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Individually actuated cantilever arrays for cell force spectroscopy

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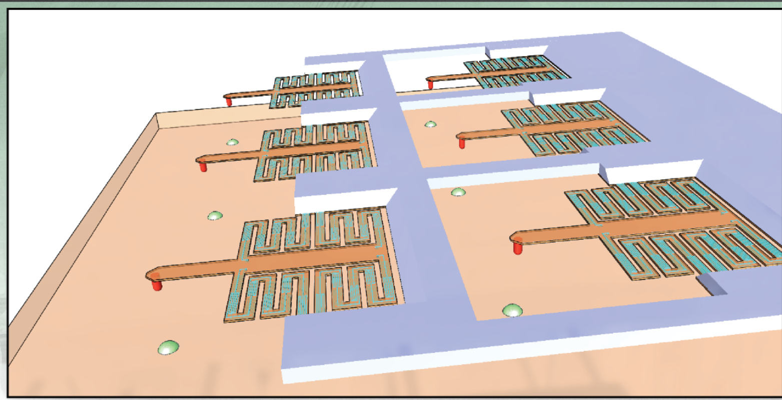
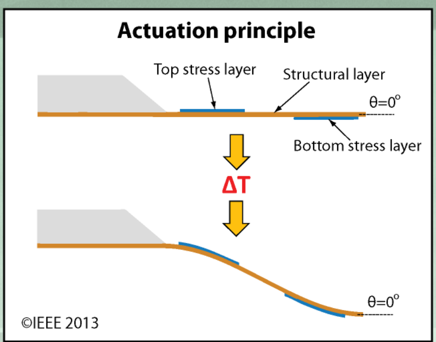
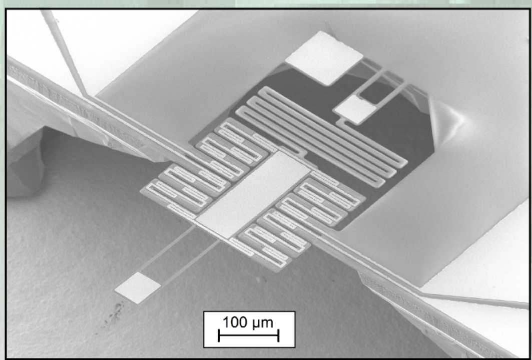
Motivation: Based on the strong correlation between a cell's stiffness and whether it is cancerous or not, Cross et al. (Nature Nanotech. 2007) showed that AFM probing of cells allowed reliable differentiation between cancerous and healthy cell groups. Hence, MEMS devices conceived specifically for biomechanical probing of cells may become highly valuable tools for cancer studies and diagnostics. To increase efficiency, we aim to develop arrays of individually actuated devices that parallelize cell force spectroscopy measurements, as shown in the image to the right.



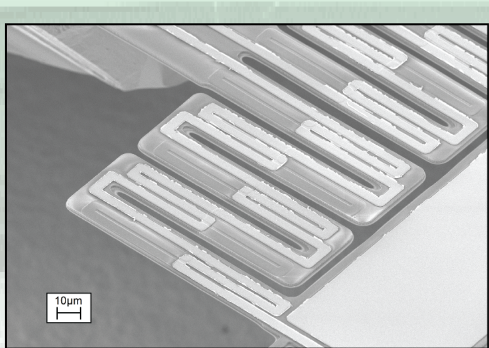
Novel cantilever actuation method



- Balanced top and bottom stress layers.
- Endpoint angle θ remains constant.
- Meandered actuation spring enhances deflection range.



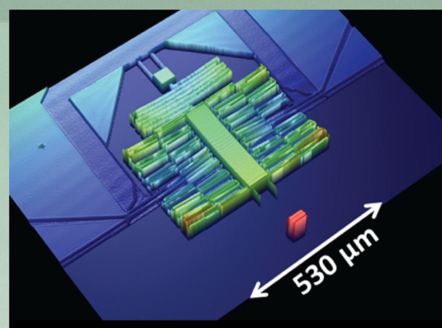
SEM image of a finalized thermally actuated device. ©IEEE 2013



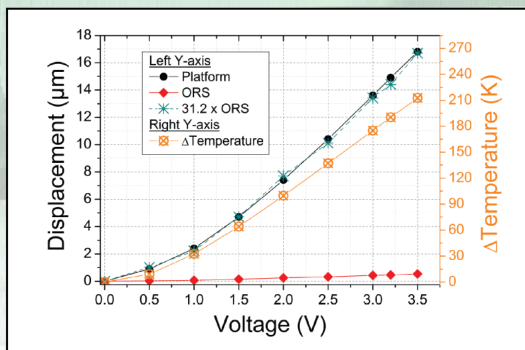
A meandered bimorph actuation spring. The top electrode gives clear material contrast, while the bottom electrode is visible as a weak impression into the structural layer. ©IEEE 2013

Mechanical characterization

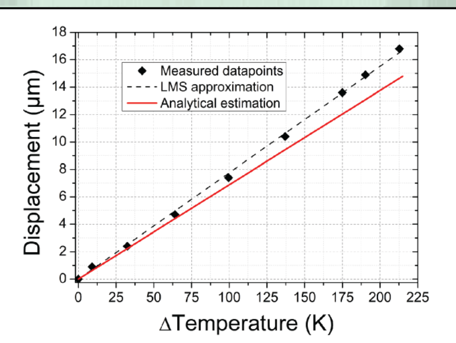
- A Veeco Wyko NT1100 white light interferometer was used to measure the displacement.
- The temperature was measured simultaneously by monitoring the resistivity change.



