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A soft robotic actuator using dielectric minimum energy structures

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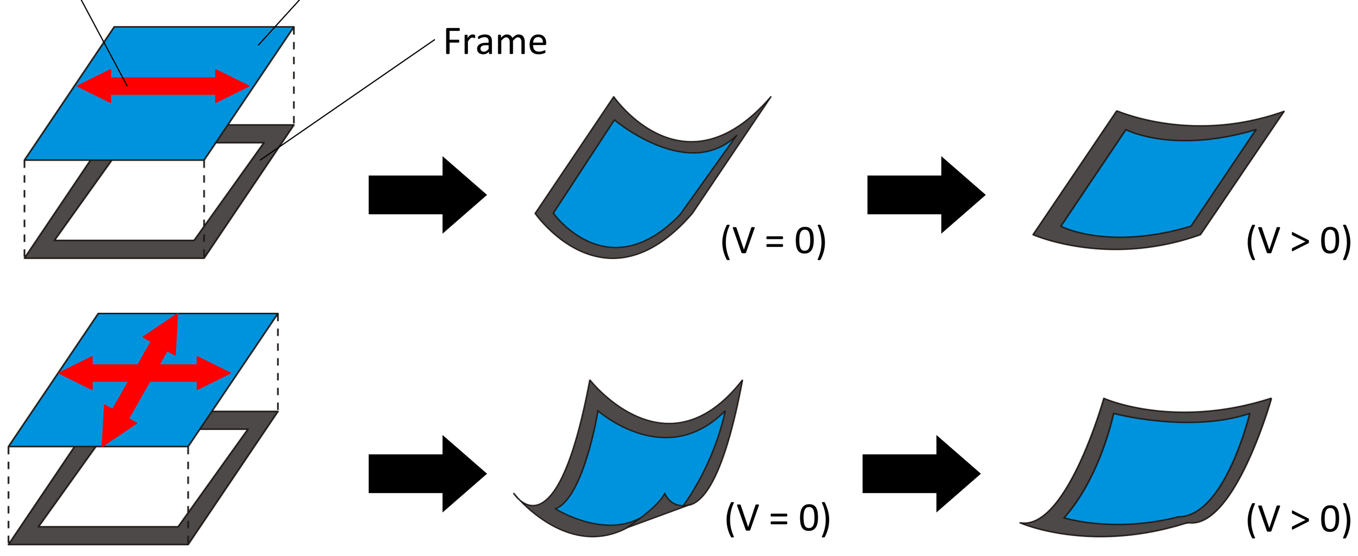
Abstract

Soft robotics is an exciting field of robotics that shows many advantages over traditional approaches using rigid materials, such as safe human-robot interaction, bio-inspired mechanisms for efficient locomotion, adaptive morphology and re-configuration of robot body. The objective of this study is to develop an artificial-muscle-based actuator for soft robotics using dielectric elastomer minimum energy structures (DEMES) [1]. DEMES are capable of large actuation stroke and consist of a pre-stretched dielectric elastomer actuator (DEA) laminated onto a flexible frame, which makes it easy to obtain both simple and complex shapes. We report on the fabrication and characterization of a prototype capable of one-dimensional bending actuation. For the DEA, several combinations of ion-implanted PDMS membranes [2] and uniaxial pre-stretch ratio were used. The actuators are characterized by measuring the deformation and output force vs. applied voltage.

