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Controlled curvature electrode array with ionic electroactive polymer-based micro-actuators for cochlear implantation

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► To cite this version:

Ahmad Itawi, Tourel Guillaume, Renato Torres, P. Sidambaram, Sofiane Ghenna, et al.. Controlled curvature electrode array with ionic electroactive polymer-based micro-actuators for cochlear implantation. 2023 Conference on Implantable Auditory Prostheses July 9-14, 2023, Jul 2023, North Lake Tahoe, United States. . hal-04196389

HAL Id: hal-04196389

<https://hal.science/hal-04196389>

Submitted on 5 Sep 2023

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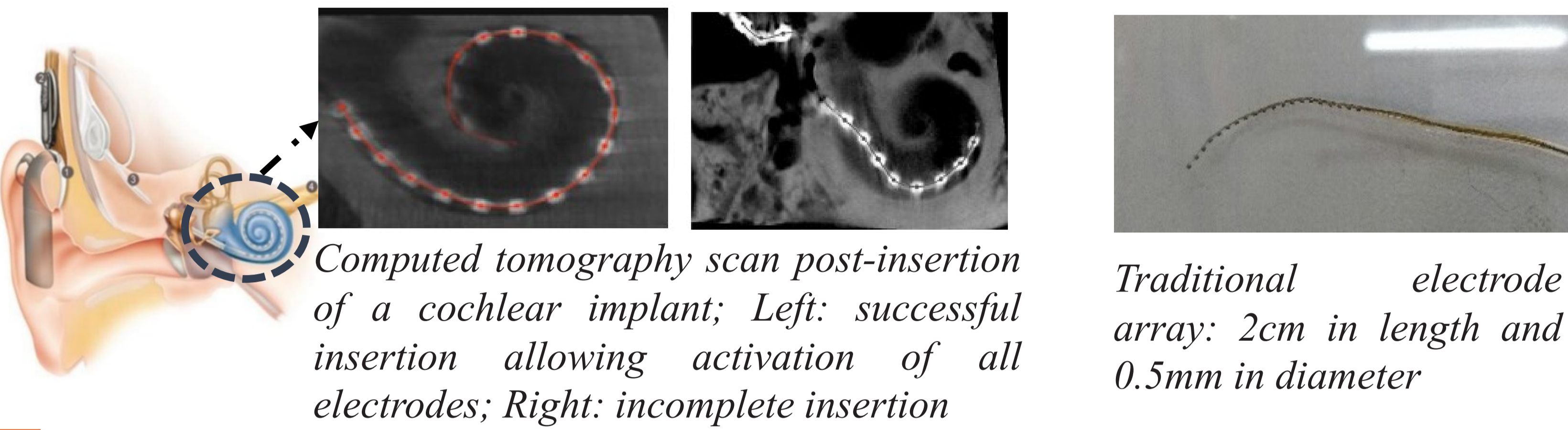
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Issue

