Subsurface Structure Characterization Using Remote Bias EFM

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Outline

- Remote Bias - Electrostatic Force Microscopy (RB-EFM)
- Motivation
- COMSOL Multiphysics
  - Models
  - Test Structures
- Results
- Conclusion

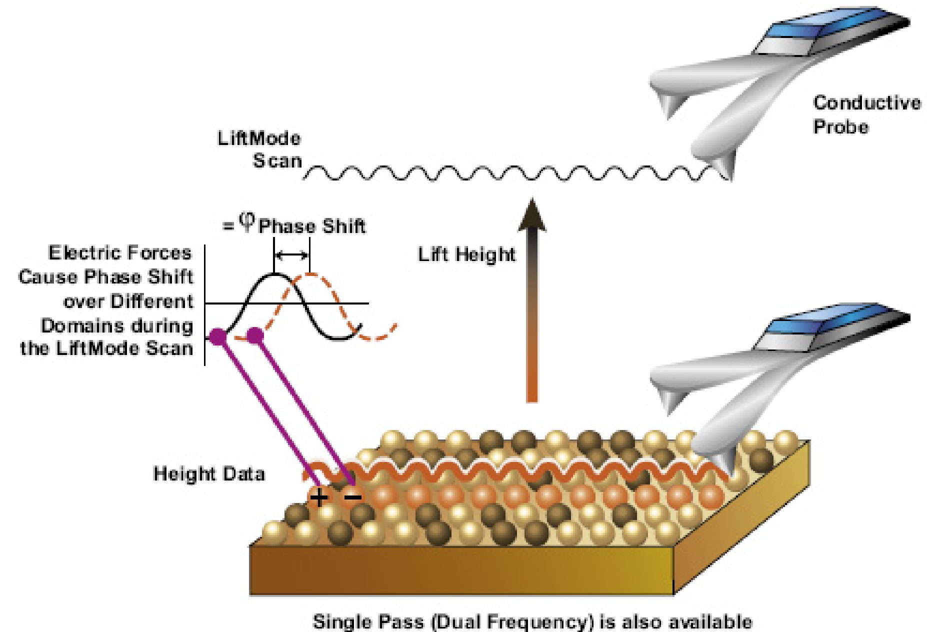
Electrostatic Force Microscopy

- A non-contact implementation of Atomic Force Microscopy (AFM)
- Indirectly measures work function of sample at subnano scale

$$F_{electrostatic} = \frac{1}{2}\frac{\partial C}{\partial z}\Delta V^2$$

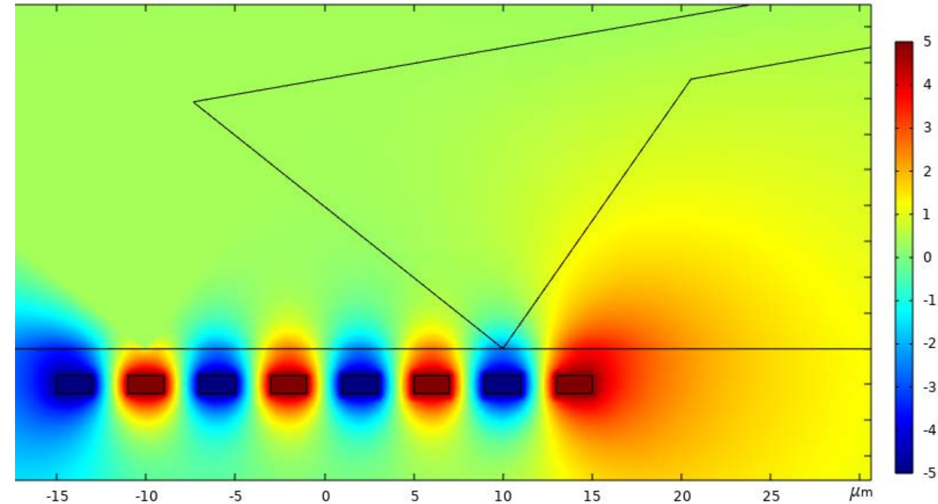
$$\Delta V = V_{tip} - V_{sample} - V_{CPD} = 0.$$

- Used to characterize electrical properties and topography of samples
- Especially useful in materials research



