EuroEAP 2014
International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles
Linköping, 10-11 June 2014
Organized and supported by 'European Scientific Network for Artificial Muscles – ESNAM' (www.esnam.eu)
COST Action MP1003

Poster ID:
2.2.12

DEA-based deformable cell culture system

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Abstract

We present a deformable cell culture system based on dielectric elastomer actuator (DEA). Understanding how the mechanical environment can affect cells functions could lead to significant advances in diseases diagnosis and drug development. Most available technologies offer low screening throughput, an important limitation considering the statistical nature of cellular studies. We previously reported an array of micro-DEAs for cell stretching application [1], [2]. Our DEA-based solution has the potential to replace current technologies and overcome the high screening throughput limitation.

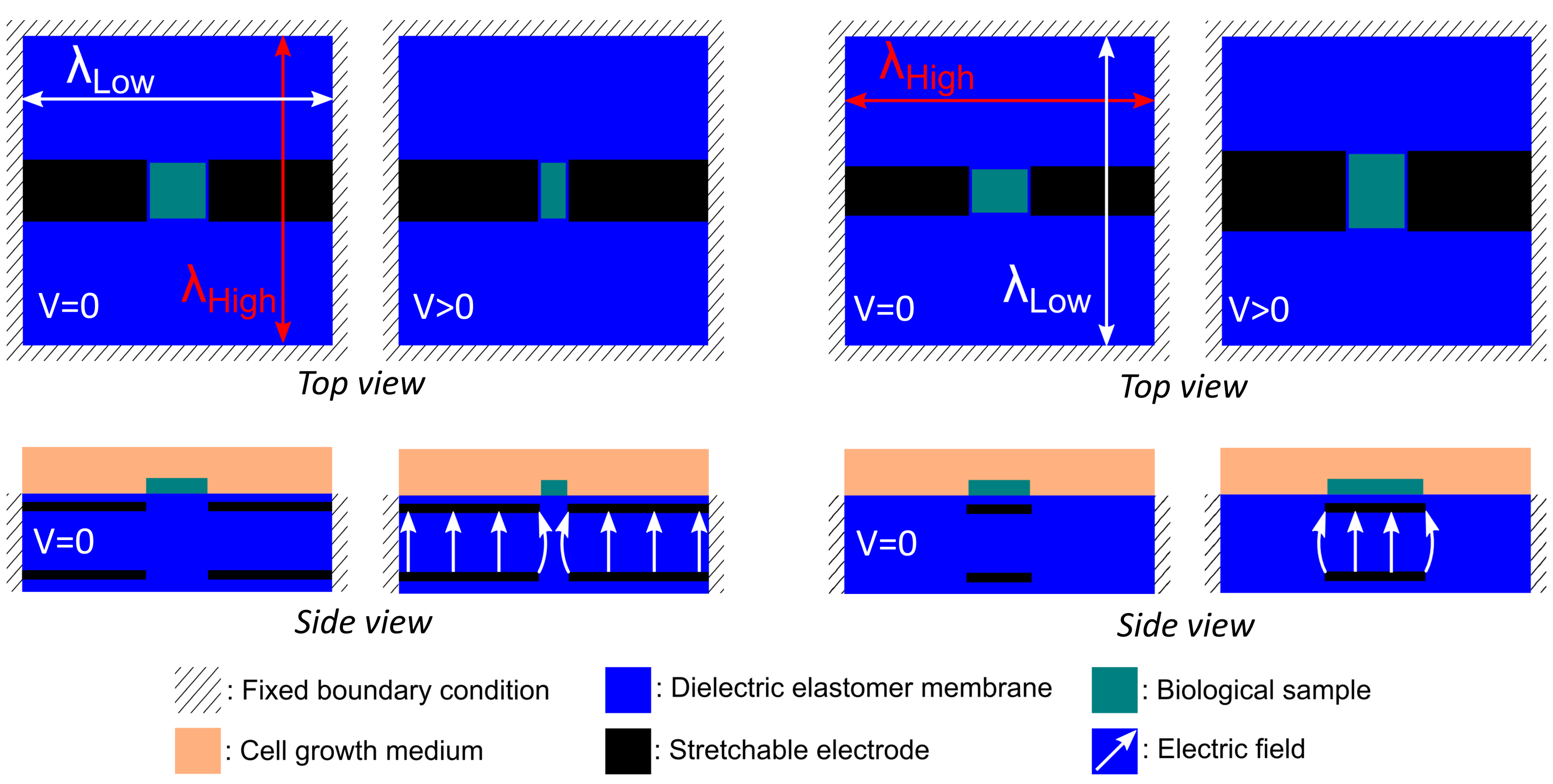
We present a new generation of devices, developed to better address cell biologists requirements. Two different devices were developed to apply periodic (1-5Hz) compressive or tensile strain greater than 10% on a 2mm x 2mm biological sample. Their original designs exploit non-equibiaxial pre-stretch of a silicone membrane and stress induced in passive regions of DEAs. Our technology is now compatible with high resolution optical microscopy for real time monitoring of morphology and chemical activity of the biological sample. This new generation of devices also significantly improves the electric field confinement and provides a fully biocompatible environment.

