Artificial Sphincter based on Electrically Activated Polymers (EAP)

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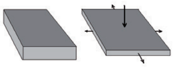
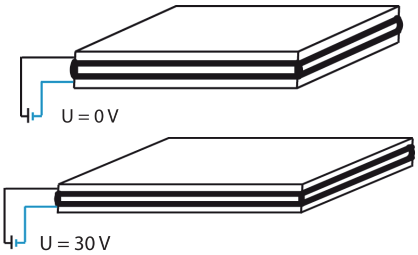
INTRODUCTION



Severe stress urinary incontinence is a relevant problem in the western countries. The most efficiently treatement is the implantation of an artificial sphincter. The solution of choice nowdays is the AMS 800™, which has some disadvantages. Some of these could be faced using an artificial sphincter based on EAP actuators. To achieve such a muscle suitable for clinical application, the electric voltage, which powers this kind of device has to be kept in the order of magnitude 30 V. An asymmetric bending plate structure is constructed to examine the behaviour of EAP actuators at low voltages. While the thickness of the actuator of about 1 micron allows to achieve a mechanical force output even at these low voltages, the asymmetric design gives the opportunity to easily measure the relation between mechanical force and voltage.

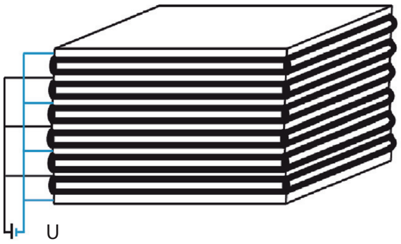
EAP ACTUATOR

The Electically Activated Polymer (EAP) is in principle a capacitor: it consists of two electrodes and a polymer, for example silicone, in between. When a voltage is applyed to the electrodes, they contract due to electrostatic forces and squash the incompressible polymere, which becomes longer due to volume conservation.



The polymer is squashed by the charged electrodes and therefore becomes longer.

For in vivo applications, the electrical tension must not exeed about 30 V. In order to generate high enough electrostatic forces to squash the polymer in spite of these low tensions, the EAPs must be very thin (about 1 micron). As the mechanical force generated by a single layer of polymere is not high enough for an artificial sphincter, a multilayer structure is used.

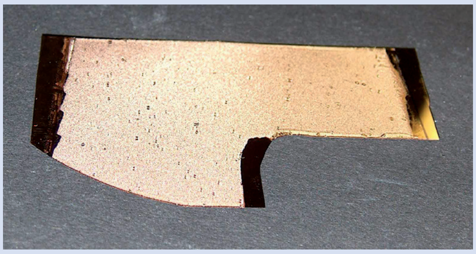


A multilayer EAP generates high enough mechanical forces with low electrical tensions.

To achieve an uniform mechanical force output, the electrodes have to be poled alternatively to the opposite voltage sign. Poling the electrodes to the same sign to obtain a repelling force would move all the electric charge to the outer electrodes, like in a Faraday cage, resulting in no force output.

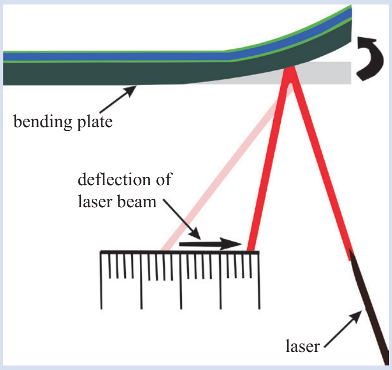
BENDING VS. FORCE

The experimental EAP produces quite small forces. They will be measured using a bending plate gadgetry. Therefore, the EAP is sticked on a 30 microns thick single crystal silicon plate (cut from wafer). When the EAP becomes longer due to applied voltage, the stress forces induce a tortional moment in the silicon plate, which bends. By measuring the bending radius of the plate, the forces acting on it can be evaluated.



The EAP is fixed on a piece of 30 micron thick silicon wafer.

The bending radius is measured by light pointer methode. A laser beam is reflected at the uncoated side of the silicon plate. When the plate bends, the laser beam is deflected, and the deflection is detected by 2D photosensitive detector. By using different filters to tune the laser intensity, bending radii of up to several thousand meters can be measured.

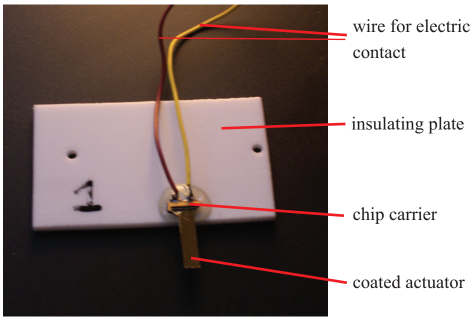


Bending due to polymer activation

To get a relation between force vs. bending radius, the Stoney formula is used, which relates the bending of a metal plate and the surface strain acting on it. The formula is slightly modified to fit the experimental setup

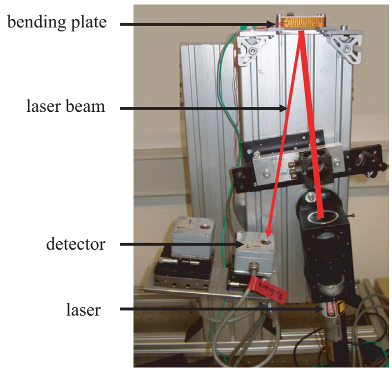
EAP DESIGN

Actuators of about 2 x 0.4 cm², cut from the wafer, are examined. A gold film 10 nm thick is sputtered on the wafer, subsequently a 1 micron thick polymer film is coated on the gold. Finally, another gold electrode completes the sandwich structure. The samples are bucked with the coated wafer and fixed on a holding device to easen the handling.



An actuator on its holding device

The proprieties of the actuator are tunable through the polymer characteristics as dielectric constant and elastic modulus. While a higher dielectric constant allows to apply a higher voltage, and therefore grant a higher strenght output, the effects of the elastic modulus are still a matter of investigation.



Picture of the light pointer apparatus

The gadgetry is rotable by 360° to achieve different levels of pre-bending of the silicon plate and calibration. The effects of pre-bending of the device are still to be examined in future experiments.

CONCLUSION AND ACKNOWLEDGEMENT

Several improvements are aimed at with respect to existing commercial models of artificial sphincters. As the device works over an external power supply, like a small battery, the voltage and therefore the strenght of the muscle can be tuned postsurgically without any further surgical intervention. The device, working on a capacitor principle, allows furthermore arbitrary long opening times of the sphincter and, coupled with an adequate monitoring system, a fast response to abrupt changes of bladder pressure.

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