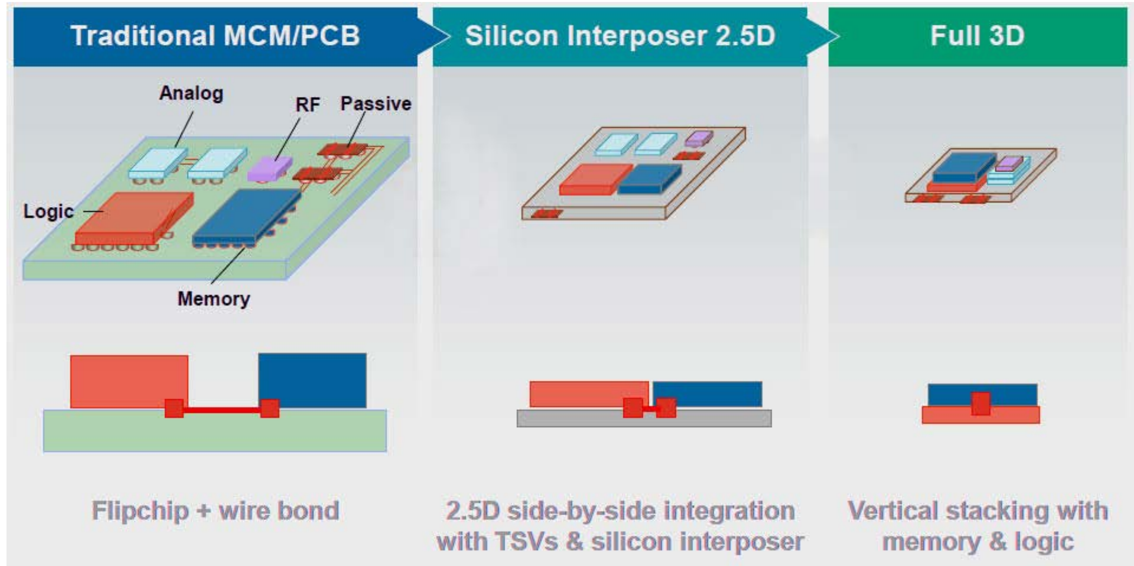
Remote Bias EFM

- Variant of EFM
  - Bias is placed on test structure
- Can be used to measure the effects of buried charge and capacitance gradient (force)[1]
- E&M forces allow characterization of subsurface structures



Motivation

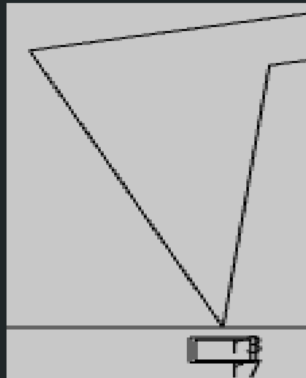
- New paradigms for constructing ICs
- Moving to 3D ICs
- Subsurface structures need a method of testing/verification

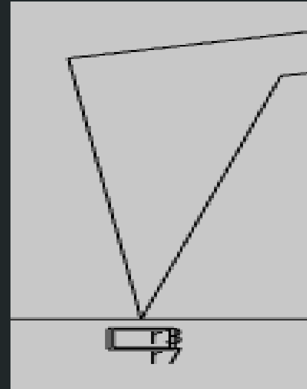


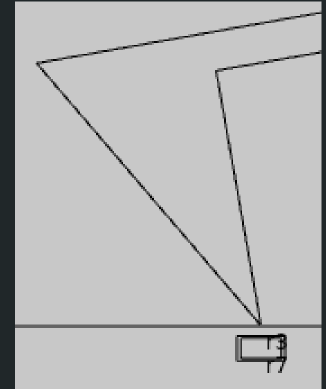
RB-EFM Models - Tip Specs

- Tip Geometries*
  - Symmetric Tip
  - Leading Edge Tip
  - Trailing Edge Tip

*35° tip

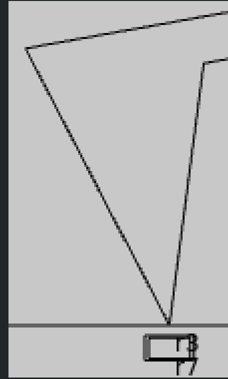


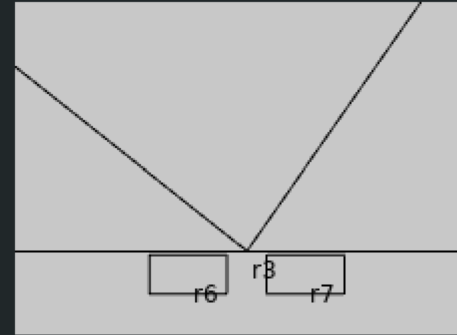


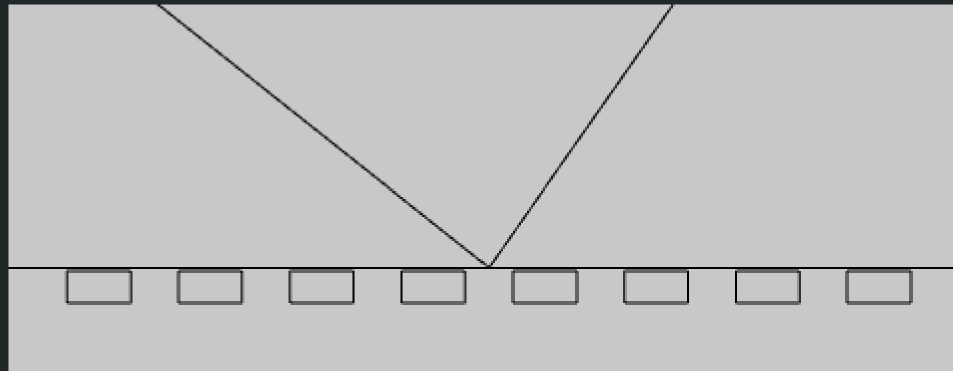


RB-EFM Models - Test Structures

- Strip Characterization*
  - Single Strip
  - Double Strips
  - Interdigitated Multi Strips



