Better, Smaller, Faster: MEMS Force Probes

Joey Doll

Stanford Microsystems Lab

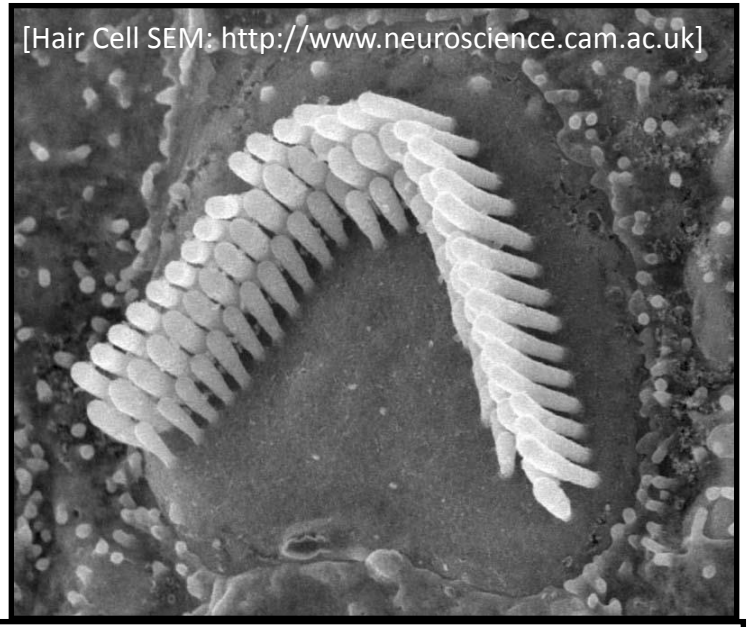
Group Meeting, 2/11/09

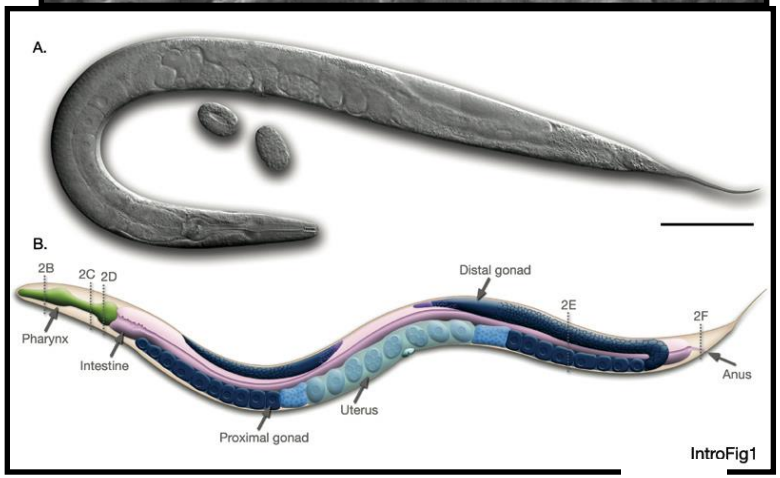
Outline

- Overview
- Process Debugging
- Piezoresistor Noise
- Next Steps

Motivation

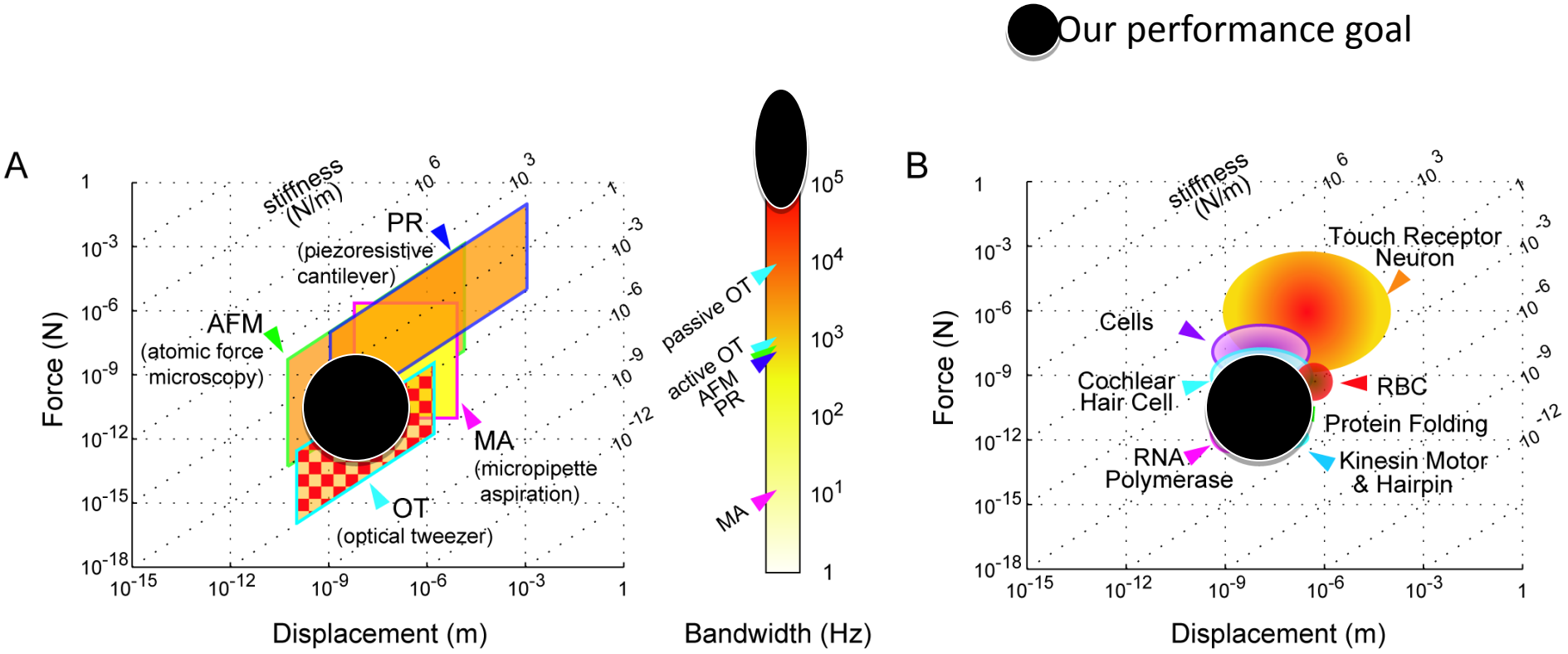
- Rapid (10µs) force transduction by hair cells in the inner ear and touch receptor neurons
- Combine actuation and force sensing on-chip to increase bandwidth
- Piezoelectrically actuated cantilevers with piezoresistive force sensing
- Other applications, e.g. chemical sensing, scanning probe microscopy