I - DEA designs for stretching and compressing cells

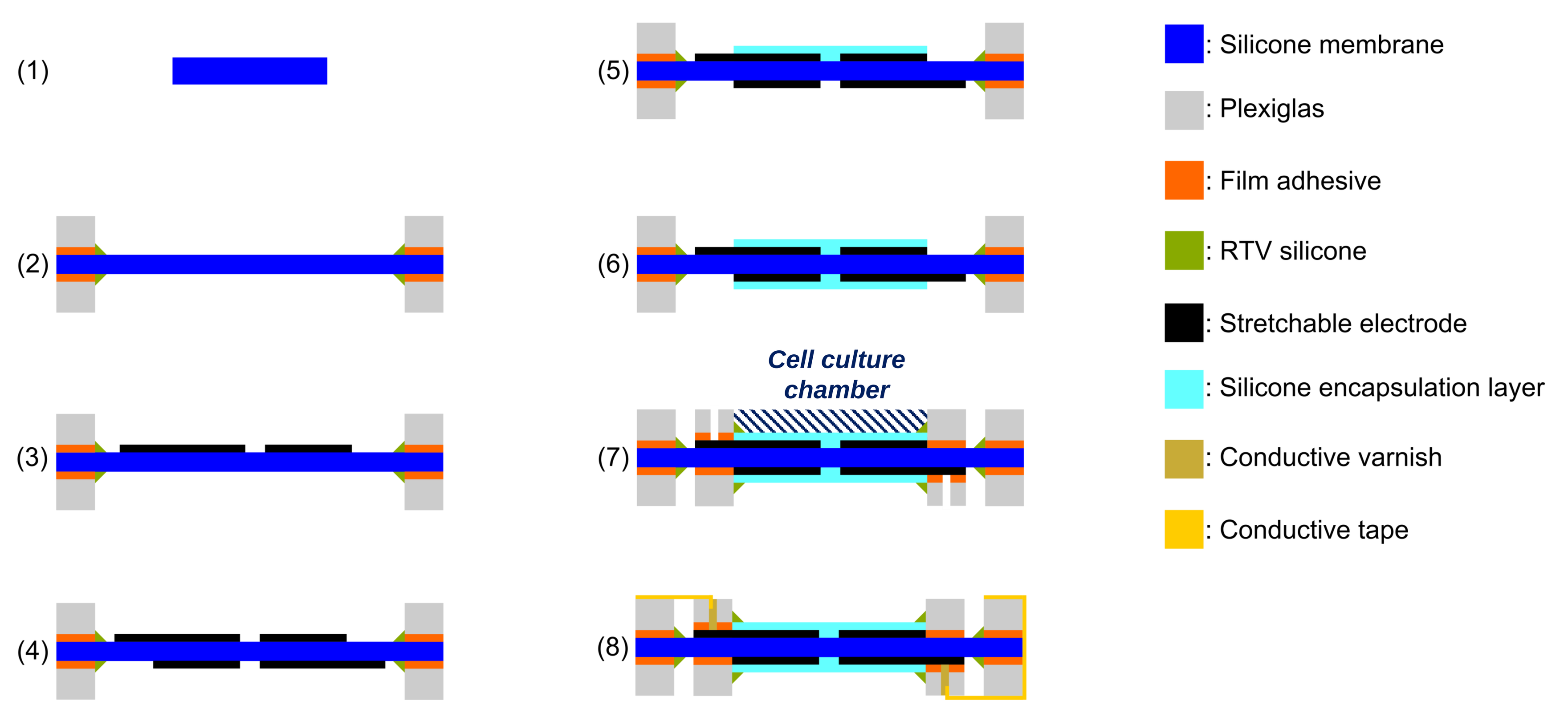
Single actuators were developed to apply mechanical stress on small (4mm²) cell populations. Our designs are based on a silicone membrane under highly non-equibiaxial pre-stretch (L_{High}/L_{Low}=3) and provide:

- **High optical transparency**
- **Good electric field confinement**
- **Biologically relevant actuation frequency (1-5Hz)**
- **Large actuation strain (>10%)**
- **Biocompatible environment**
- **Array compatible solution**

Uniaxial compressive strain | **Uniaxial tensile strain**



II - High yield and reliable fabrication process



(1)………Blade casting of a 70µm thick Sylgard DC186 membrane.
(2)………Apply and hold highly non-equibiaxial pre-stretch on the membrane.
(3)-(4)…**Pattern stretchable electrodes*** on both sides of the membrane.
(5)-(6)…Pattern a 2-3µm thick encapsulation layer of silicone over the electrodes
(7)………Create and seal the cell culture chamber
(8)………Make the electrical contacts.

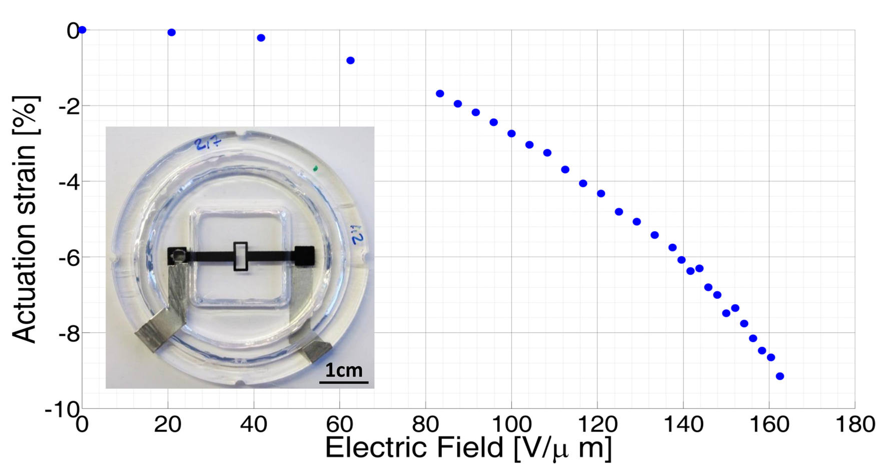
*** See poster 2.2.18 for more information on our stretchable electrodes**