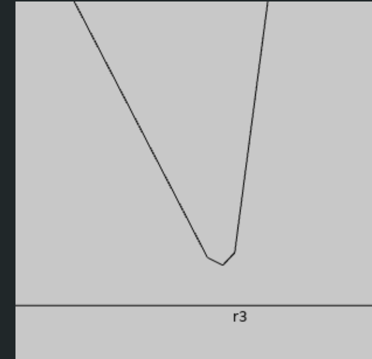


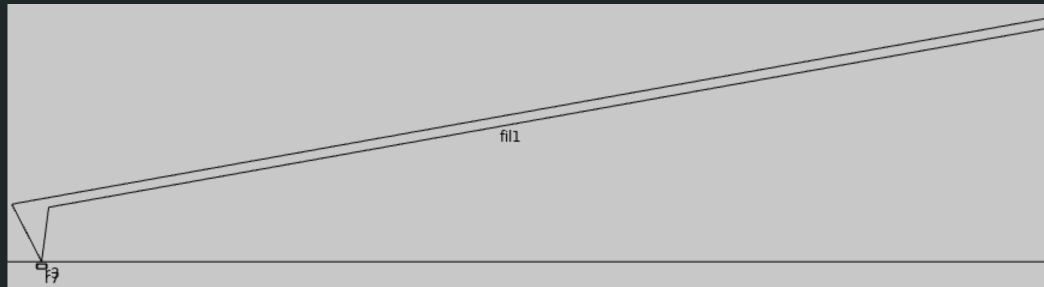


*2um wide; 1um thick

RB-EFM Models - Additional Specs

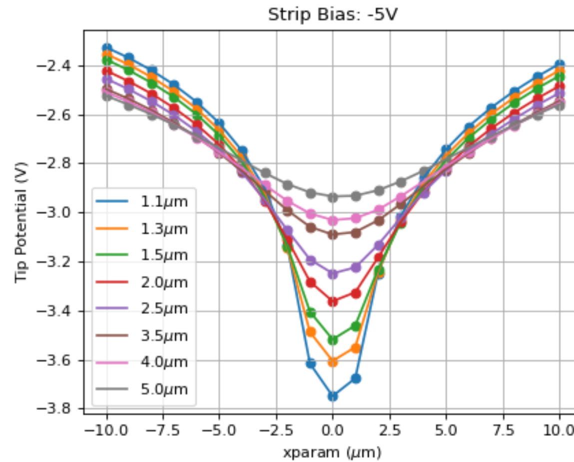
- Substrate Material
  - SiO_2 & HfO_2 Substrates
- Tip Radius
  - 20nm tip radius
- Cantilever Angle
  - 10° Cantilever Angle