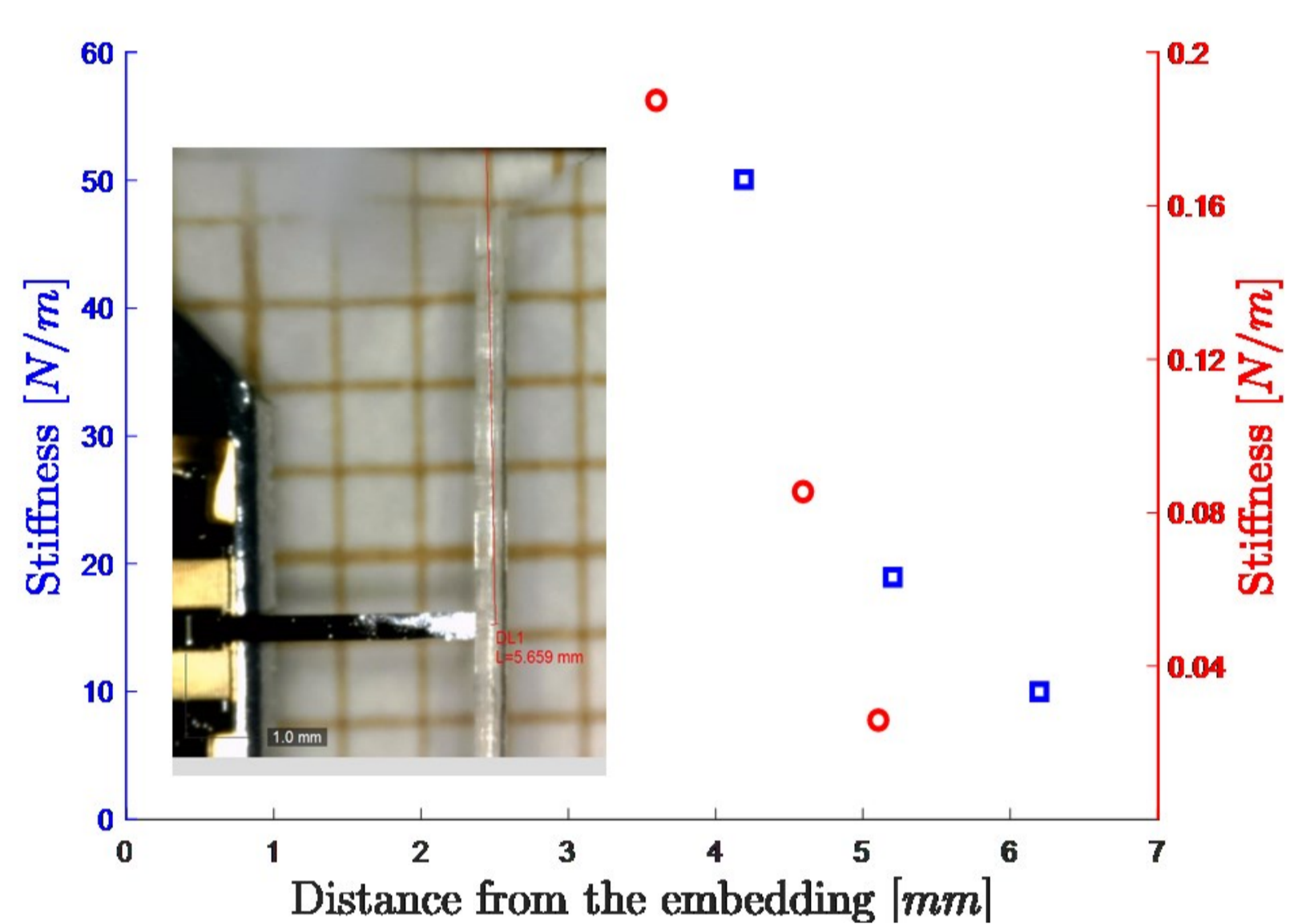
Cochlear implantation is the standard therapy for patients with severe to profound hearing loss. Currently, the most difficult task during implant surgery is inserting the electrode array (EA) properly into the scala tympani ramp of the patient's cochlea.



Computed tomography scan post-insertion of a cochlear implant; Left: successful insertion allowing activation of all electrodes; Right: incomplete insertion

