COMSOL SIMULATION STUDY OF THE EFFECT OF PROBE TIP SHAPE ON THE MEASUREMENT OF AN ELECTRICAL FIELD GRADIENT GENERATED BY MICROELECTRONIC TEST STRUCTURES

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SOCIETY OF PHYSICS STUDENTS

NIST

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  - Cantilever Effect
  - Importance of Tip Shape
  - Clearance Effect
  - Differential Voltage
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- Conclusions
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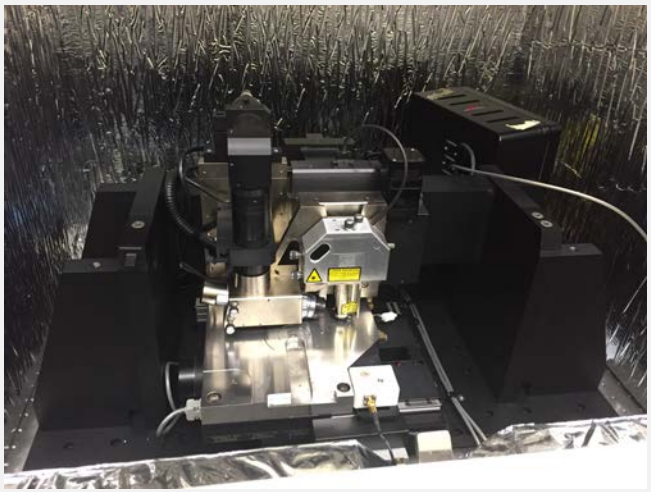
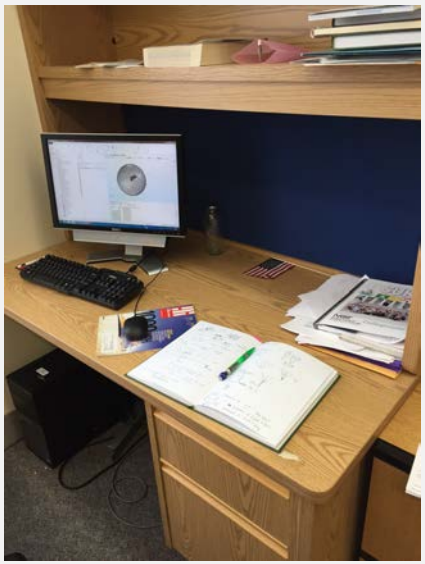
- References





MOTIVATION

- Precise nano-scale measurements
- Use of Scanning Kelvin Force Microscopy (SKFM)
- Electric Field Measurements are HIGHLY dependent on the shape of the probe
- Design an Electrical Tip Shape Profiler Reference Material

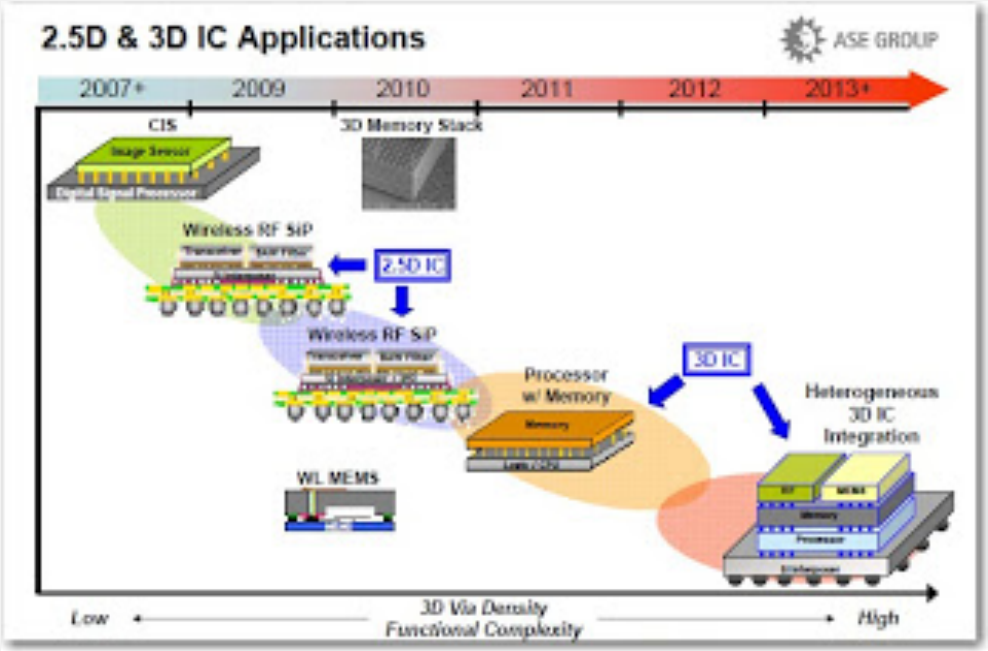
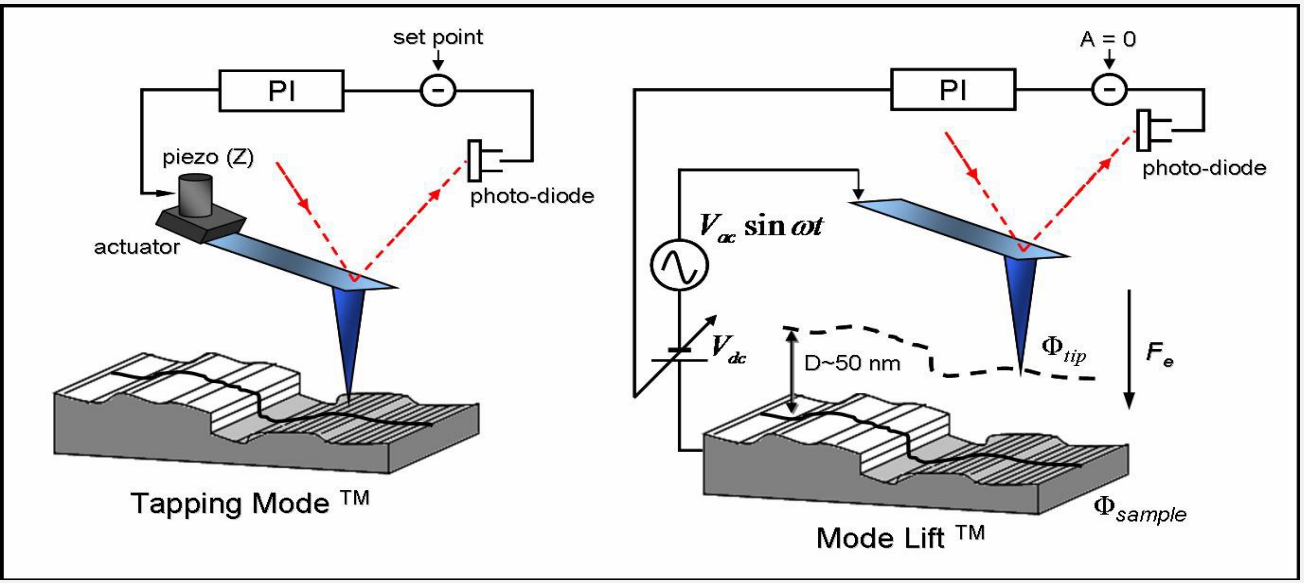


Image from Semiconductor Manufacturing & Design Community

WORKING PRINCIPLES OF SKFM

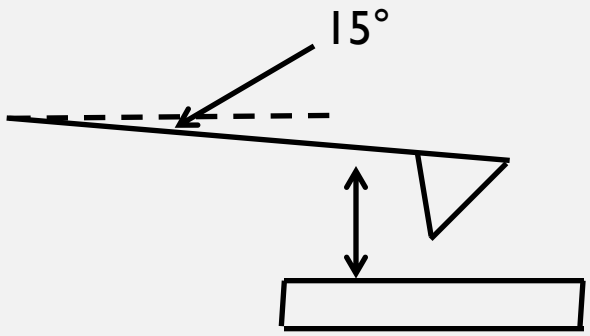


(Kaja's PhD THESIS 2010)

Image credit: Kaja

- Tapping Mode vs. Mode Lift

Scanning Kelvin Force Microscope (SKFM)



