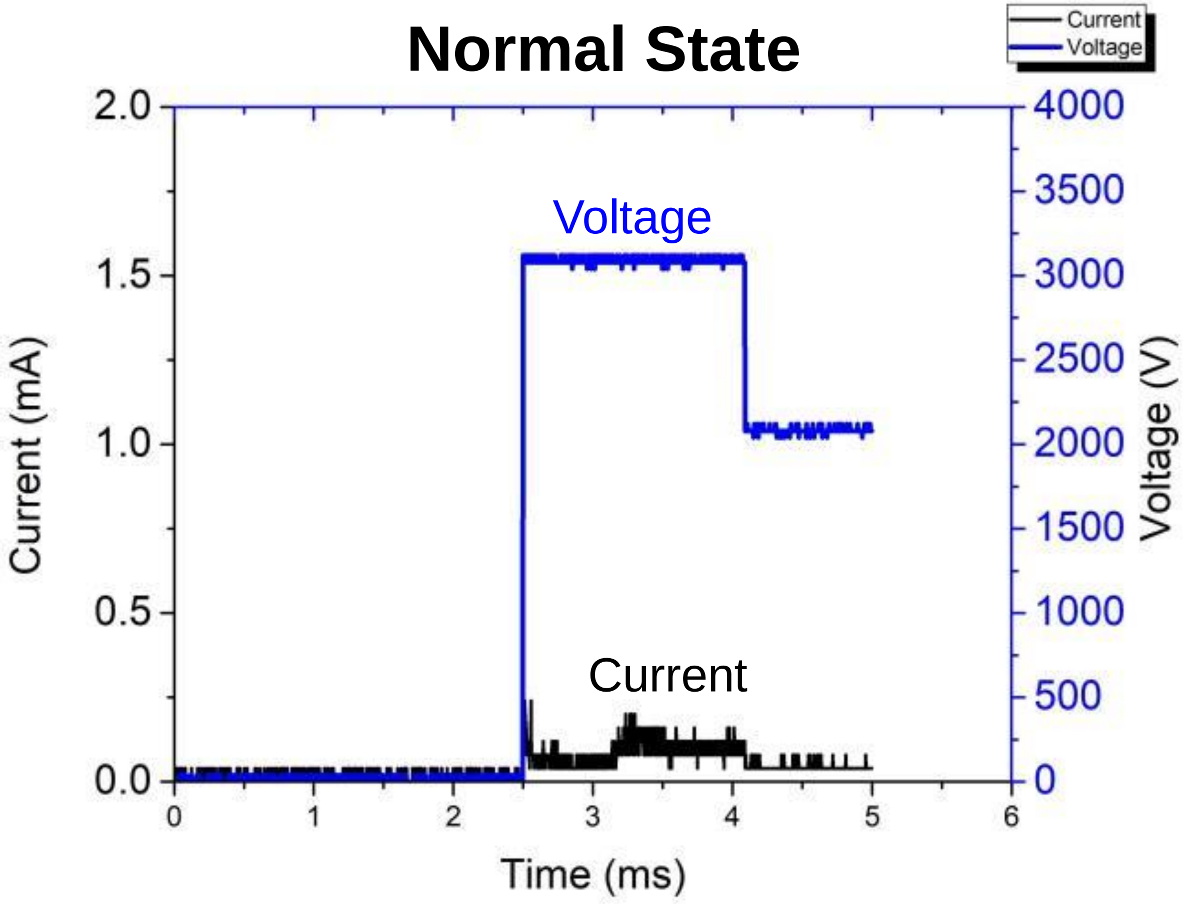
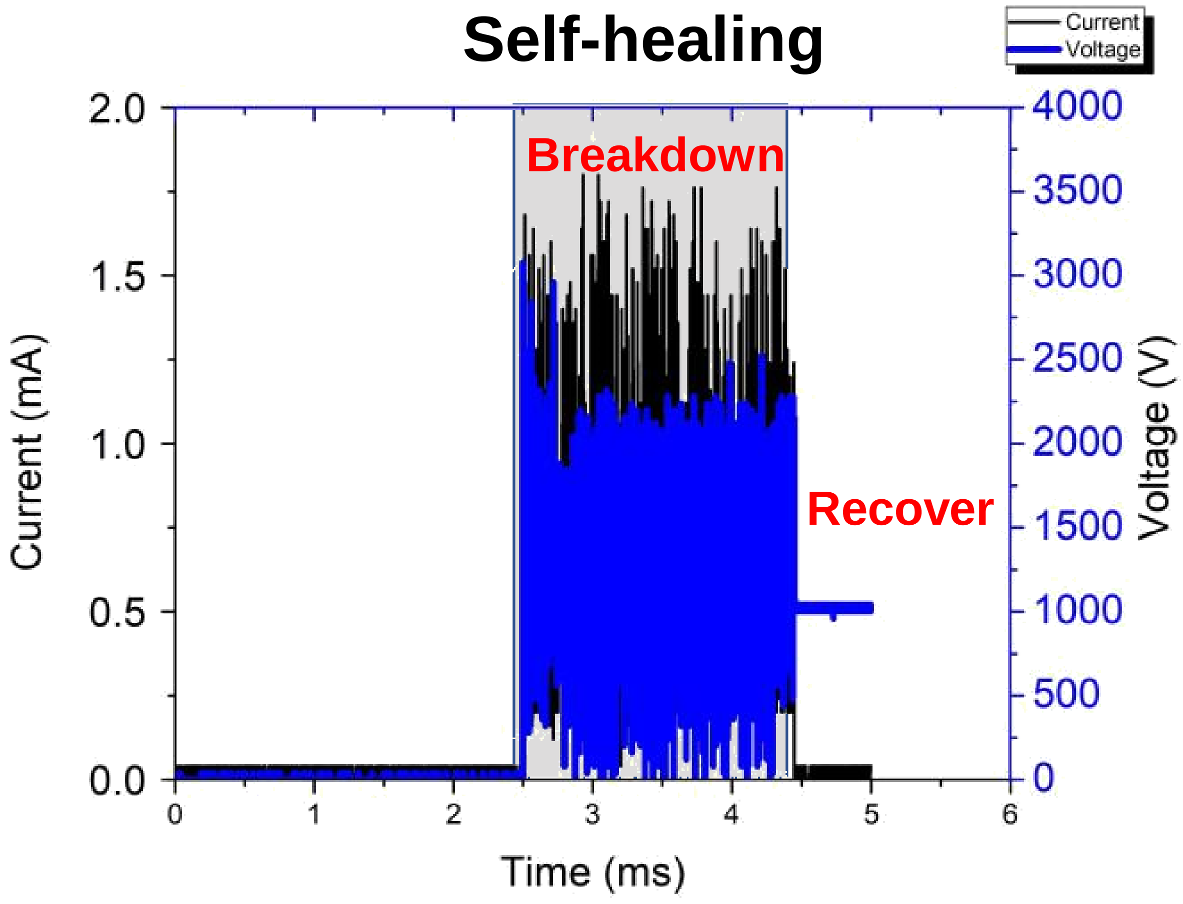


(a)



(b)

since the fluid electrode is flowable and the soft elastomer cover layer is squeezable

Summary and discussion

- We propose a **flexible, stretchable and self-healing** electroadhesive pad.
- We describe **a new simple method and material** to fabricate stretchable and self-healing electroadhesive pads.
- After the electrical breakdown or physical penetration , the adhesive pad can **recover back and still work**, since the fluid electrode is flowable and the soft elastomer cover layer is squeezable.
- It can be used to improve the function of electroadhesive devices in existing applications, such as **grippers, clutches, medical devices, and wall-climbing robots.**
- It can also be used in **soft robotics**, where the traditional rigid metal pads are not stretchable and easy to be breakdown.

Thank you!

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