References

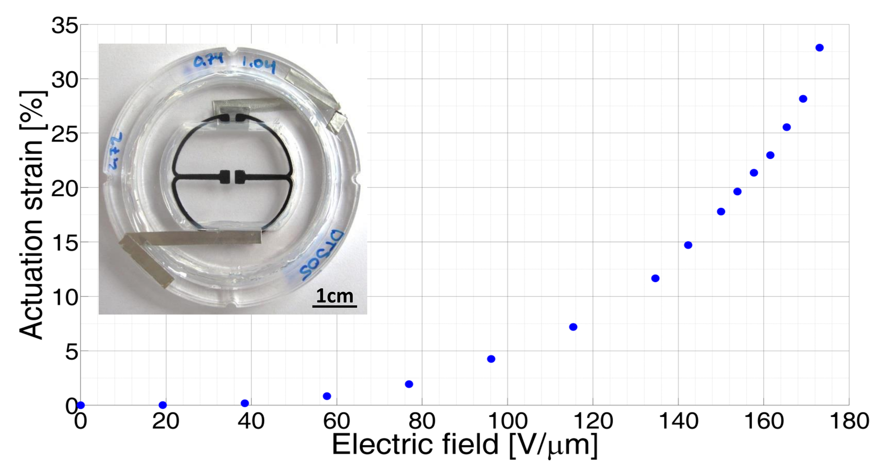
1. A. Poulin, S. Rosset and H. R. Shea, Electro Active Polymer Actuators and Devices , San Diego, 2014.
2. S. Akbari and H. R. Shea, Sensors and Actuators A: Physical 186, pp. 236-241, 2012.
3. S. Akbari, S. Rosset and H. R. Shea, Applied Physics Letters, vol. 102, p. 071903, 2013.

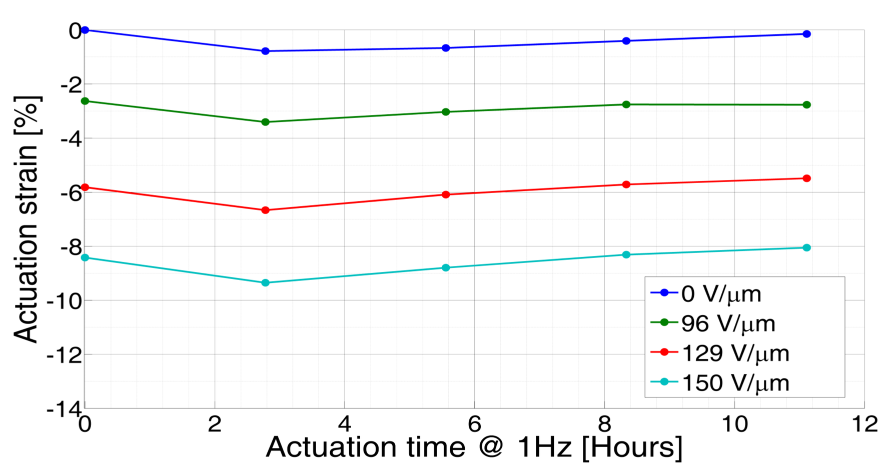
III - Large actuation strain and good stability