COMSOL MODEL BUILDER

Domain Probe

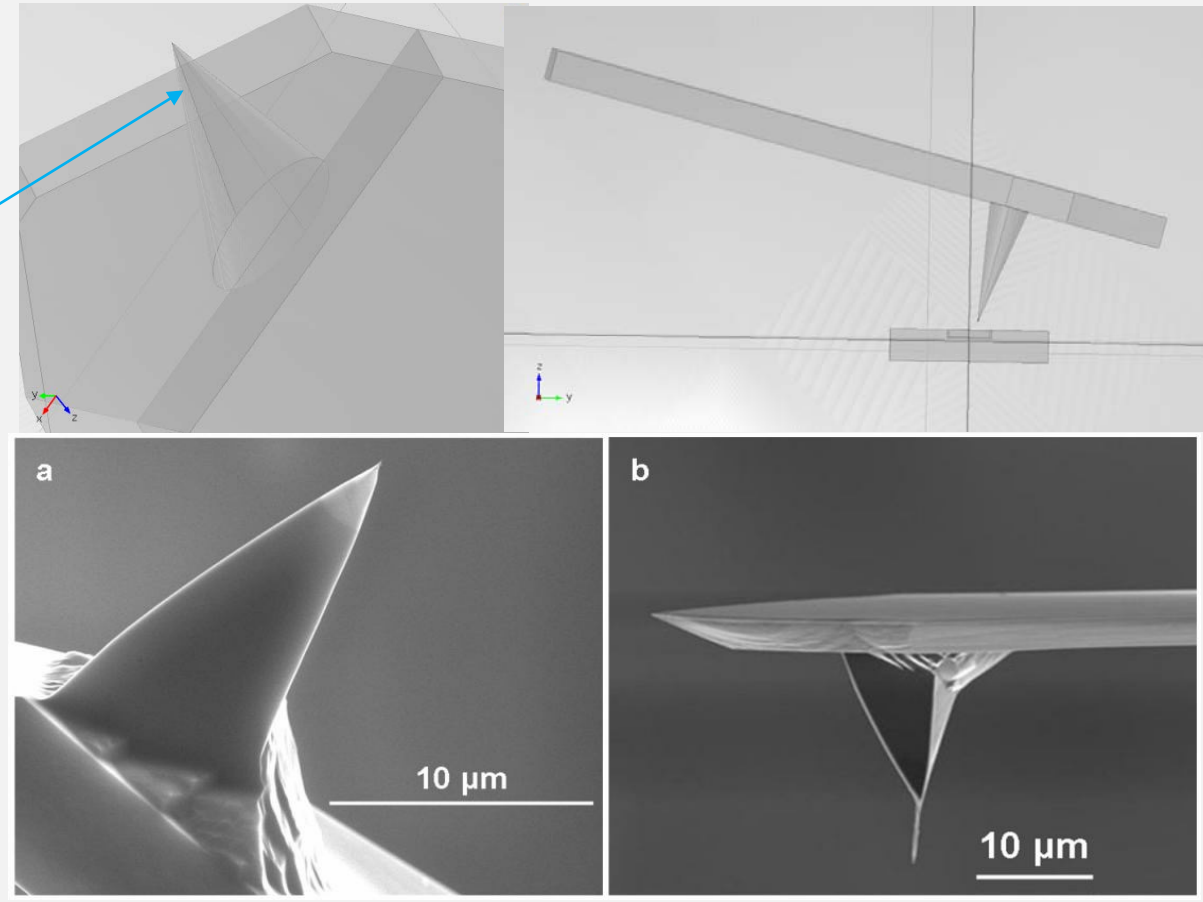
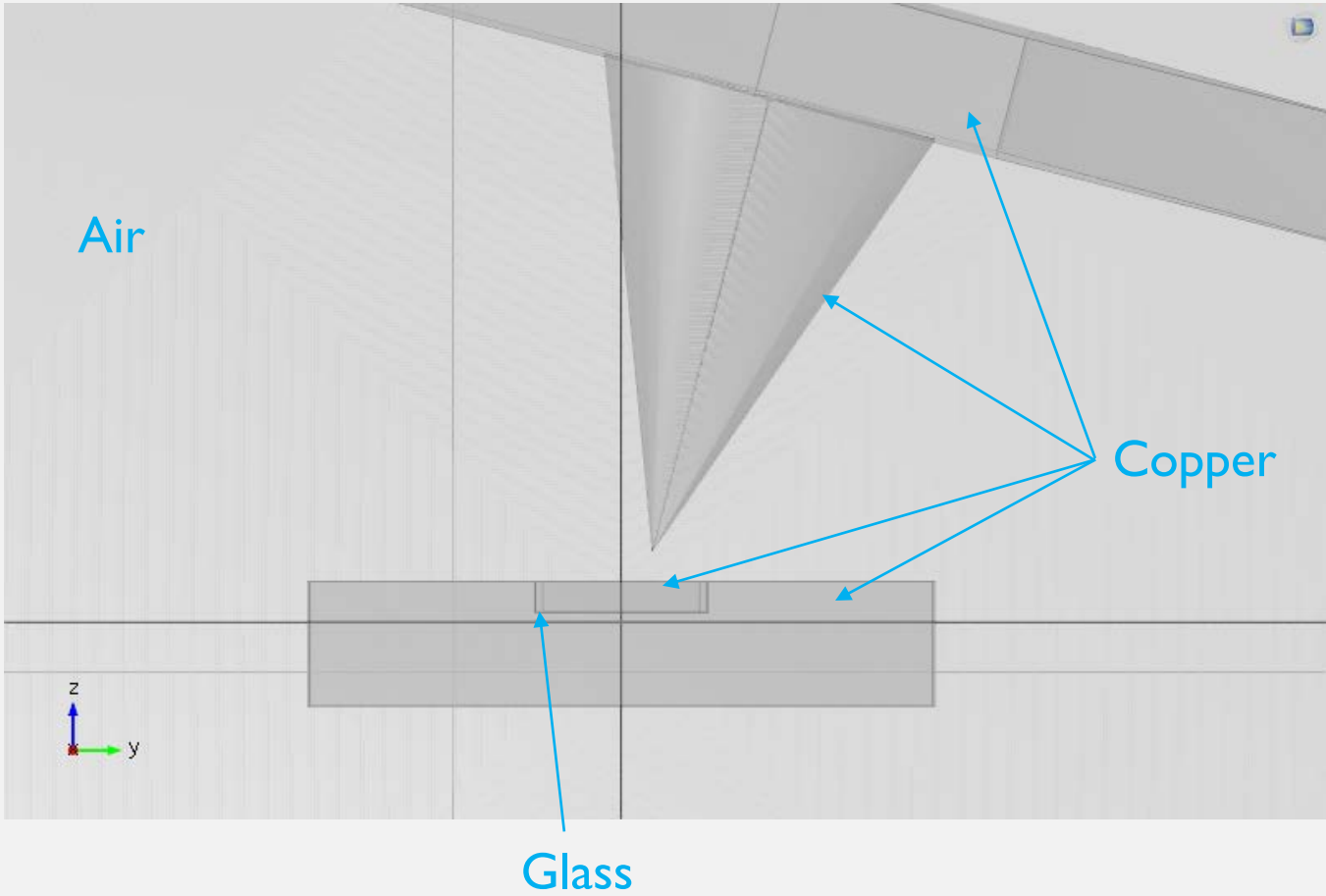


Image credit: Kaja

(Kaja's PhD THESIS 2010)

