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Manufacturing of ionic polymer-metal composites (IPMCs) that can actuate into complex curves

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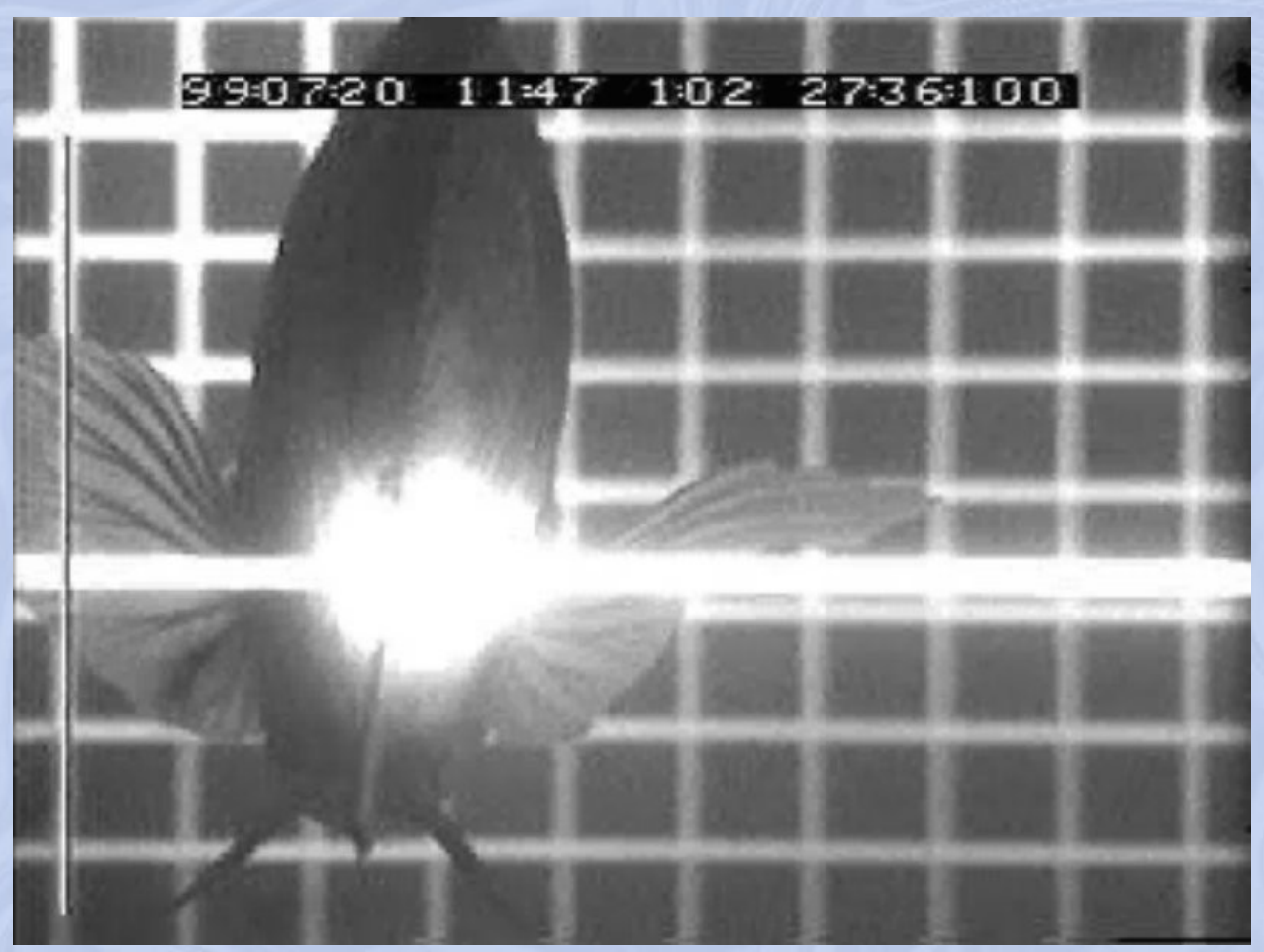
University Of Bristol

Motivation

Can we ever make anything as gracious as this ...

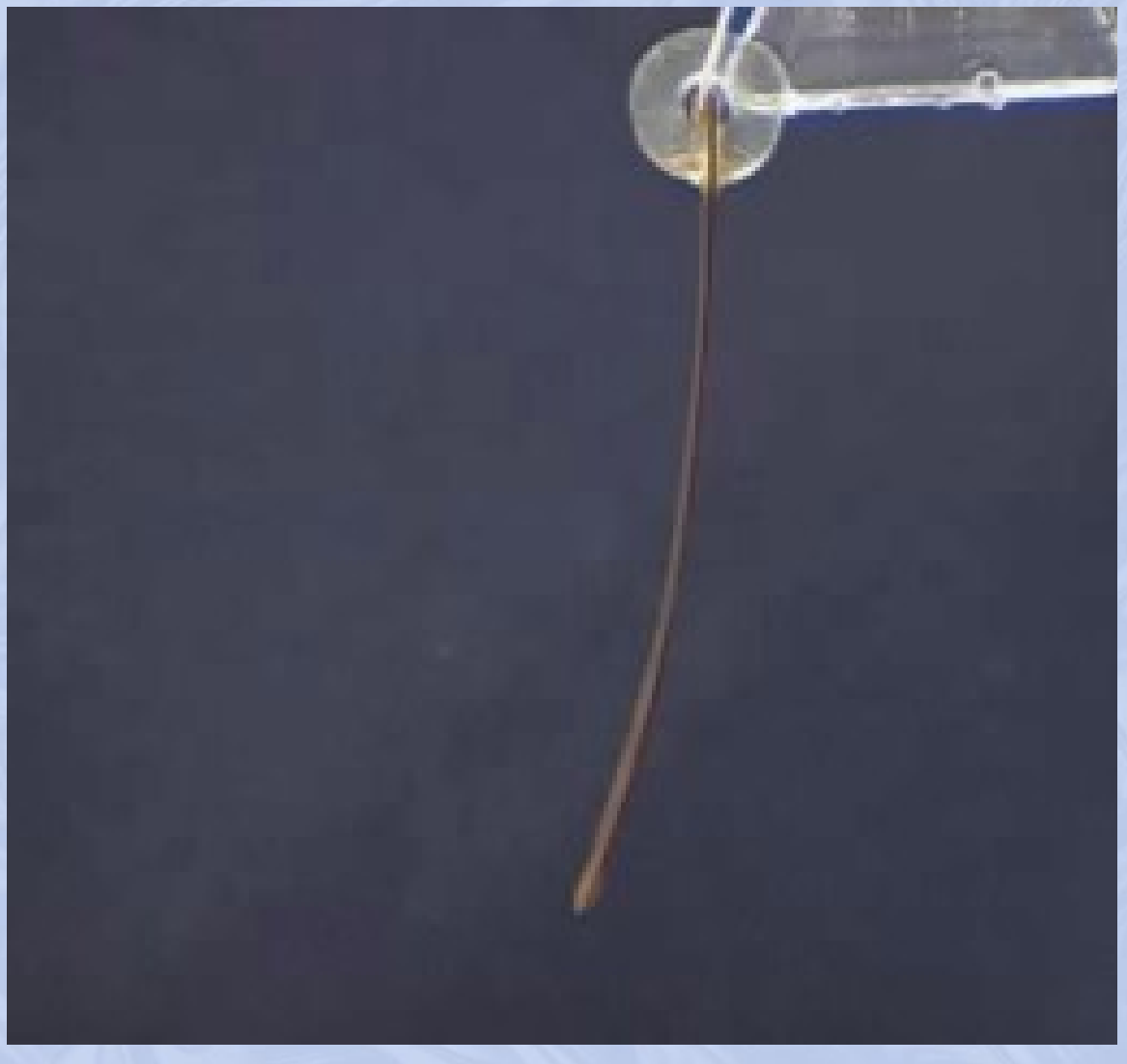
Pelagia jellyfish



Pectoral fin locomotion in a bluegill *(Lepomis macrochirus)*
Drucker and Lauder (1999) J. Exp. Biol. 202: 2393-2412.
http://www.people.fas.harvard.edu/~glauder/

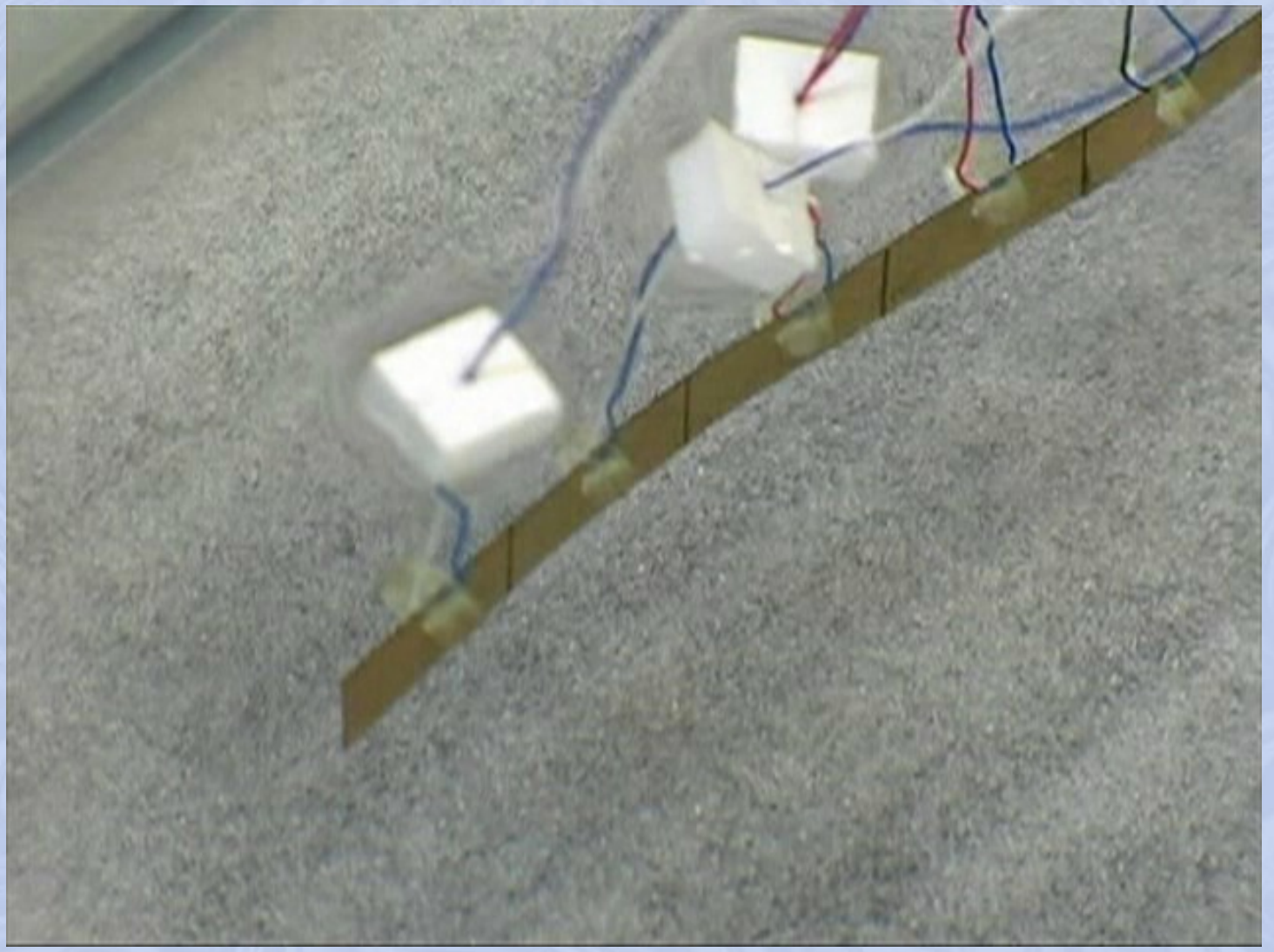
Motivation

... by using anything
that can only bend like this?



Bent actuated shape of IPMC

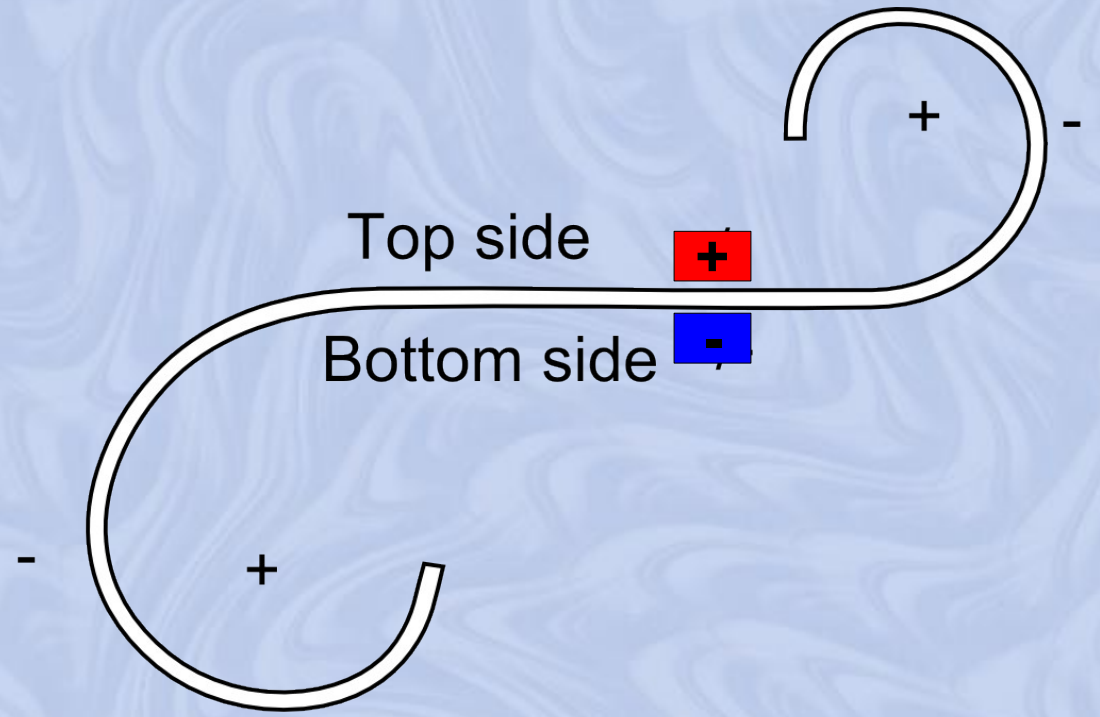
Motivation



Nakabo et al. (2004)

Objective

To realize an IPMC actuator, which can actuate into a complex shape, when powered from a single power source.



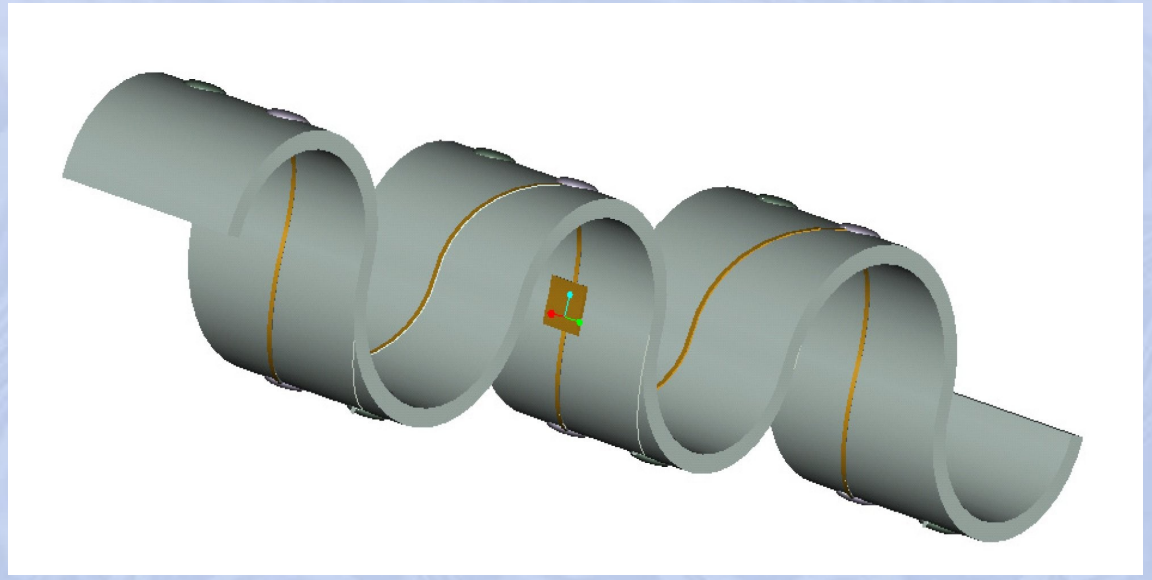
Past work – 3D EAP structures

IPMC manufactured in a 3D shape

Kim & Shahinpoor (2003)

Past work - “slithering IPMC”

Concept



Realization

Shahinpoor & Kim (2005)

Past work - four segment “snake”

Four-segment ribbon “snake”, connected in reverse polarity

Eamex Corp., Japan
http://www.eamex.co.jp/video/snake_new.wmv

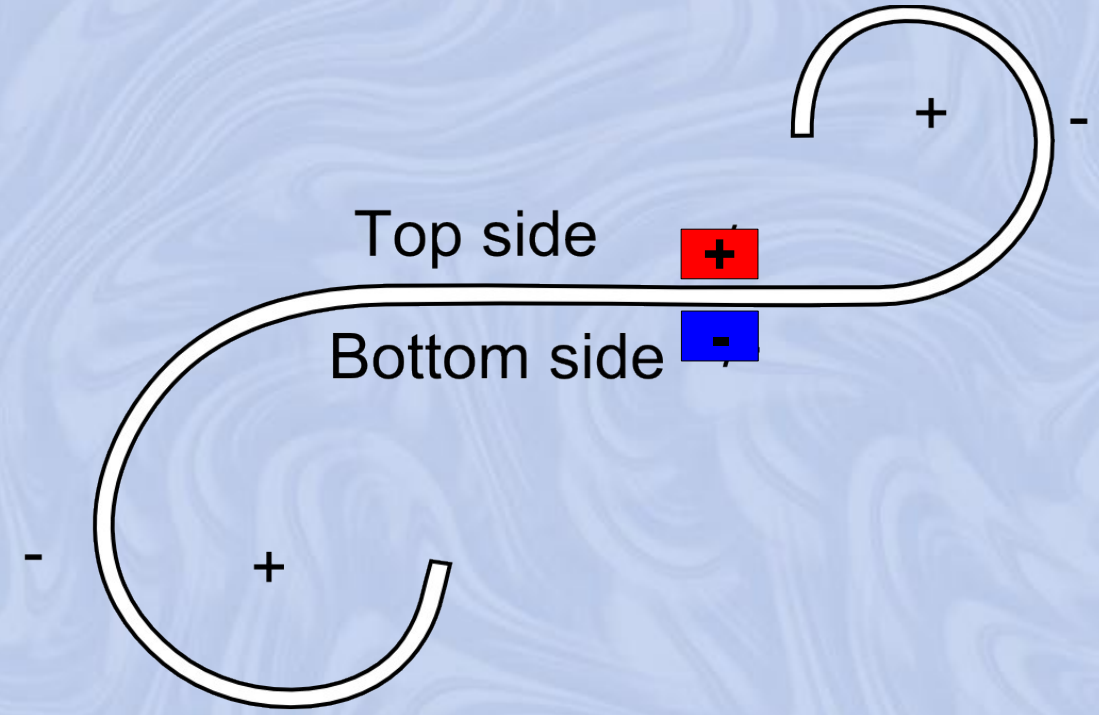
Past work - four segment “snake”

Four-segment ribbon “snake”, connected in reverse polarity

Eamex Corp., Japan
http://www.eamex.co.jp/video/snake_new.wmv

Our approach

Easy to manufacture multi-segment single sheet IPMC.