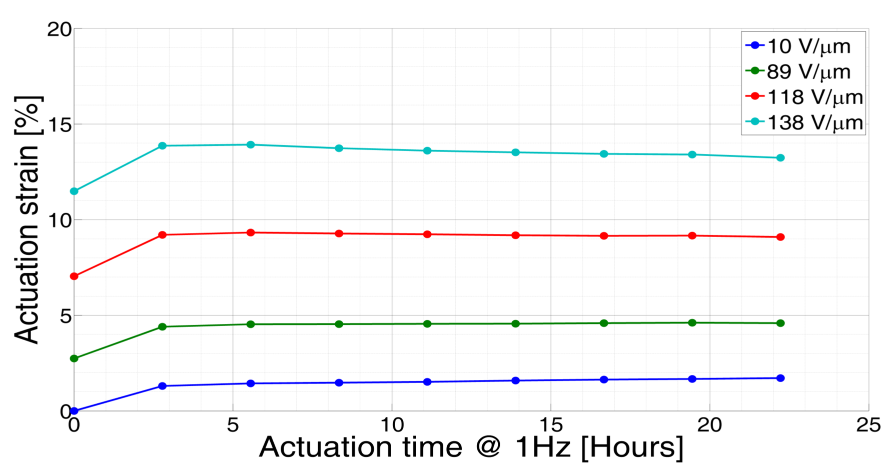
Uniaxial compressive strain



Uniaxial tensile strain





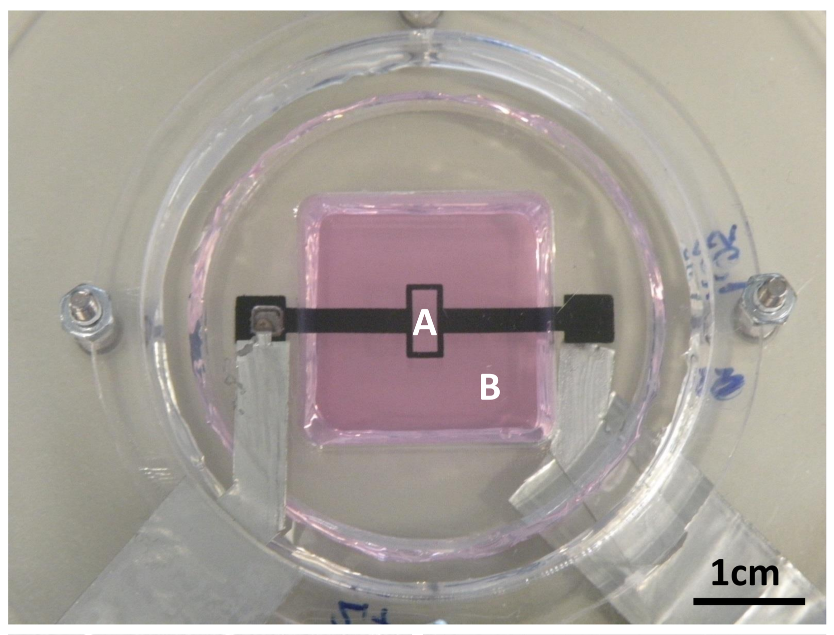


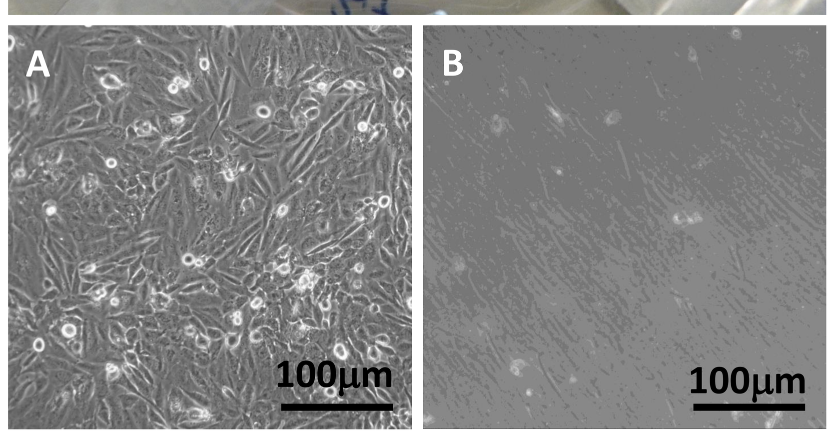
- Up to **10% compressive strain** on a 4mm² area.
- **Good actuation strain stability** over more than 10 hours of periodic actuation at 1Hz.

- Up to **35% tensile strain** on a 4mm² area.
- **Good actuation strain stability** over more than 20 hours of periodic actuation at 1Hz.