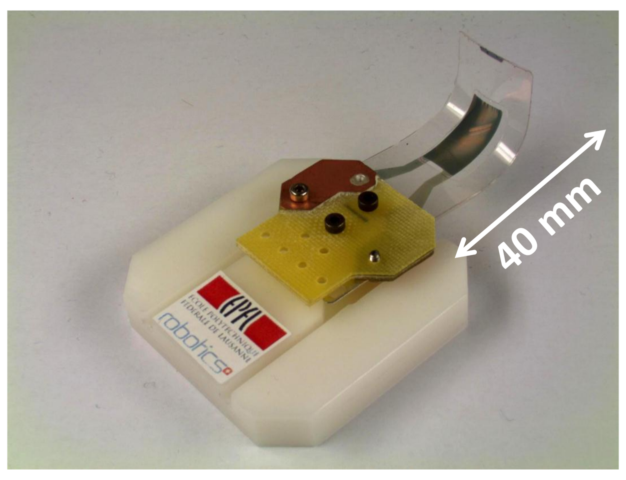
Dielectric minimum energy structure (DEMES)



When a stretched DEA is laminated onto a flexible frame, the strain energy of the DEA is partially transferred into bending energy of the frame. Minimization of these two energies results in a complex structure whose shape depends on the frame geometry, on the membrane thickness, and on the mechanical parameters of the membrane (pre-stretch ratio, stiffness,…). When a voltage is applied, expansion of DEA releases the bending energy of the frame, which tends to move back towards its initial shape.

Prototype of DEMES

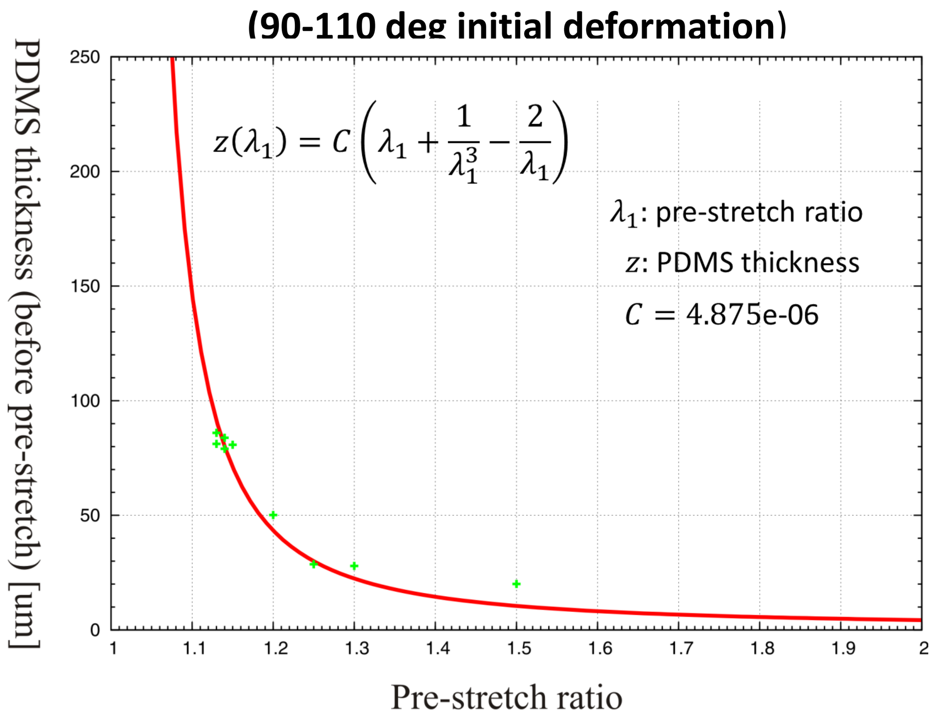
8 DEMES prototypes were fabricated for characterization. Pre-stretch ratio is calculated from experimental results to obtain a specific initial deformation angle.