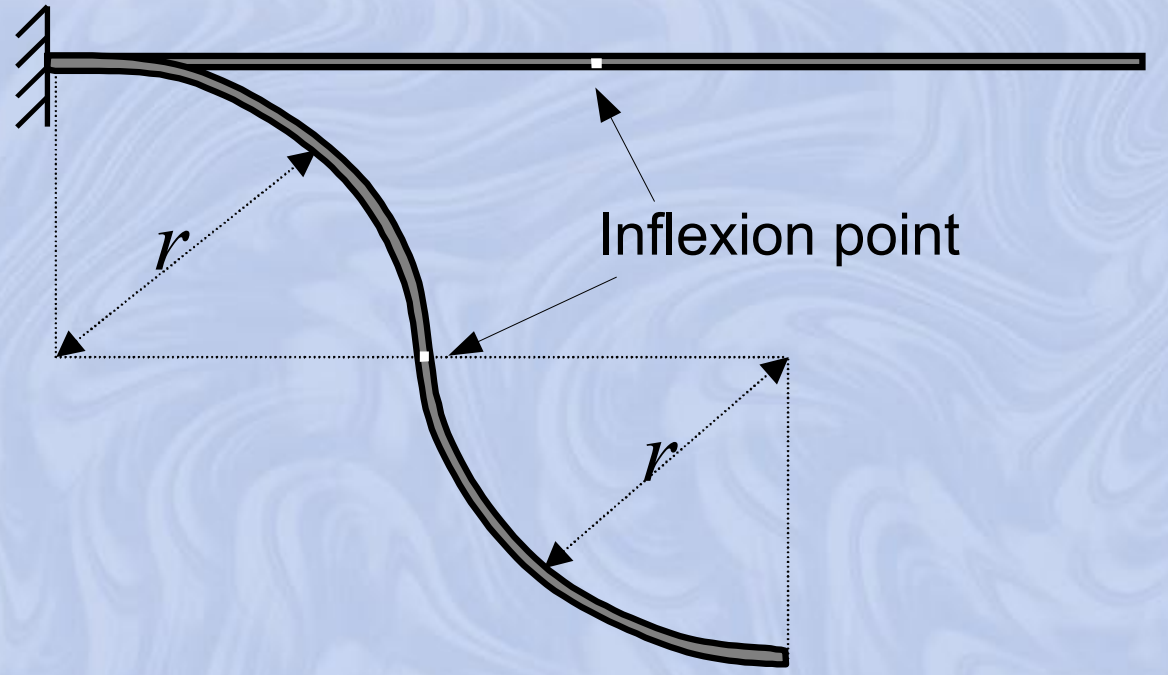
Need to enable:

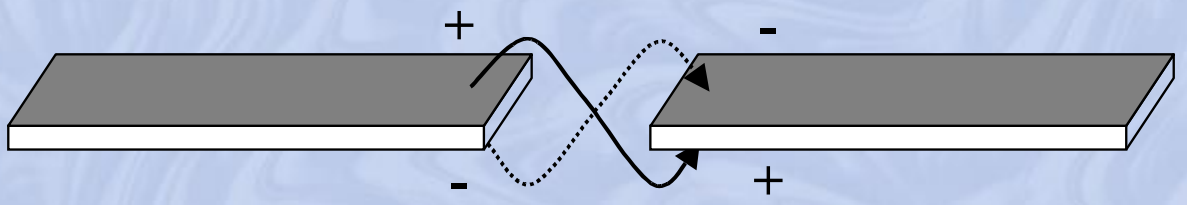
- Opposite curvature
- Variable curvature

Key elements:

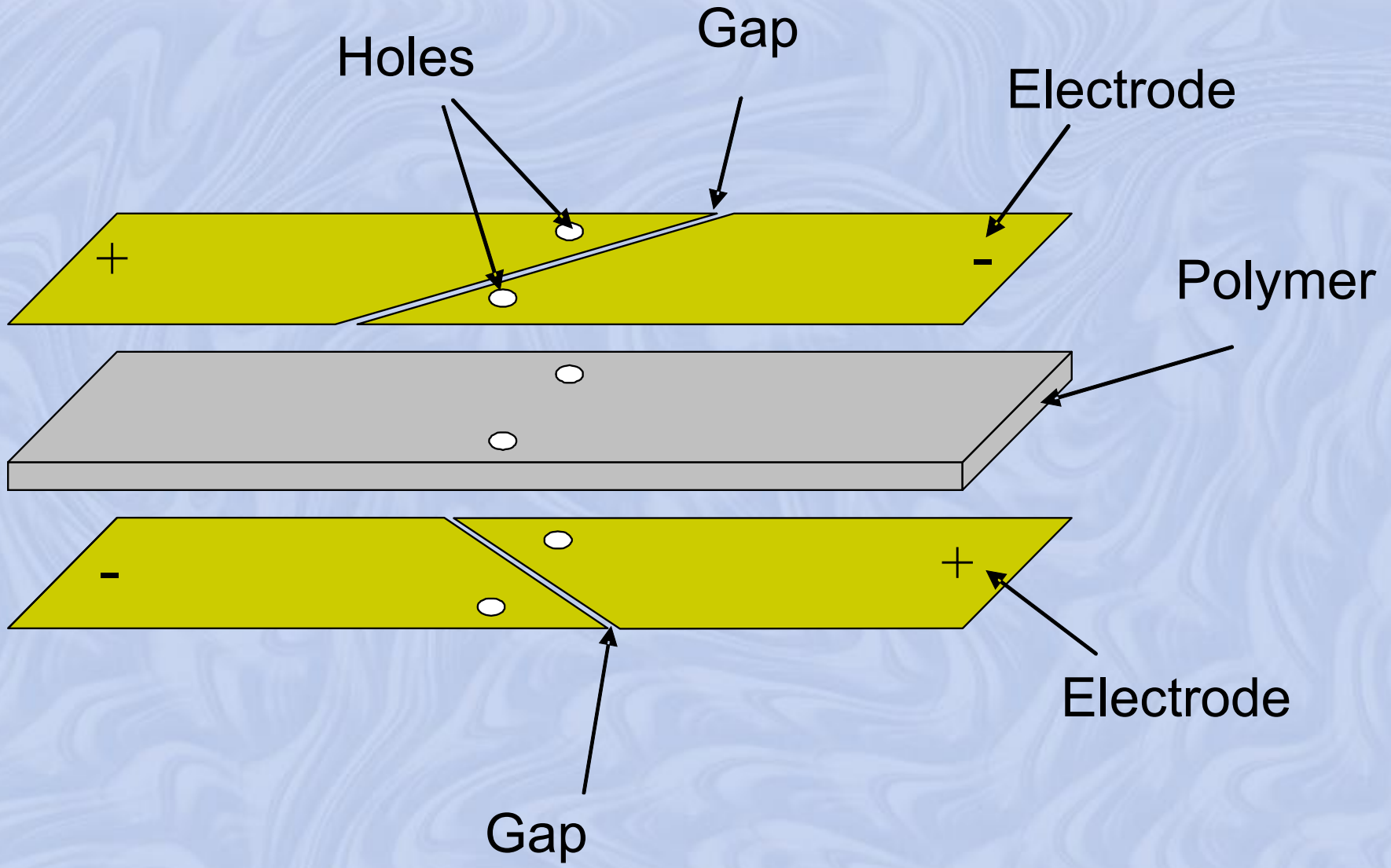
- Reversing connection between adjacent segments
- Electrode overlap within a segment