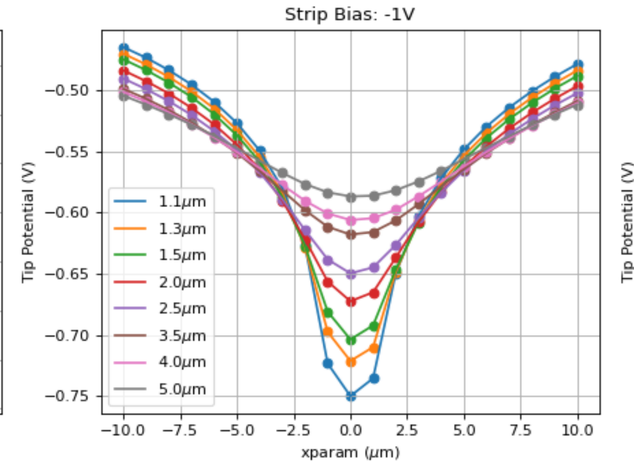




Single Strip Results- Remote Bias

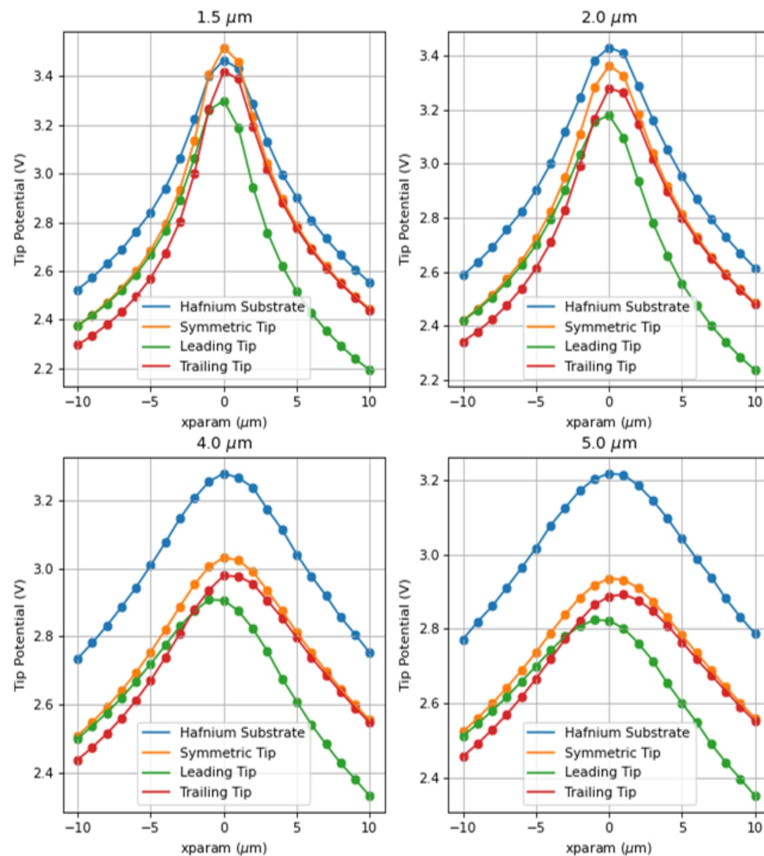
- Potential doesn't drop off significantly
- Peak height drops off at ~0.5V/um close to surface
- Peak height drops off at ~0.2V/um further from surface





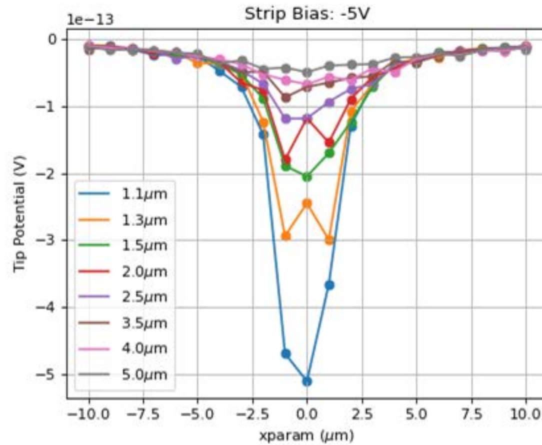
Single Strip Results- Tip Shapes

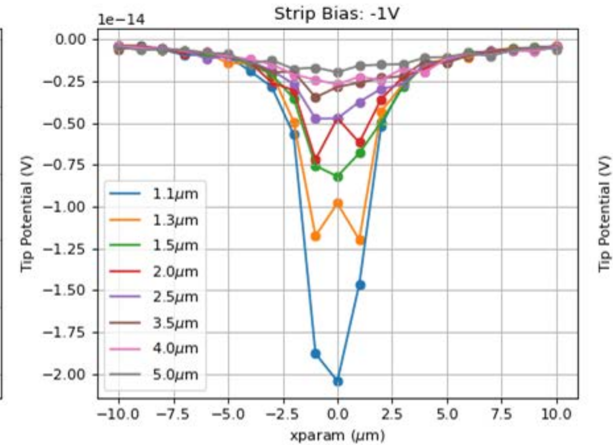
- Peak shifts with tip shape
- HfO_2 efficiently propagates signal
- Can detect shallow subsurface structures



Single Strip Results- Force on Cantilever

- Similar shapes throughout
- Force drops off significantly more rapidly
- FWHM independent of bias
- Finer meshing or scan parameter can alleviate swings





Conclusions

- Can characterize single biased strip to certain depth
- Can distinguish between adjacent lines (Double Strip results)
- Choice of interdigitated biases greatly affects resolvability (Multi Strip results)

Future Work

- Add more variability in models
  - Materials of strip, liners, and substrate
  - Types of subsurface structures
- Create more directed parameter space
- Add effects of impurities in materials
- Automate data extraction and plotting

Citations

- [1] Kopanski, J. , You, L. and Obeng, Y. (2018), Remote Bias Induced Electrostatic Force Microscopy for Subsurface Imaging, APS March Meeting 2018 Scientific Program, Los Angeles, CA, [online], https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=924700
- [2] Desai, A. (2020), 2.5D and 3D ICs: New Paradigms in ASIC
- [3] Cantilever / Probe Specification https://www.brukerafmprobes.com/p-3866-oscm-pt-r3.aspx