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# Compliant Au electrodes on wrinkled and functionalized polydimethylsiloxane for dielectric elastomer actuators

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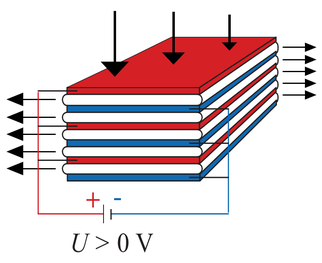
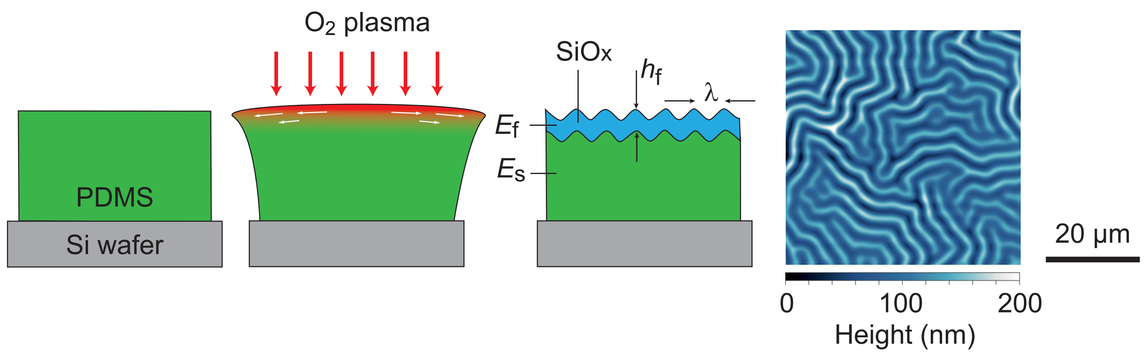
## Introduction

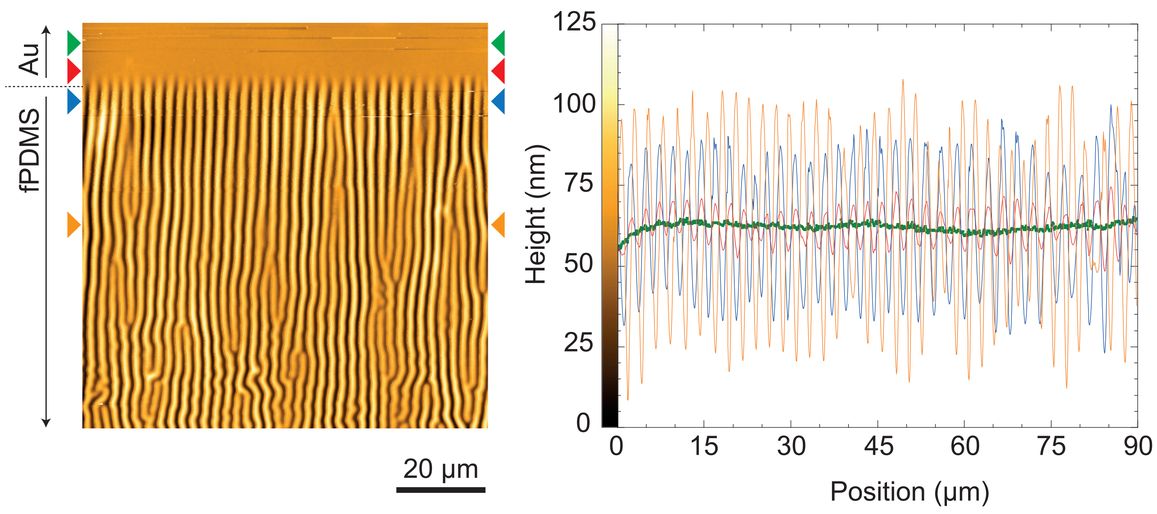



Dielectric elastomer actuators (DEA) are unique due to their large deformation capability of several ten percent [1]. Many applications as actuators, sensors, and electric generators have been proposed in recent years. They're considered as the most promising candidates for artificial muscles as they show strains and stresses comparable to human skeletal muscles. The low adhesion of Au to PDMS has been reported in the literature [2]. Here, we demonstrate that MPTMS can be used as a soft molecular adhesion layer for Au to PDMS. Specifically, we have fabricated compliant Au electrodes allowing sub-micrometer DEA to be operated at much higher electric fields.