Enabling opposite curvature

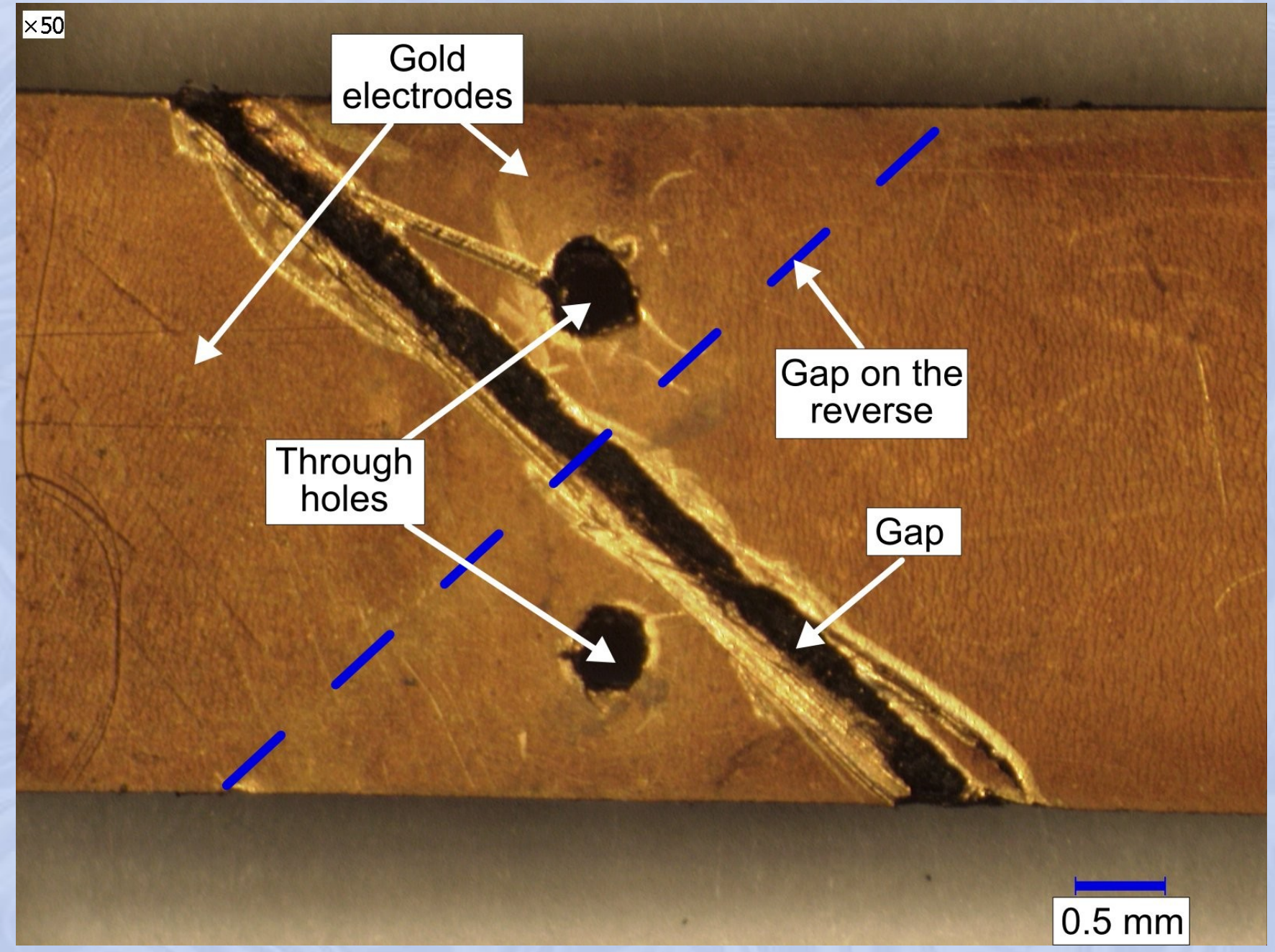




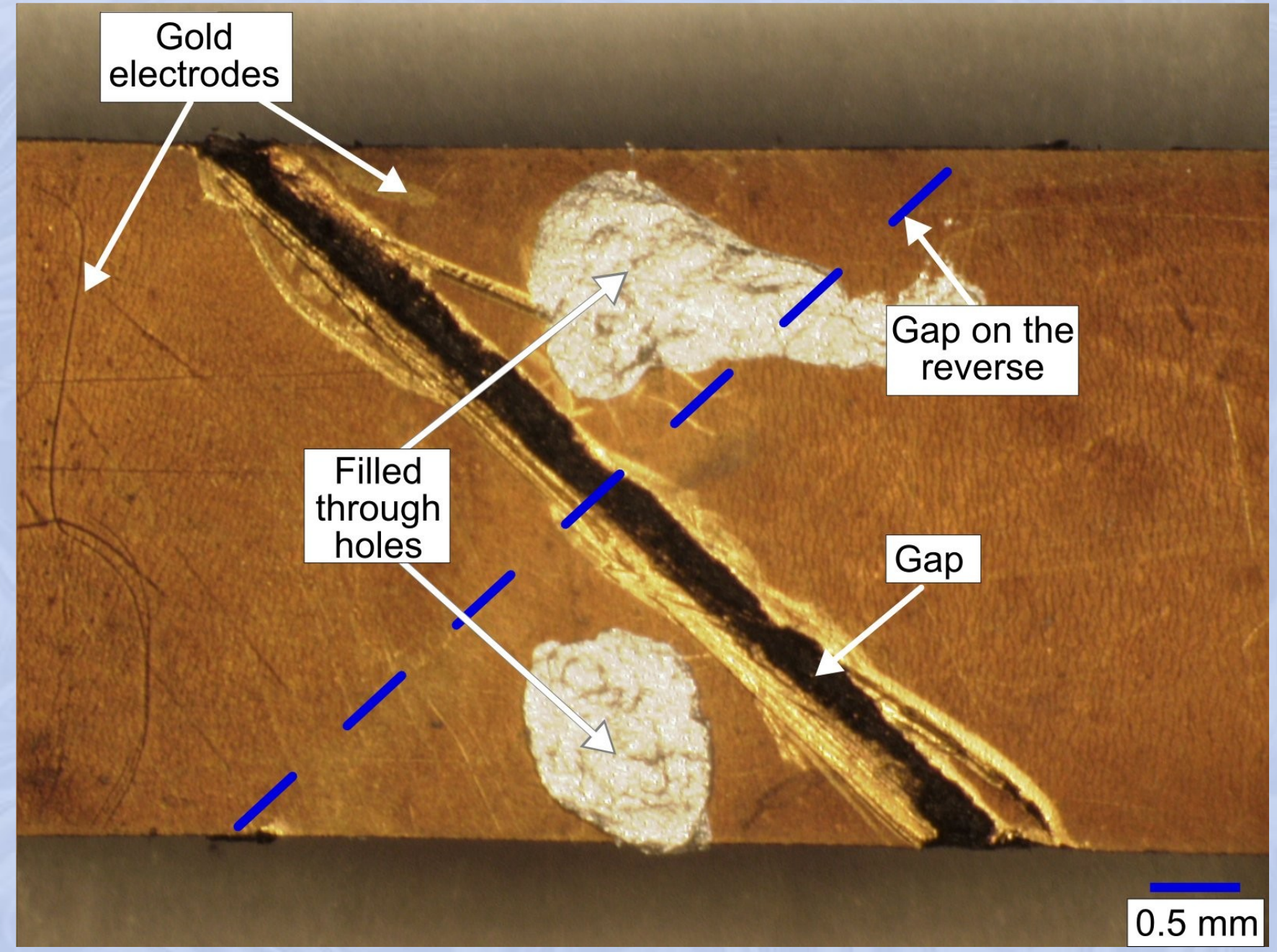
Enabling opposite curvature



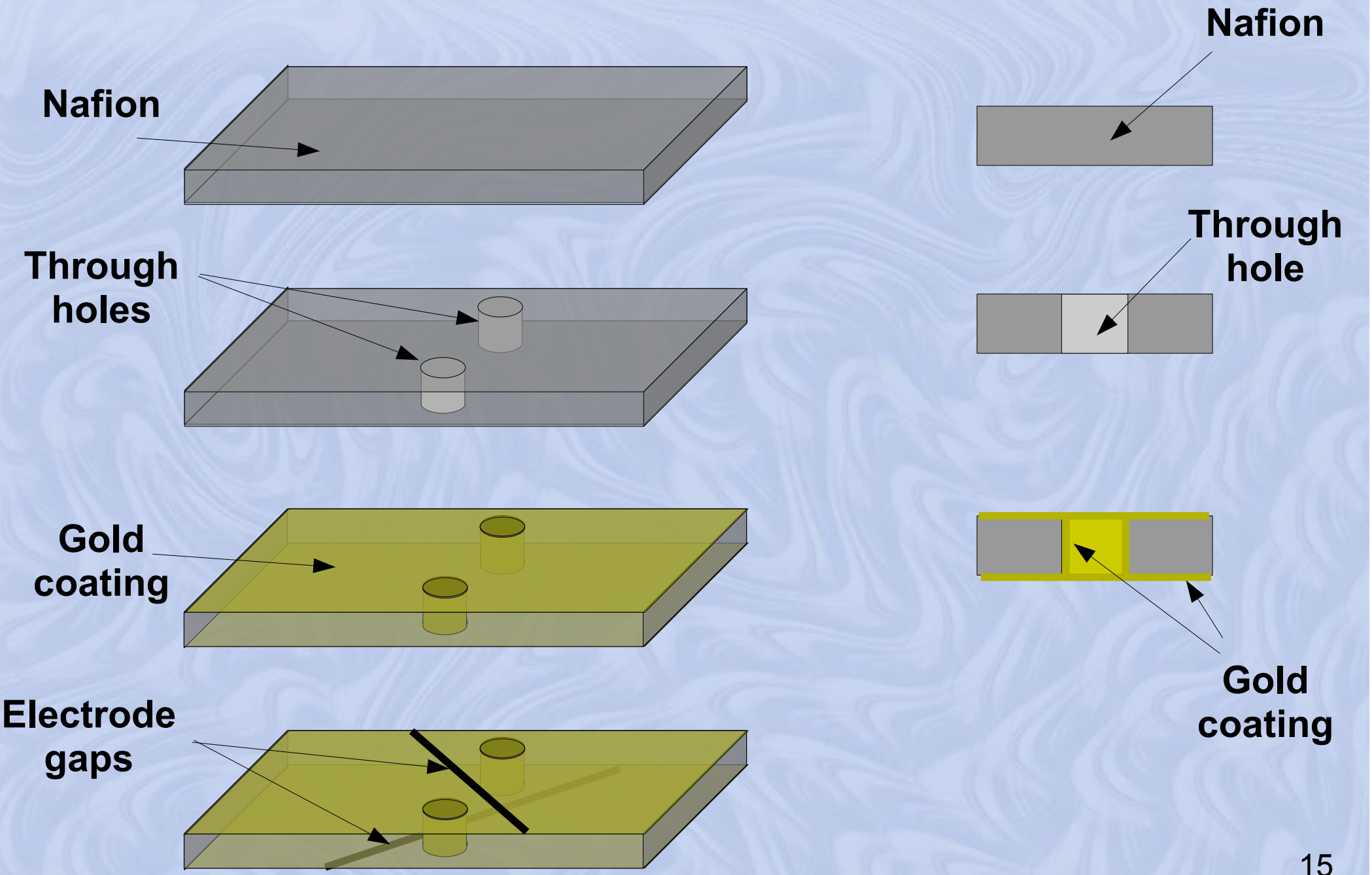
Reversing connection - manufacturing



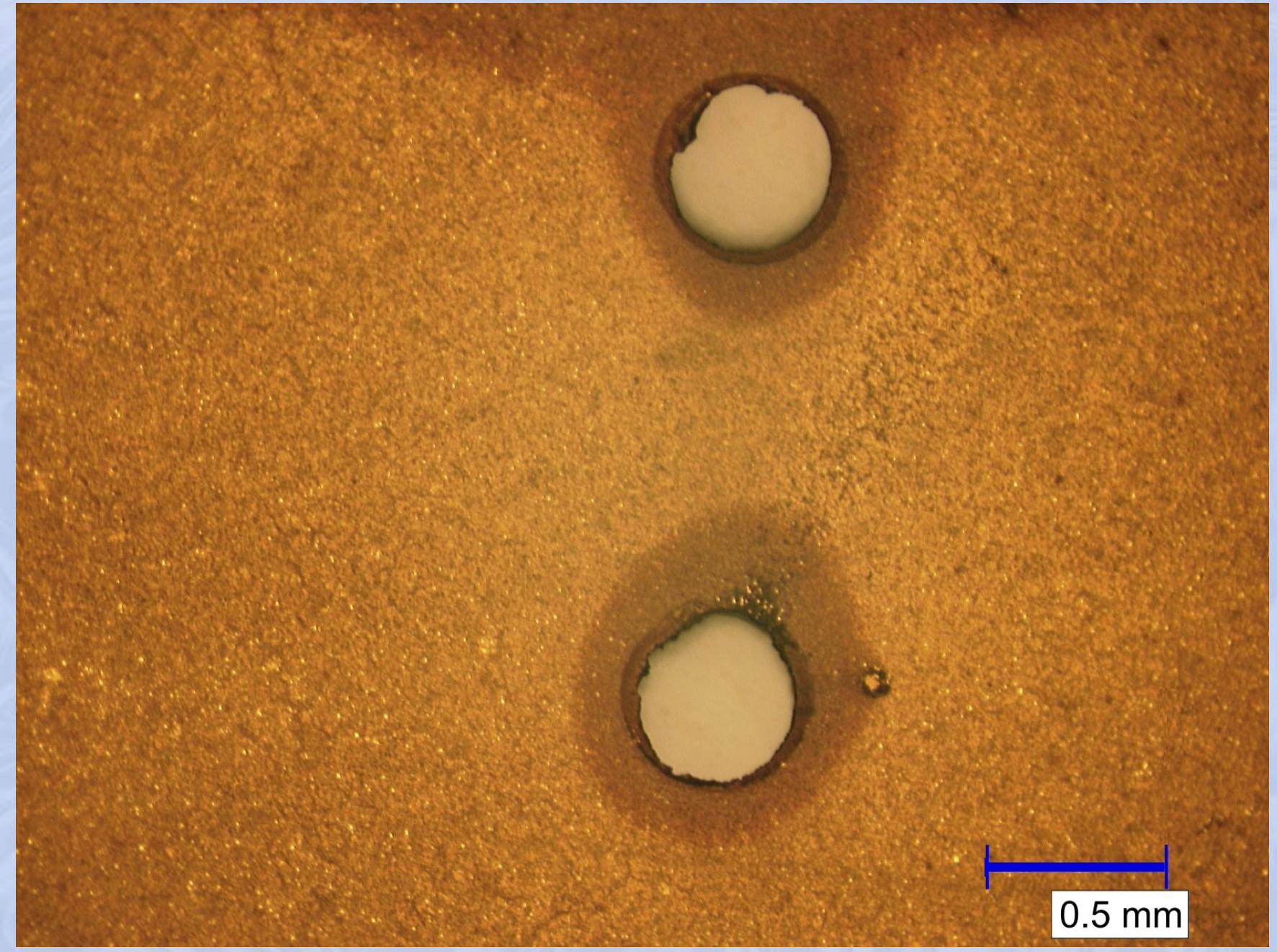
Reversing connection - manufacturing



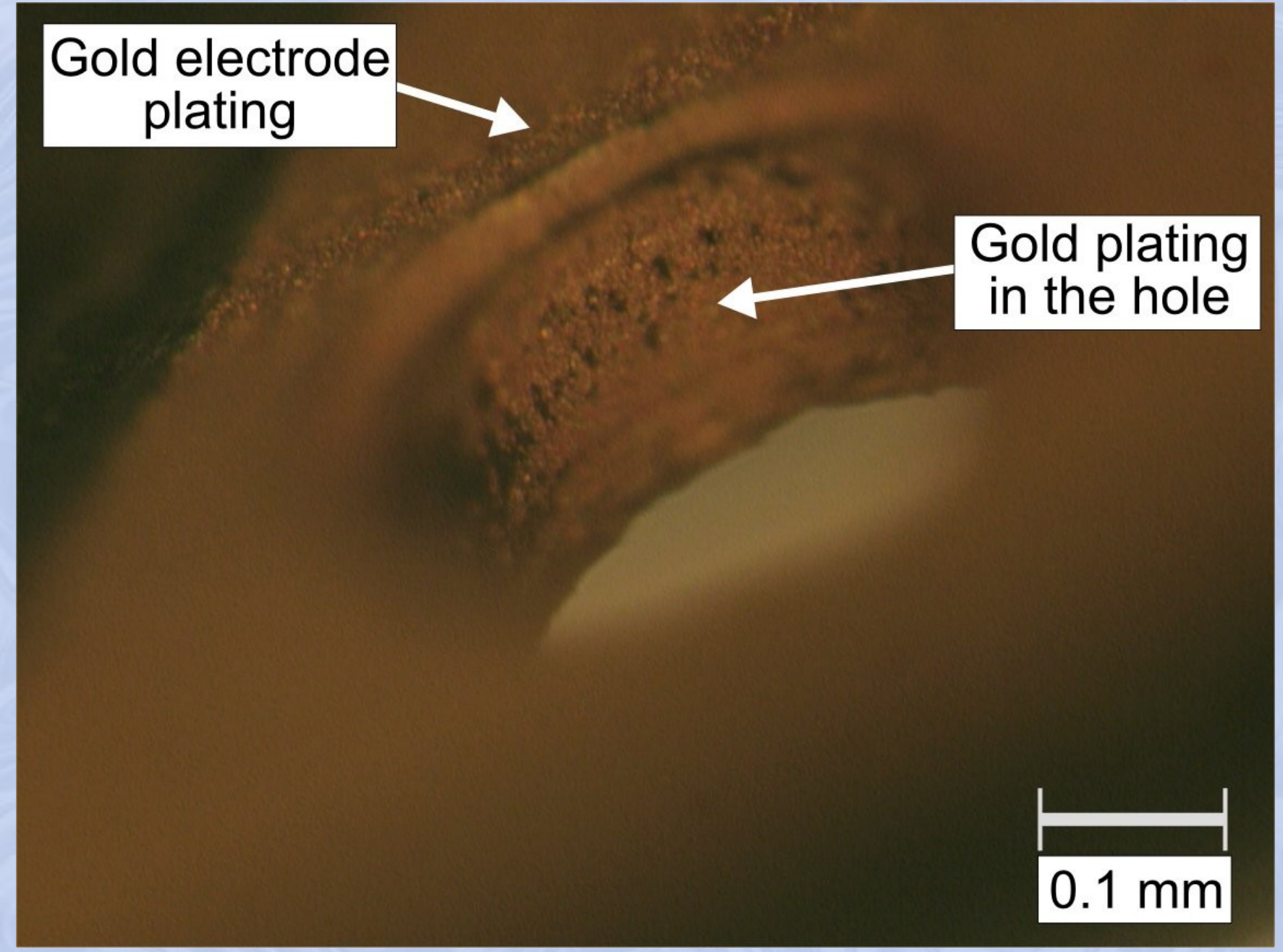
Reversing connection - manufacturing



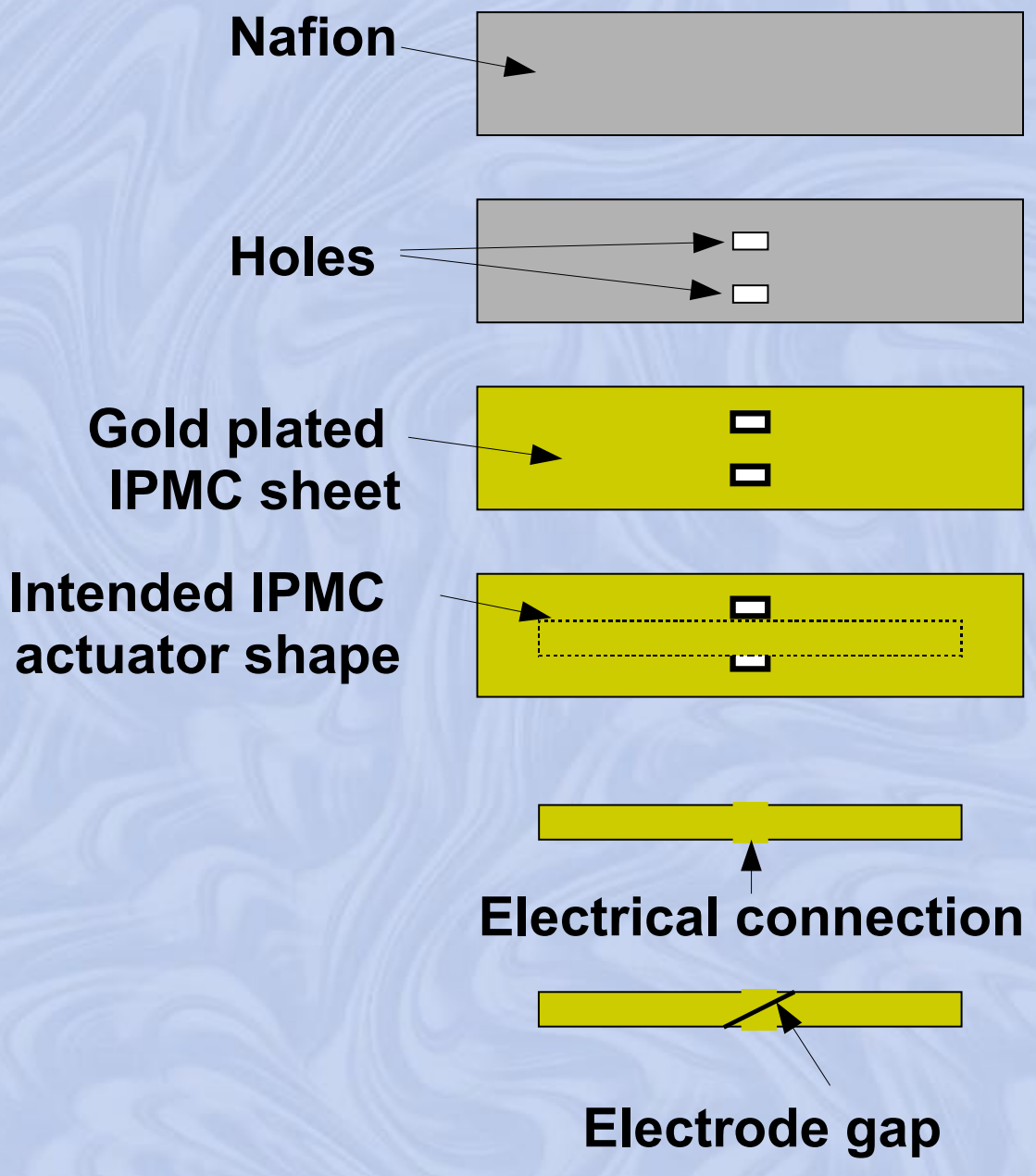
Reversing connection - manufacturing



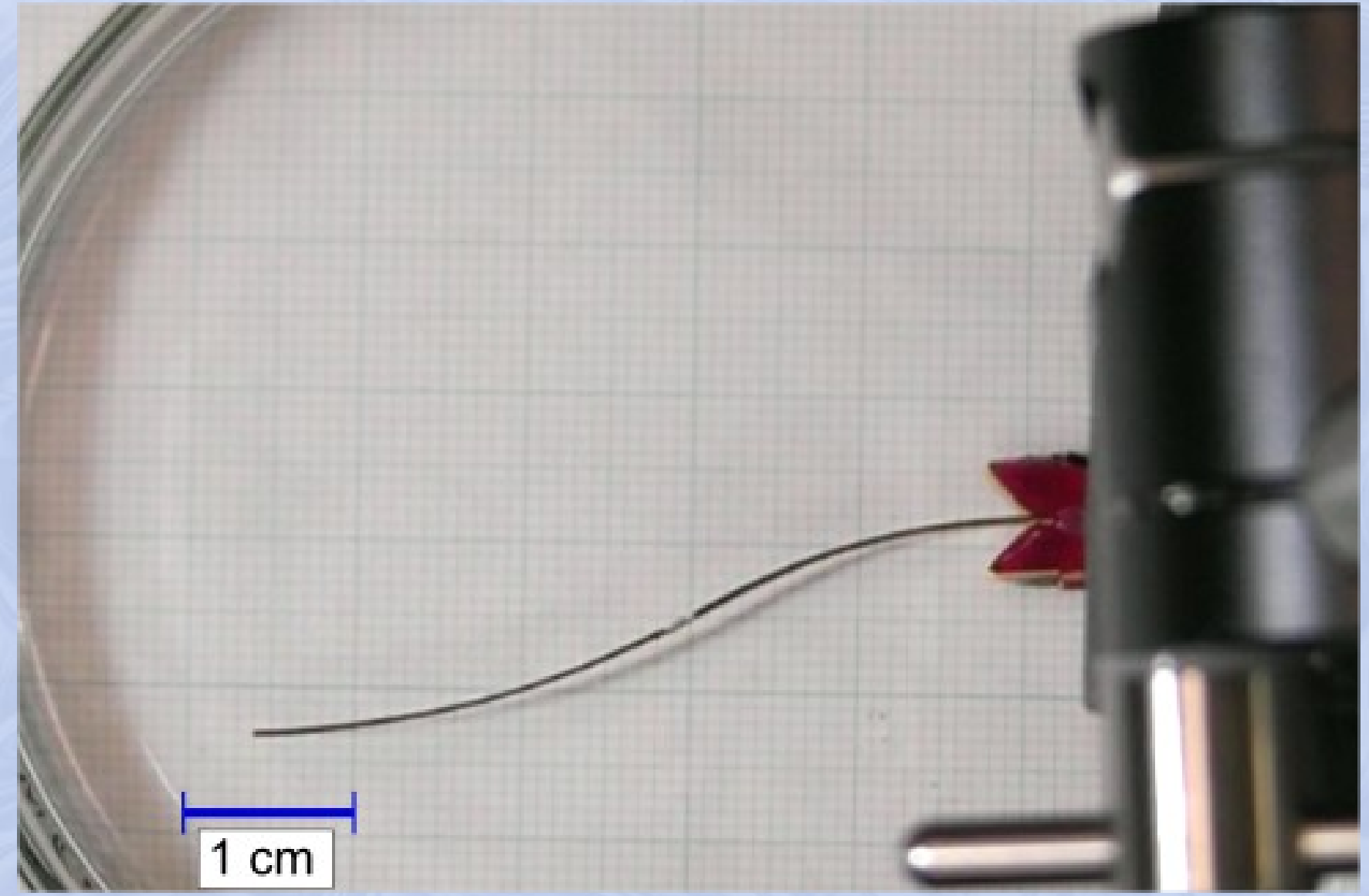
Reversing connection - manufacturing



Reversing connection - manufacturing



S-curve with reversing connection

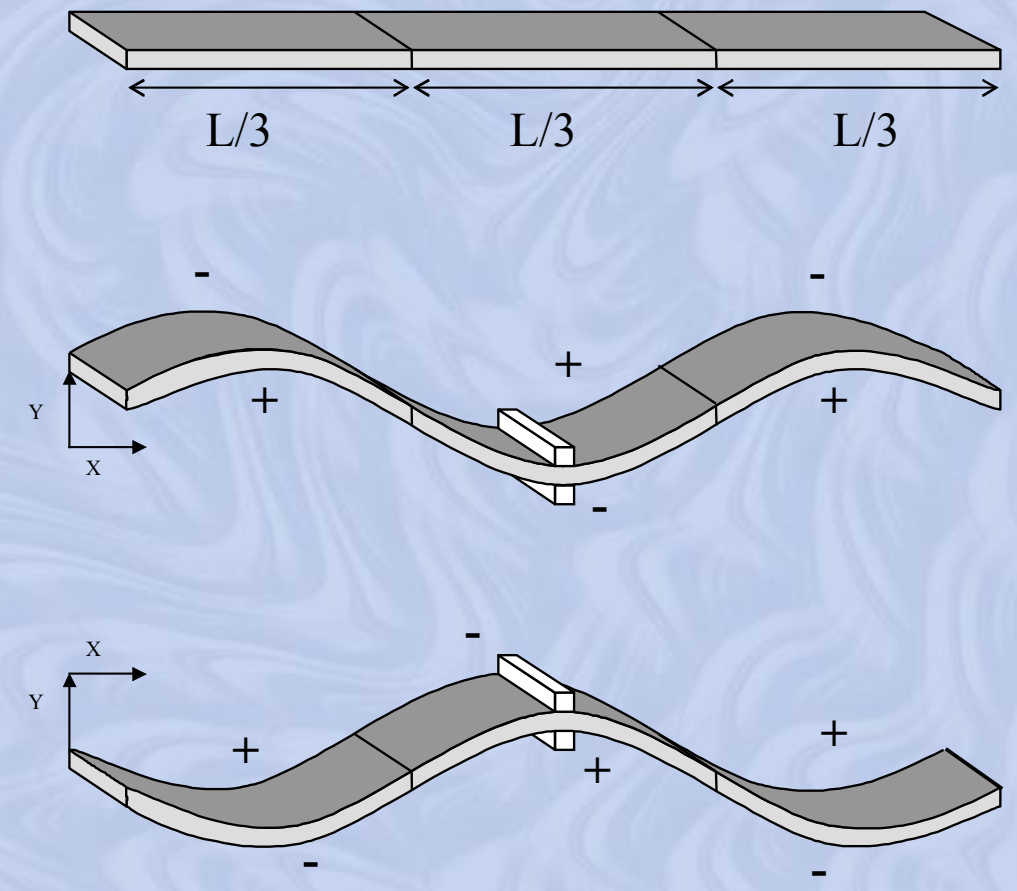


"Flapping wings" with reversing connection

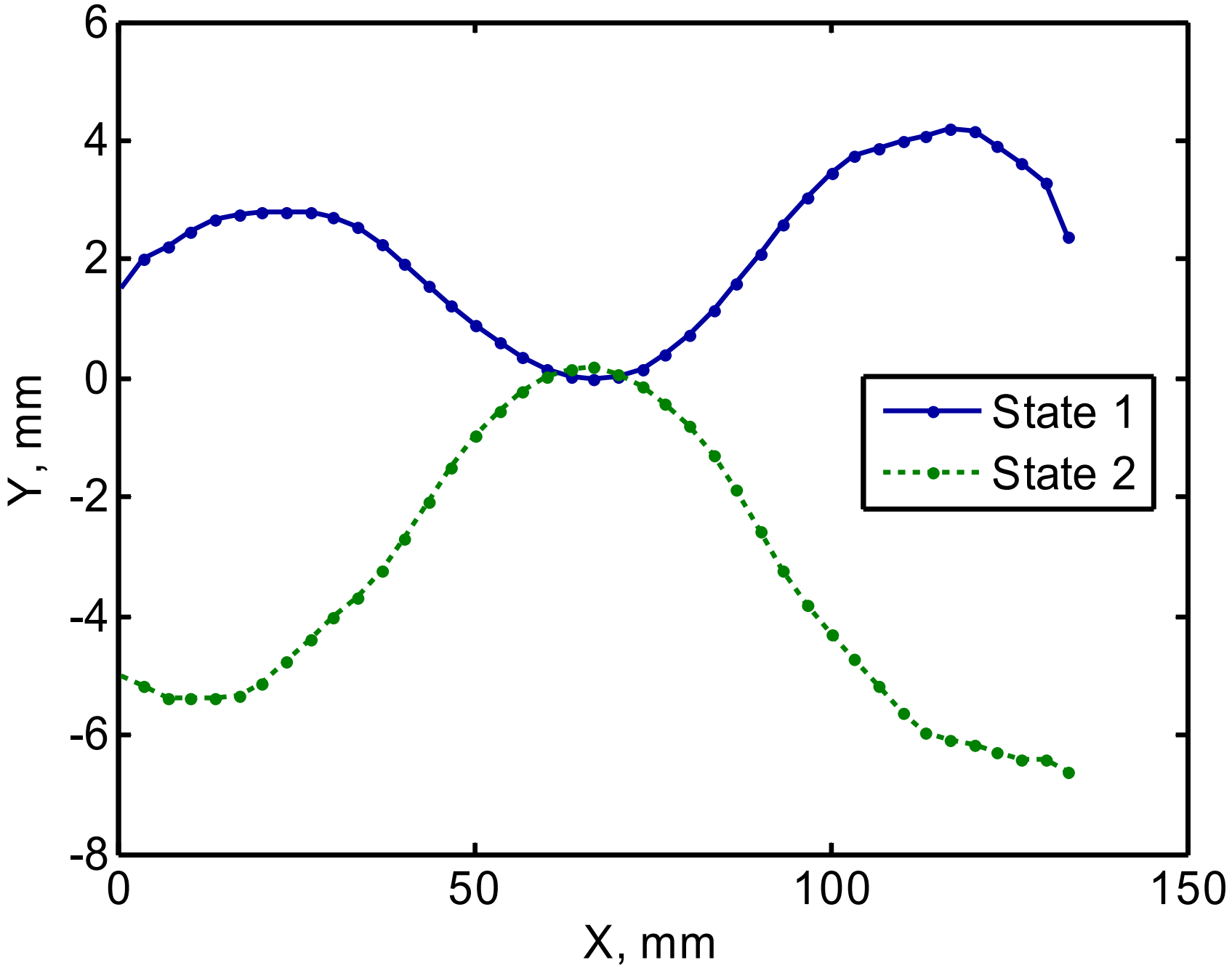
No reversing connection

With reversing connection

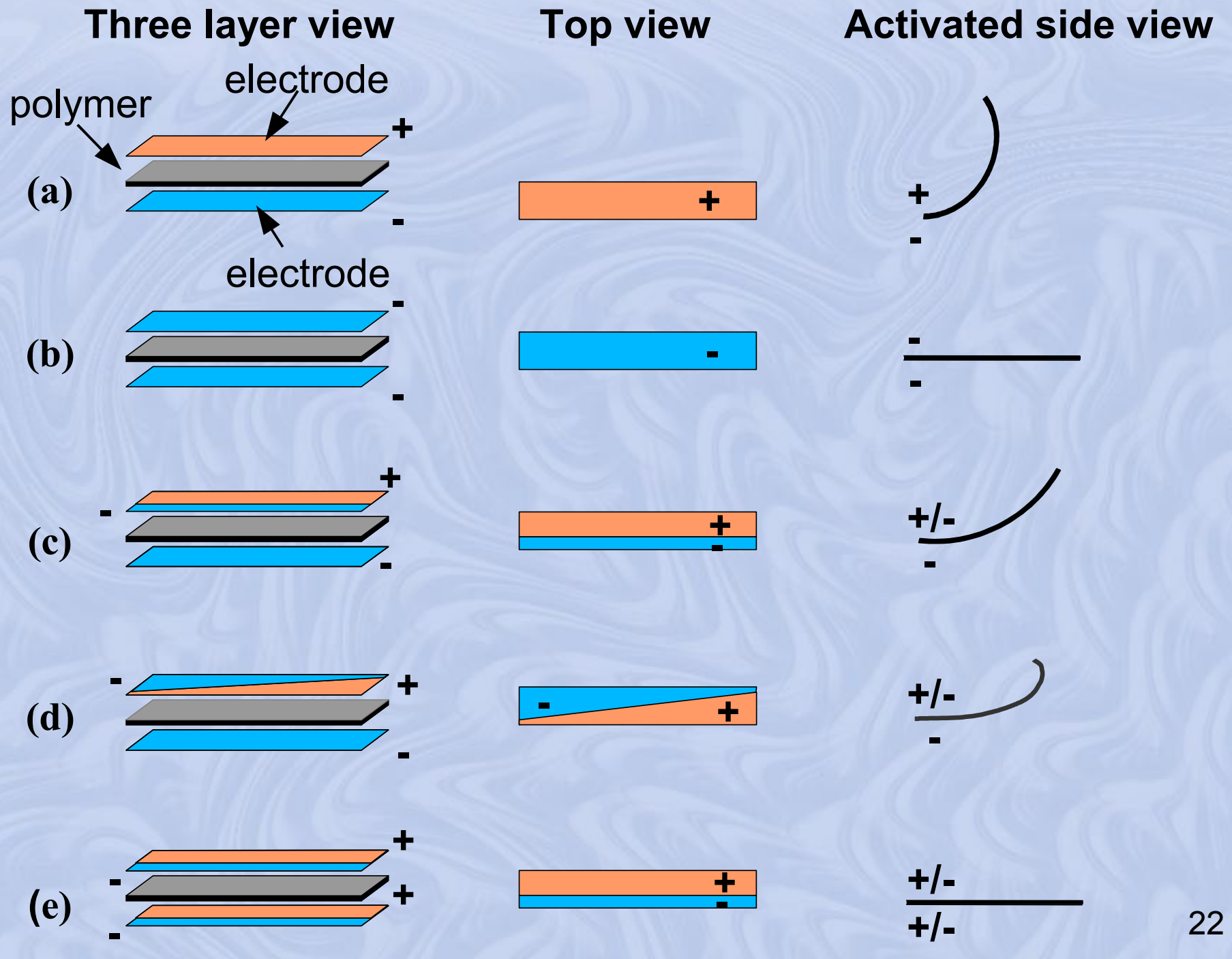
Flapping wings
Environmental Robots, Inc.