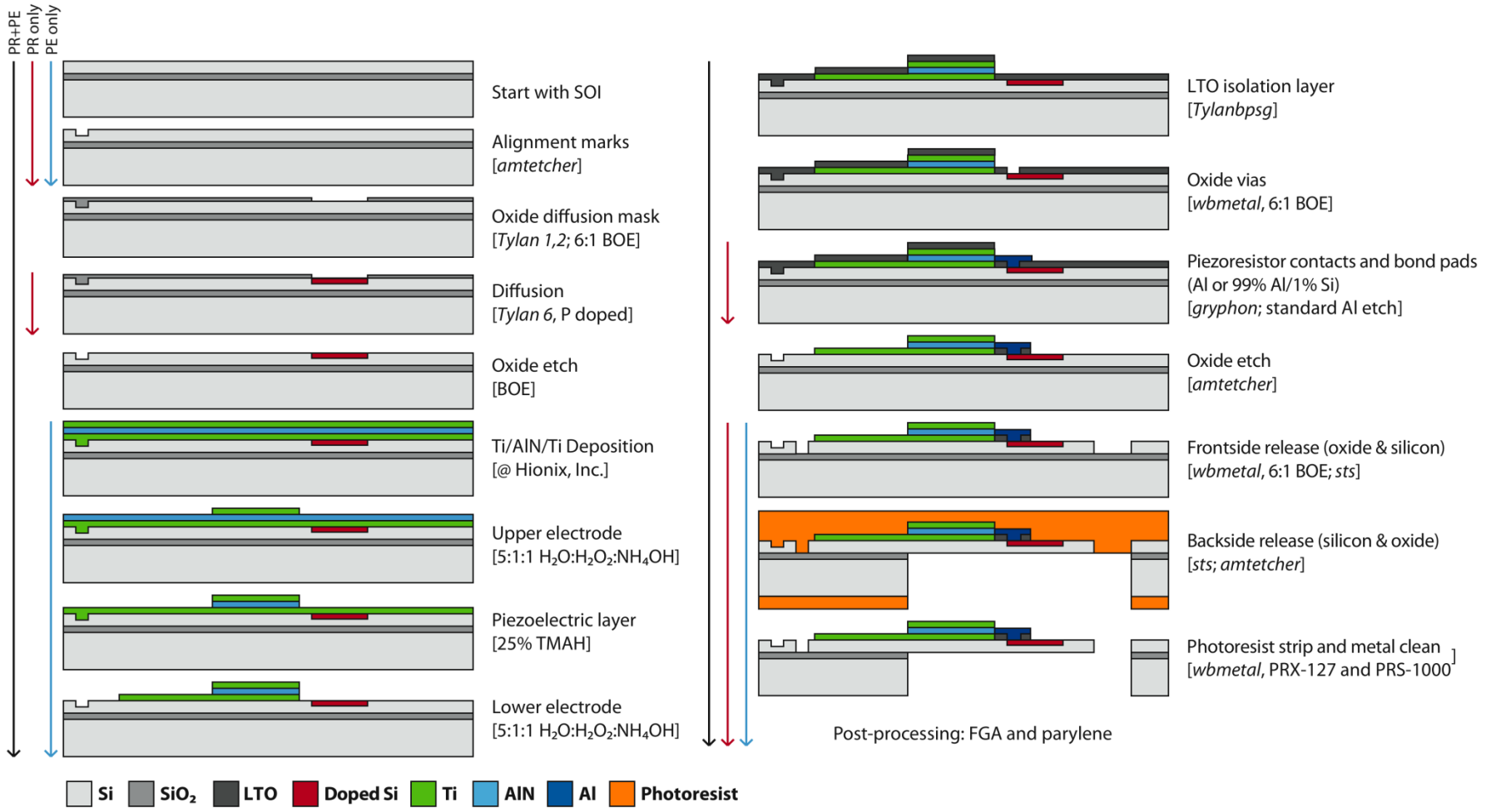
[*C. elegans* anatomy (bar = 100 um: http://www.wormatlas.org]