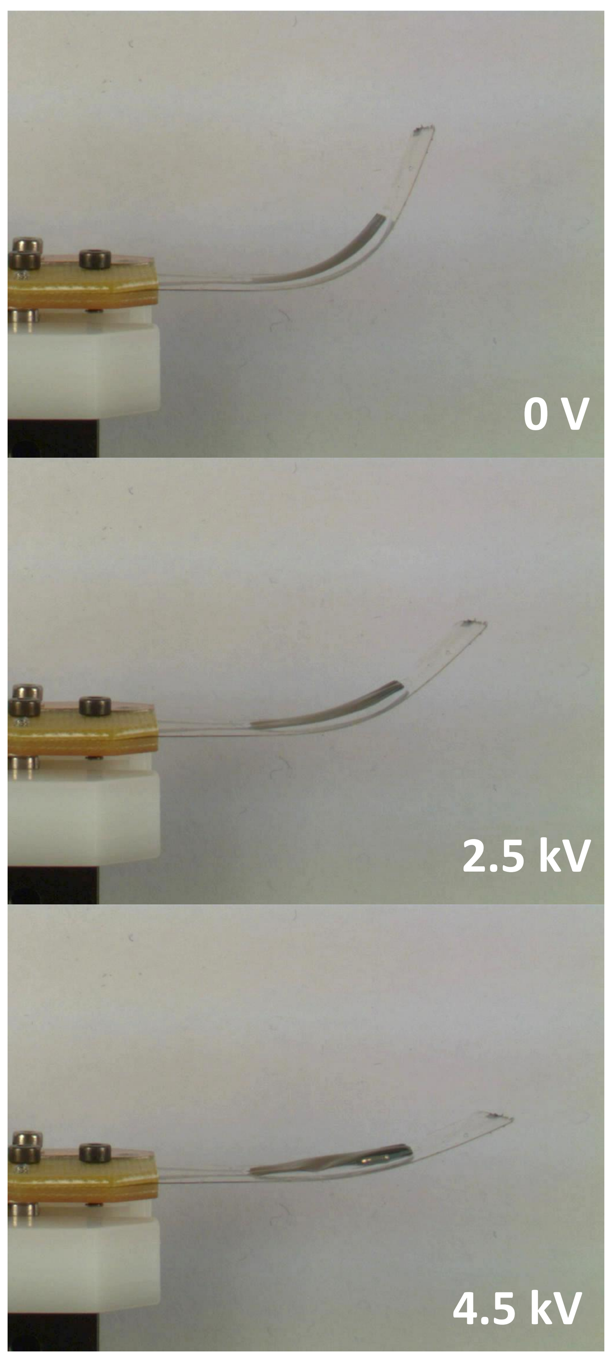
Fabrication condition

Pre-stretch ratio : 1.233 (for 90deg, actuator 1-7)
1.165 (for 60deg, actuator 8)
Pre-stretch condition : uniaxial
PDMS membrane thickness : ~50mu
Electrodes : ion-implantation
Frame material : silicone based adhesive foil
Frame thickness : ~100mu
Frame dimension : 20mm X 40mm

PDMS thickness versus pre-stretch ratio (90-110 deg initial deformation)