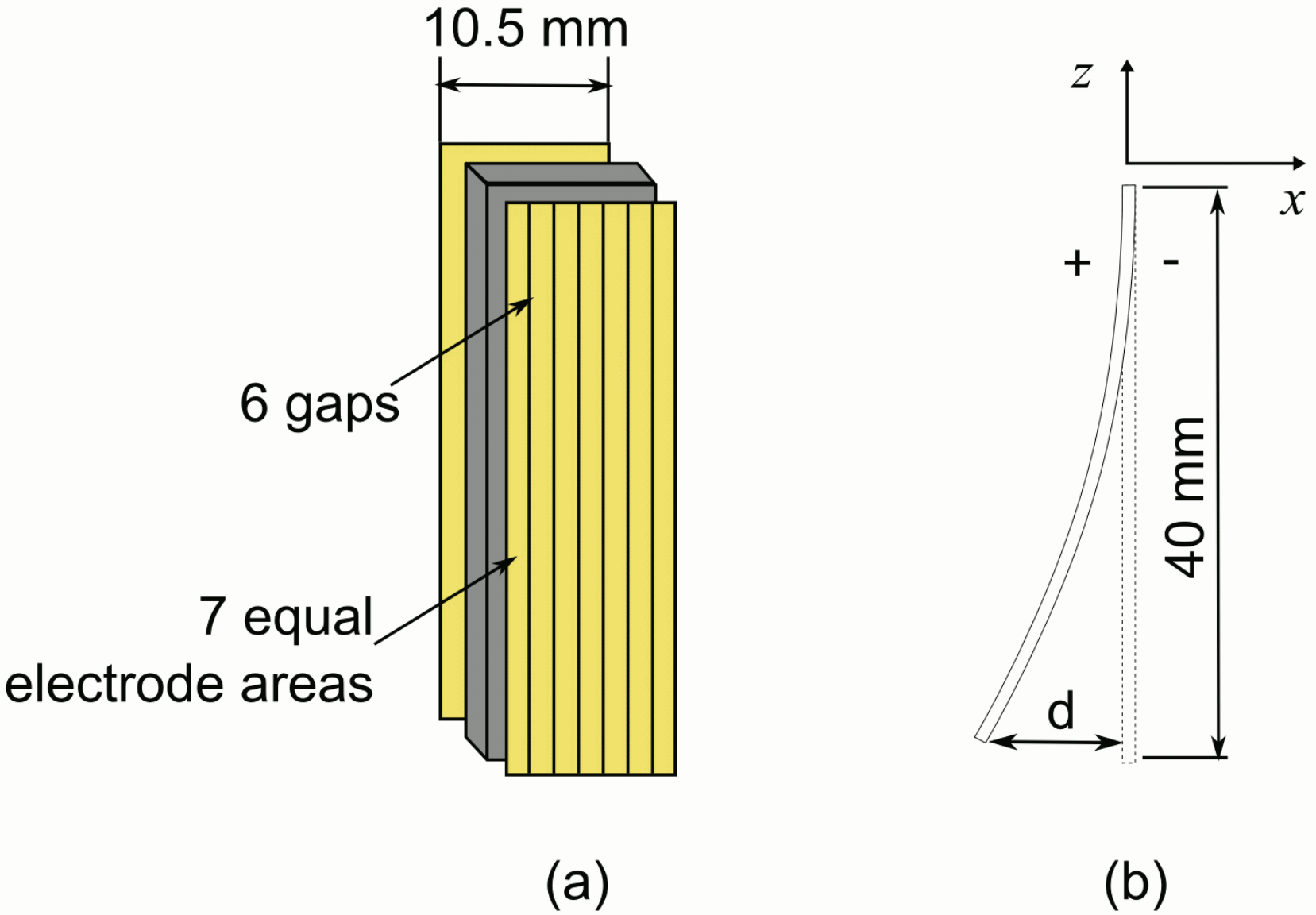
“Flapping wings” with reversing connection