Performance Goals

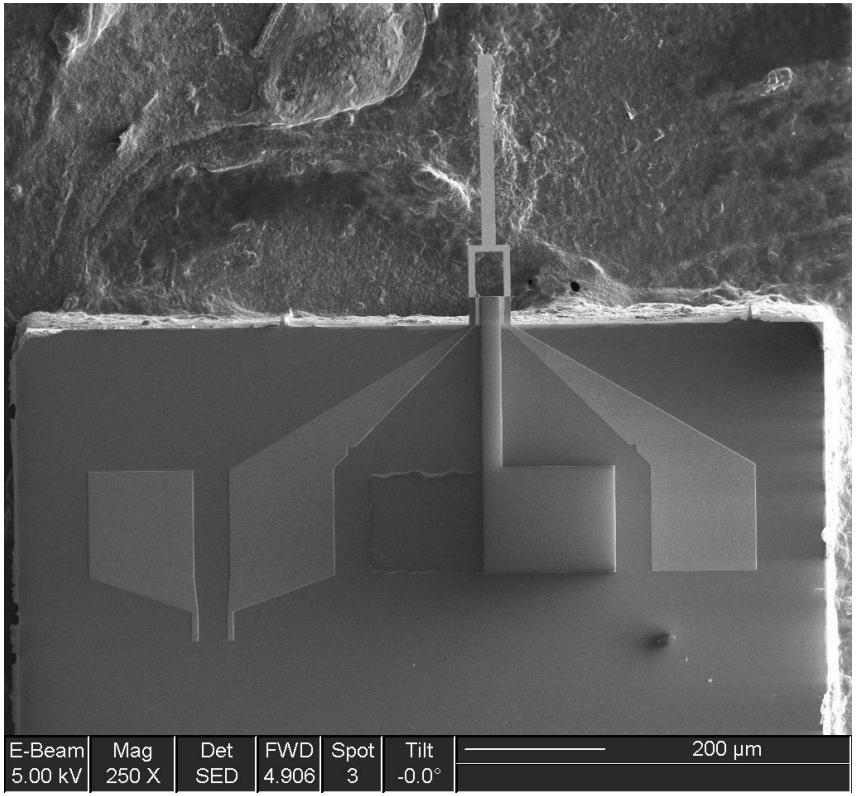


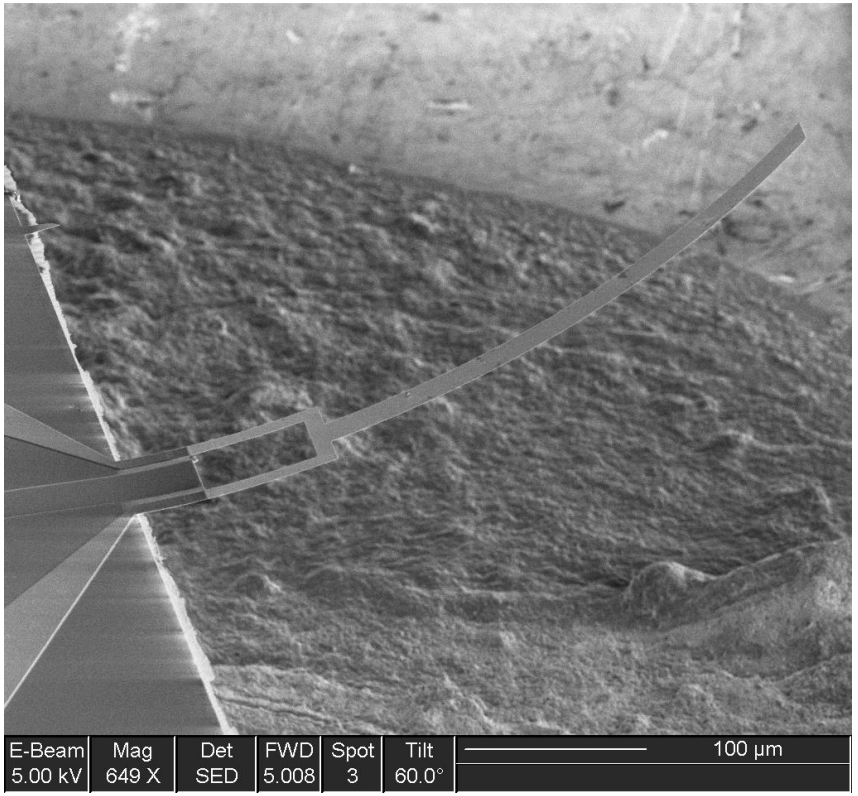
Park et al, PNAS 2007

Fabrication Process

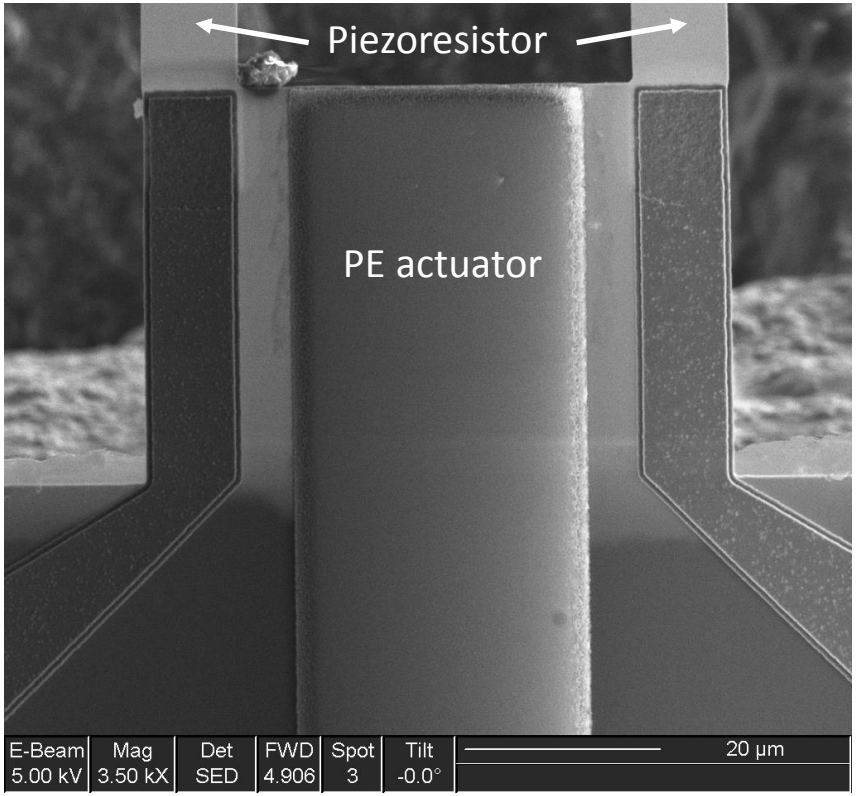


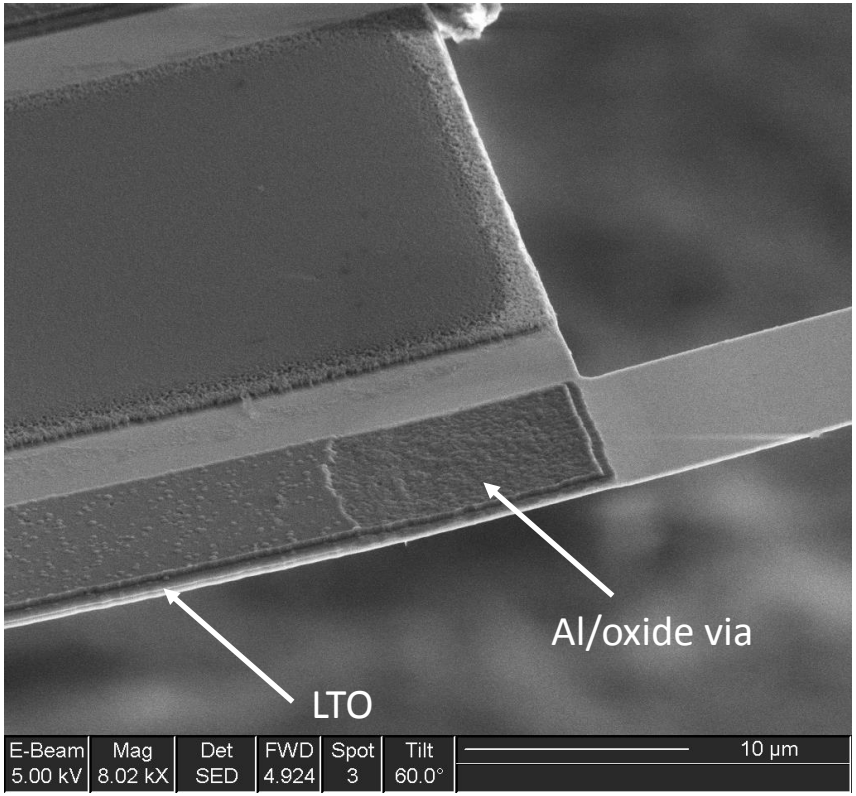
Fabrication Process



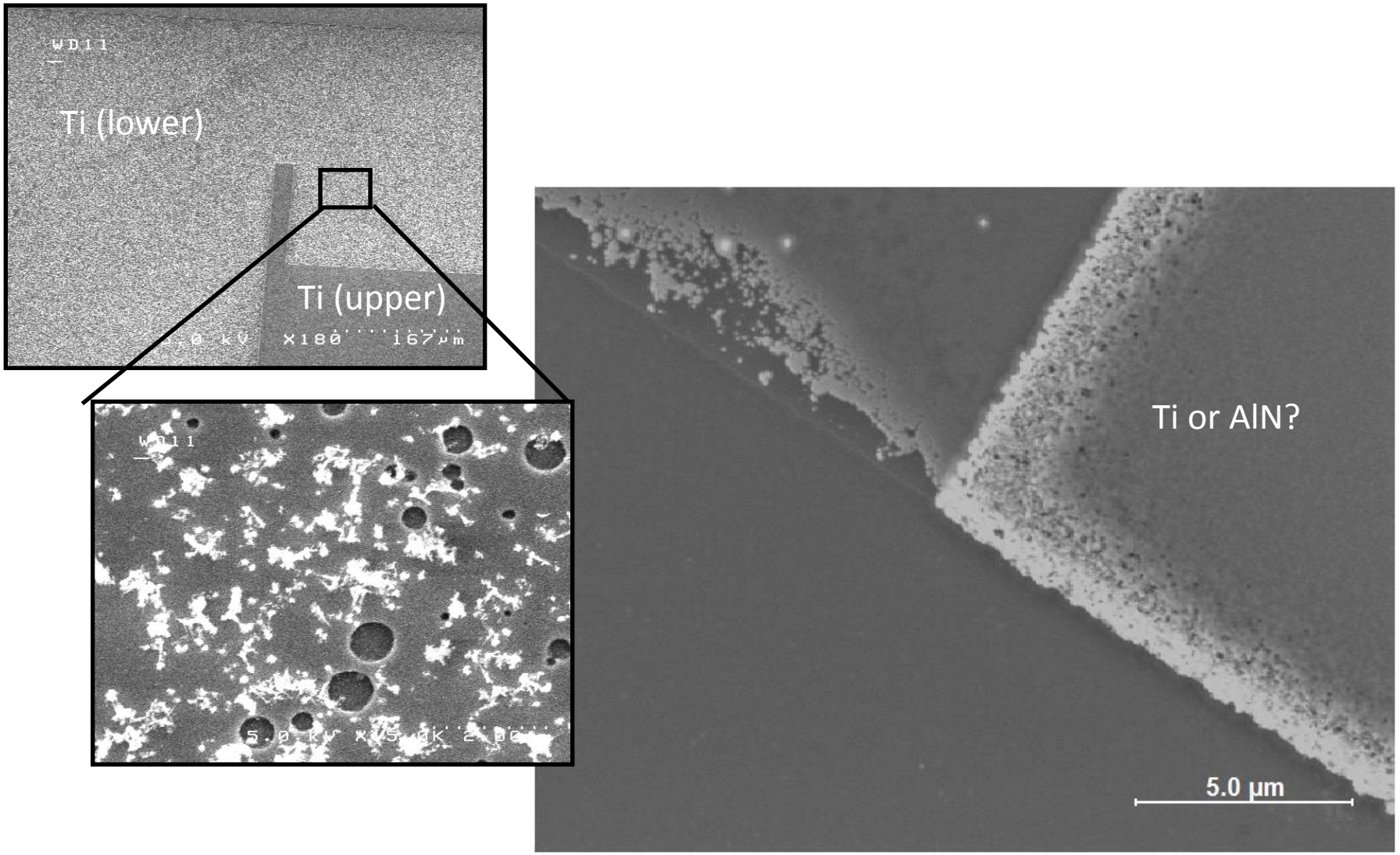


Fabrication Process





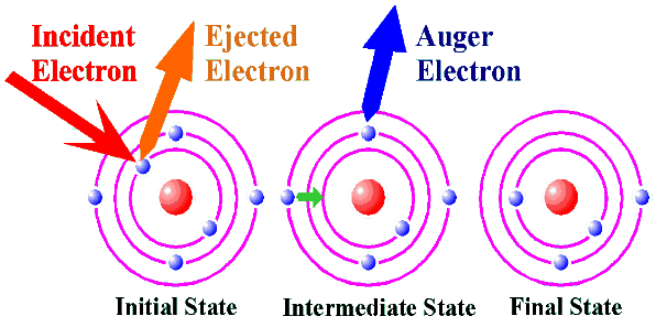