Traditional electrode array: 2cm in length and 0.5mm in diameter

Stiffnesses and Required forces



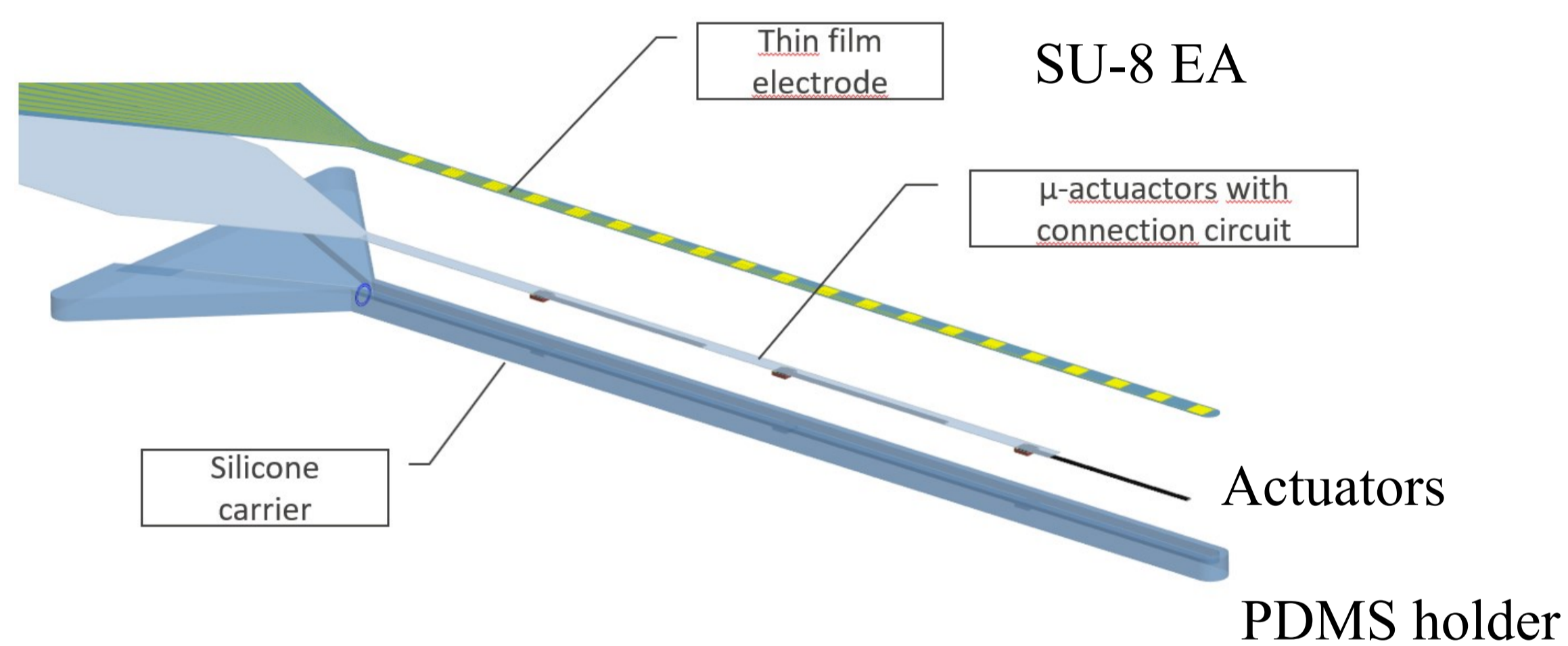
Comparison of the stiffness for a round silicon bar with / without traditional platinum electrodes and connection wires.

Conclusion: the stiffness of the silicon bar alone is 500 lower than silicon with traditional platinum electrodes.

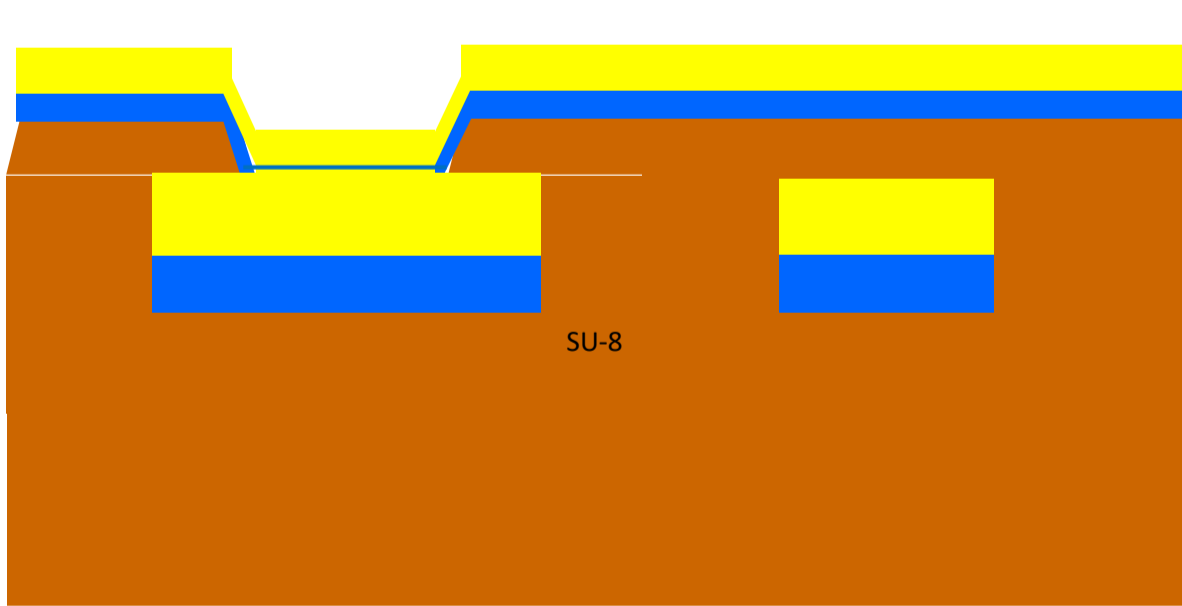
At 5mm from the embedding 20 μ N of force is necessary to move silicon alone of 500 μ m in diameter