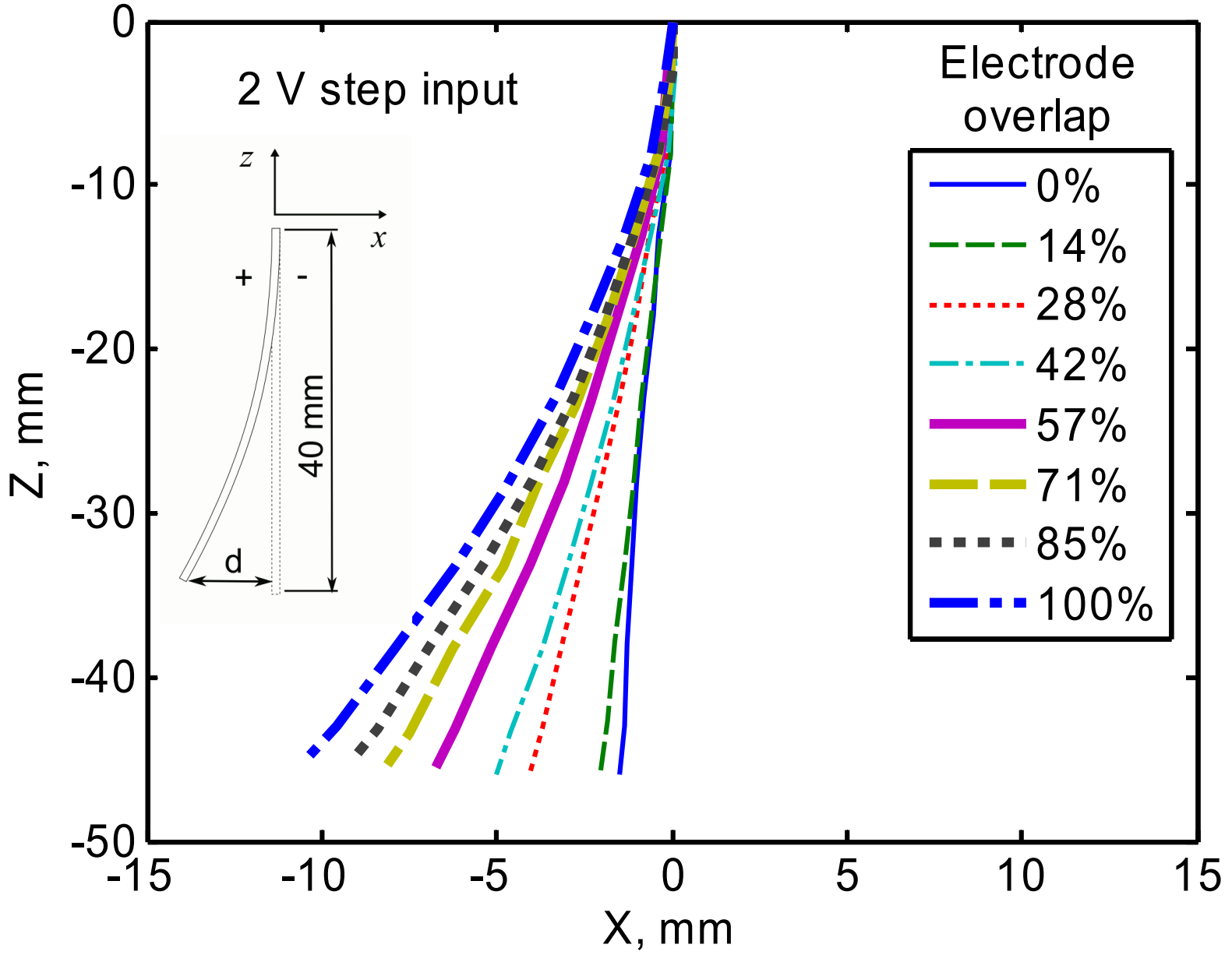
Variable curvature by electrode overlap



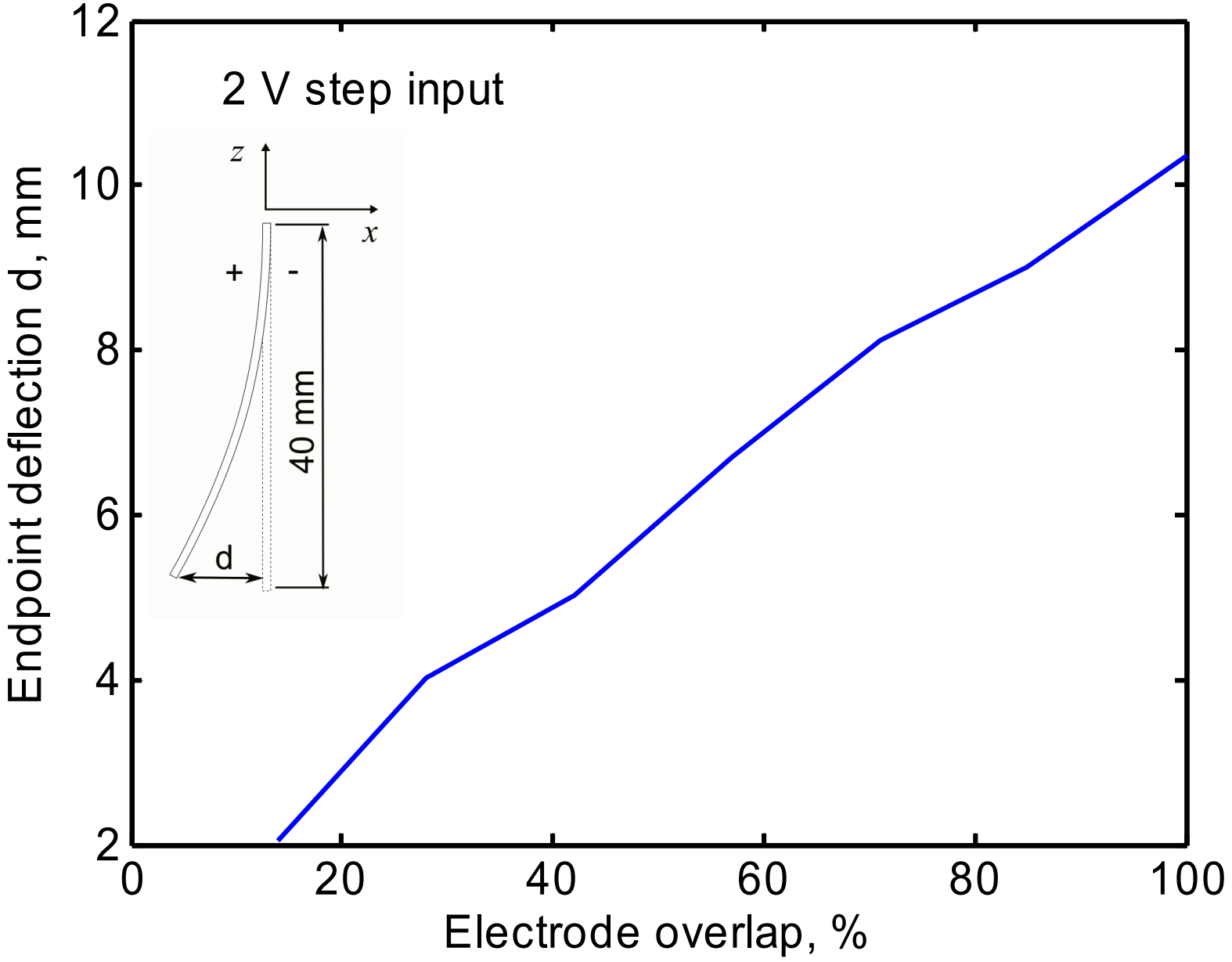
Variable curvature segment - experiment



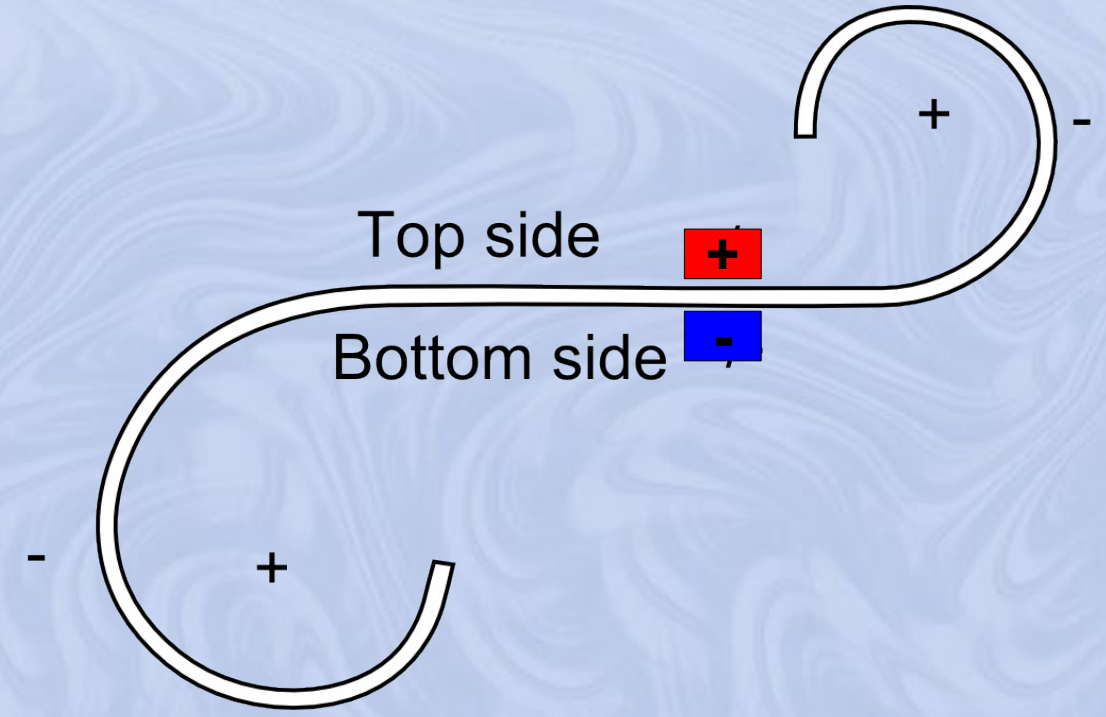
Variable curvature segment - experiment

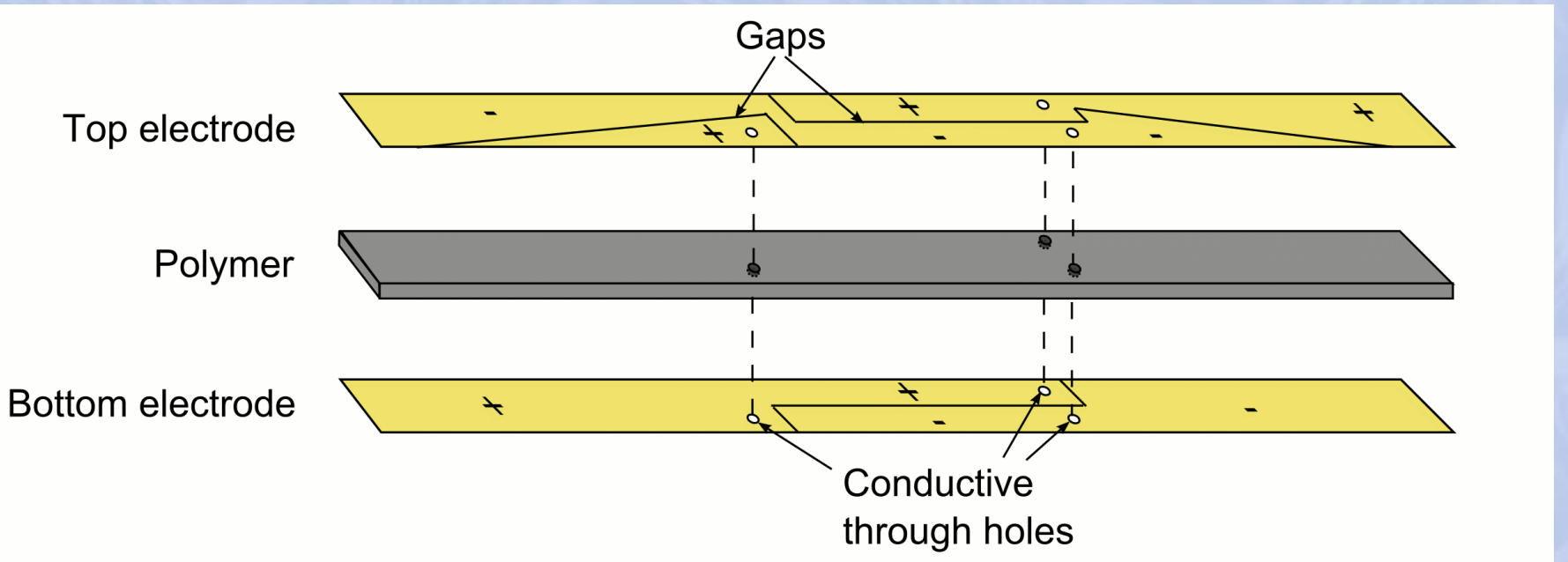


Variable curvature segment - experiment

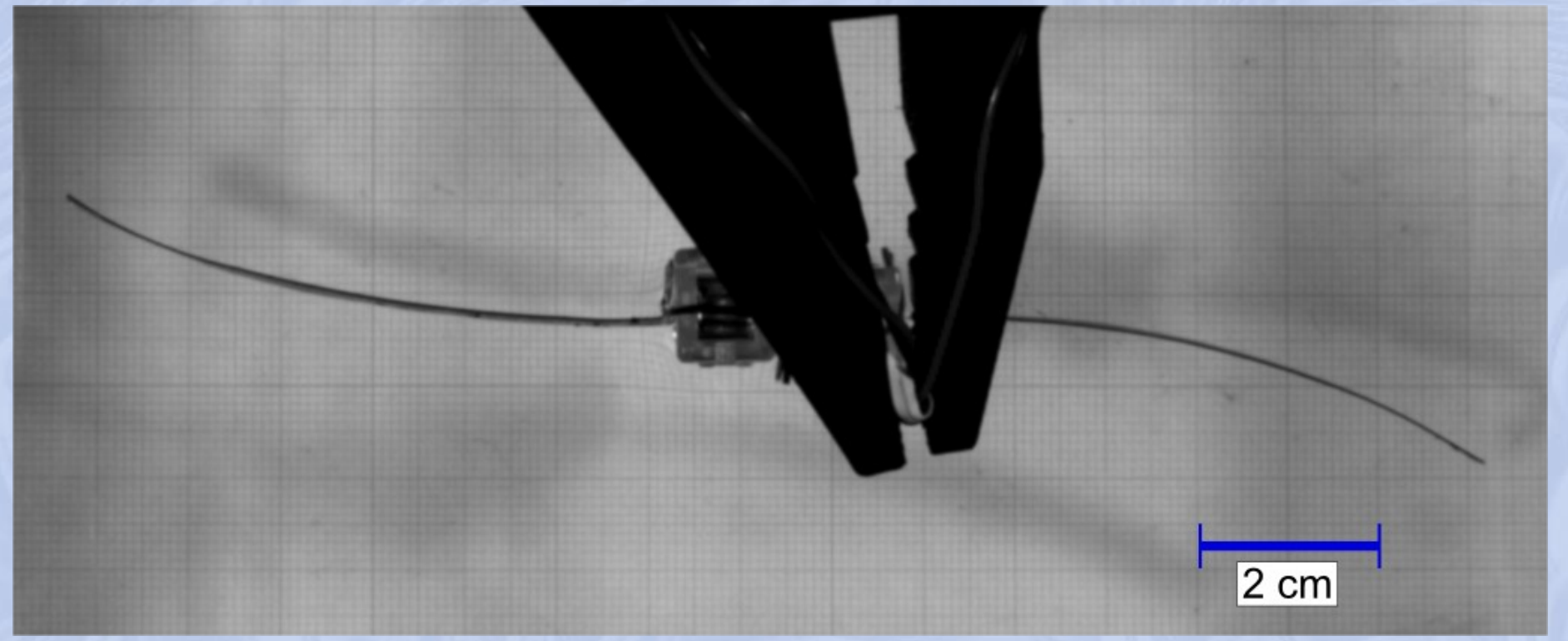


Reversing connection + electrode overlap

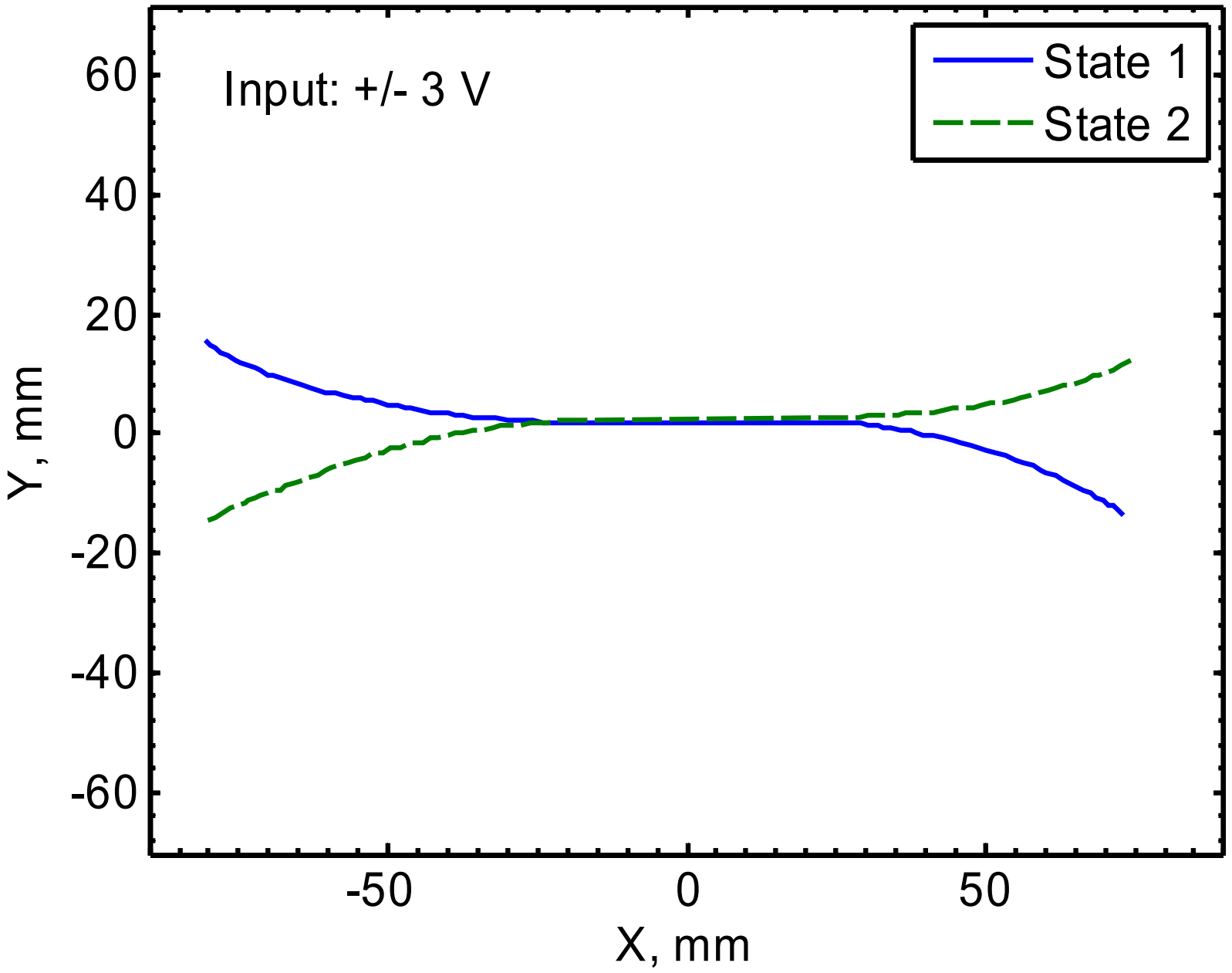




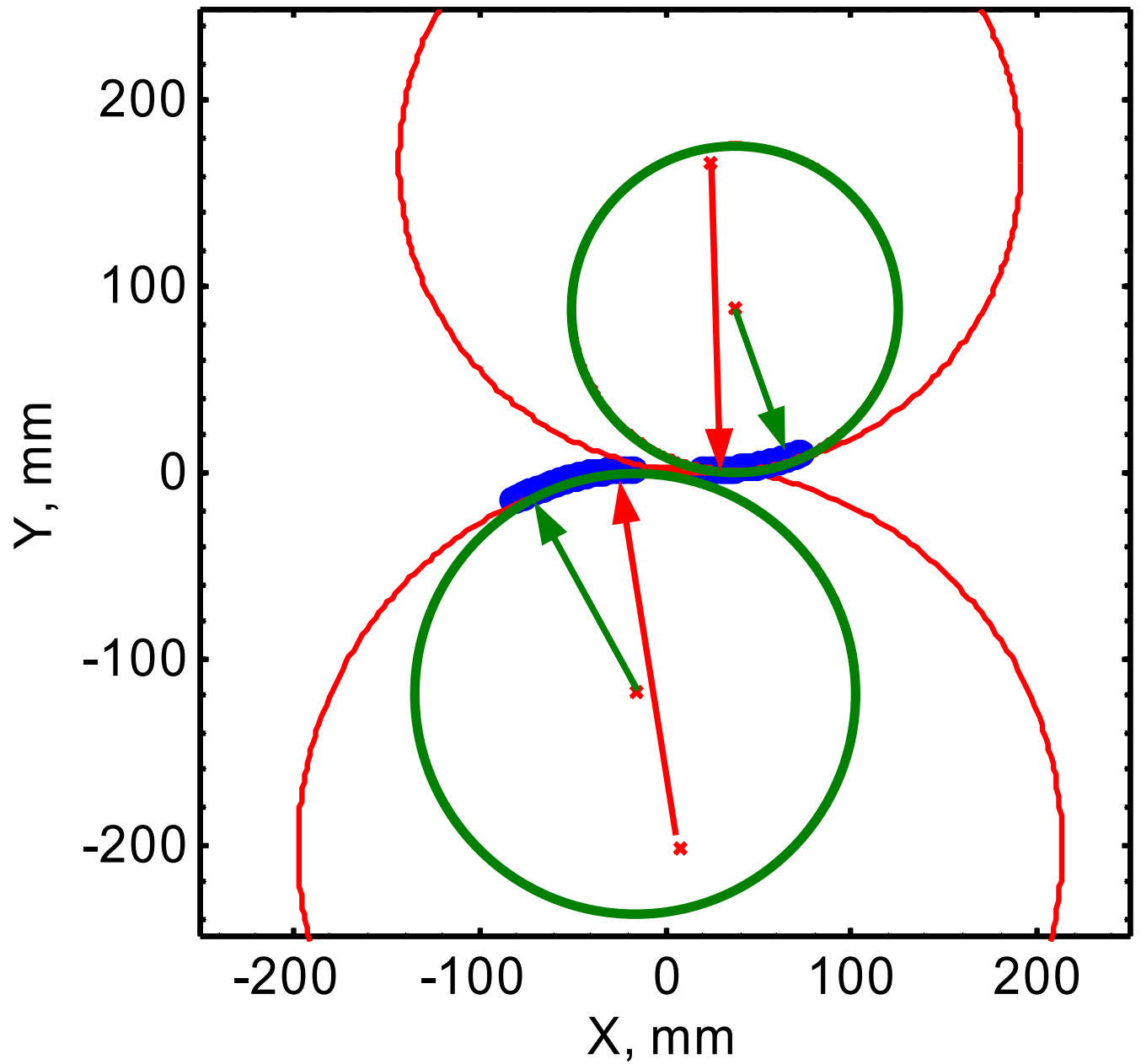
IPMC S-curve with variable curvature



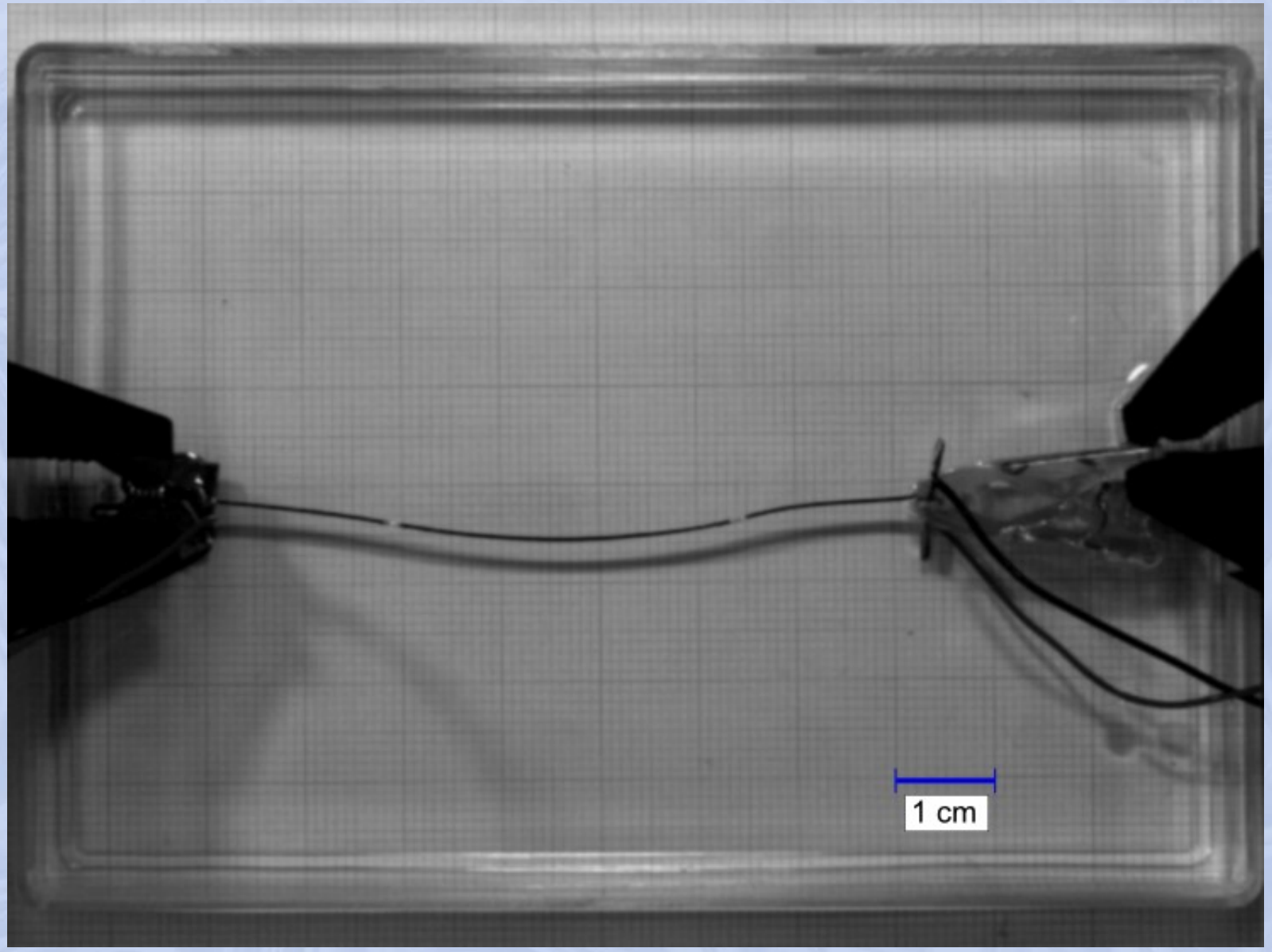
IPMC S-curve with variable curvature



IPMC S-curve with variable curvature

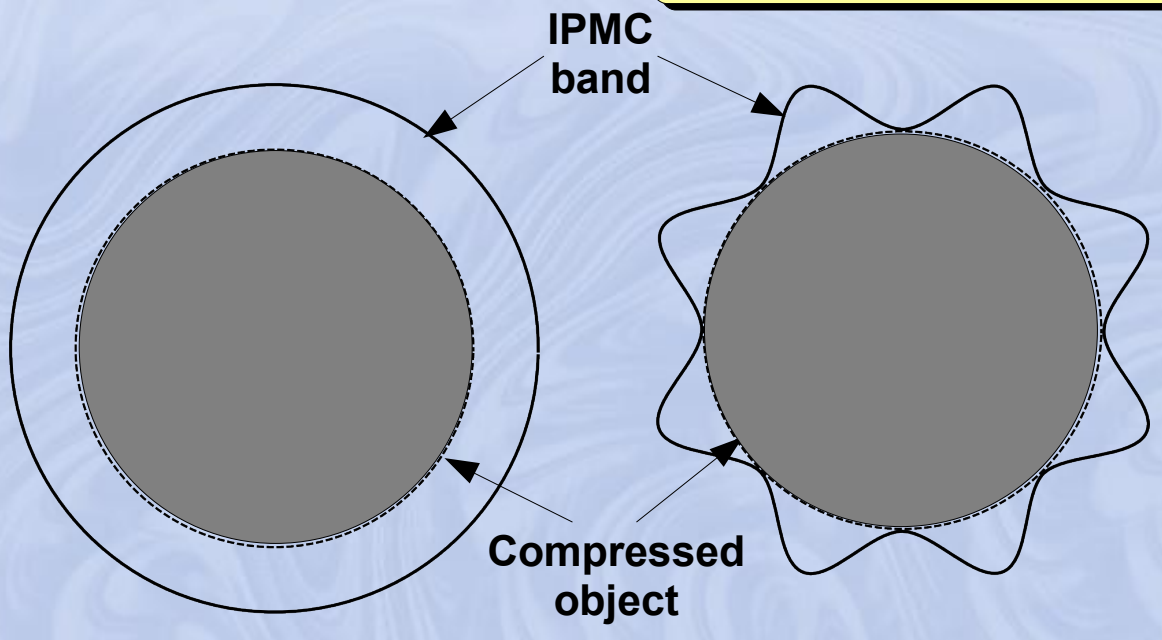


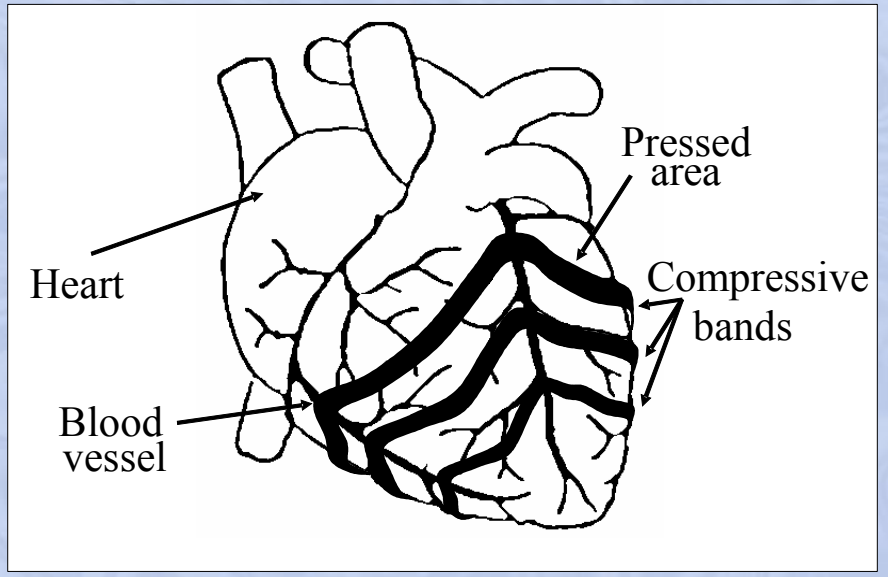
Applications – buckled beam actuator



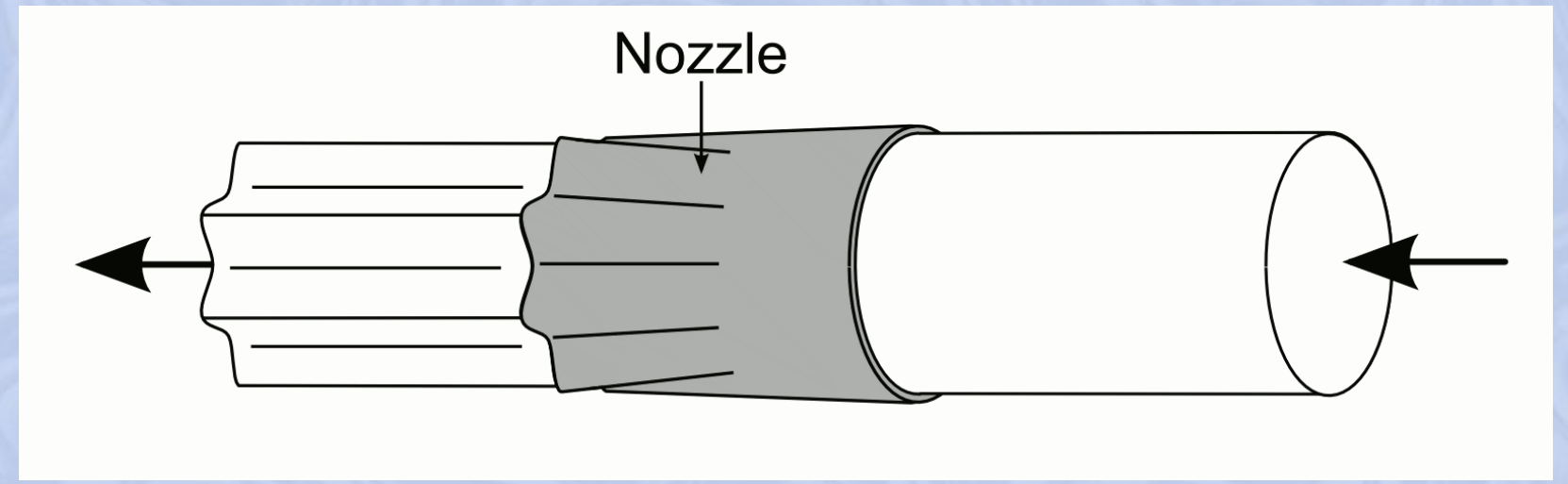
Applications

Compression devices



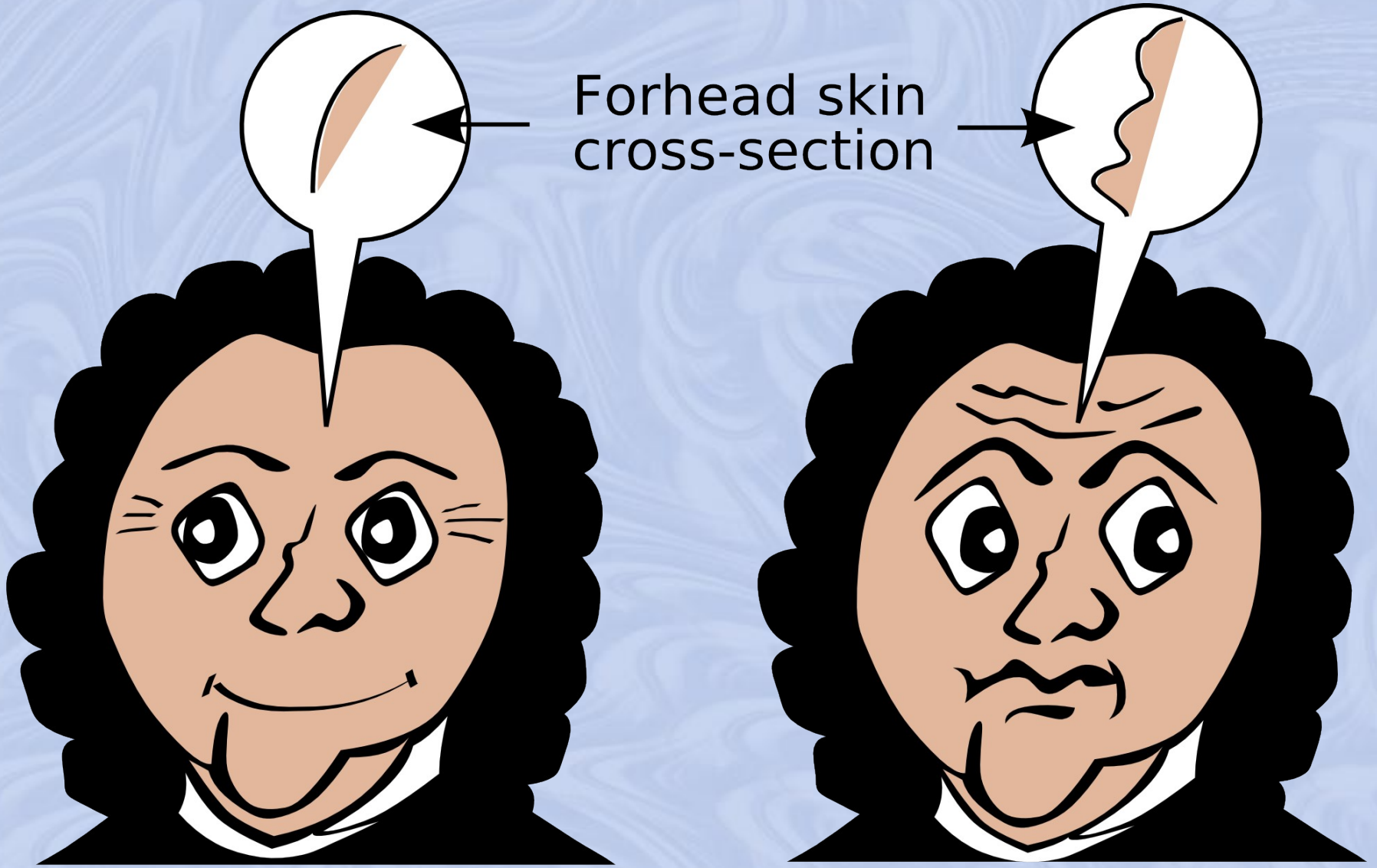


Nozzles and forming devices