Mystery Etch Processes



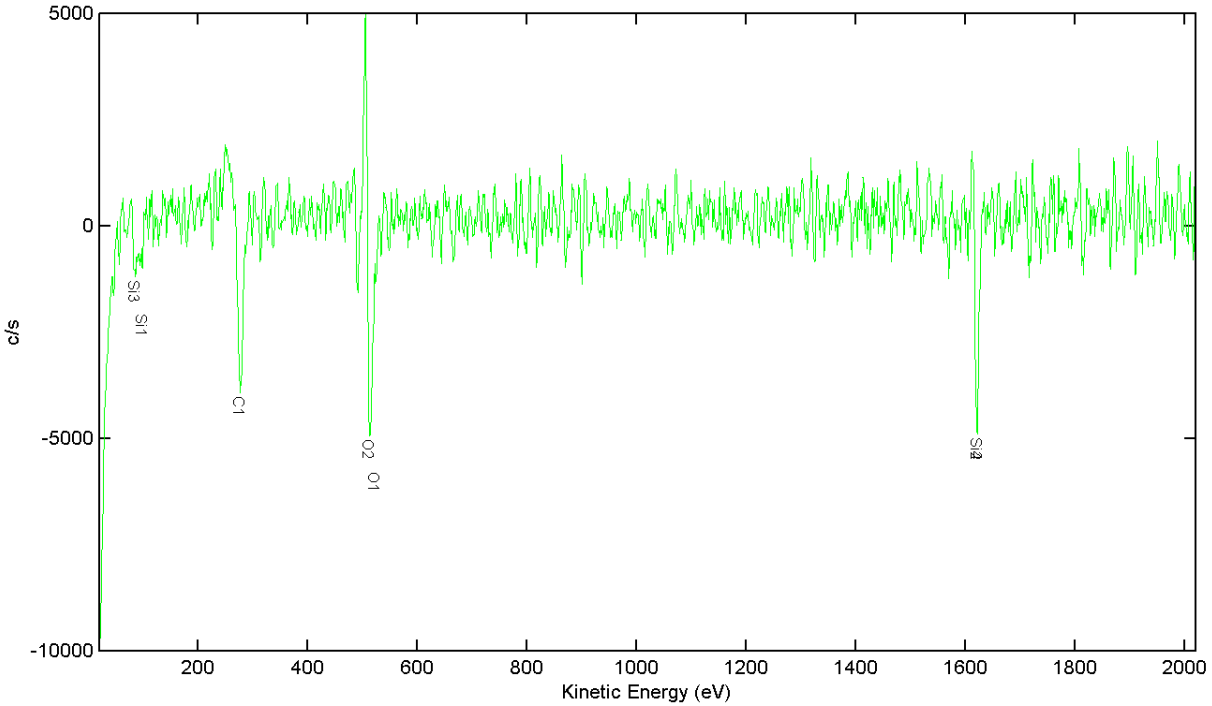
Disappearing Thickness

- Device layer started out 340nm thick
- But measured 180nm during fab
  - Zygo measures silicon and oxide
  - Nanospec measures oxide
- Majority of carriers are at the surface, so could be a major problem
  - AlN presputter
  - TMAH etch
  - LTO etch

Auger Electron Spectroscopy (AES)