Problem solving

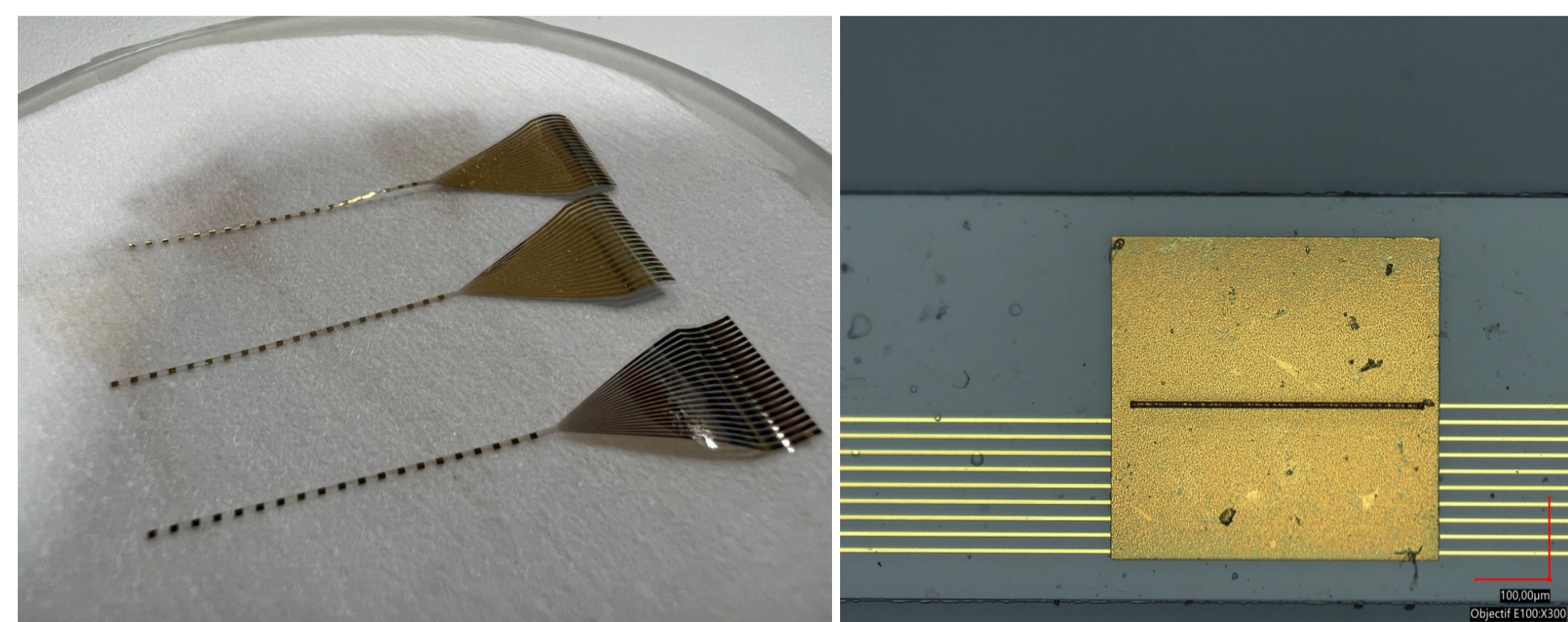
A new prototype with low stiffness to reduce friction forces allowing better control of insertion process, facilitate the work of surgeon and decrease the probability of trauma. We propose to associate very thin film electrode array with electronic conducting polymer based microactuators