Applications

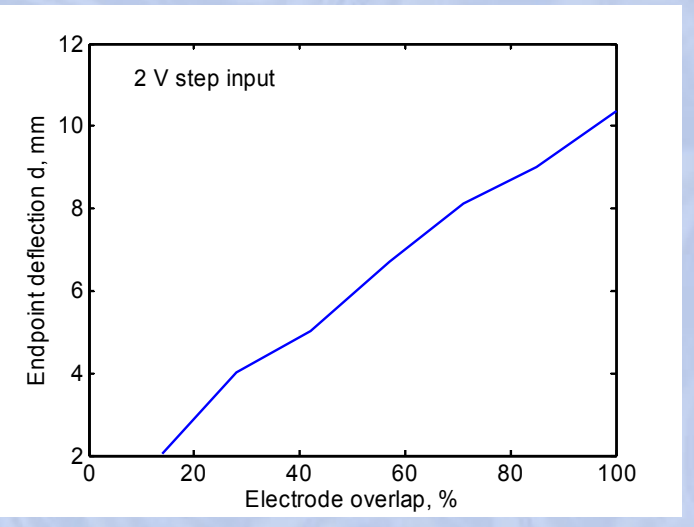
Robotic facial expression



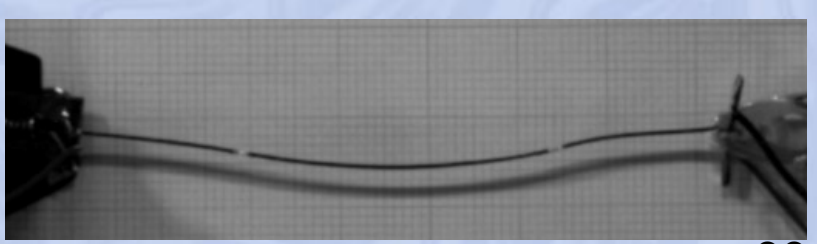
Conclusions

1. We proposed and tested successfully a method for manufacturing and electrically connecting adjacent IPMC segments, which enables bending with opposite curvature.

2. We proposed and tested successfully an IPMC segment, designed to bend with any fraction of its full bending ability under given electrical input by varying electrode overlap.



3. We demonstrated the usefulness of these components for building devices, which can actuate into complex curves.



Acknowledgments

Dr. Kinji ASAKA of AIST, JAPAN for helpful discussions about the impregnation-reduction process for manufacturing of IPMC actuators.

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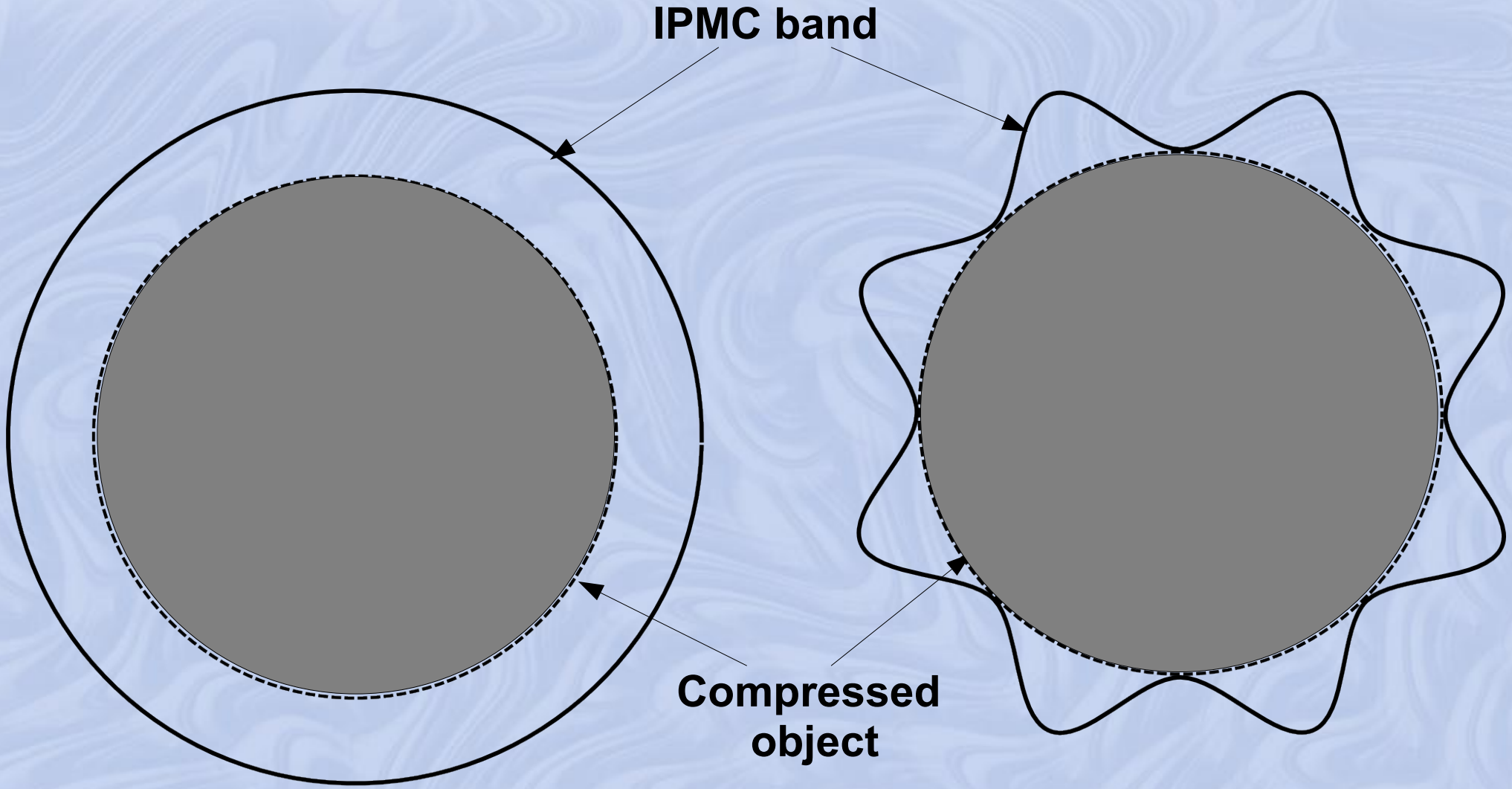
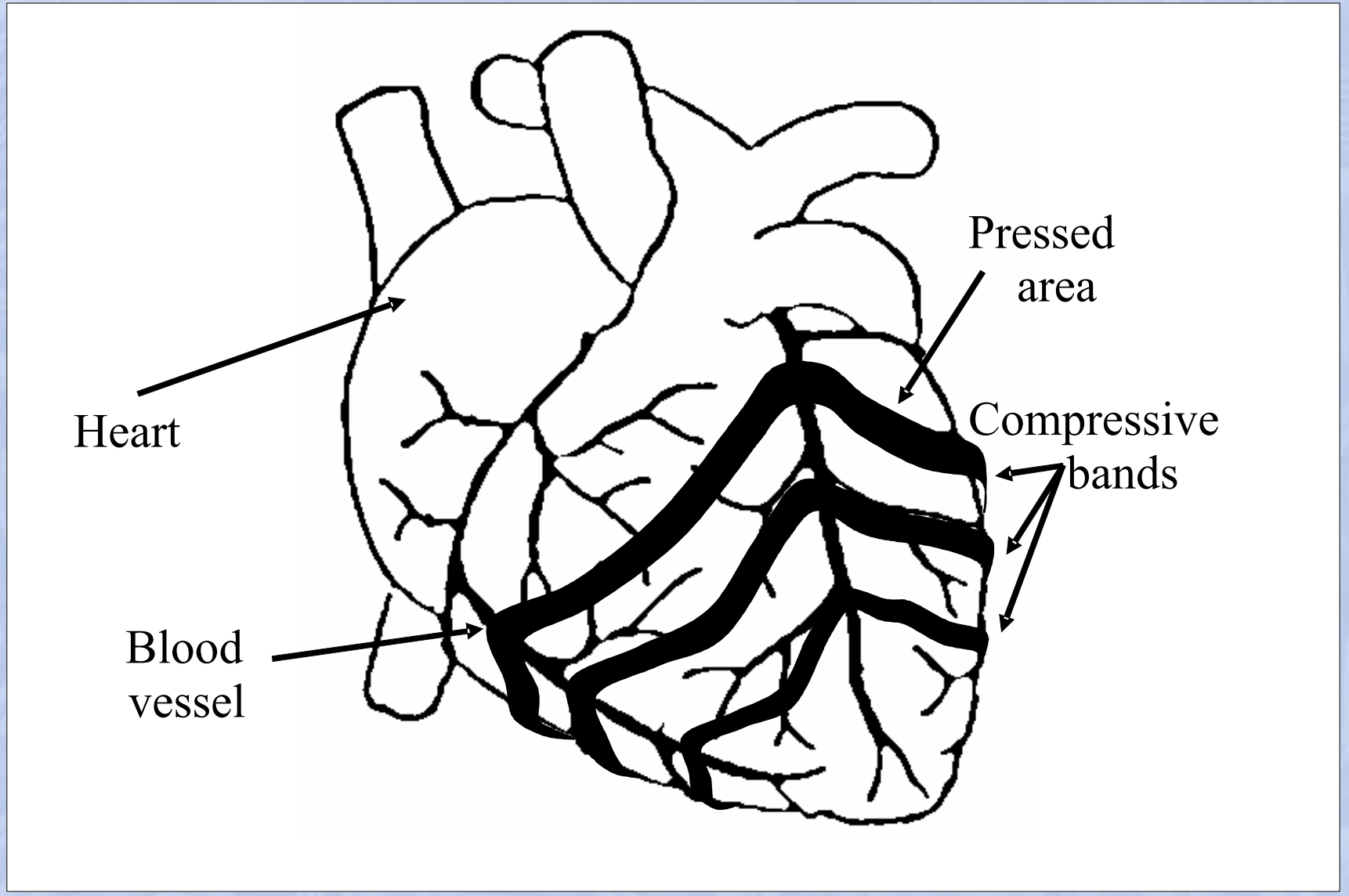
Thank you for your attention!

