Investigating the detection limit of subsurface holes under graphite with atomic force acoustic microscopy

Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

NanoM2

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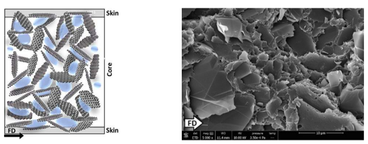
Background & Motivation

- A size scale reduction to the nanoscale still requires non-destructive testing (NDT) techniques for flaw detection.



- Traditional NDT techniques such as ultrasonics are limited by diffraction.
- Scanning acoustic microscopy (SAM) has shown a resolution of a few µm's but higher resolution is required for "nano"materials.

Characterization techniques with nanoscale resolution?

Atomic Force Microscopy (AFM)

- Non-destructive, generally considered a surface characterization technique, however…

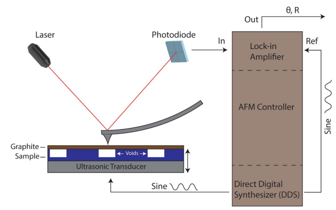
Advances in AFM techniques using ultrasound can reveal <u>subsurface</u> structures

- These techniques are not well characterized, both qualitatively and quantitatively
- Detection limits and their capabilities on stiff materials are unknown

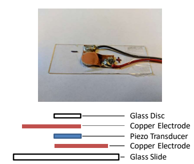
Objectives

1) Implement atomic force acoustic microscopy (AFAM) for subsurface imaging
2) Determine its detection limitations for a given material system
3) Investigate the various imaging parameters that may influence subsurface defect detection

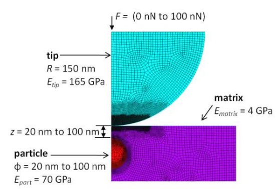
Atomic Force Acoustic Microscopy

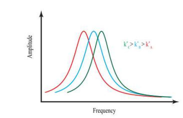


Ultrasonic Transducer



- Acoustic waves excited from below the sample while the cantilever is in contact with the surface

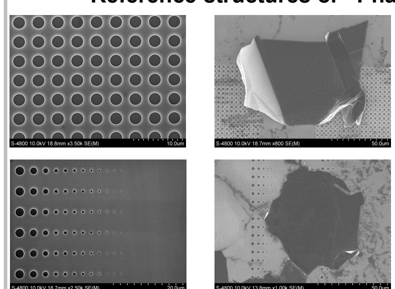




- Shift in contact resonance with stiffer materials

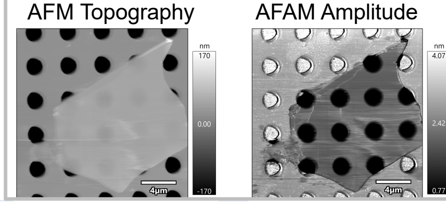
- Cantilever amplitude varies due to changes in the local mechanical properties beneath the tip

Reference structures or "Phantoms"



- Si substrate with pre-patterned 2.5 µm diameter holes
- Si substrate with pre-patterned 2.5 µm – 20 nm diameter holes

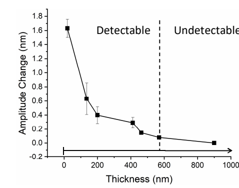
AFM Topography   AFAM Amplitude

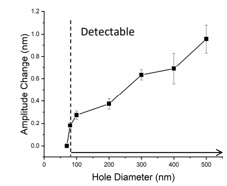


- 30 nm thick graphite flake suspended over 2.5 µm holes

Results

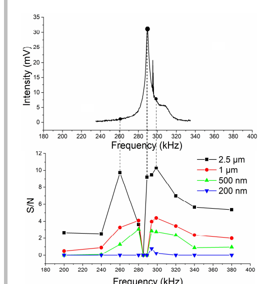
Influence of graphite thickness and hole size





- Maximum graphite thickness of 570 nm for observable contrast
- Smallest detectable defect size of 80 nm through 140 nm of graphite

Effect of frequency on subsurface imaging



- Optimal drive frequency +10 kHz above contact resonance
- Increased contrast for small holes closer to contact resonance frequency

Additional information on influence of various operating parameters

Conclusions

- Implemented and characterized AFAM technique for subsurface imaging
- Determined detection limitations and established differences between thickness/defect size
- Investigated other parameters and their influence on subsurface imaging

Acknowledgements

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