Sub-surface Imaging with Photo Thermal Actuation

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INTRODUCTION

In the semiconductor industry, the need for characterization of subsurface features of wafers on a sub-nanometer level becomes ever more important. With Scanning Subsurface Probe Microscopy[1] (SSPM), the smallest features can be measured with high resolution.

SCANNING SUBSURFACE PROBE MICROSCOPY

In SSPM, high frequency ultrasound waves are combined with AFM measurements to detect viscoelastic properties of subsurface features. For quantitative, high resolution SSPM measurements, a clean driving signal for actuation is required.

Current piezo actuation techniques suffer from unwanted resonances and reflections introduced by the whole mechanical system. Implementation into production processes prohibits bottom actuation by ultrasound transducers. Thus, There is a need for a clean, top side actuation method for SSPM.

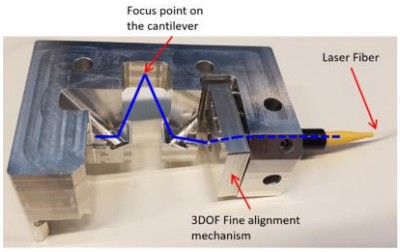

Figure 1. Photothermal excitation add-on for a commercial AFM. The laser steering mechanism for blue laser, which is used to drive the cantilever.

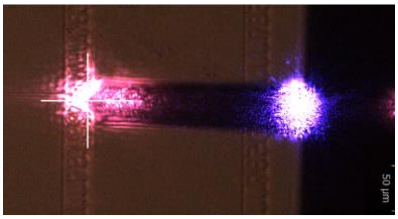

Figure 2. Optical image showing the blue (405nm) excitation laser at the base of the cantilever and the probe infrared (850nm) laser at its tip.

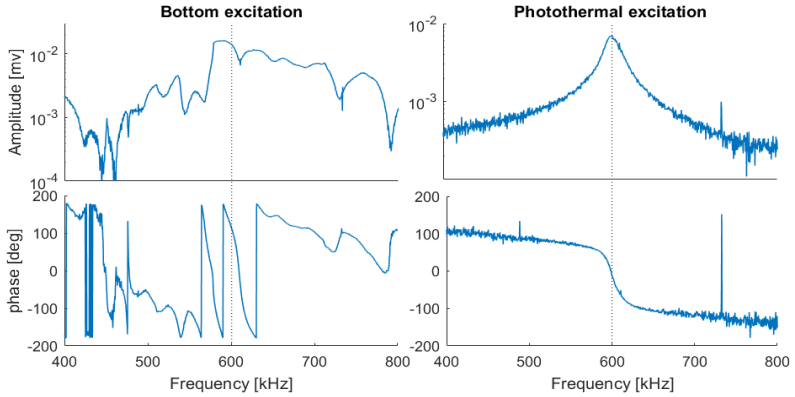

Figure 3. Frequency response of a commercially available cantilever (Nanotools NCHAu) in contact with the silicon sample surface measured using bottom excitation (left) or Photothermal excitation (right).

PHOTOTHERMAL ACTUATION

A modulated light source incident on the cantilever can induce vibrational motion of the cantilever due to the bimetal effect. This is known as Photo Thermal Actuation (PTA). We have designed and realized a PTA setup and integrated onto a conventional AFM system.

RESULTS

- Operational PTA add-on for AFM system (figure 1).
- Successful alignment of both OBD and excitation beams (figure 2).
- Successful actuation and characterization of a cantilever up to 35 MHz.
- Significant reduction in unwanted excited resonances and reflections as compared to piezo actuation (figure 3).
- Very clear sub surface images obtained (figure 4)

CONCLUSION

- PTA allows clean driving of AFM cantilevers
- Top side actuation technique.
- Significant SNR improvement over existing piezo actuation techniques.
- Techniques allows for quantitative Frequency Modulation SSPM

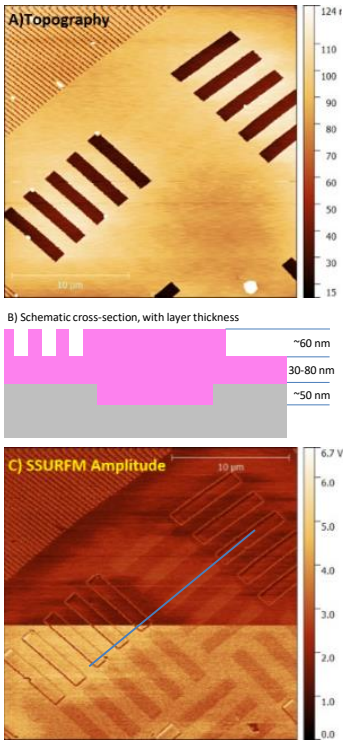

Figure 4: Sub-surface AFM images of an overlay alignment marker captured with Photothermally actuated SSPM[1] technique. The topography image (A) shows only the features in the top resist layer. The marker sample also includes buried features, as illustrated in the cross-section schematic (B), which are visible in the SSPM image (C). The line in panel (C) corresponds to the cross-section location. The contrast inversion in the SSPM image is due to a deliberate change in excitation parameters.

[1] M.H. van Es *et al.* Ultramicroscopy, Volume 184, Part A, 2018, Pages 209-216.

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ECSEL Joint Undertaking

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