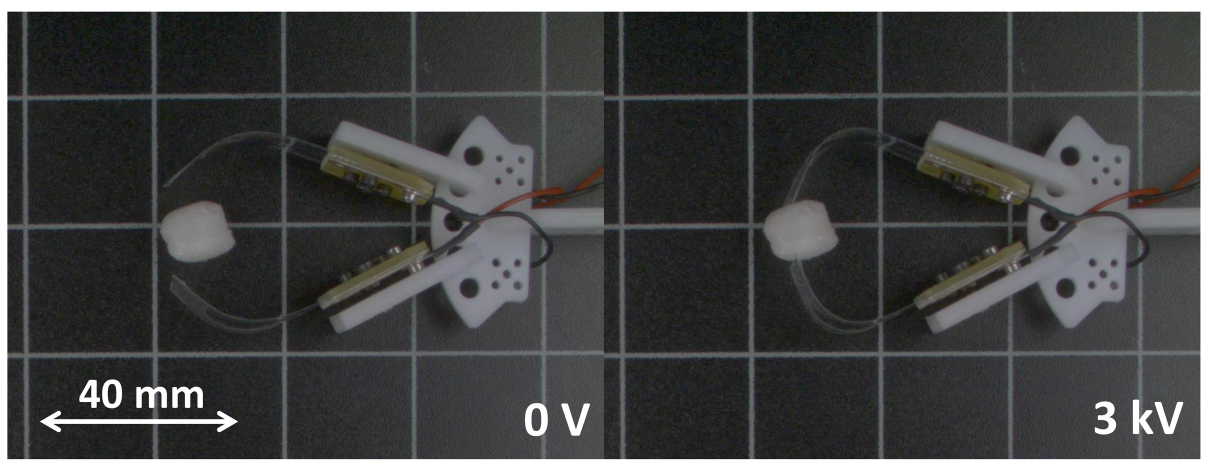


Behavior of the prototype (actuator 8)



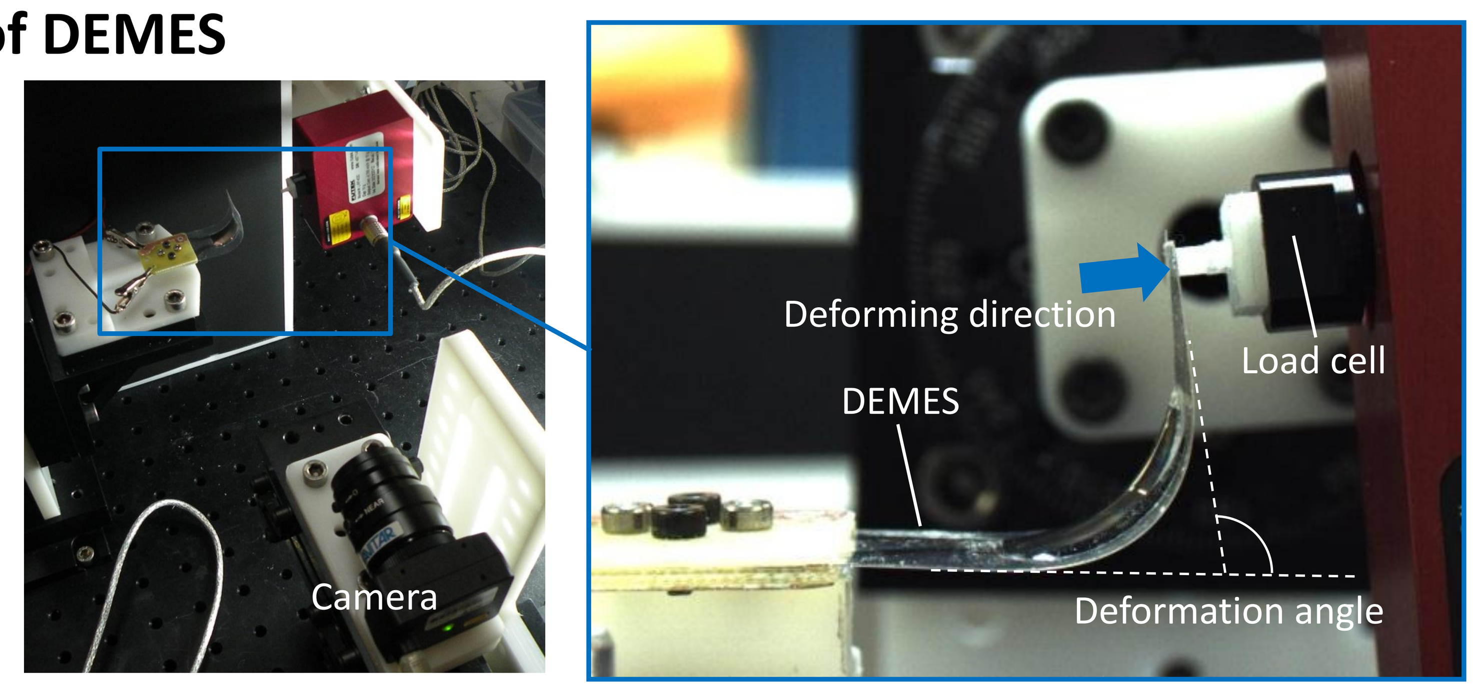
DEMES gripper

A DEMES-based demonstrator has been built in the form of a robot hand that has two flexible arms, able to manipulate an object by grasping motion.