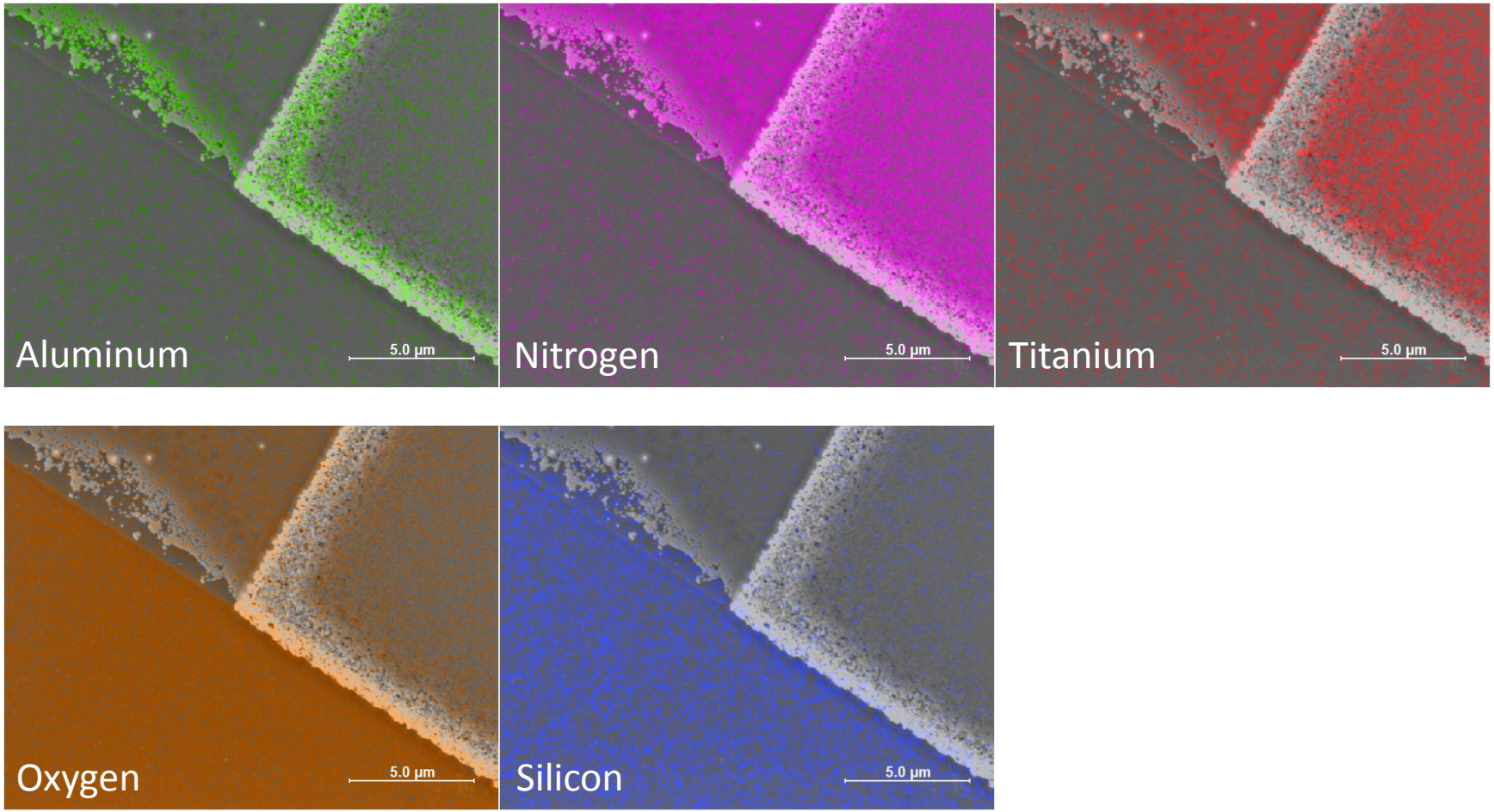


- Semi-quantitative
- E-beam spatial resolution
- Sensitivity to ~1%
- Compare with XPS