Electrode array fabrication



SU-8 photoresist is used as the structural element for the EA. On a first SU-8 layer 20 gold lines are patterned with a width of 10 μ m separated by 10 μ m. Then a second SU-8 layer is deposited with via to obtained contact between bottom gold layer and encapsulated lines



SU-8 electrode array and one gold electrode in detail

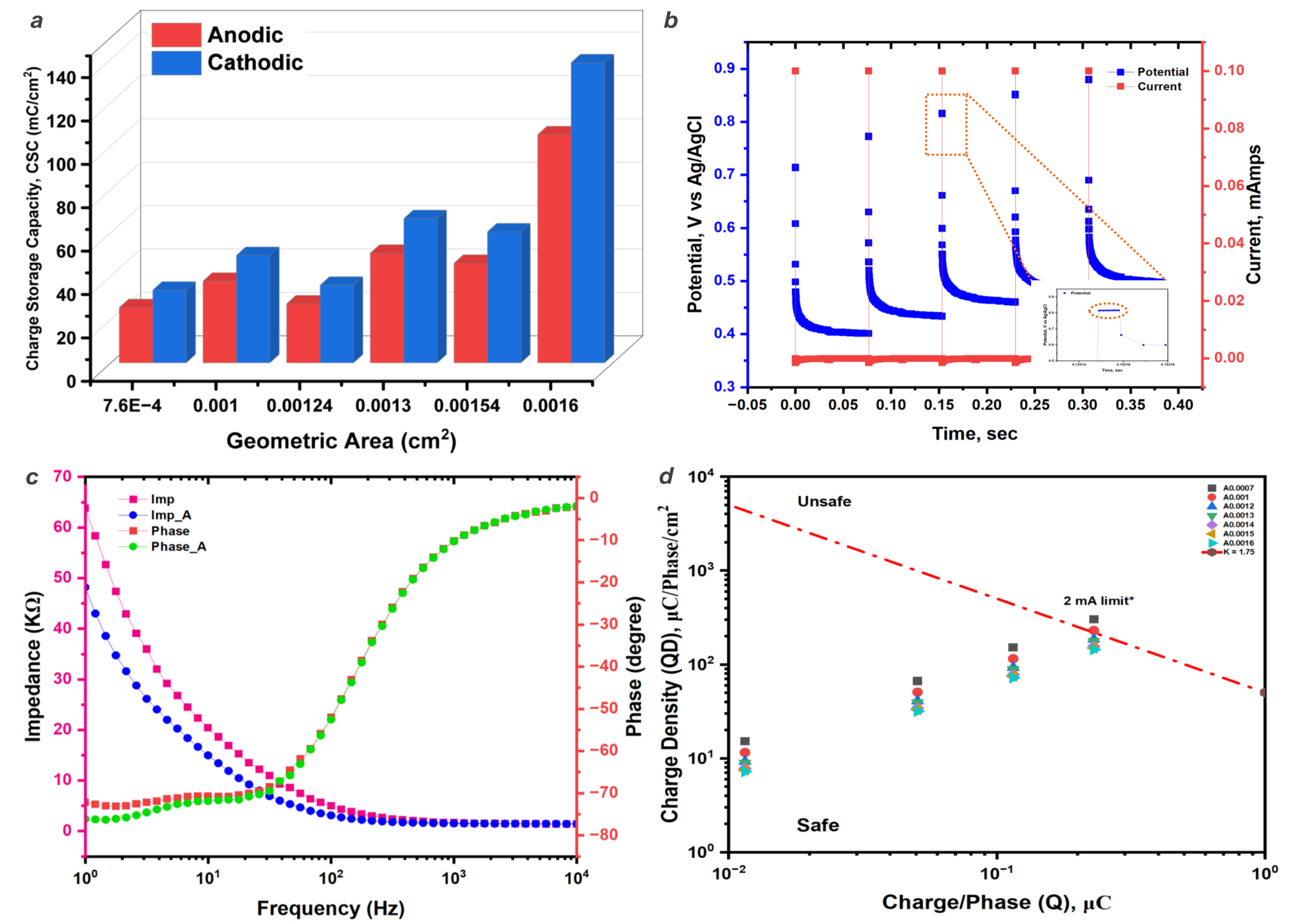
Electrode array stiffness is measured at 1mm of the clamping point: 0.08 μ N/ μ m