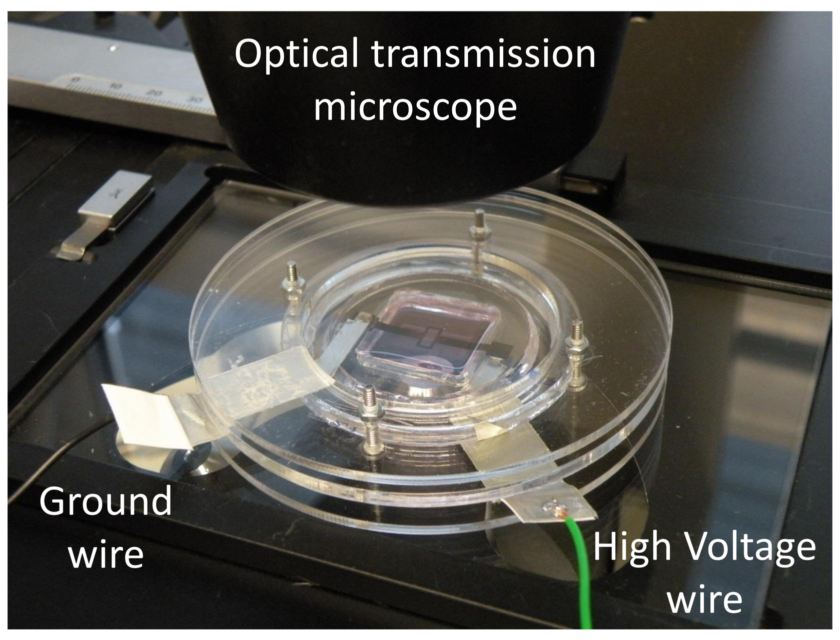
IV - Biological tests with living cells

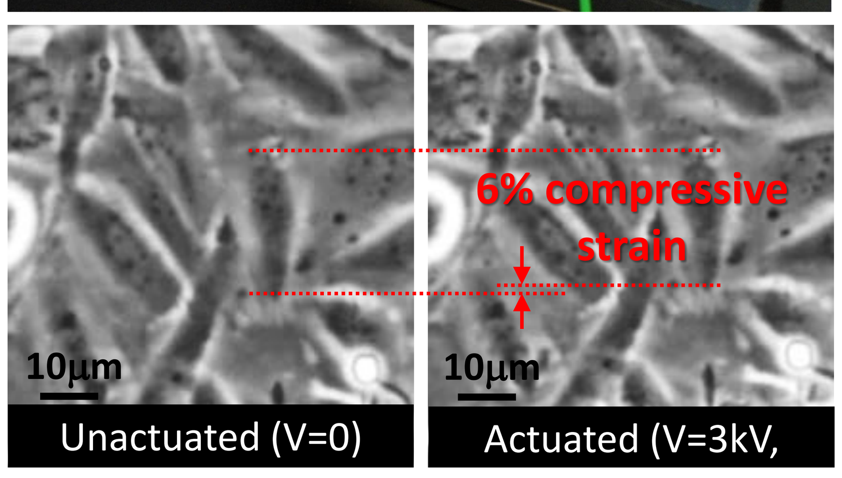
As a first proof of concept, osteoblast cells were **locally seeded and cultured** on our deformable cell culture system.





Confluent cell culture in the high strain area | **Absence of cells** in the low strain area





Our device was used to **periodically expose living osteoblasts cells to mechanical strain.** Every second the sample was exposed to 6% compressive strain.

Conclusion and outlook

We developed two DEAs for periodic compression and stretching of small a cell population. Their novel designs provide good electric field confinement for improved biocompatibility, and optical transparency for inspection of the biological sample.

Up to 10% compressive strain and 35% tensile strain could be achieved with our device at biologically relevant frequencies (1-5Hz). The actuation strain of the device showed good stability over tens of thousands of actuation cycles.

A small population of osteoblast cells was locally seeded and cultured on our device. The living biological sample was then periodically compressed by 6% at a frequency of 1Hz.

Future work will look at the effects of cell growth medium on the device performance. In order to provide a solution with high throughput capabilities, the presented designs will be miniaturized and implemented in an array configuration.

Acknowledgments

This research was supported by the Swiss National Science Foundation (SNSF) under Grant No. 200020_140394, Grant no. No. 200020_153122 and the SNSF R'equip program. 206021_139187.

Participation to this conference was partially supported by COST (European Cooperation in Science and Technology) in the framework of ESNAM (European Scientific Network for Artificial Muscles) - COST Action MP1003.