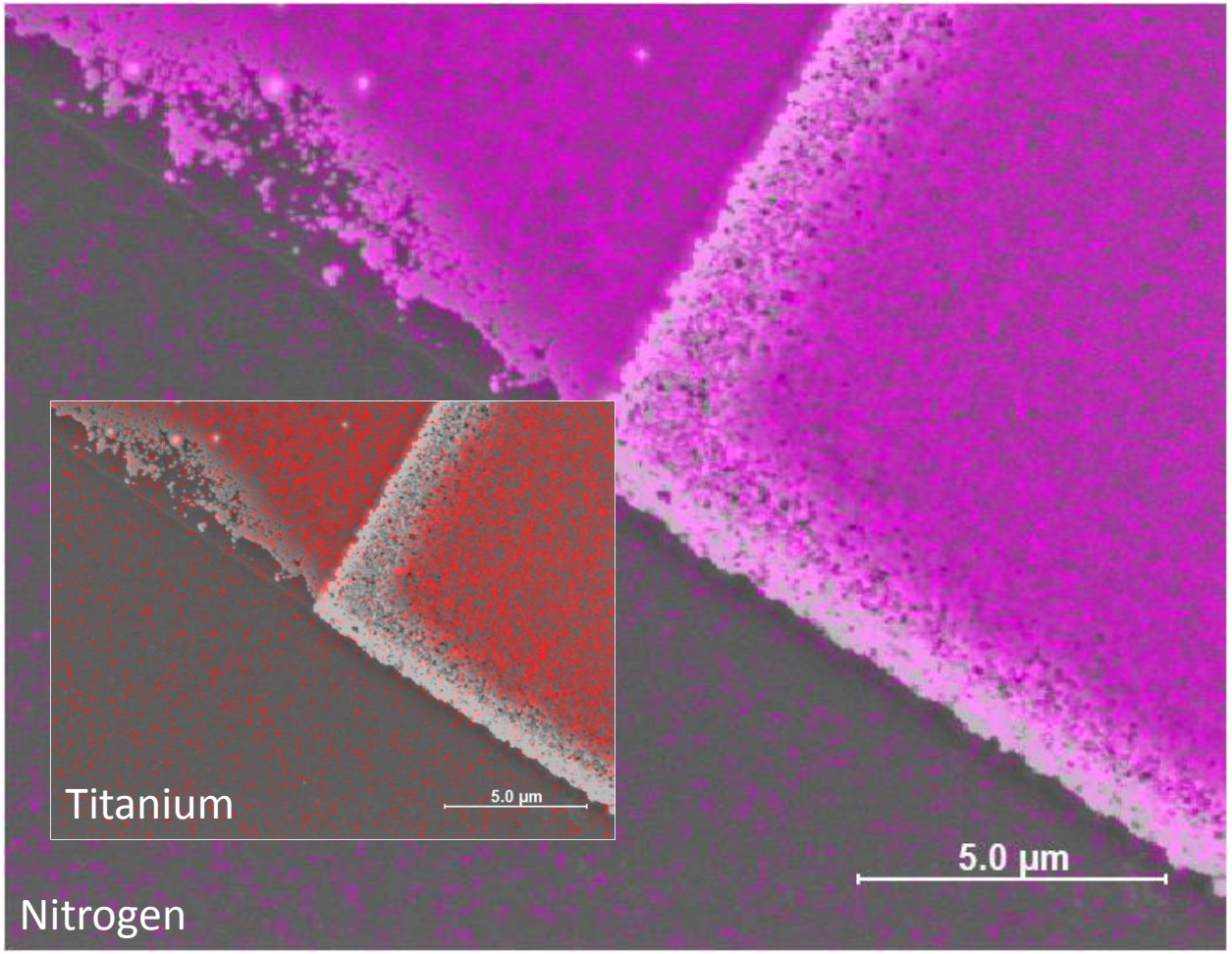


http://www.thermo.com/eThermo/CMA/Images/Various/158Image_17512.gif

AES Characterization



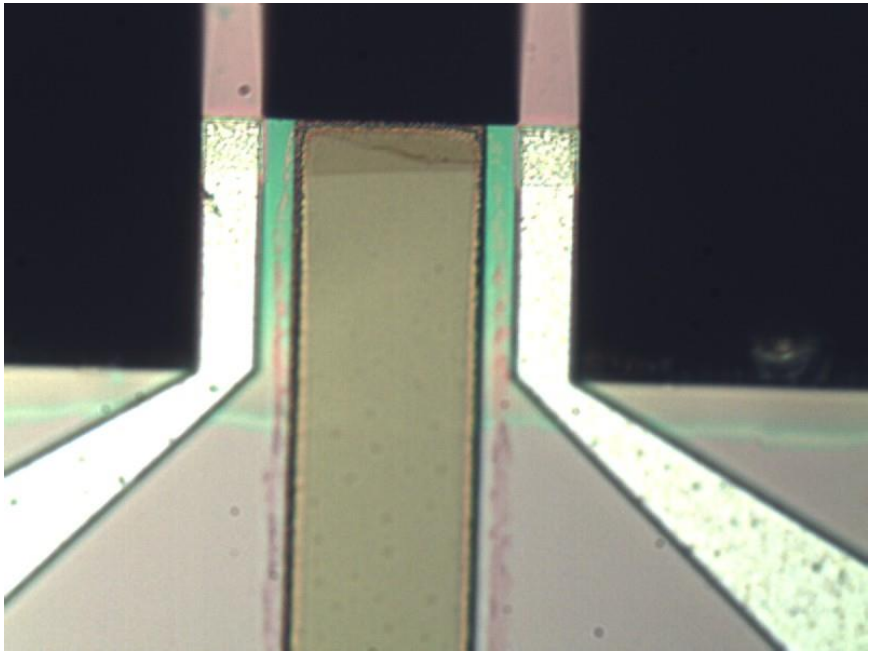
AES Interpretation



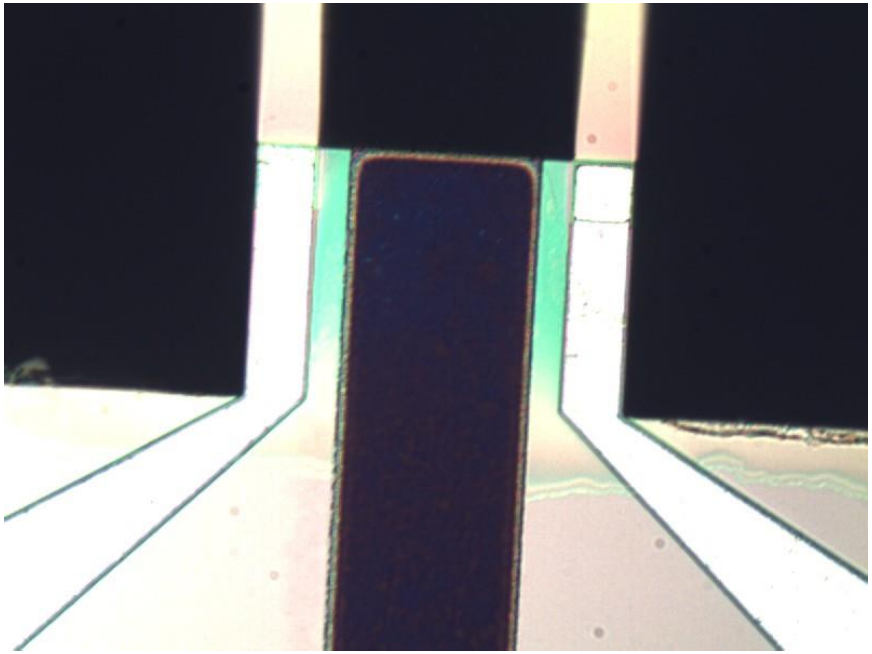
The surface of the titanium electrodes has become nitrided.
Also picks up nitrogen from AlN.