COMSOL MODEL BUILDER

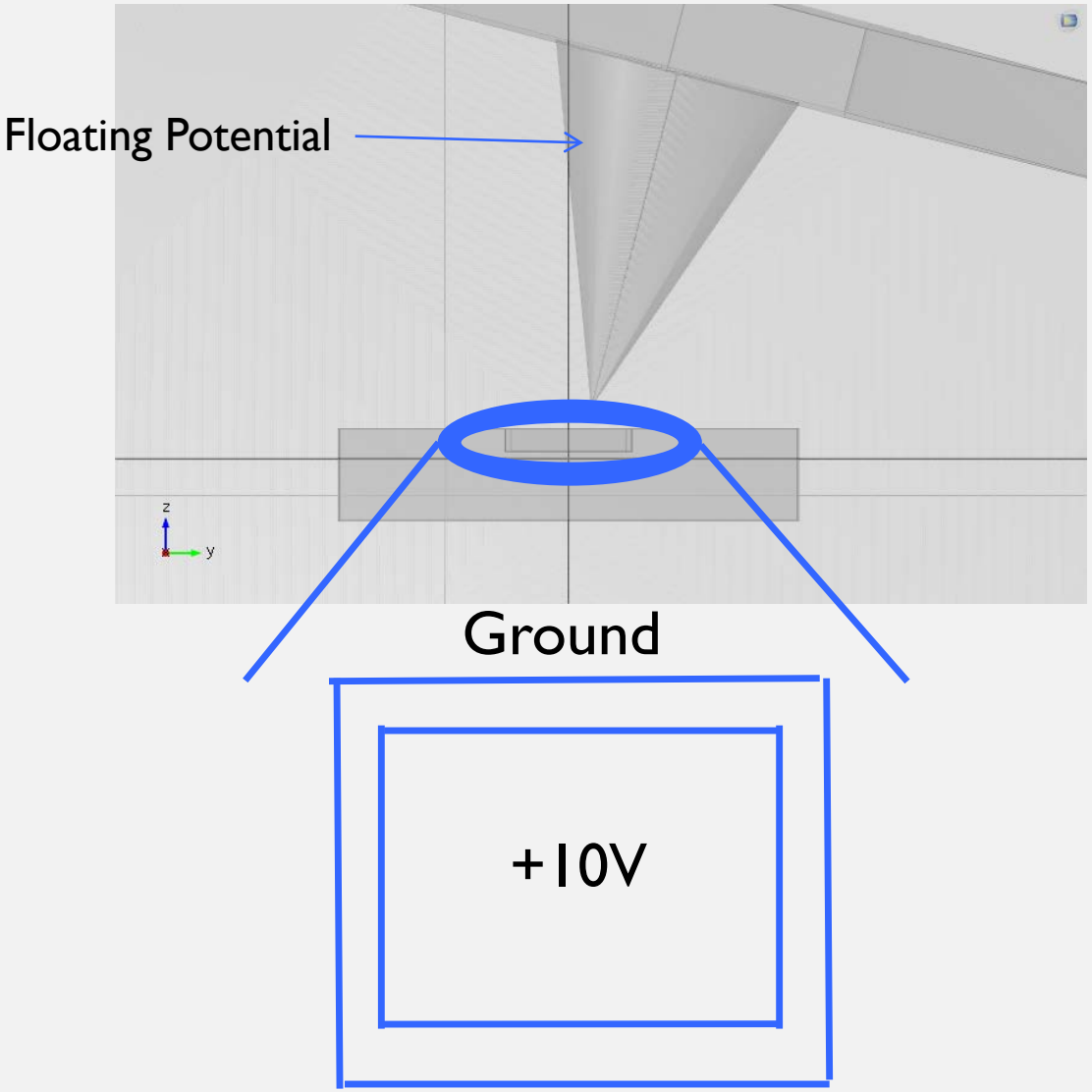
Materials



COMSOL MODEL BUILDER

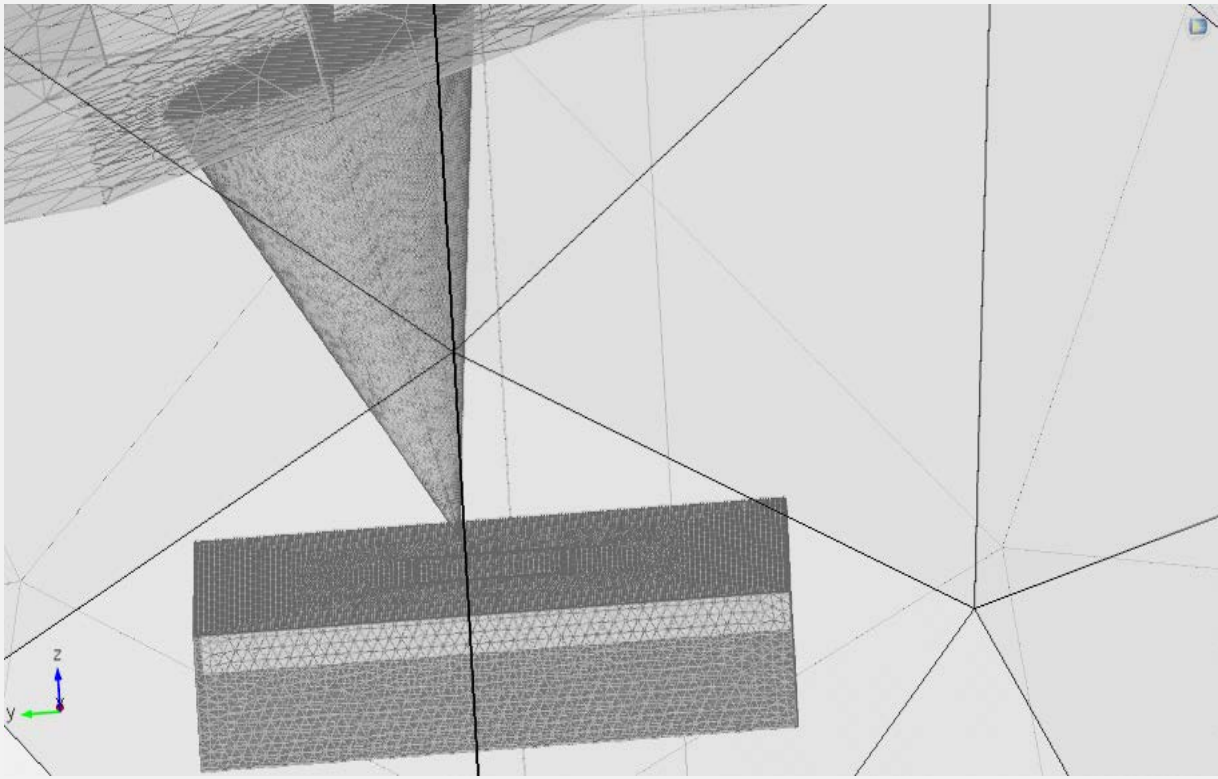
Electrostatics

- Charge Conservation
- Zero Charge
- Floating Potential
- Biasing
- Ground



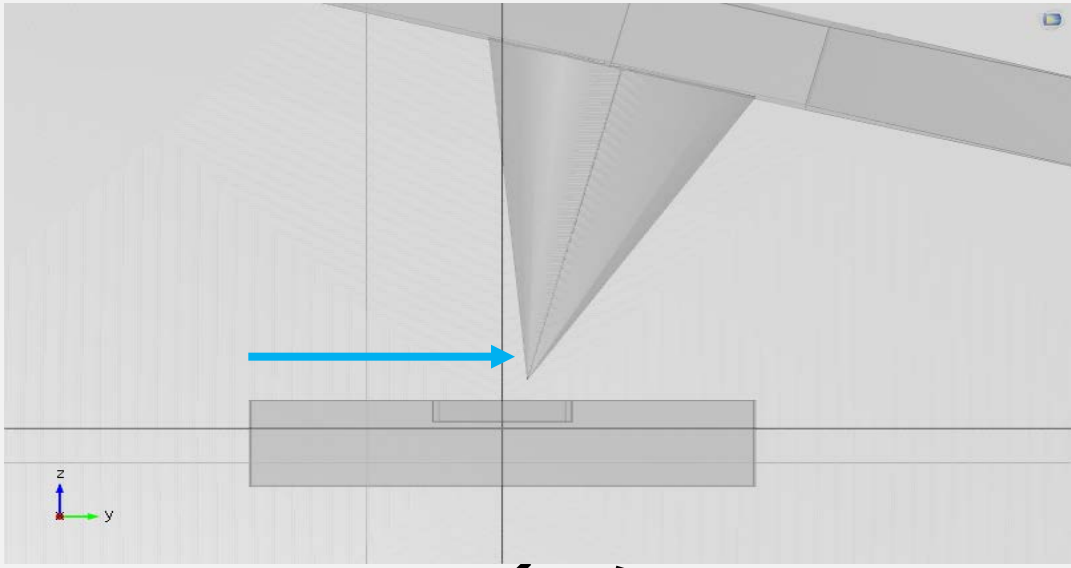
