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Electrically activated polymer microstructures for artificial sphincters

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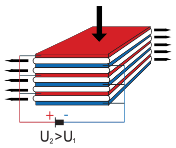
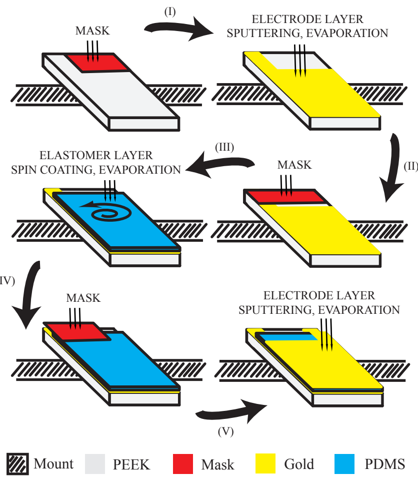
Introduction



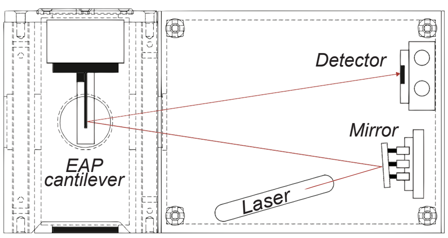
Continence disorder is a common (up to 10 % of the population in Western society [1]) devastating physical disability often accompanied with social isolation. Actual invasive treatments of fecal incontinence (FI) show a high rate of revision surgery and morbidity often due to tissue erosions, atrophy or infections [1] so treating FI successfully has great potential for the MedTech market. Electrically activated polymer (EAP) actuators have a promising future in the field of sensors, robotics and medical applications, especially for artificial muscles based on their outstanding performance including milli seconds response, mechanical strains of more than 10 % and power-to-mass densities similar to natural muscles.

Preparation of EAP microstructures



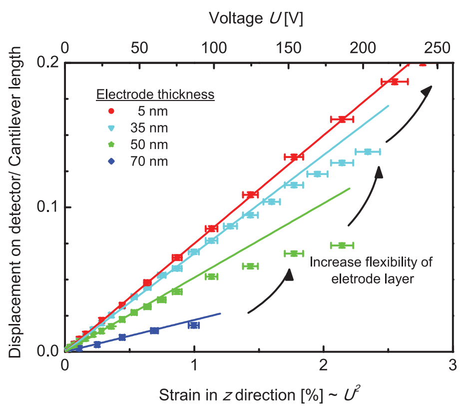
A 3-inch PEEK substrate is coated with gold by either magnetron sputtering or thermal evaporation **(I)** followed by spin-coating of PDMS **(II+III)**. Next PDMS is thermally polymerized and covered with a second metal layer **(IV+V)**. This asymmetric single EAP structure is characterized by actuation as a cantilever bending bar.

Characterization method

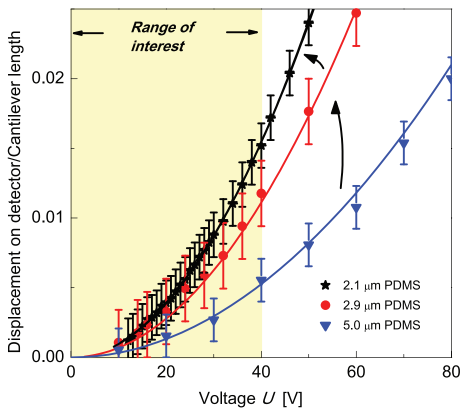


EAP actuator

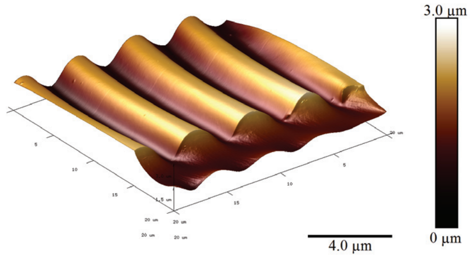
(I) Improved actuation by reduction of the electrode layer thickness [3]



(II) Improved actuation by reduction of the elastomer layer thickness [3]



Stretchable electrodes



Deposition of 1 nm Cr on uniaxial stretched elastomer films creates oriented wrinkles on the surface due to compressive strains between the film and the elastomer substrate. The wavelength and amplitude of the wrinkles can be adjusted:

$$\lambda = 2\pi h \left[\frac{(1-\nu_s^2)E_f}{3(1-\nu_f^2)E_s} \right]^{\frac{1}{3}} \quad [4]$$

Wrinkles are observed for strains above 2 %, where the period λ is a function of the height of the applied film h, the Poisson's ratio ν_s and ν_f and the Young's modulus of the film E_f and the substrate E_s respectively.

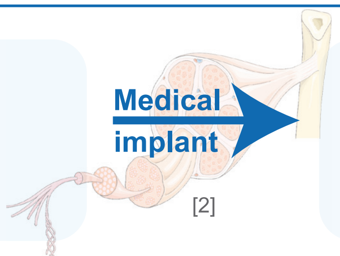
The figure above shows oriented wrinkles with a period of 5.5 μm and an amplitude of 1.4 μm for uniaxial strains of 30 %. To achieve response times in the range of ms, 20 nm of Au are sputtered on the wrinkled film resulting in a sheet resistance of the electrode below 100 Ω.

The way to biomimetic artifical muscles

(I) Actuation voltages in the range of *kV*

(II) Elastomer layer thickness in the range of *μm*

(III) Electrode layer with *high stiffness* (Au, Cr, ...)



(I) Actuation voltages *lower than 40 V*

(II) Elastomer layer thickness in the range of hundreds *nm*

(III) Electrode layer *high*ly stretchable (wrinkles, liquid metal alloy, ...)

[1] "Urinary and Faecal Incontinence", H-D. Becker, A. Stenzl, D. Wallwiener and T. Zittel, Springer-Verlag, Berlin Heidelberg (2005)

[2] http://www.eurostemcell.org/

[3] F. M. Weiss, T. Töpper, B. Osmani, C. Winterhalter, B. Müller, "Impact of electrode preparation on the bending of asymmetric planar electro-active polymer microstructures", Proc. SPIE 9056:905607 (2014)

[4] A.L. Volynskii, S. Bazhenov, O.F. Lebedeva, N.F. Bakeev, "Mechanical buckling instability of thin coatings deposited on soft polymer substrates", J Mater Sci 35:547 (2000)

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