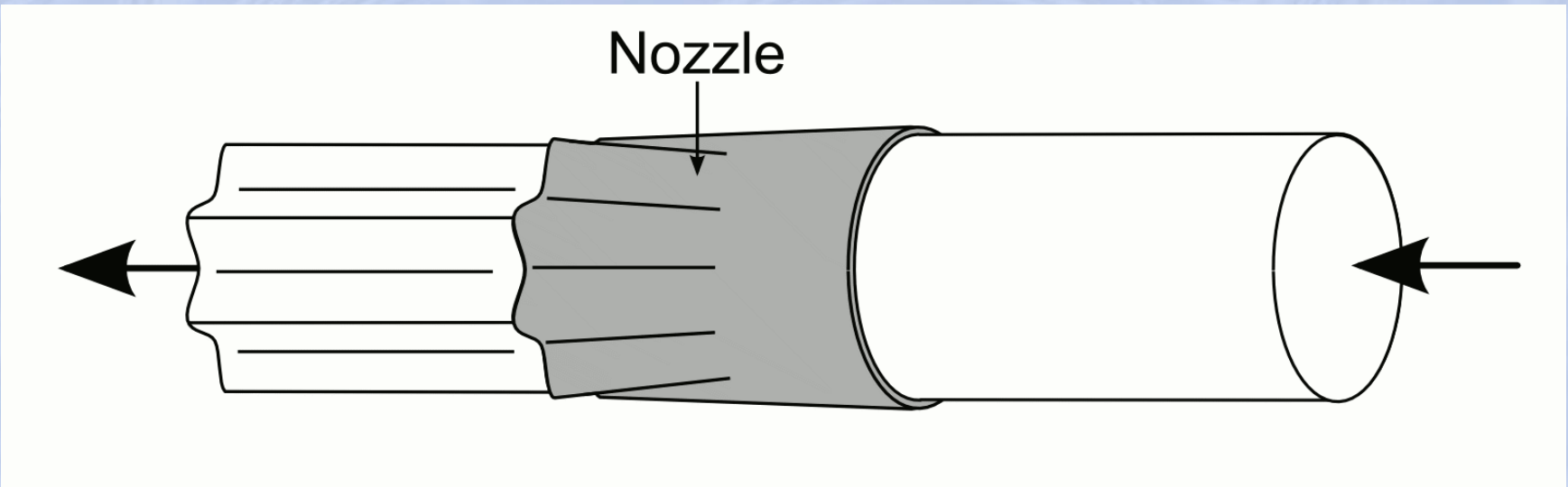
Applications – compression devices

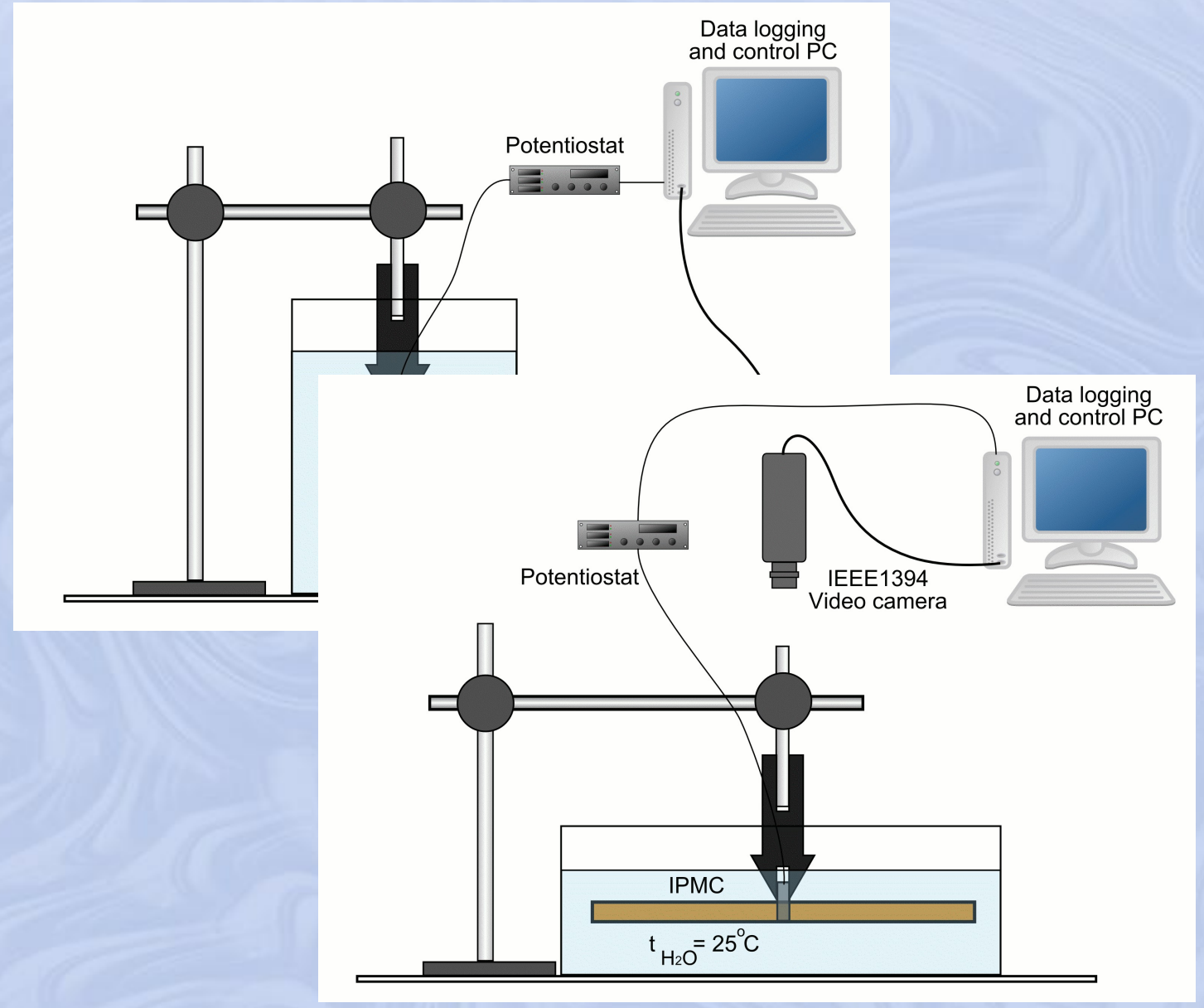


Applications – compression devices

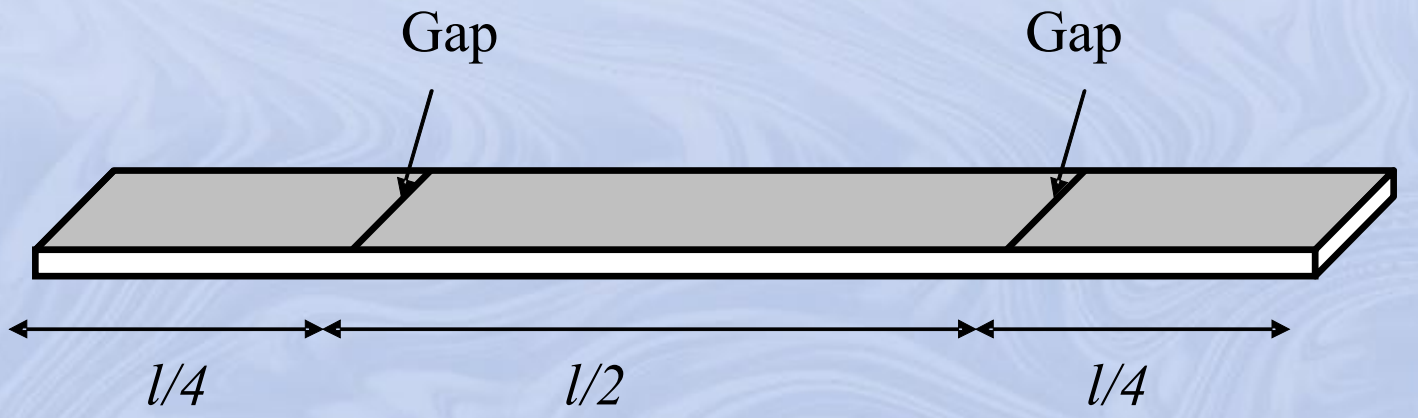


Applications – nozzles and forming

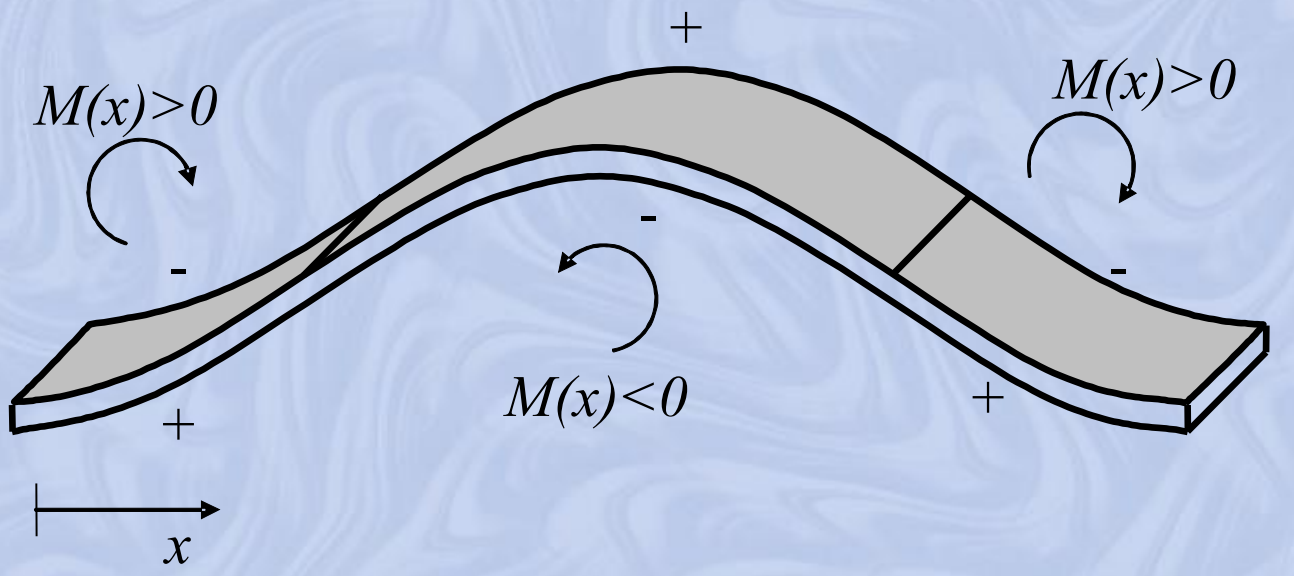


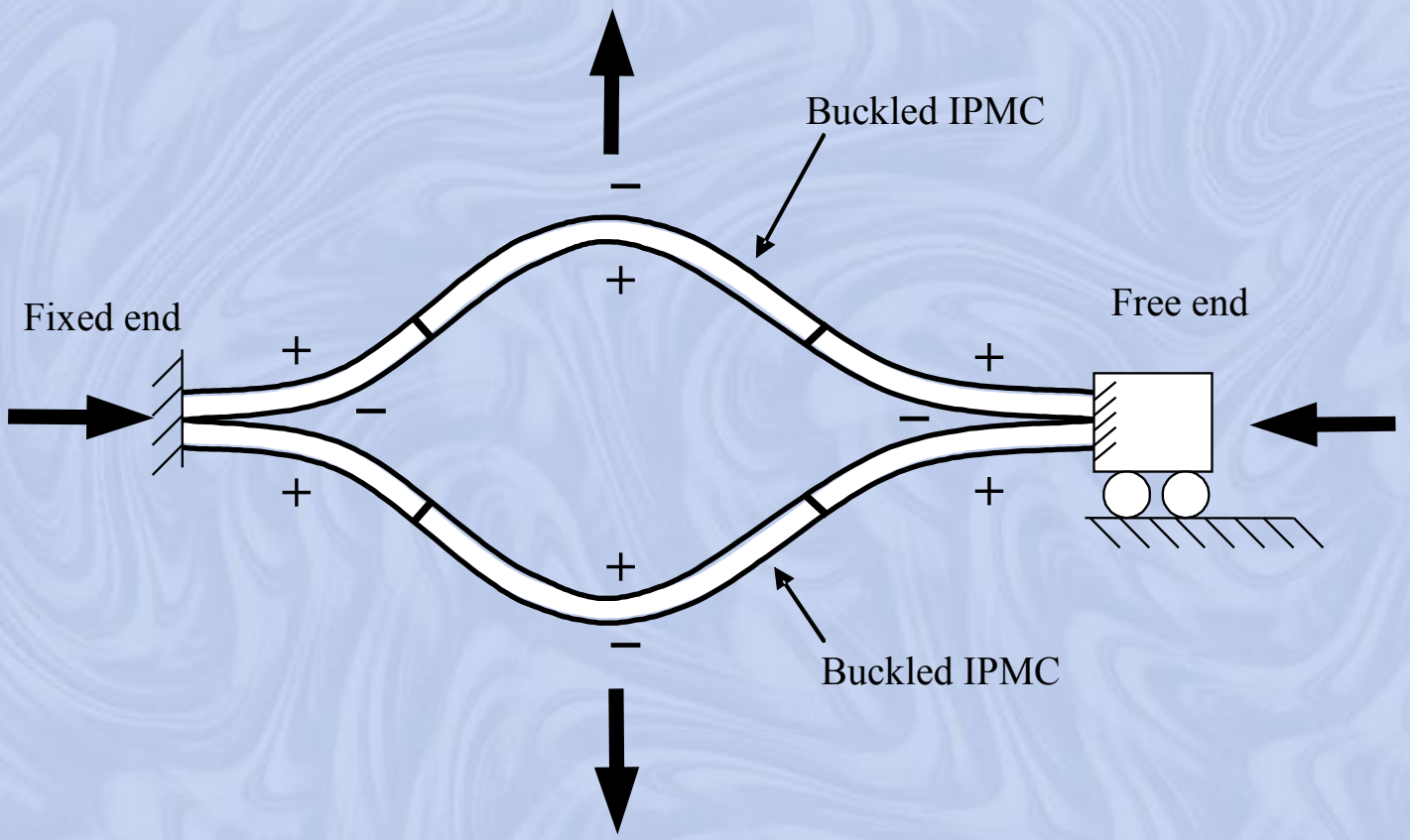

Data logging
and control PC
Potentiostat
Data logging
and control PC
Potentiostat
IEEE1394
Video camera
IPMC
t H2O = 25°C

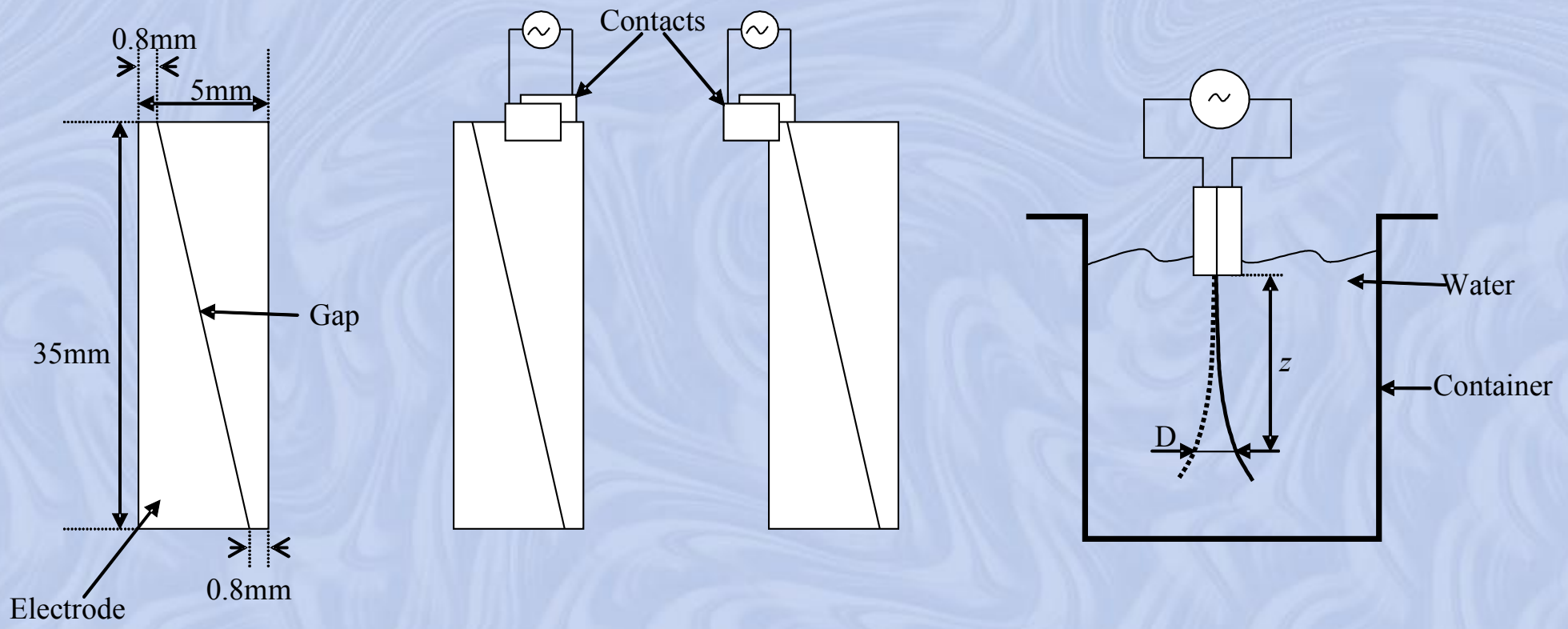
(a)

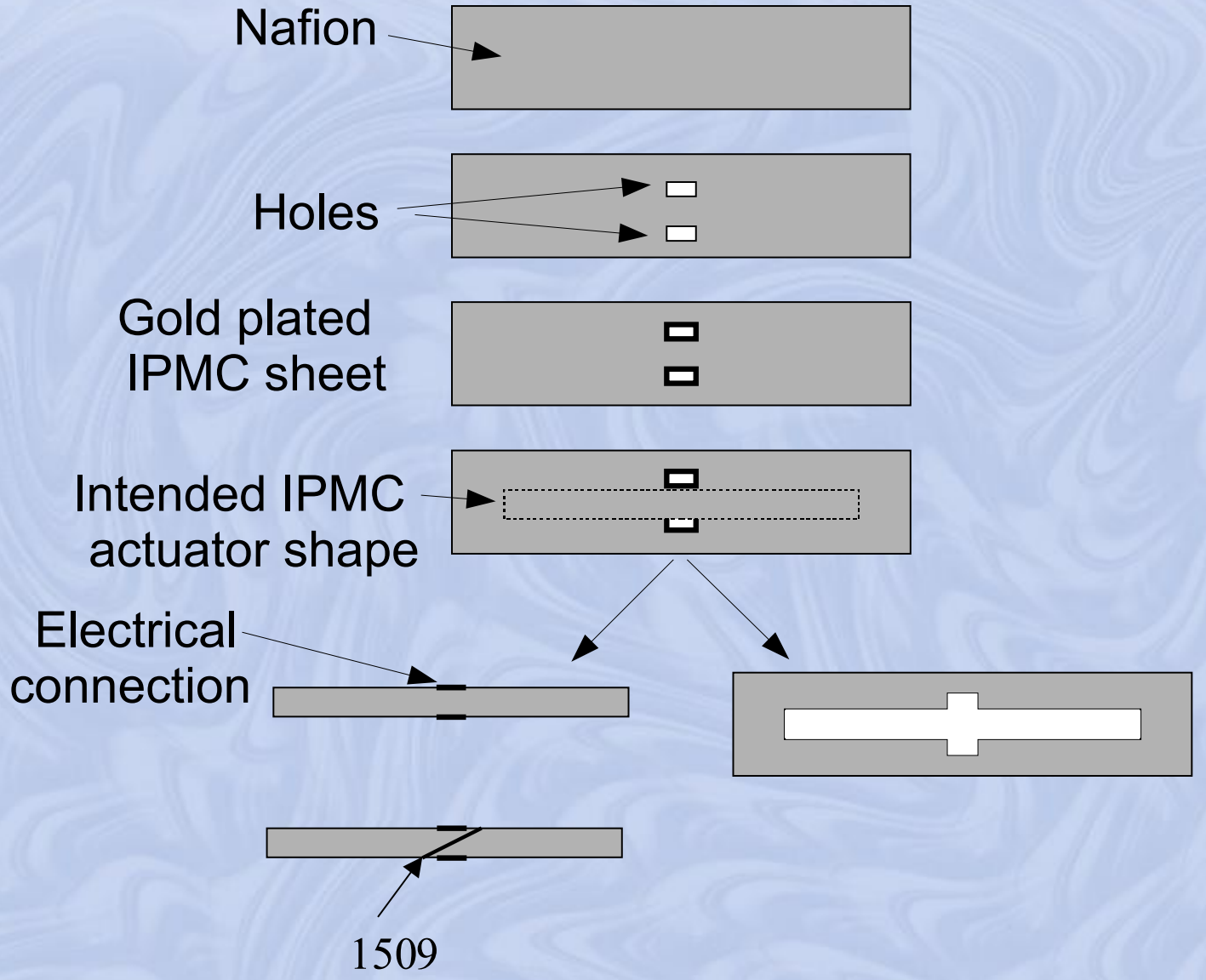


(b)



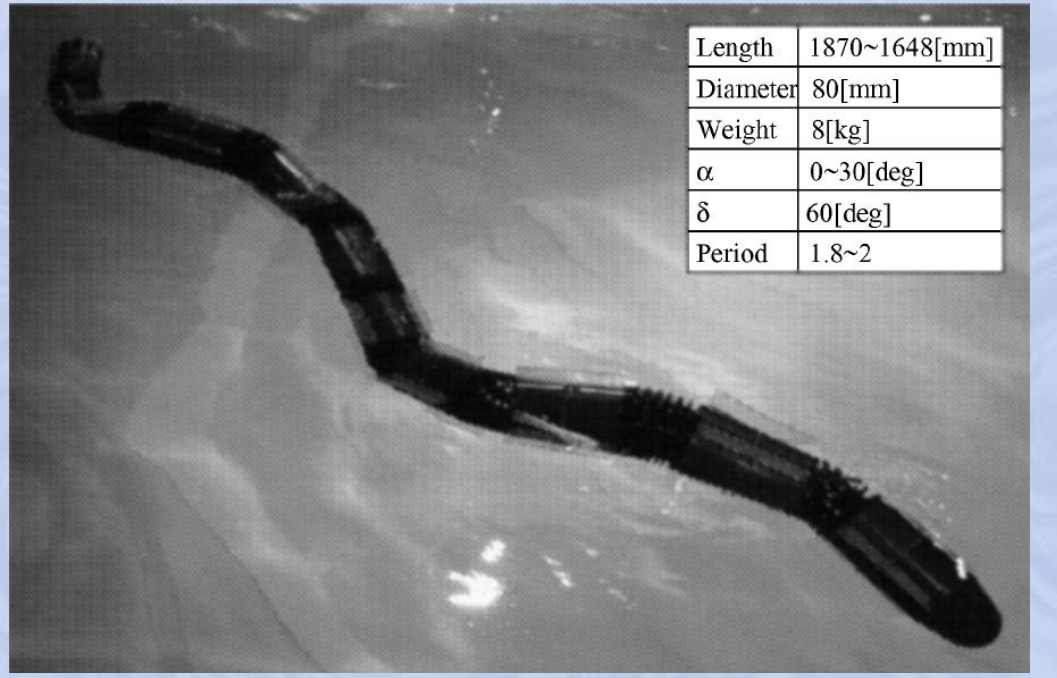

Buckled IPMC
Fixed end
Free end
Buckled IPMC

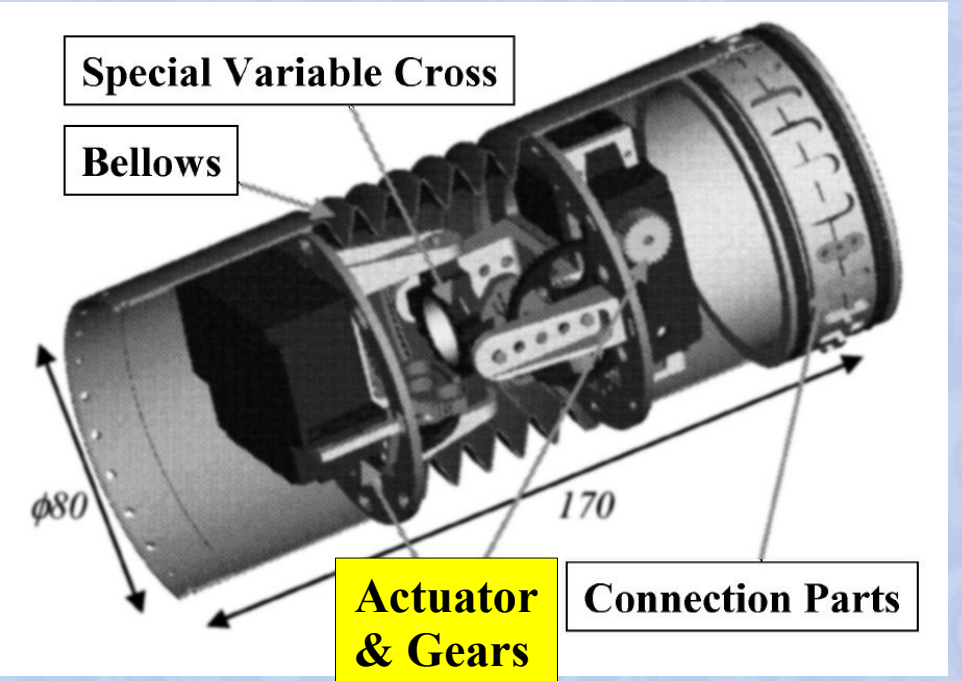

0.8mm
5mm
35mm
Gap
Electrode
0.8mm
Contacts
Water
Container
z
D
(a)
(b)
(c)
(d)


Nafion
Holes
Gold plated
IPMC sheet
Intended IPMC
actuator shape
Electrical
connection
1509

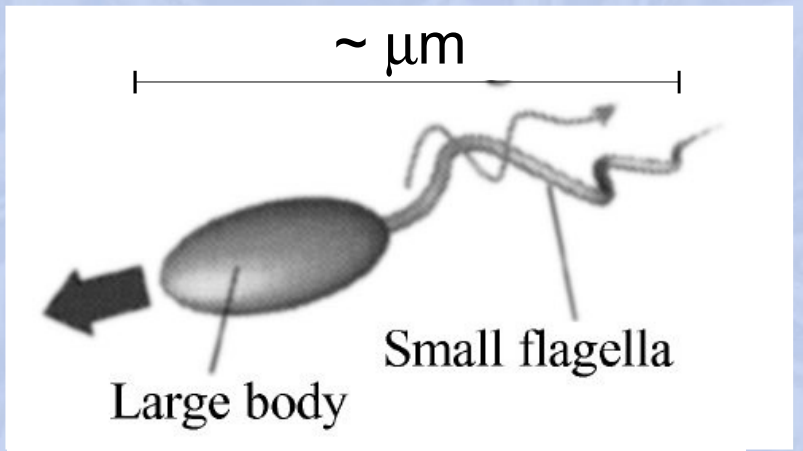
Introduction – bio-mimetic actuator needs