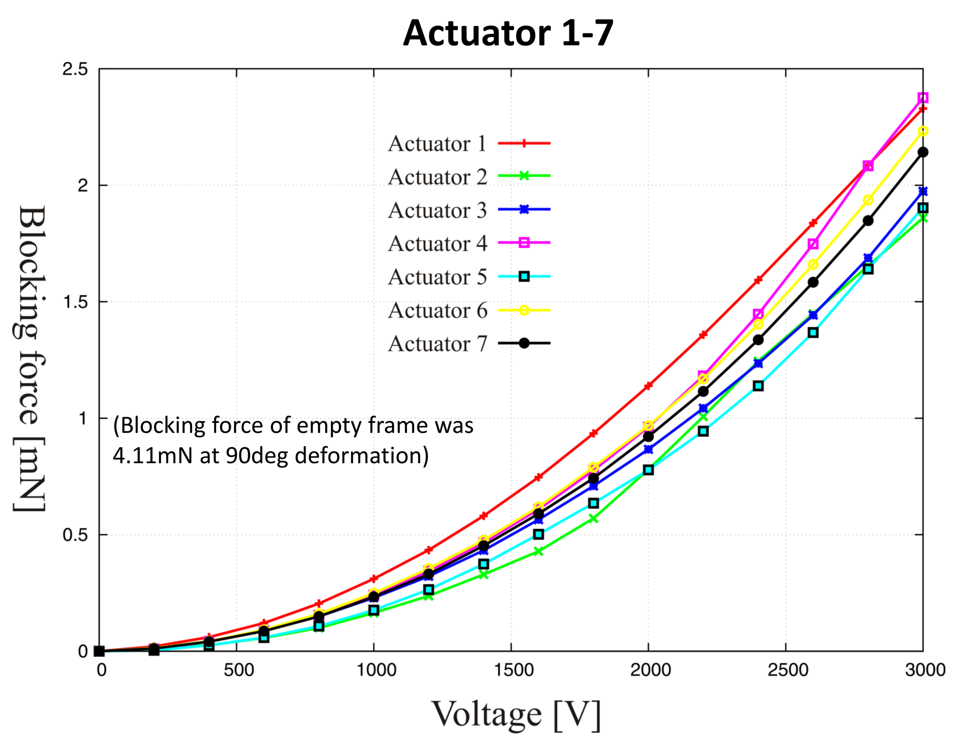


Characterization of DEMES

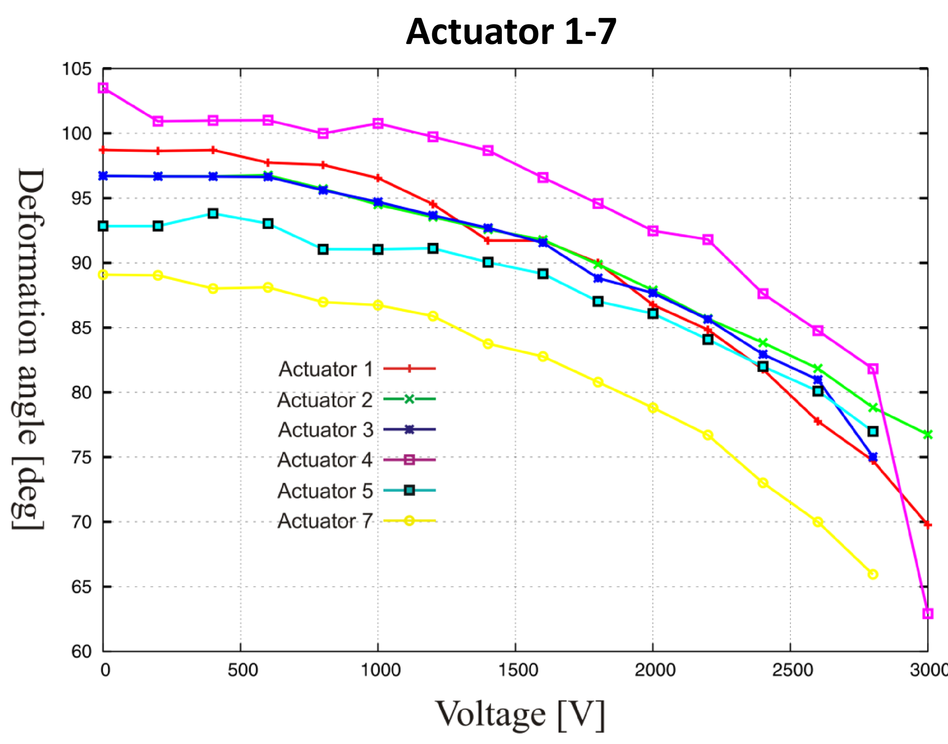
The blocking force and deformation angle are measured using a load cell and image processing (MATLAB). The resonance frequency is also measured to understand dynamic characteristic of DEMES.