COMSOL MODEL BUILDER

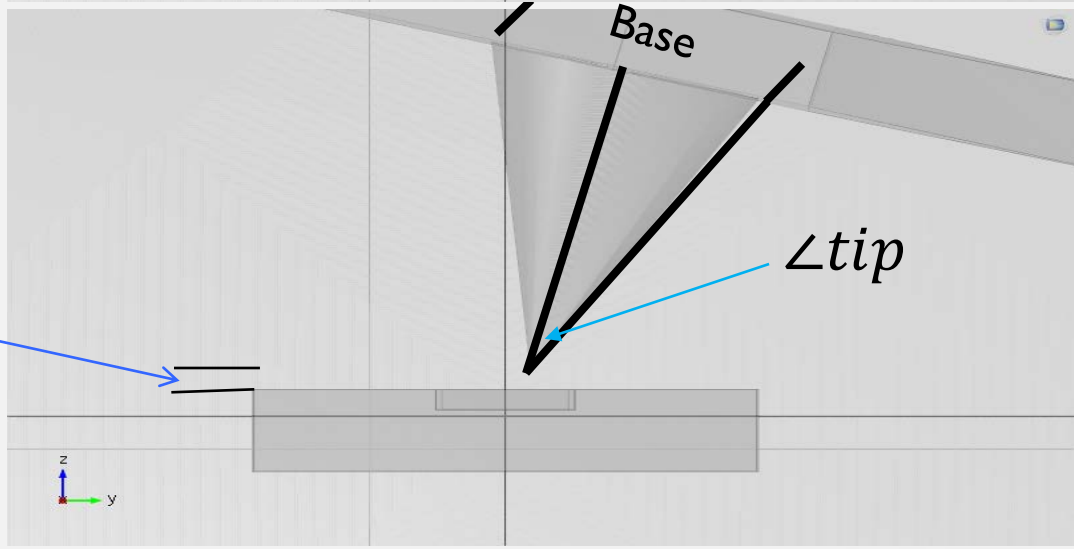
Meshing

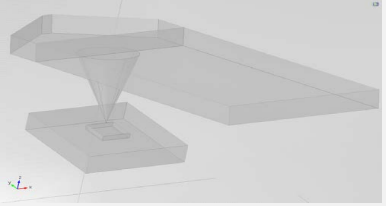


COMSOL MODEL BUILDER

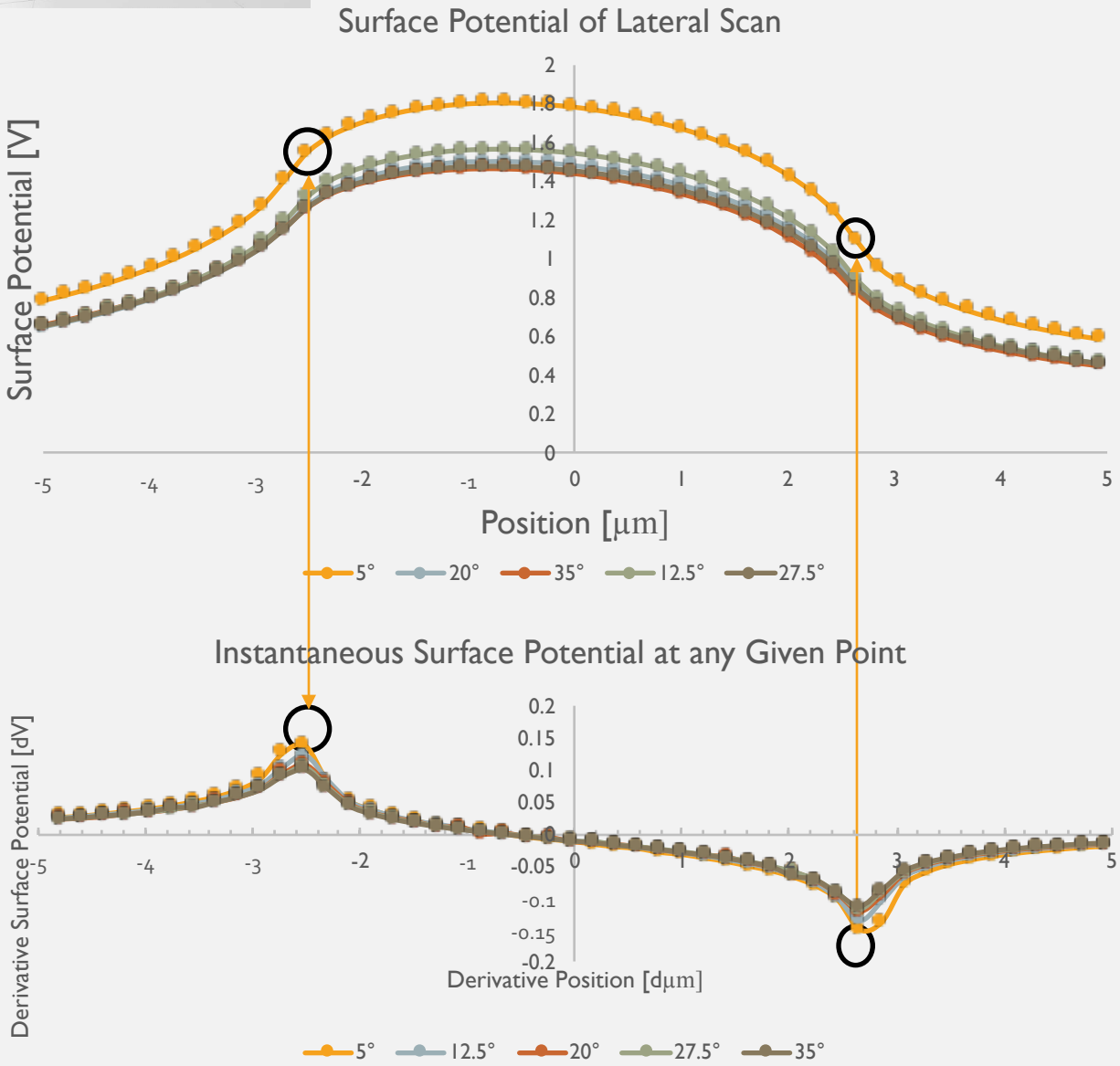
Parametric Sweep





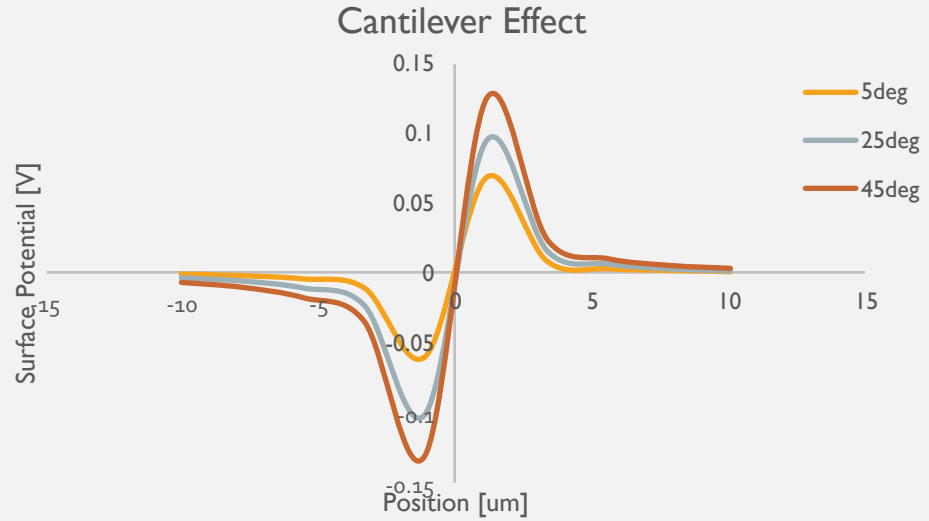


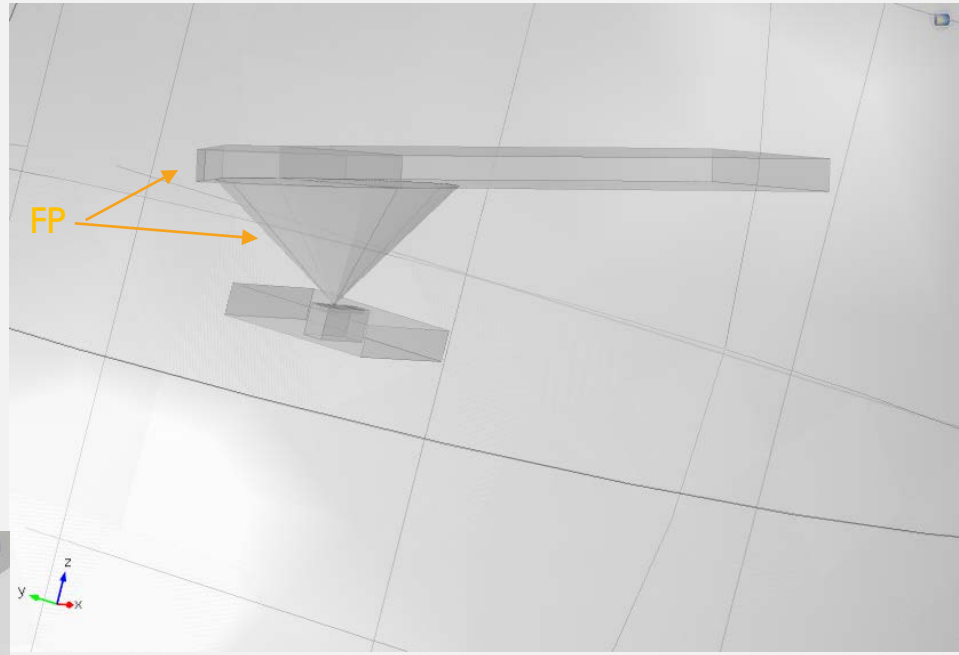