Conclusion: At 1mm of the clamping point, to move the EA by 500 μ m, a force of 40 μ N is needed

Conclusion

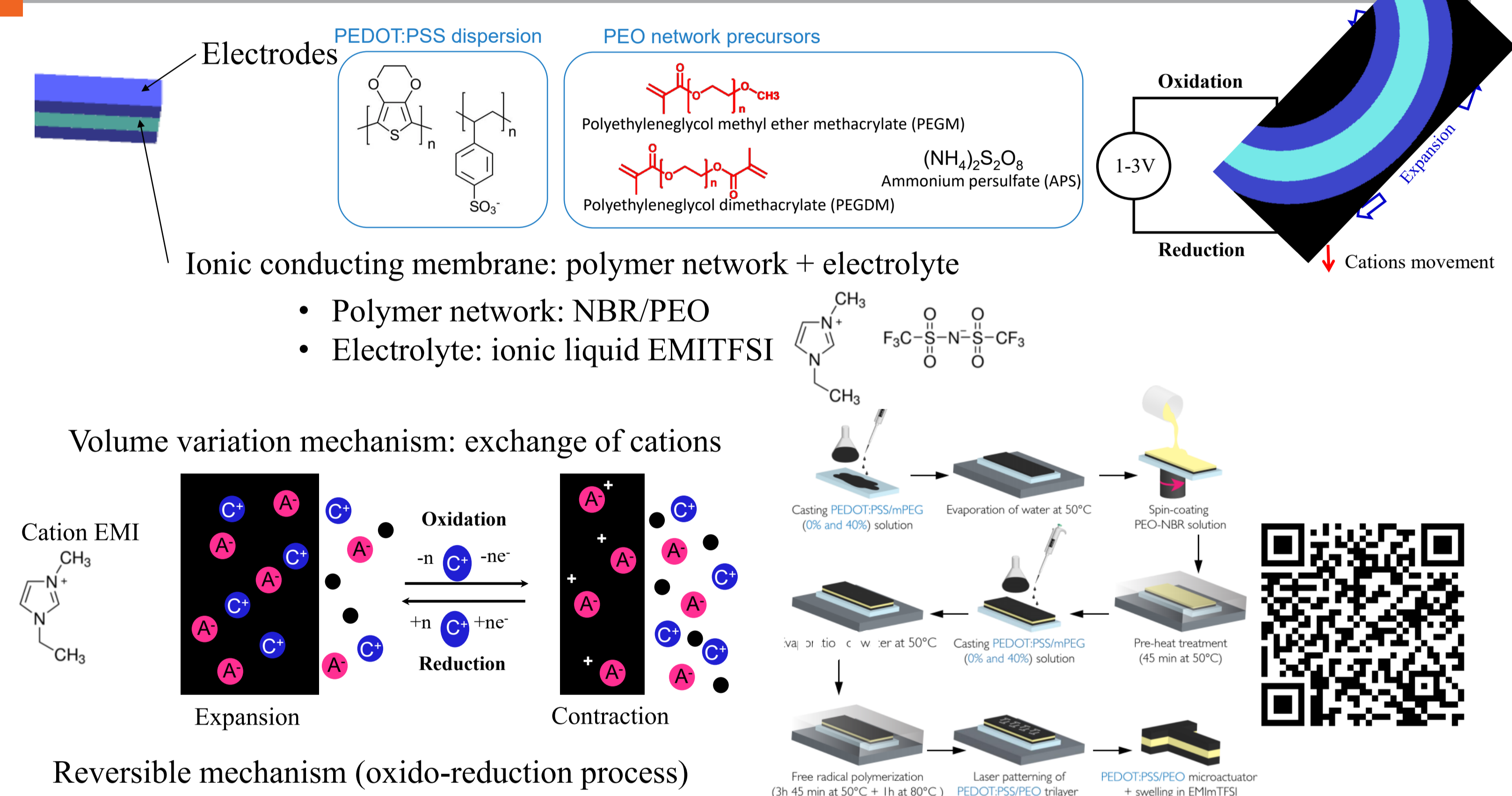
- Electrode array with adaptable stiffness was fabricated and optimized.
- The micro-actuators were optimized to obtain enough forces to bend EA.
- Insertion into the 3D printed cochlea model until a 360° angle was achieved with an actuator added to SU-8 electrode array.