Spiral locomotive HELIX Robot (T. Takayama & S. Hirose, 2002)

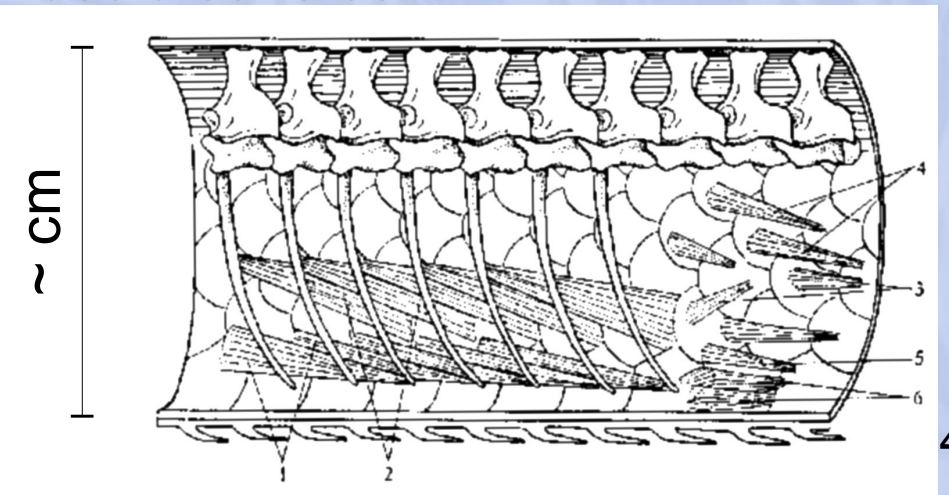




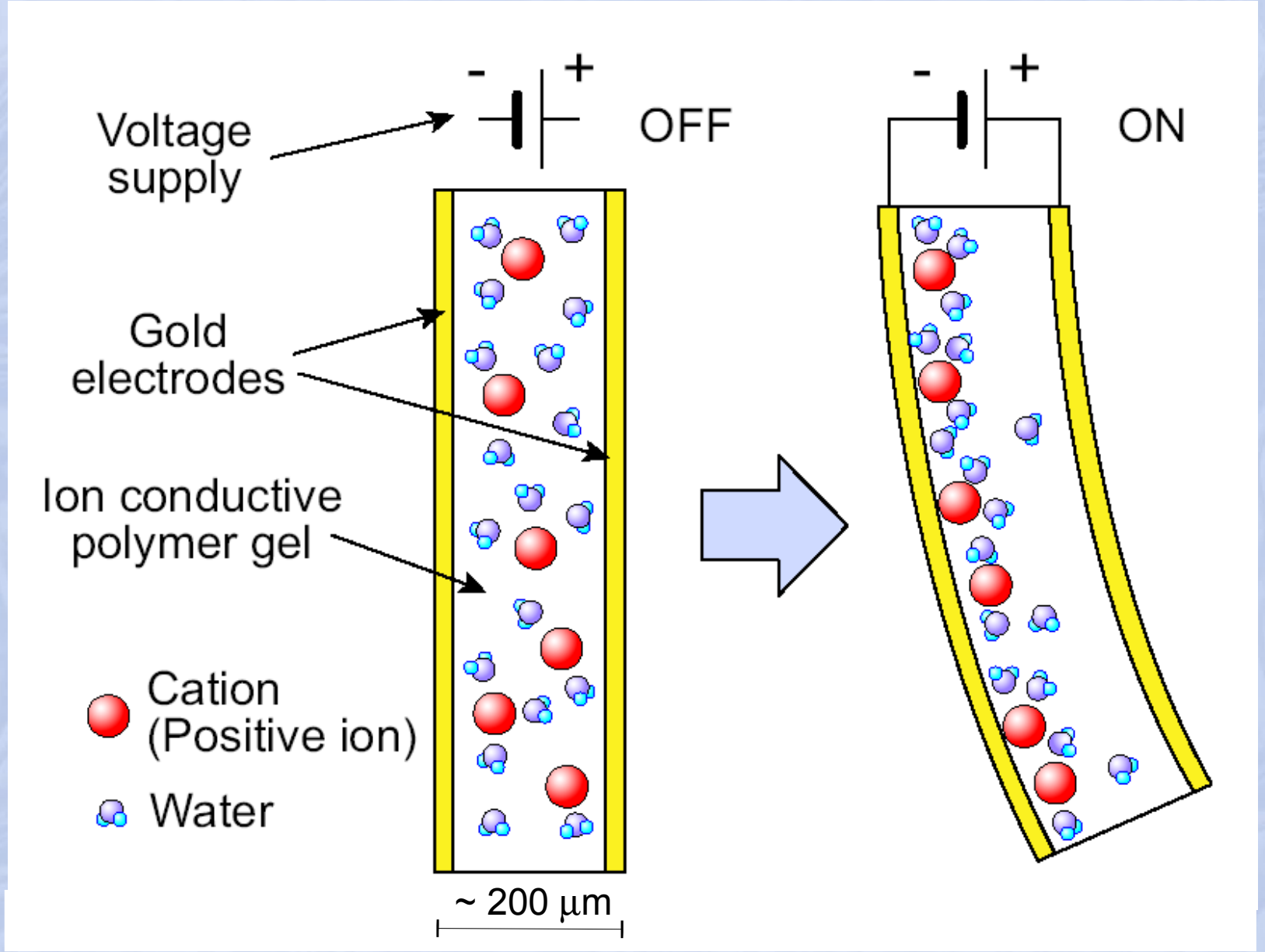
HELIX Robot inspiration



Snake ribs, vertebrae and skin linked by muscle bundles.

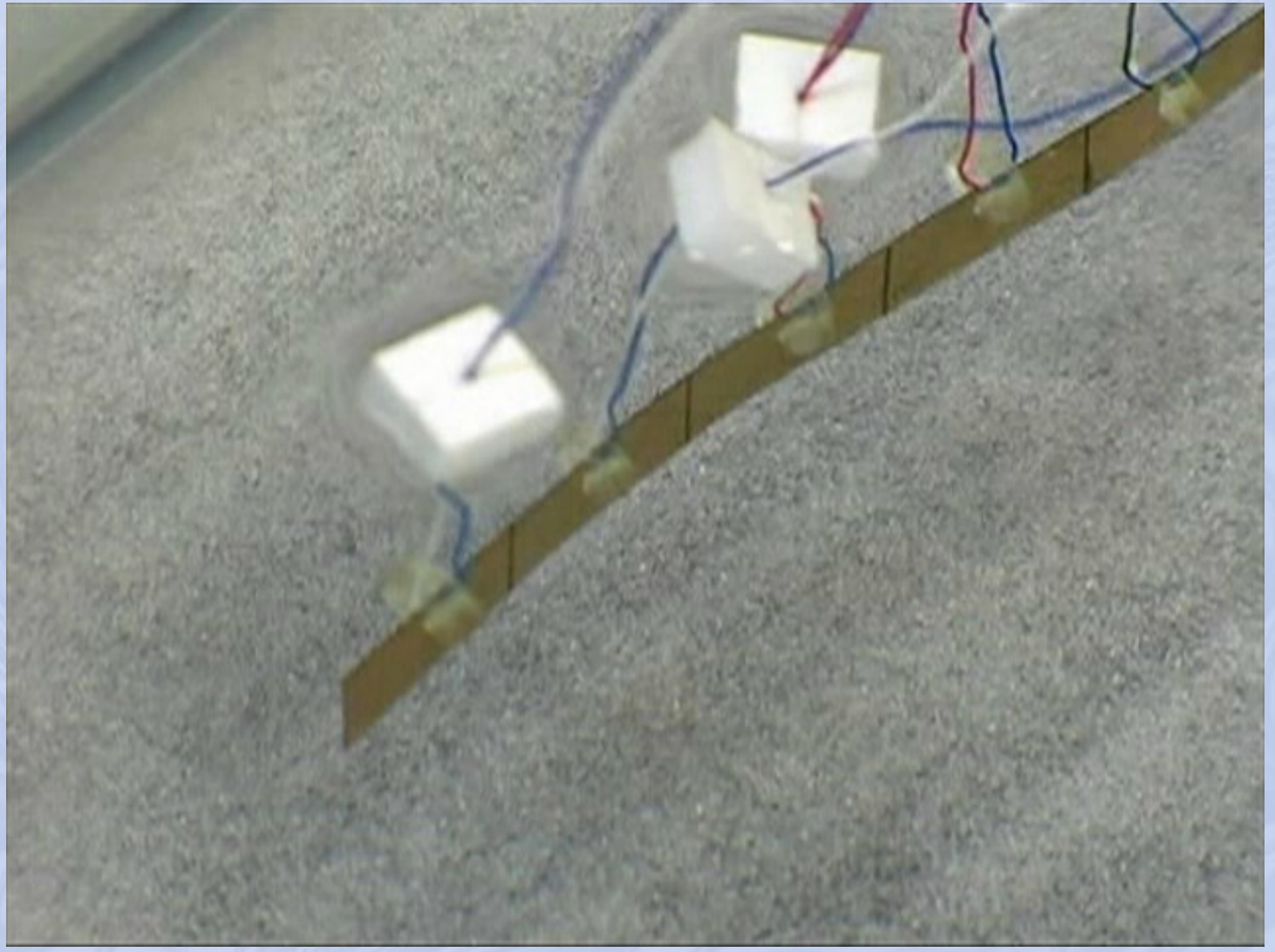


Introduction – IPMC



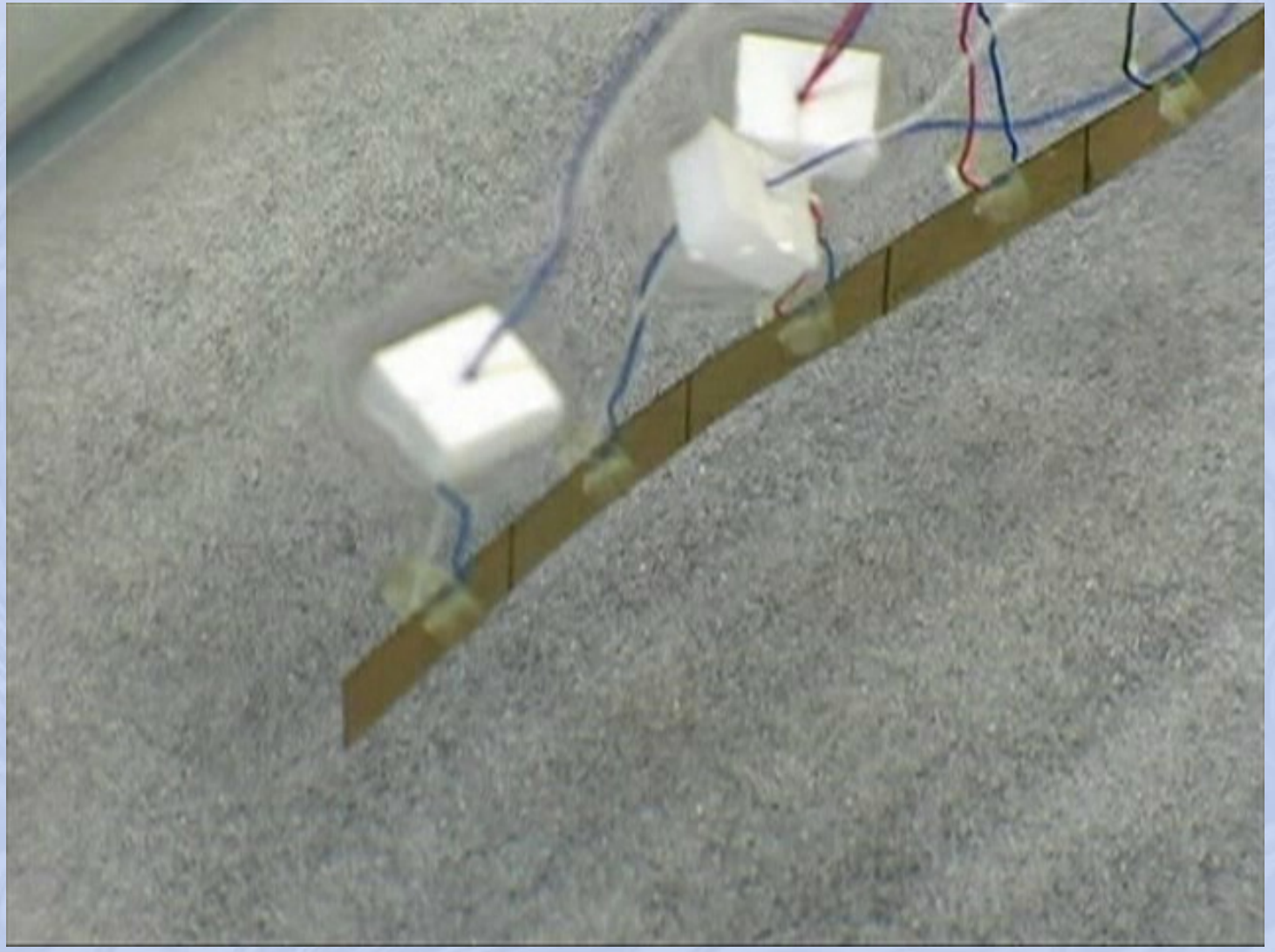
Maximum voltage limit ≈ 1.23 V (onset of water electrolysis)

Introduction – eel-like swimming robot



Nakabo et al. (2004)

Introduction – eel-like swimming robot



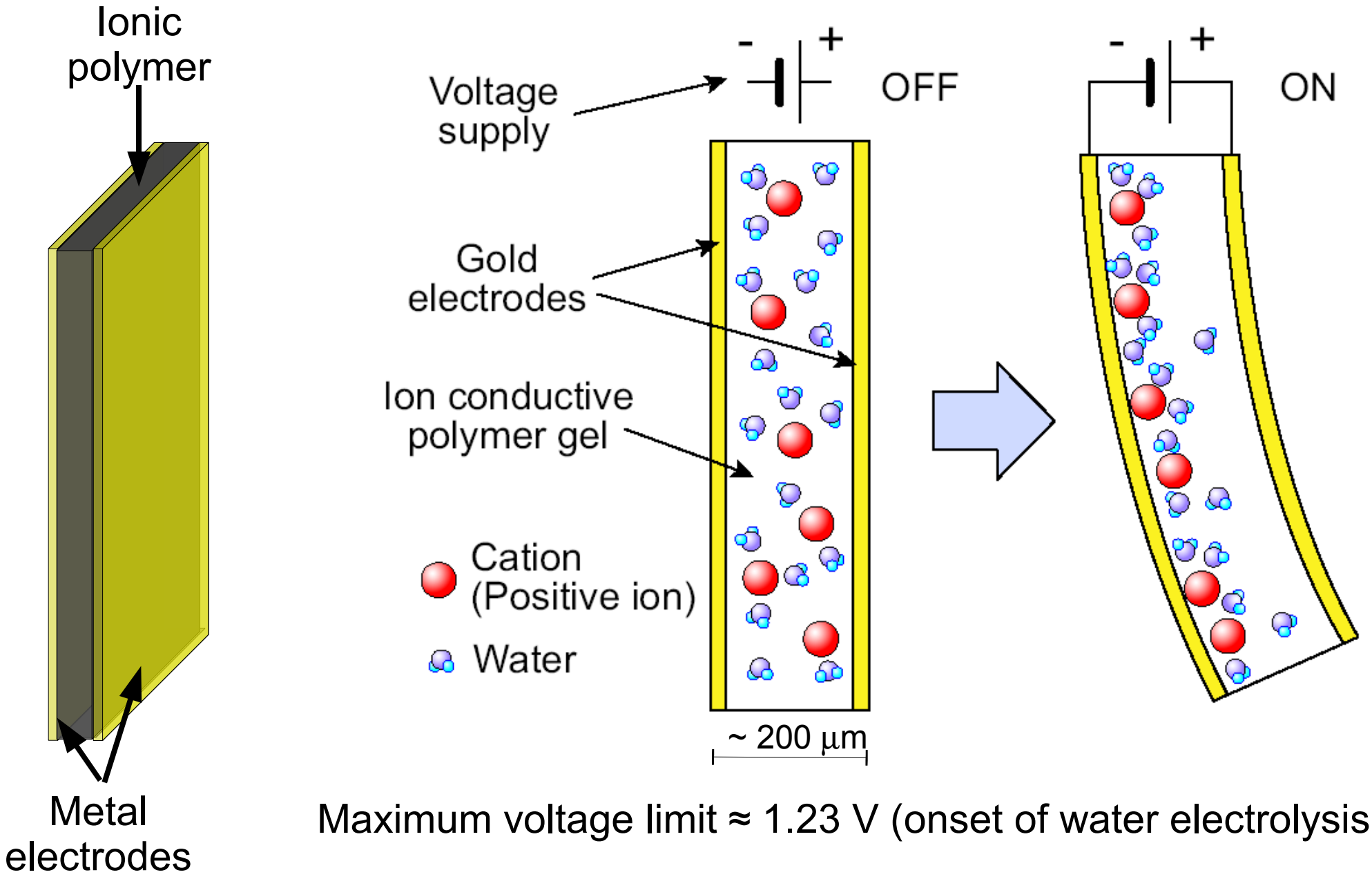
Nakabo et al. (2004)

Current swimming speed: few mm/s

To improve swimming speed:

- Increase of beat frequency
- Increase of beat amplitude

IPMC

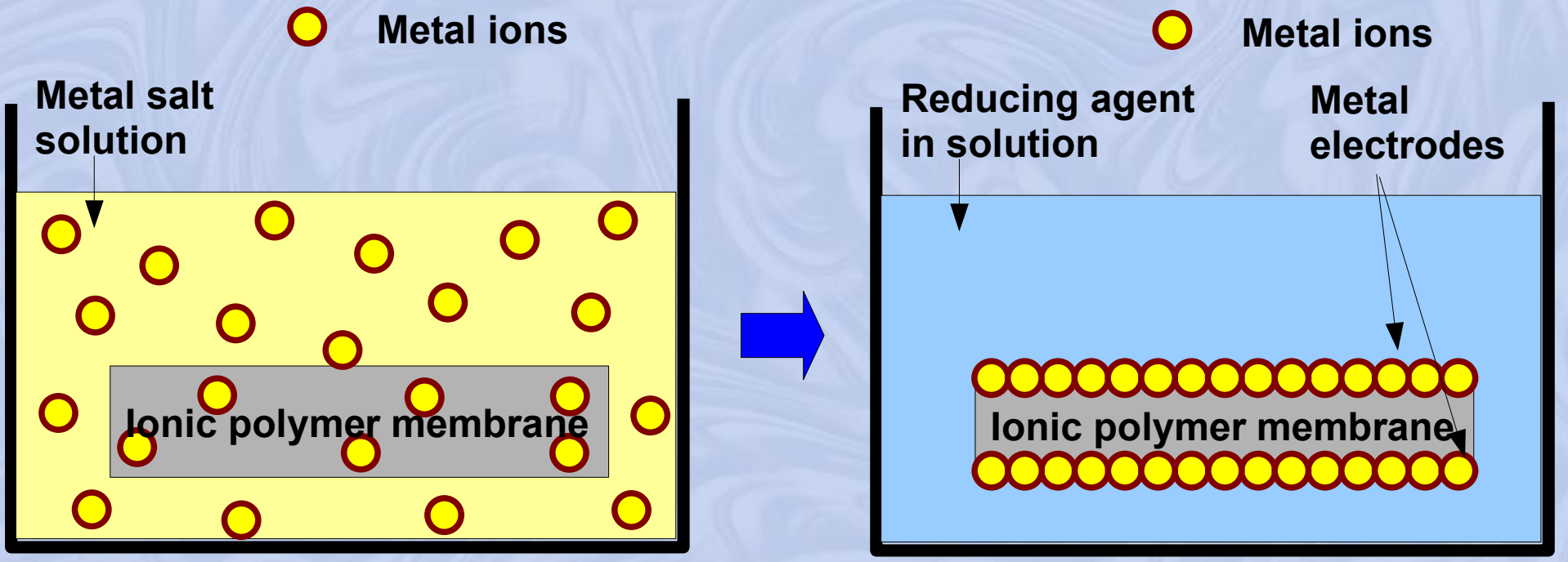


Maximum voltage limit ≈ 1.23 V (onset of water electrolysis)

IPMC - manufacturing

Impregnation – Reduction method of chemical plating

(For gold-plating - Oguro et al. (1999))



For improved electrode penetration polymer membrane is pre-treated by sandblasting and multiple impregnation-reduction cycles are done