IMPORTANCE OF TIP SHAPE

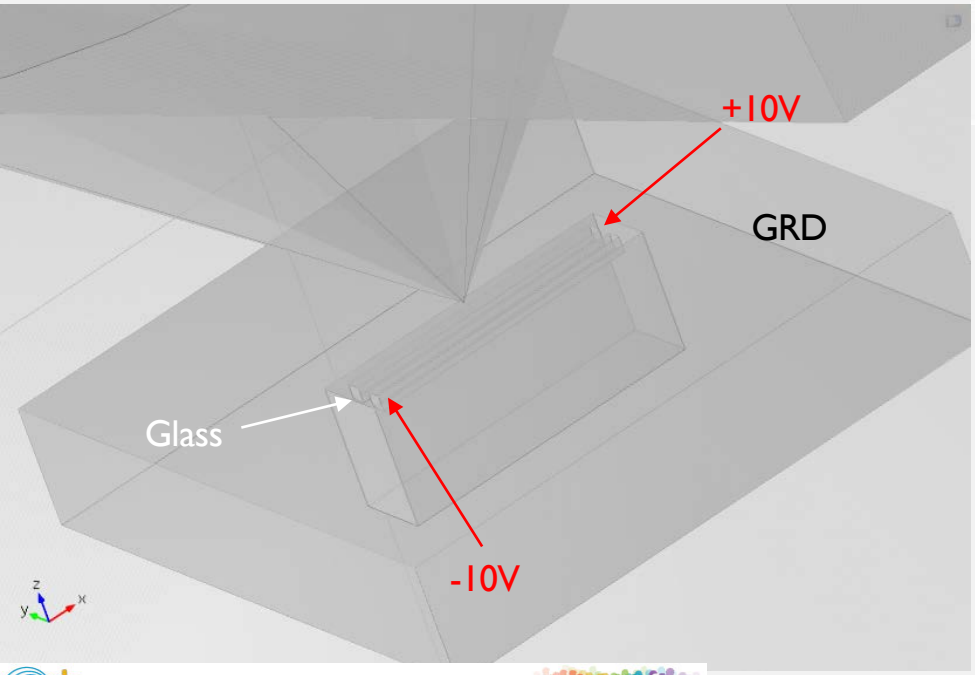


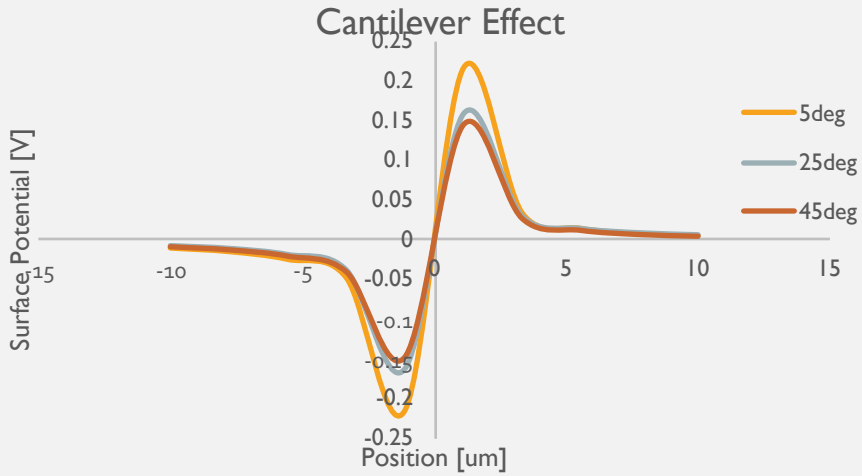
- The Surface Potential dependency on the shape of the tip
- Sharper vs. Blunter tips
- 5°
  - (-2.52 , 0.140)
  - (2.66 , -0.149)
- 35°
  - (-2.52 , 0.101)
  - (2.66 , -0.113)

