

Electrostatically actuated probes for Scanning Sub-surface Ultrasonic Resonance Frequency Microscopy

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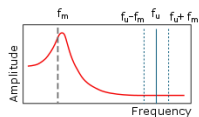
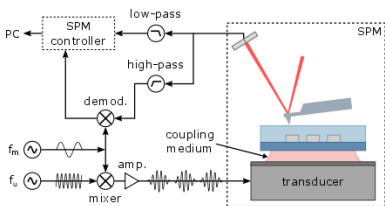
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INTRODUCTION

Scanning Subsurface Ultrasonic Force Microscopy (SSURFM) relies on high frequency ultrasound in combination with Atomic Force Microscopy to detect viscoelastic properties of buried materials with high spatial resolution. The key ingredient is a very high frequency ultrasound wave which is amplitude modulated at the sensing cantilevers resonance frequency.



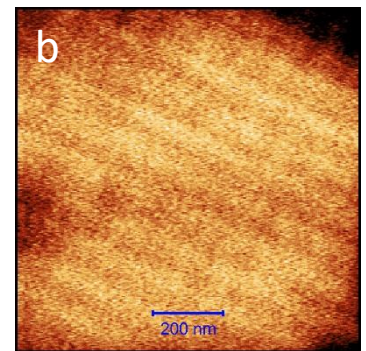
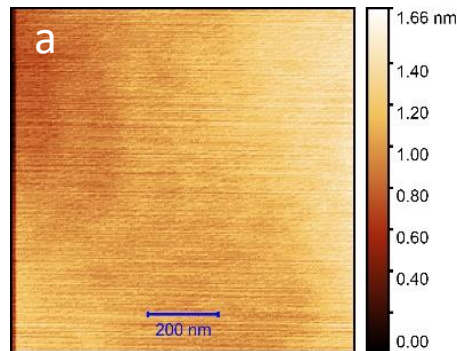
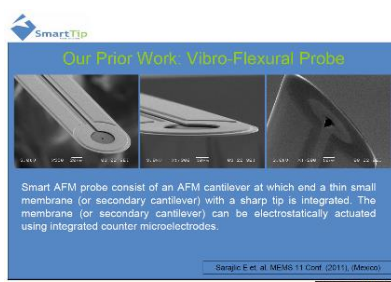
(a) Sketch of SSURFM setup; (b) Sketch of excitation (blue) and detection (grey) frequencies with the cantilever's resonance (red)

CLEAN EXCITATION

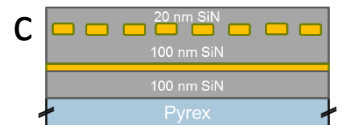
Ultrasound transducers can not always be used (e.g. industrial waferstages) so excitation on the top side is needed. Also, piezo excitation suffers from unwanted reflections and resonances. Robust and quantitative SSURFM methods need a clean driving signal.

SmartTip's electrostatic membrane probes provide those advantages.

- Actuation at the location of interest: the tip
- First contact resonance of driving structure >15MHz (est.)
- Amplitude >10nm



(a) Topography and (b) frequency shift image of dense gold lines in SiN measured with a SmartTip electrostatic membrane cantilever. Schematic cross section of this sample is shown in (c). Pitch of the gold lines is 100nm. Cantilever stiffness 4N/m (est.); $f_u=20\text{MHz}$; $f_m=600\text{kHz}$ (1st contact resonance). Thanks to the QuTech consortium for providing these samples



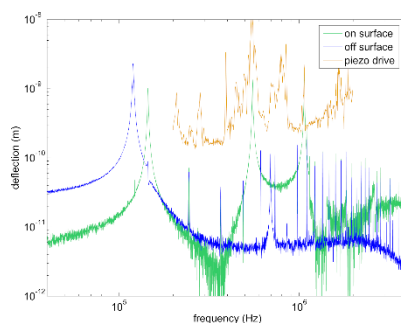
CUSTOM DEVELOPED TIPHOLDER

We developed a custom tipholder to be able to use the on-chip contacts for actuation while staying compatible with Park's tip holder design. Challenges:

- Small contact pads
- Strict dimensional and angular requirements



Realized design of Park AFM compatible tip holder with contact pins for electrostatically actuated membrane probes.



Comparison of electrostatic actuation (on and off surface) with piezo driven actuation. Note that this AFM system has many digital noise peaks at regular frequency intervals. The drive spectrum is actually very smooth.

DISCUSSION

Electrostatically actuated probes enable SSURFM from the top side with very little added complexity to the AFM system. This is a great benefit for miniaturization to integrate into e.g. parallel AFM systems. They also enable quantitative analysis due to their clean drive spectrum. Specifically Frequency Modulation-SSURFM (FM-SSURFM) is possible due to the cleanliness of this drive method (see poster "Frequency Modulation Subsurface Ultrasonic Force Microscopy").

CONCLUSION

Electrostatically actuated membrane probe tips are used for SSURFM imaging of buried features

- Top side actuation;
- Enables FM-SSURFM tracking due to its clean drive spectrum;
- Robust and easy to set up compared to piezo excitation;
- simple, small and light to integrate into (miniaturized) AFM systems.