Electrode array characterisations



Electrochemical Characterisation: a) Charge storage capacity (CSC) plotted against different electrode area; b) Chronopotentiometric data for anodic-first asymmetric charge balanced pulse; c) Impedance @ 1 kHz of electrode before and after stimulation; d) Charge densities at various electrode geometries for safe stimulation with Shannon's limit of $k = 1.75$.

Actuator: principe and fabrication

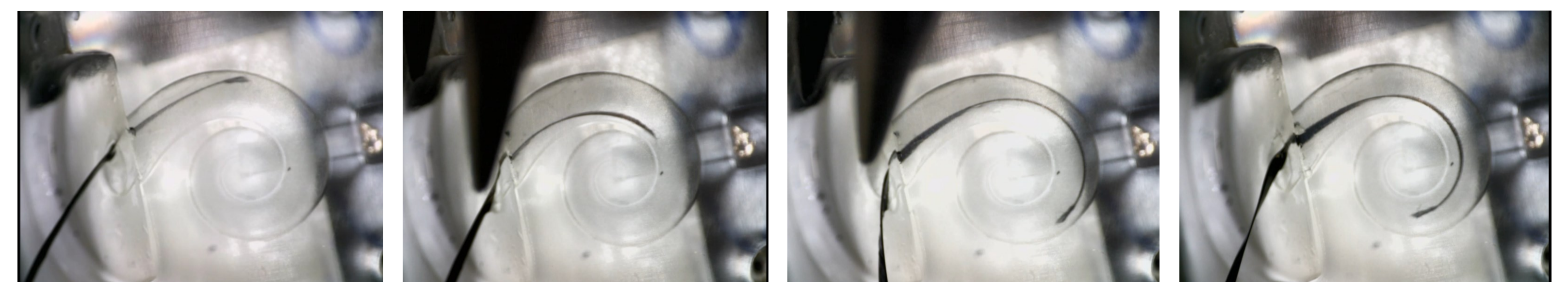


Actuator thickness 53 μ m: PEDOT:PSS/POE 20 μ m + NBR/PEO 13 μ m + PEDOT:PSS/POE 20 μ m

Distances from clamping point →	5mm	10mm	15mm	15mm
	1.5V 1Hz	1.5V 1Hz	1.5V 1Hz	1.5V 0.1Hz
Force (μ N)	60	50	40	80

Conclusion: forces produced by the actuator are enough to move the EA

Results of insertion



Micro-actuator added along an EA.

DC voltage (1-2 V) is applied to detach EA from the lateral wall and avoid friction with implant prototype.

Conclusion: 360° angle was achieved but this can be improved by further stiffening the base of the prototype

Perspective

- Additional electrochemical measurements will be carried out on the EAs.
- The assembly steps of the three elements will continue and be optimized.
- The insertion forces will be evaluated in order to minimize them, coupled with the simulations.

Acknowledgments: This work was partly financially supported by the French National Research Agency with PIA EQUIPEX LEAF (ANR-11-EQPX-0025), RENATECH, and ROBOCOP (ANR PRCE 19 CE19) projects.



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