CANTILEVER EFFECT

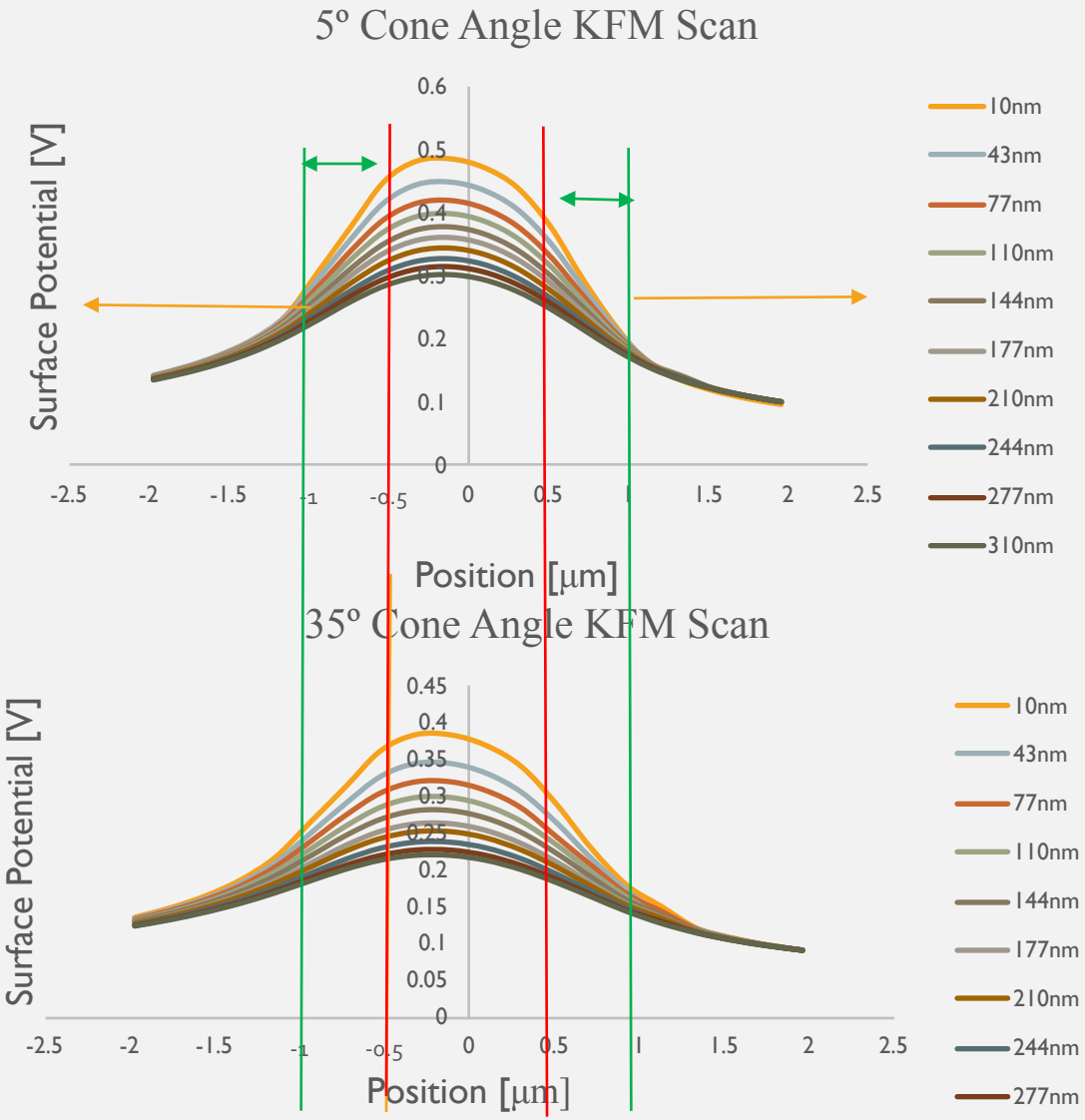


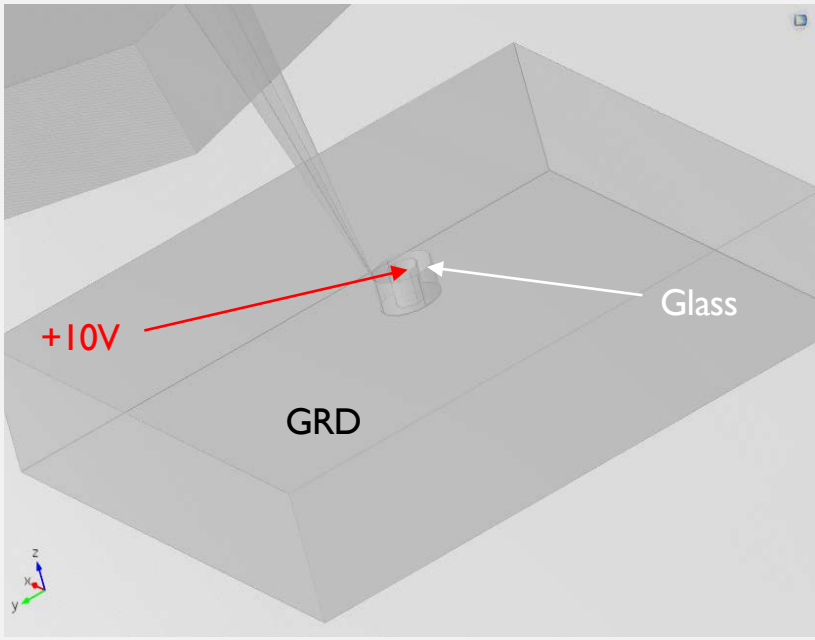




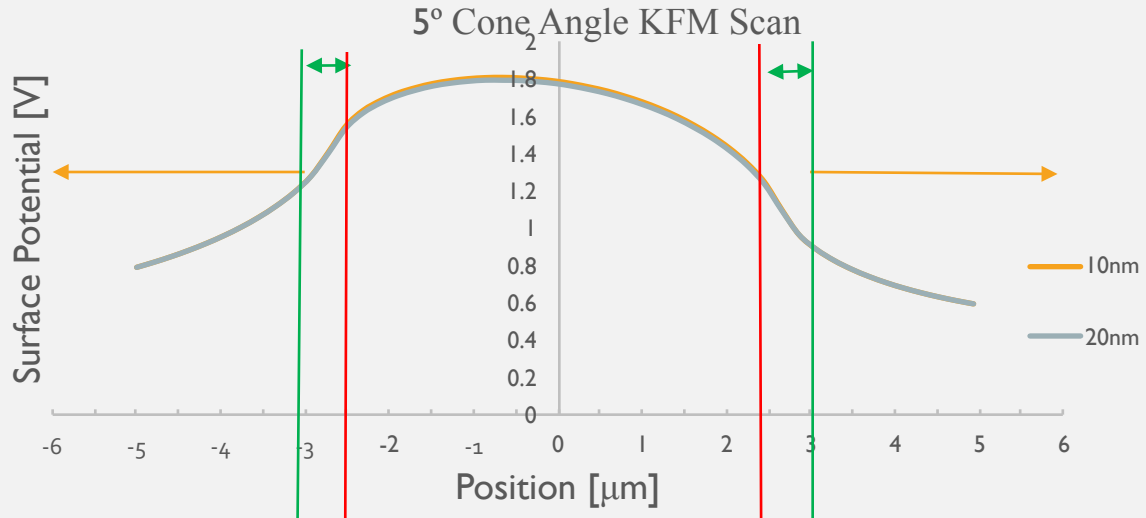


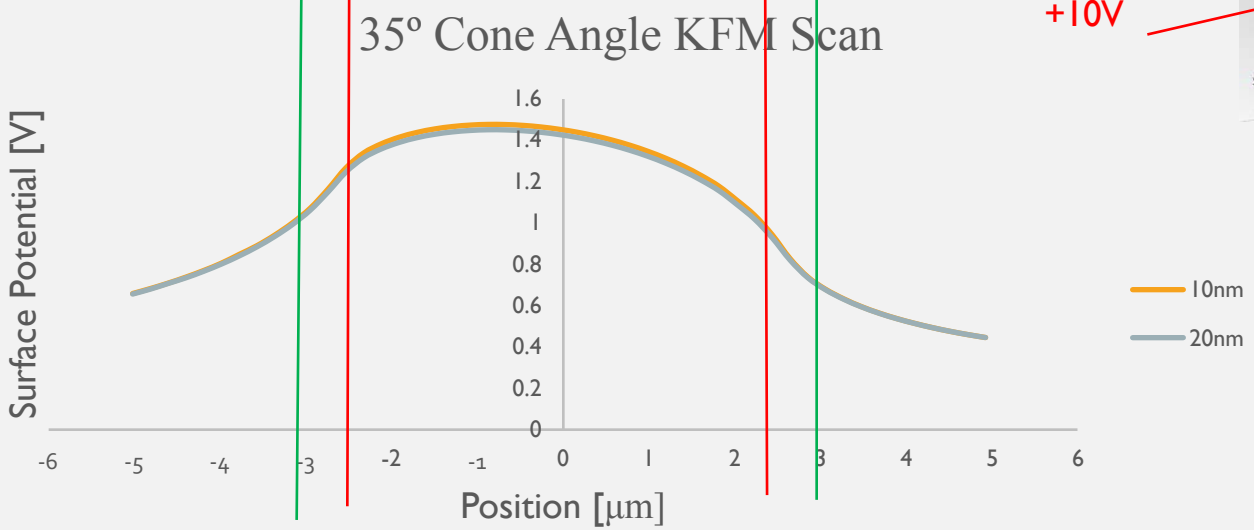
CLEARANCE EFFECTS ON SURFACE POTENTIAL

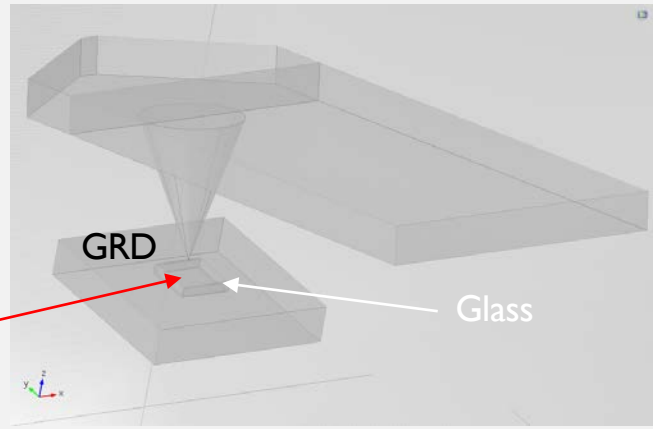