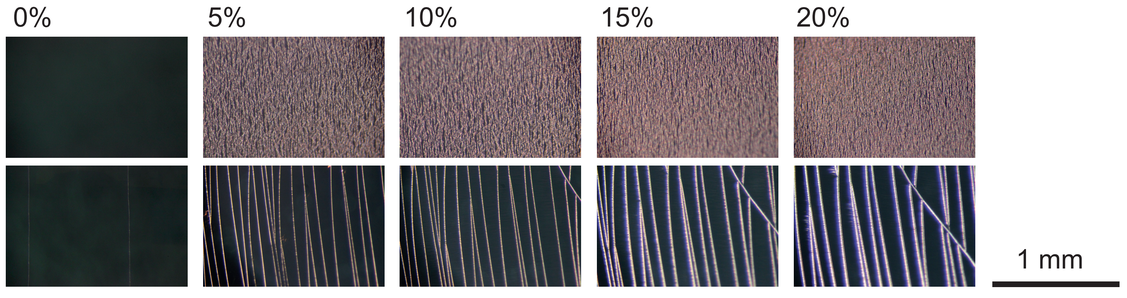
## Surface reformation of PDMS




Schematic illustration of the PDMS surface modification using oxygen plasma. Wrinkles with a periodicity of (2 ± 0.3) µm arise due to the mismatch of the elastic moduli and the thermal expansion coefficients of the oxidized film $E_f$ and the bulk PDMS $E_s$. In addition, the oxidized PDMS surface was functionalized with (3-mercaptopropyl)trimethoxysilane (MPTMS) acting as a soft molecular adhesive for the sputtered Au electrode.