AES Interpretation

No FGA

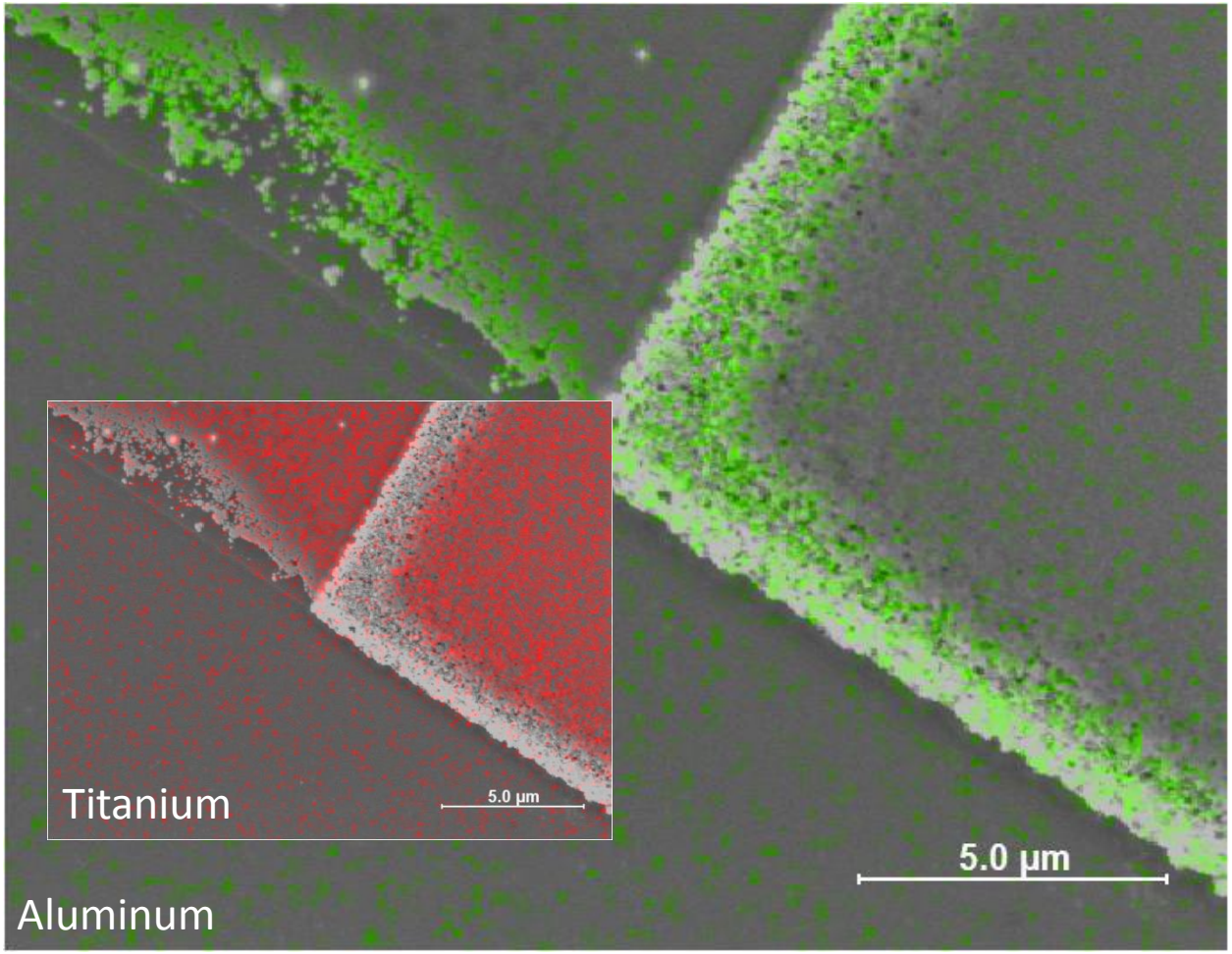


450C FGA, 1 hour



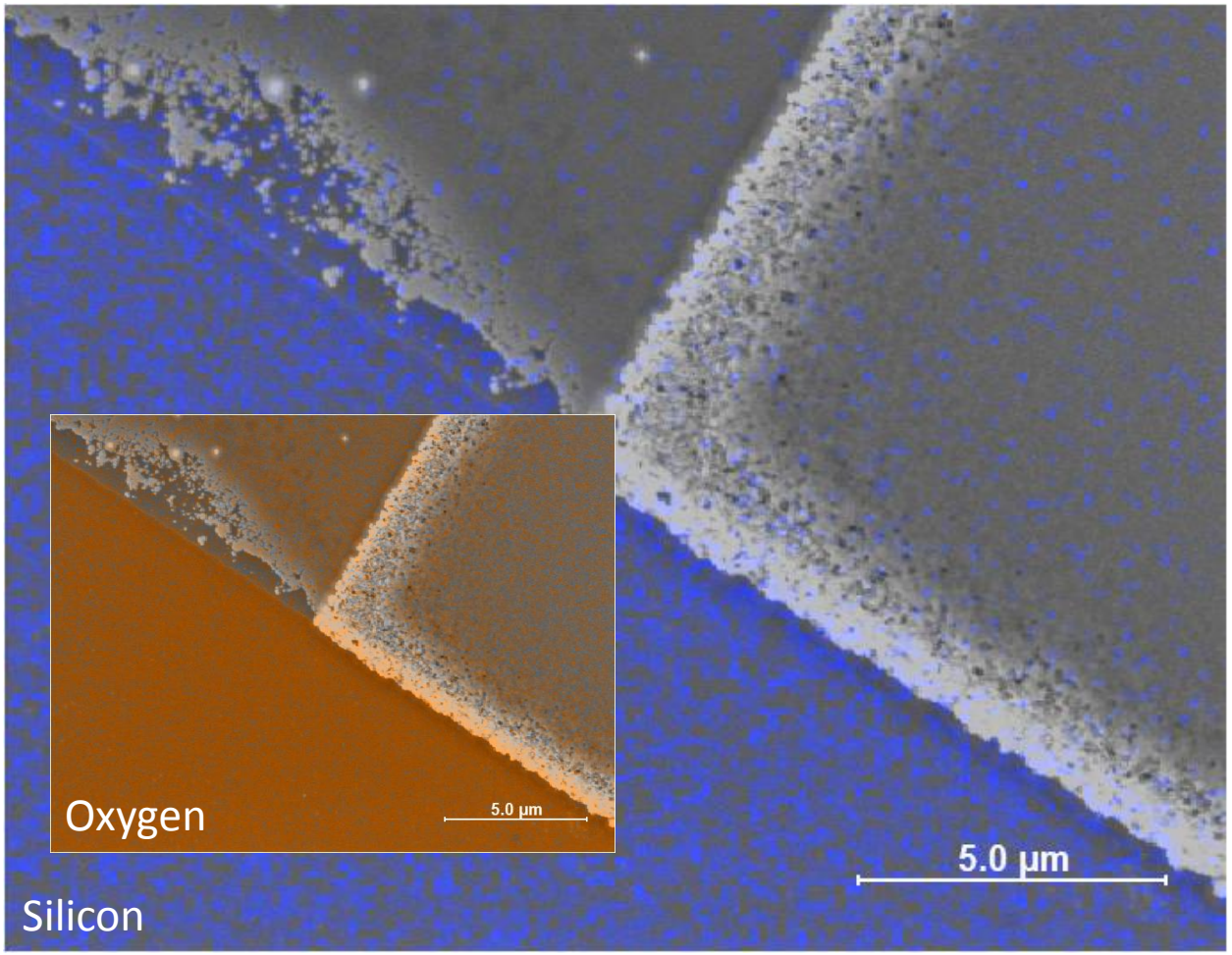
Which explains why the Ti changed colors after the forming gas anneal (N2 and H2).
(But what about the hydrogen distribution?)

AES Interpretation



The Ti electrodes were attacked at the edge.

AES Interpretation



The bottom aluminum nitride layer was etched through to the silicon (oxygen scaling).
This suggests that the doped silicon may have been attacked by the TMAH.

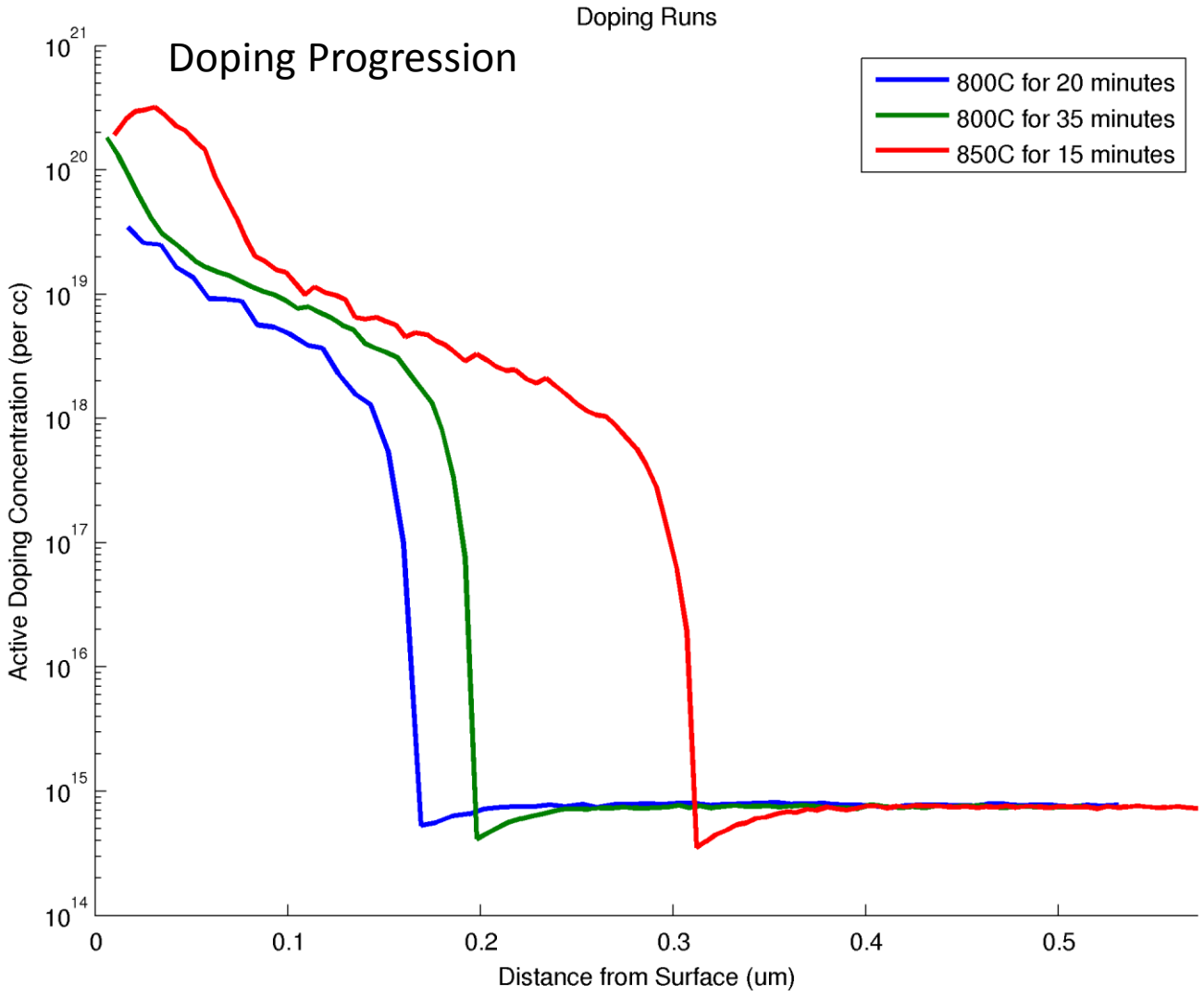
What's the Verdict?

- AES suggests that the TMAH etch attacked the underlying Si
- What about the PR resistance?
  - Measured about 6 kOhm, looks good
- Zygo on thin Si layers
- TiN, good or bad?