CLEARANCE EFFECTS ON SURFACE POTENTIAL

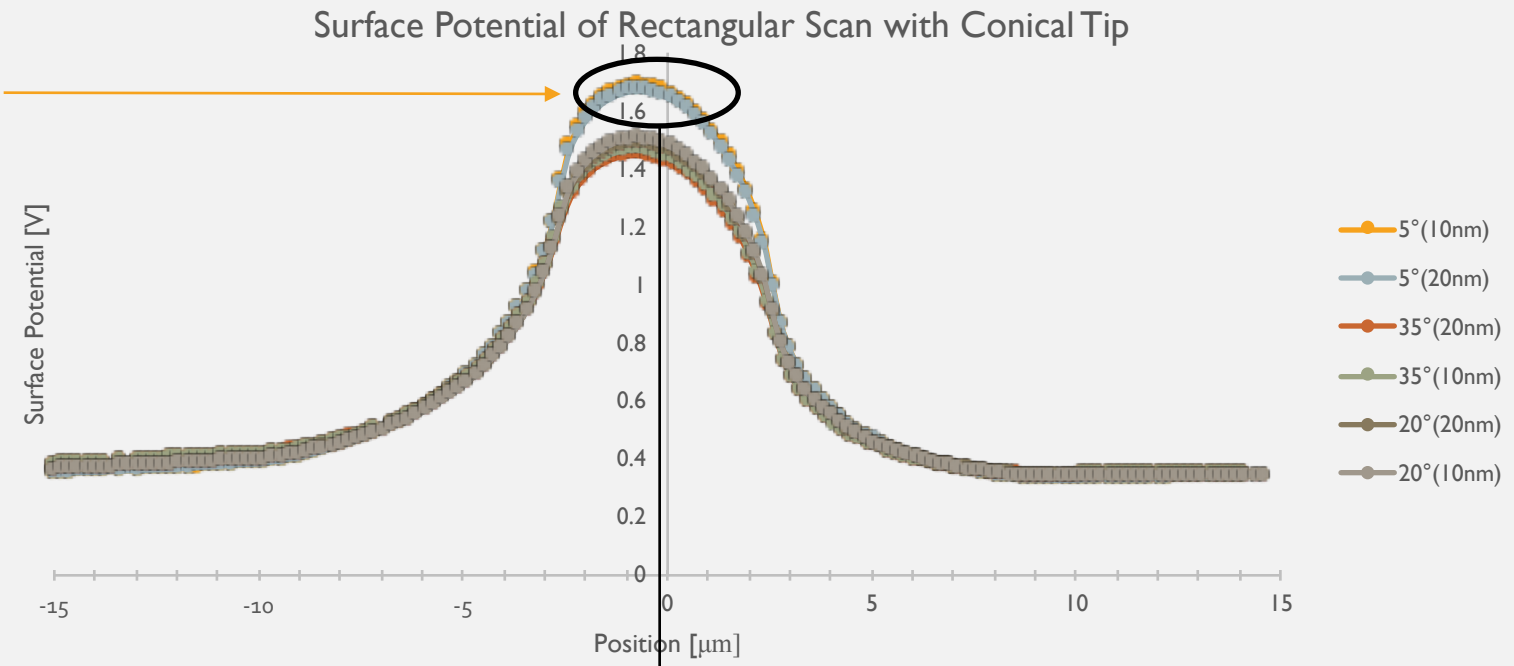




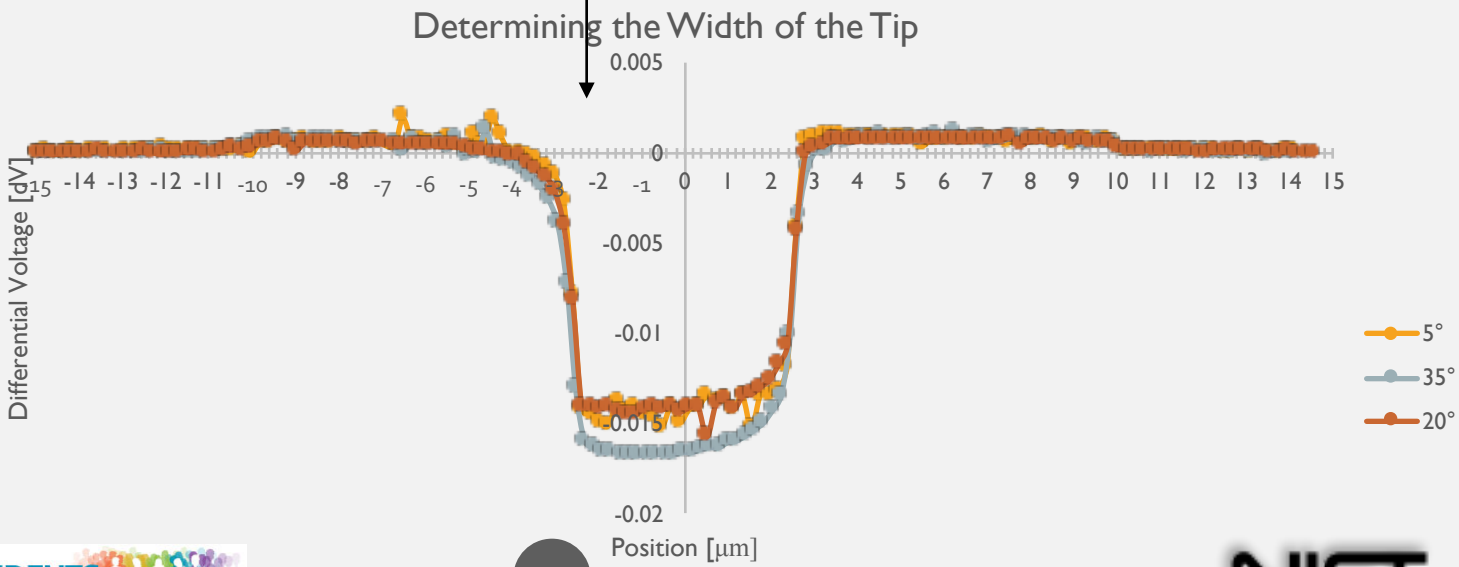


DIFFERENTIAL VOLTAGE

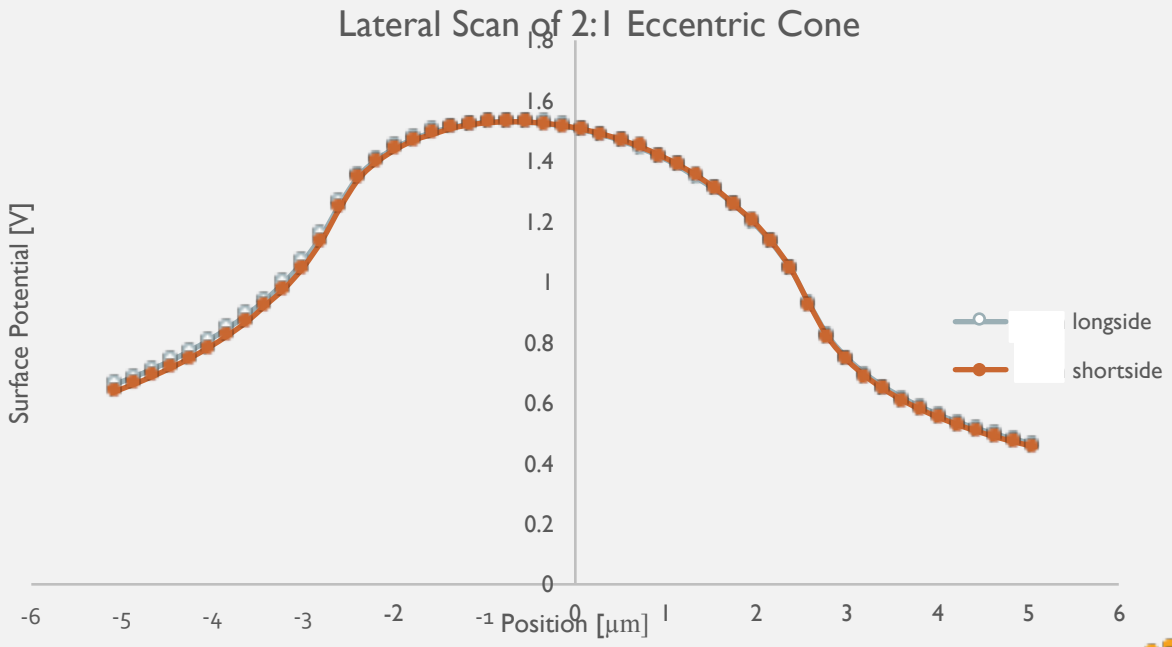
- 5° Cone Angle highest SP and most narrow width
  - Coherent results as before
  - Smaller lift height, higher SP