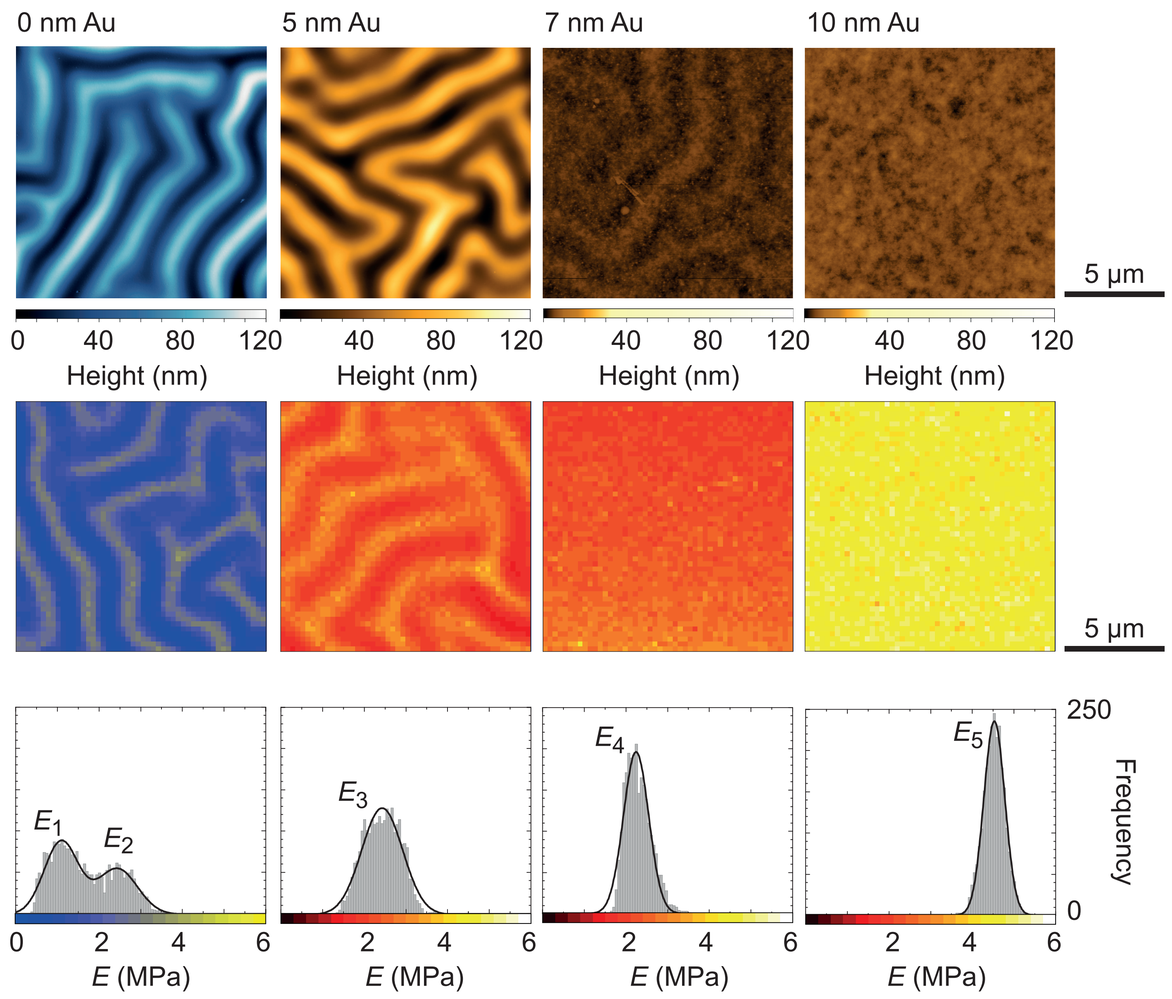



A subsequent sputtering of Au on the functionalized PDMS (fPDMS) levelled and aligned the non-oriented wrinkles near the edge Au/fPDMS. They maintained this conformation for about 100 µm before returning to a randomly oriented arrangement.




Formation of cracks during uniaxial stretch testing. Au on native PDMS was very sensitive to strains showing a high crack density compared to Au on fPDMS.

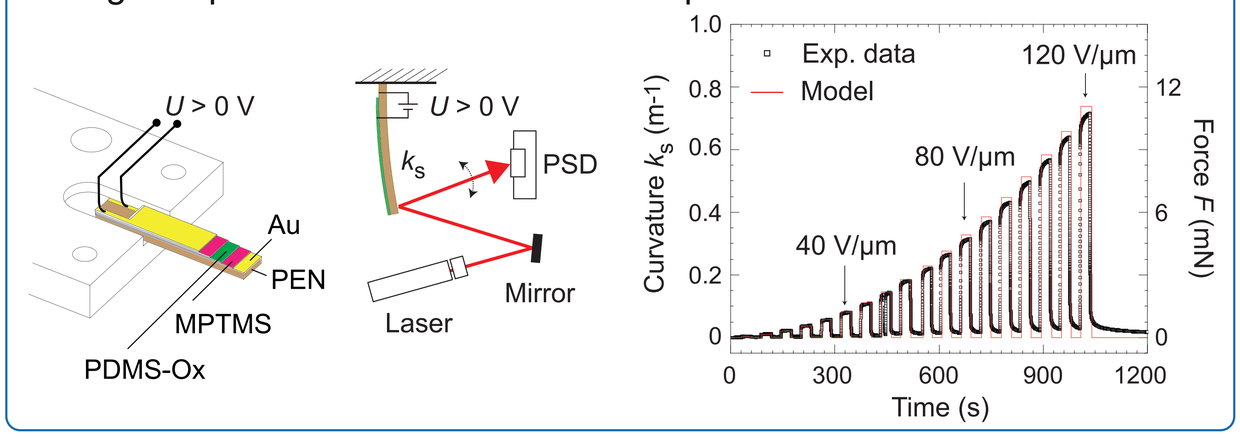
## Topology and stiffness




AFM scans and stiffness maps of the fPDMS surface for 0, 5, 7, and 10 nm Au electrodes. The initially wrinkled surface was flattened and pre-stressed after the deposition of 10 nm Au. The stiffness increase during the plasma treatment was moderate compared to other adhesion approaches.

## Fabrication of DEA

The actuation of the DEA was measured by detecting the curvature of the underlying PEN cantilever as a function of the applied voltage $U$ using an optical beam deflection technique.




## Conclusions and Acknowledgement

We have successfully fabricated compliant Au electrodes using MPTMS as a molecular adhesive for DEA. Nanoindentation measurements showed a moderate stiffness increase from 1 MPa to ~ 2 MPa qualifying this method for a soft adhesive interface. As expected, the Au electrodes showed fewer crack formations during uniaxial stretch tests. Furthermore, the critical electric field could be extended from 70 V/µm to 120 V/µm making this a promising method for the fabrication of planar sub-micrometer DEA structures. The financial support of the nano-tera.ch initiative, project SmartSphincter, as well as the Swiss Nanoscience Institute (SNI) for the financial contribution to the AFM are gratefully acknowledged.

[1] R. Pelrine et al., "High-speed electrically actuated elastomers with strain greater than 100%," Science 287(5454), 836-839 (2000).

[2] Y. L. Loo et al., "Additive, nanoscale patterning of metal films with a stamp and a surface chemistry mediated transfer process: Applications in plastic electronics," Applied Physics Letters 81(3), 562-564 (2002).

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