White light interferometry measurements were used to determine the displacement in z. ©IEEE 2013



Displacement of the central platform and the optical reference structure, plotted against voltage. Plotted is also the temperature, determined by measuring the resistivity change. ©IEEE 2013



Displacement of the central platform plotted against temperature. A linear relation was found, following our analytical estimation rather well. ©IEEE 2013

Fabrication

a) DSP Si wafer with SiO_2

b) SiO_2 patterned by RIE for release etch

c) Lift-off to pattern bottom electrodes

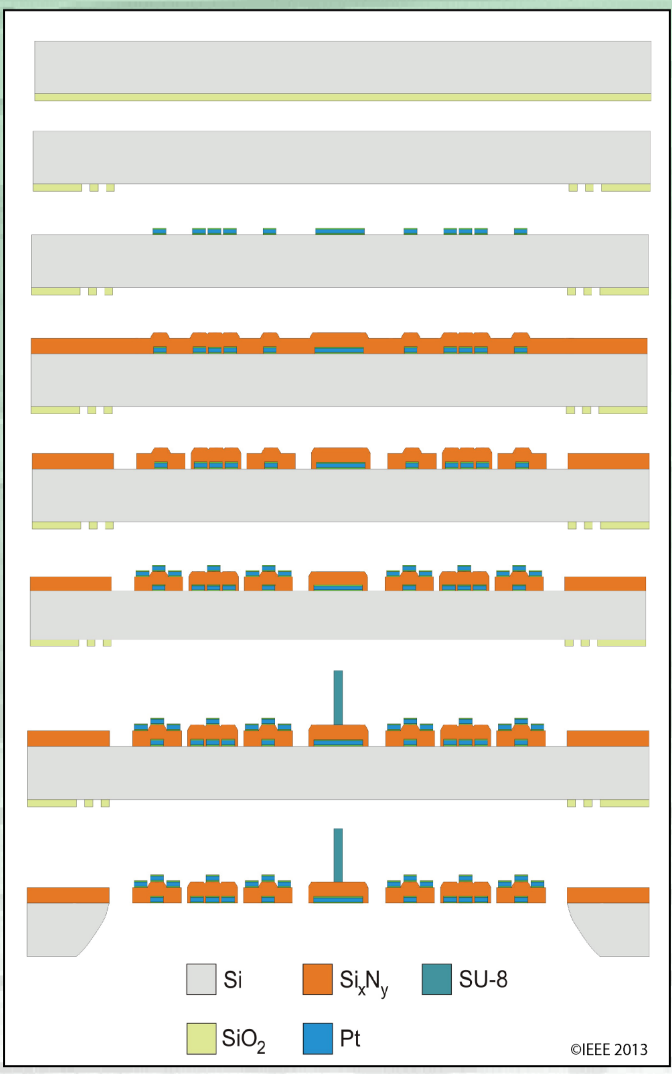
d) Deposition of PECVD Si_xN_y

e) RIE patterning of Si_xN_y layer

f) Lift-off to pattern top electrodes

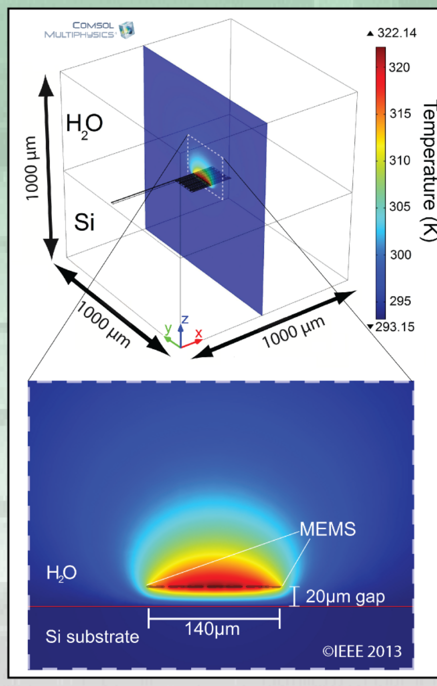
g) SU-8 structuring of tip

h) Release using DRIE and KOH etching



Simulations

- Simulation overview (top): an actuator in water, located 20 μm from the Si substrate.
- The yz thermal cross-section cuts through the acuator's center.
- The zoom-in (bottom) shows the temperature profile in proximity to the structure.
- A substantial temperature increase was reached in the electrode (~29K).
- The water temperature close to the substrate is dominated by the highly thermally conductive Si body.



Publication

J. Henriksson, M. Gullo, J. Brugger, *Integrated long-range thermal bimorph actuators for parallelizable bio-AFM applications*, IEEE Sensors Journal, Special Edition: Selected papers from the IEEE Sensors 2012 Conference, 2013.

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