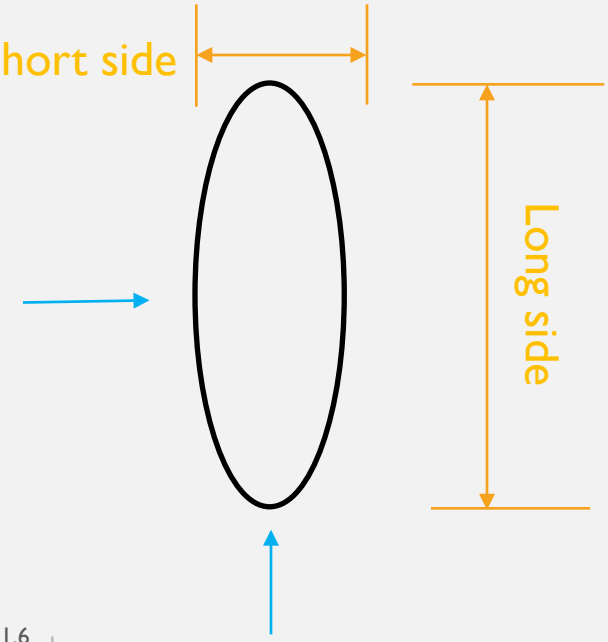


(20-10)nm

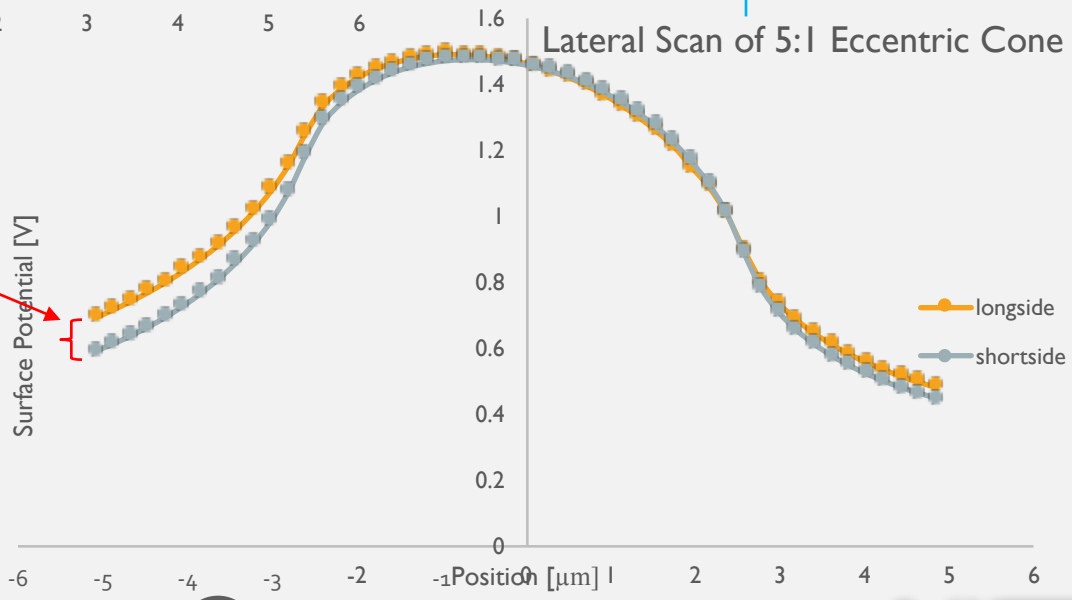


DIFFERENT SIZE RATIOS





- Noticeable gap
- Indicates the direction of scan



SUMMARY AND OUTLOOK

- Extract:
  - Base shape
  - Tip angle
  - Height

- Future work:
  - Compare

THANK YOU!

Any Questions?

References

- *How AFM Works: Scanning Kelvin Probe Microscopy (SKPM)*, Web. (http://www.parkafm.com/index.php/medias/nano-academy/how-afm-works#prettyPhoto).
- Khaled Kaja. *Development of nano-probe techniques for work function assessment and application to materials for microelectronics*. Physics. Universite Joseph-Fourier - Grenoble I, 2010. English. <tel-00515370>
- http://semimd.com/insights-from-leading-edge/2010/10/02/iftle-18-the-3d-ic-forum-at-2010-semicon-taiwan/

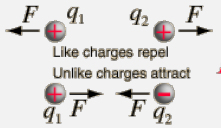
CONCLUSIONS

- COMSOL's ability to simulate SKFM
- Effect of Tip on the Surface Potential Measurement
  - Seen through development of many DUTs
  - IF SLOPE DETERMINED INSERT HERE
- Various lift heights affect Surface Potential
  - Differential Voltage Produced
- V

GOALS

- 3D COMSOL Simulation of Scanning Kelvin Force Microscopy (SKFM)
  - SKFM → Electric field measurements
- Determine the field distribution to design Electrical Tip Shape Profiler Reference Material
  - Cone Angle
  - Base
  - Height

THEORY OF SURFACE POTENTIAL



$$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$ *Coulomb's Law*

Image from HyperPhysics

Coulomb's Law – Electric force between charges

$$V_f - V_i = \frac{Fd}{q} = -Ed$$

Moving a positive charge from the bottom to the top plate requires work and raises voltage.

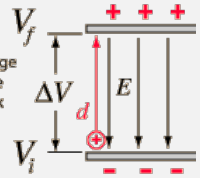


Image from HyperPhysics

Electric Potential – work per unit charge to move a point charge

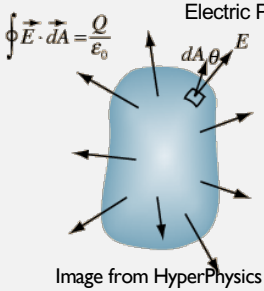


Image from HyperPhysics

Gauss's Law – Used to determine the Electric field of a Gaussian surface

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elewor.html#c2

VAN DER WAAL'S FORCES

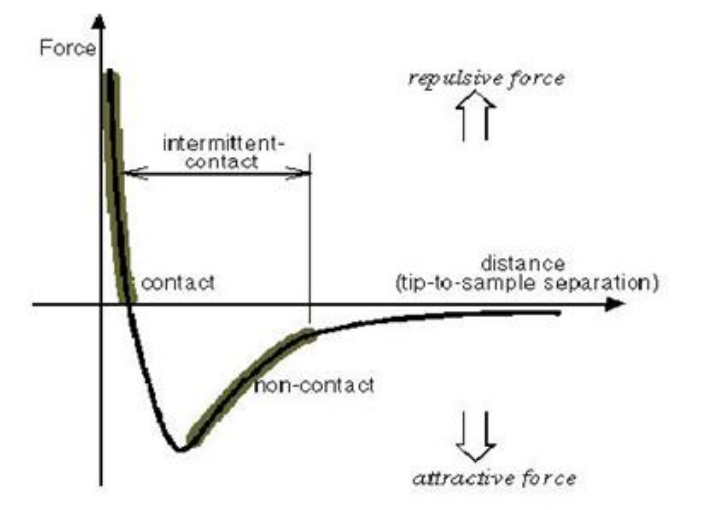


Image by

http://www.eng.usf.edu/~tvestgaa/ThinFilm/

http://mathworld.wolfram.com/FullWidthatHalfMaximum.html