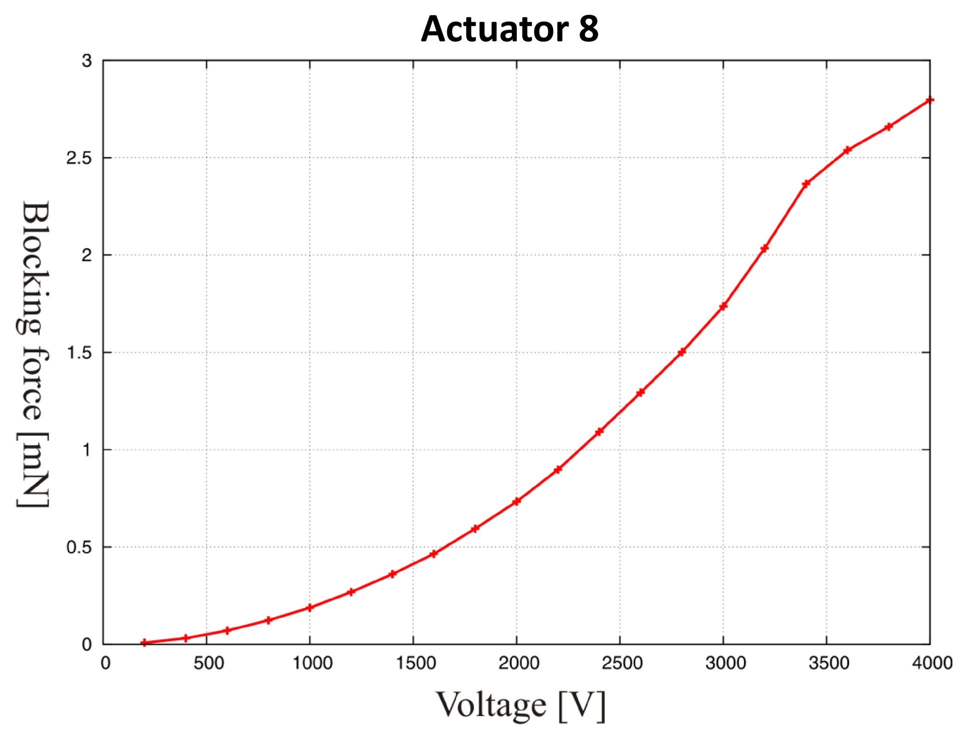


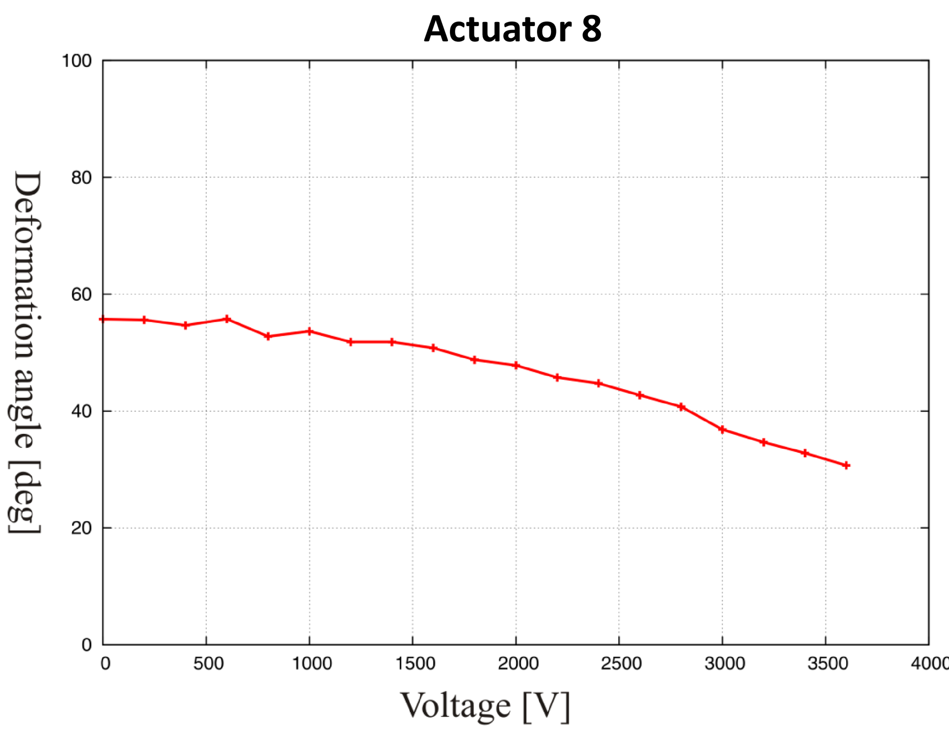
Blocking force vs. applied voltage



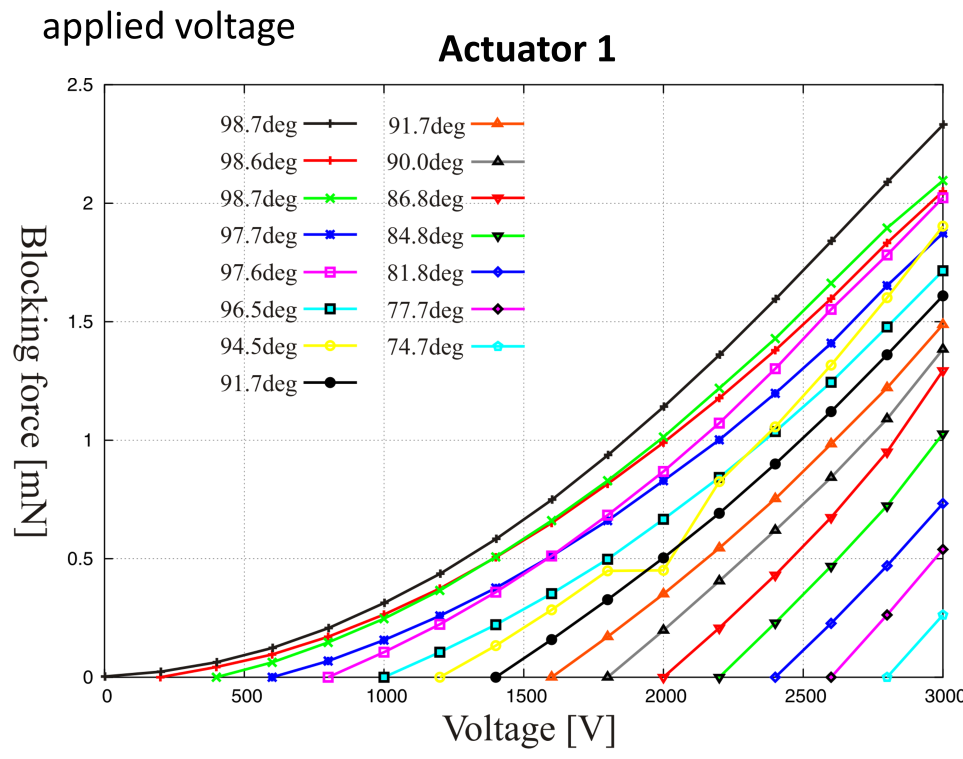
Deformation angle vs. applied voltage



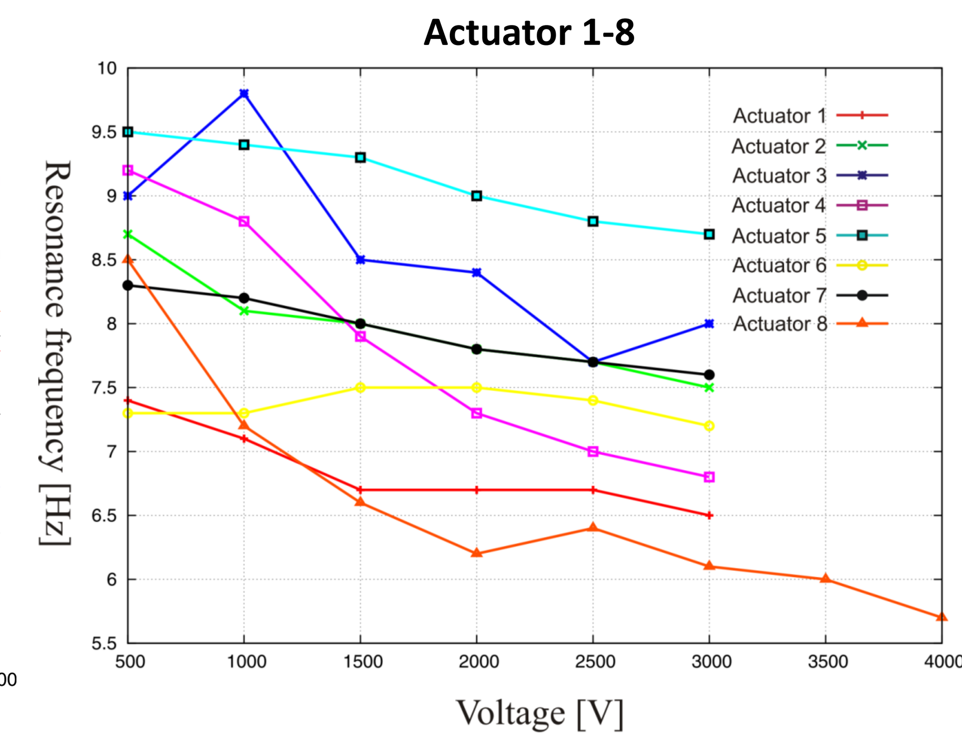




Blocking force at different initial deformation angle vs. applied voltage



Resonance frequency vs. applied voltage



Conclusion and outlook

We fabricated and characterized DEMES using ion-implanted PDMS membranes. In the experimental results, the blocking force increases and the deformation angle decreases as a function of applied voltage. Resonance frequency for all the actuators decreases as the applied voltage is increased. These results can be used for our future work, such as making a prediction model and for the optimization of the fabrication conditions or the geometry of the frame.

References

[1] G. Kofod, et al, Applied Physics A: Materials Science & Processing, 85(2): pp.141–143, 2006.
[2] S. Rosset, et al, JMEMS, vol.18, no.6, pp.1300–1308, 2009.

Acknowledgments

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