

Viscoelastic properties of Polydimethylsiloxane studied by cantilever bending

Tino Töpfer, Bekim Osmani, Florian Weiss, and Bert Müller

Biomaterials Science Center, University of Basel, c/o University Hospital, 4031 Basel, Switzerland

INTRODUCTION: The mechanical properties including viscoelasticity of micro- to nanometer-thin polymer films are crucial for efficient, electrically activated polymer (EAP) actuators [1]. Here, we demonstrate the actuation response with the cantilever bending bar method [2] as a quantitative measure of the degree of cross-linking of Polydimethylsiloxane (PDMS) films. Siloxane-based polymers are well known for their elasticity with strains levels of up to 117 % and dielectric behavior [1]. Especially, the millisecond response [1] and biocompatibility make it suitable for biomimetic applications in the human body such as artificial muscles [3].

METHODS: The 4 μm -thin polymer films were spin-coated on Polyetheretherketone (PEEK) substrates (APTIV 2000, Victrex, Lancashire, UK) with a thickness of 25 μm embedded between 15 nm-thin sputtered Au electrodes. This asymmetric EAP-microstructure was characterized by applying a voltage [2]. The actuation mode is based on the COULOMB attraction between the oppositely charged electrodes. The squeeze of the incompressible polymer results in an expansion in x - and y -direction causing a torque of the cantilever, detected by a displacement of a reflected laser beam on a position sensitive detector. Cross-linking was realized through heat curing at curing temperatures of 80 $^{\circ}\text{C}$.

RESULTS: The actuation of 0.5 h heat-cured Elastosil A/B over a period of 15 s is presented in Figure 1 for actuation voltages between 150 and 400 V. The deflection at 150 V applied voltage increases within a time period of 2 s before it reaches equilibrium. For higher actuation voltages of 300 V the maximal deflection increases according to the MAXWELL pressure quadratic with the applied voltage but drops down within a few seconds to equilibrium. The relaxation process can be characterized using the difference between maximal and equilibrated deflection d and the time constant τ . The fitted exponential function $d(t) = C \exp(-t/\tau)$ is included as a line into Figure 1. With a further increase to 400 V this effect becomes even more pronounced with a 43 % relaxation of the maximal deflection compared to a 23 % relaxation of deflection at 300 V. Furthermore this relaxation process slows down for higher applied strains to polymer network with

an increased time constant of $\tau = (1.52 \pm 0.01)$ s at 400 V compared to $\tau = (0.85 \pm 0.02)$ s at 300 V. For 2 h heat-cured polymer films no relaxation of the actuation under applied strain was observed.

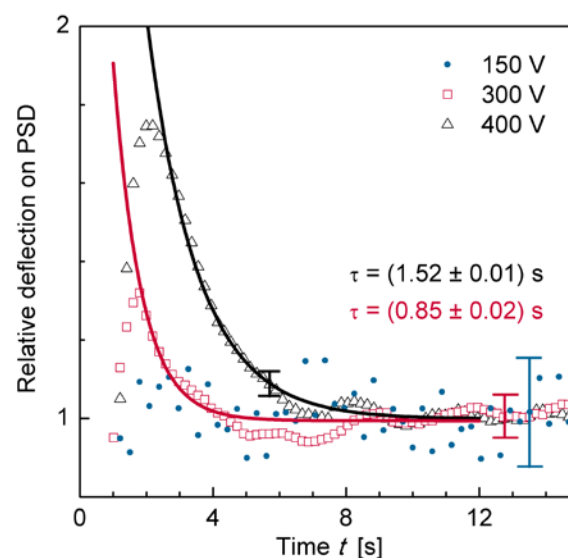


Fig. 1: Actuation of EAP-microstructures on PEEK cantilevers is presented for 0.5 h heat-cured polymer at actuation voltages of 150 to 400 V.

DISCUSSION & CONCLUSIONS: We found that polymeric thin films exhibit curing-time-dependent compliance under strain. As completely cross-linked PDMS is known to be incompressible we relate this phenomenon to the degree of network cross-linking, which is increased with curing time. Thus, the presented cantilever bending method can deliver quantities about the viscoelastic properties of a polymer film.

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