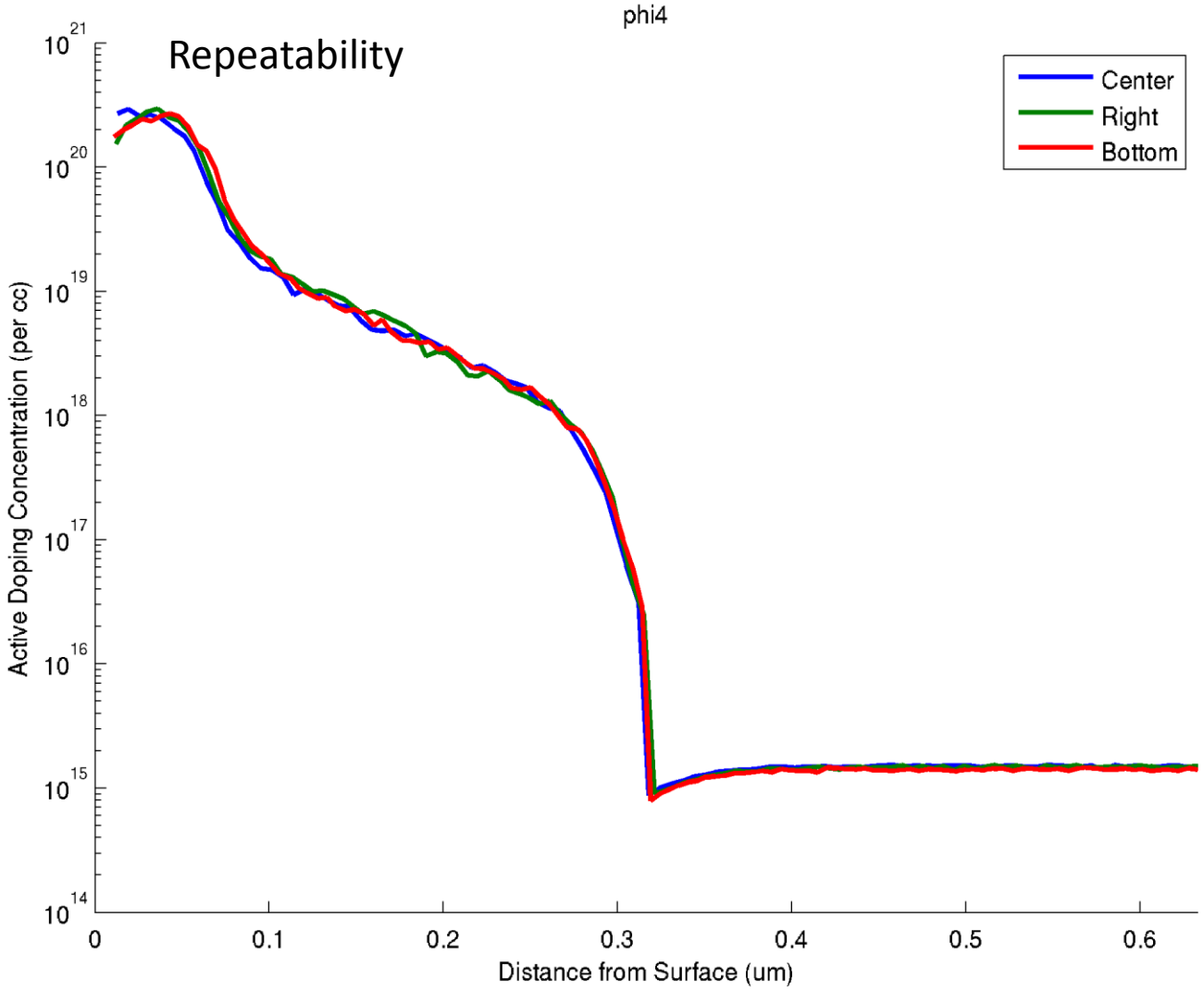
Piezoresistor Noise

- Measure alpha for diffusion
  - Determine alpha for diffusion process
  - Correlate with process/design choices
  - Update design process
- Effect of parylene coating
- Effect of fluid environment
- Stability for underwater measurements
- Help from Purnima and Anthony

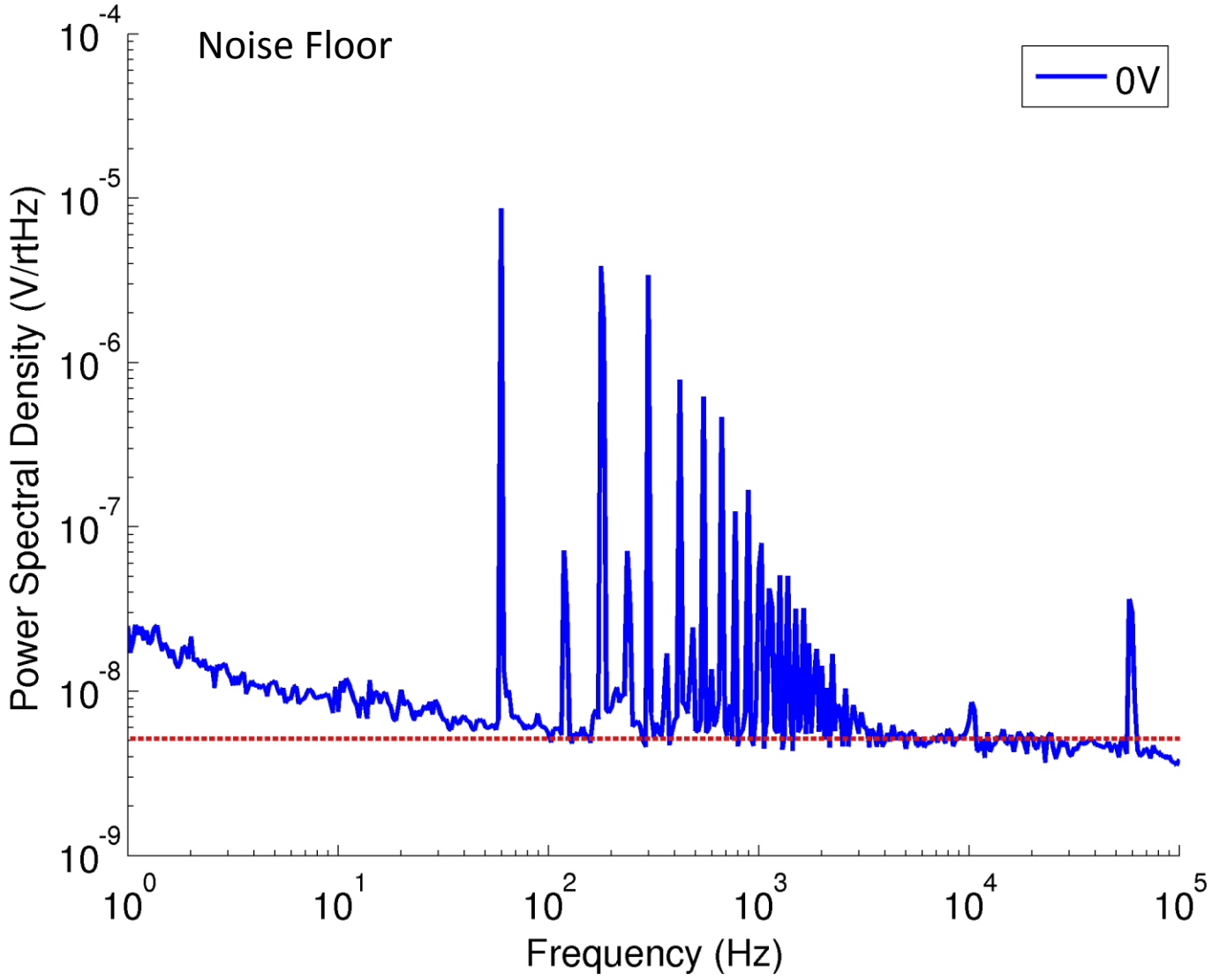
Piezoresistor Noise



Piezoresistor Noise



Piezoresistor Noise



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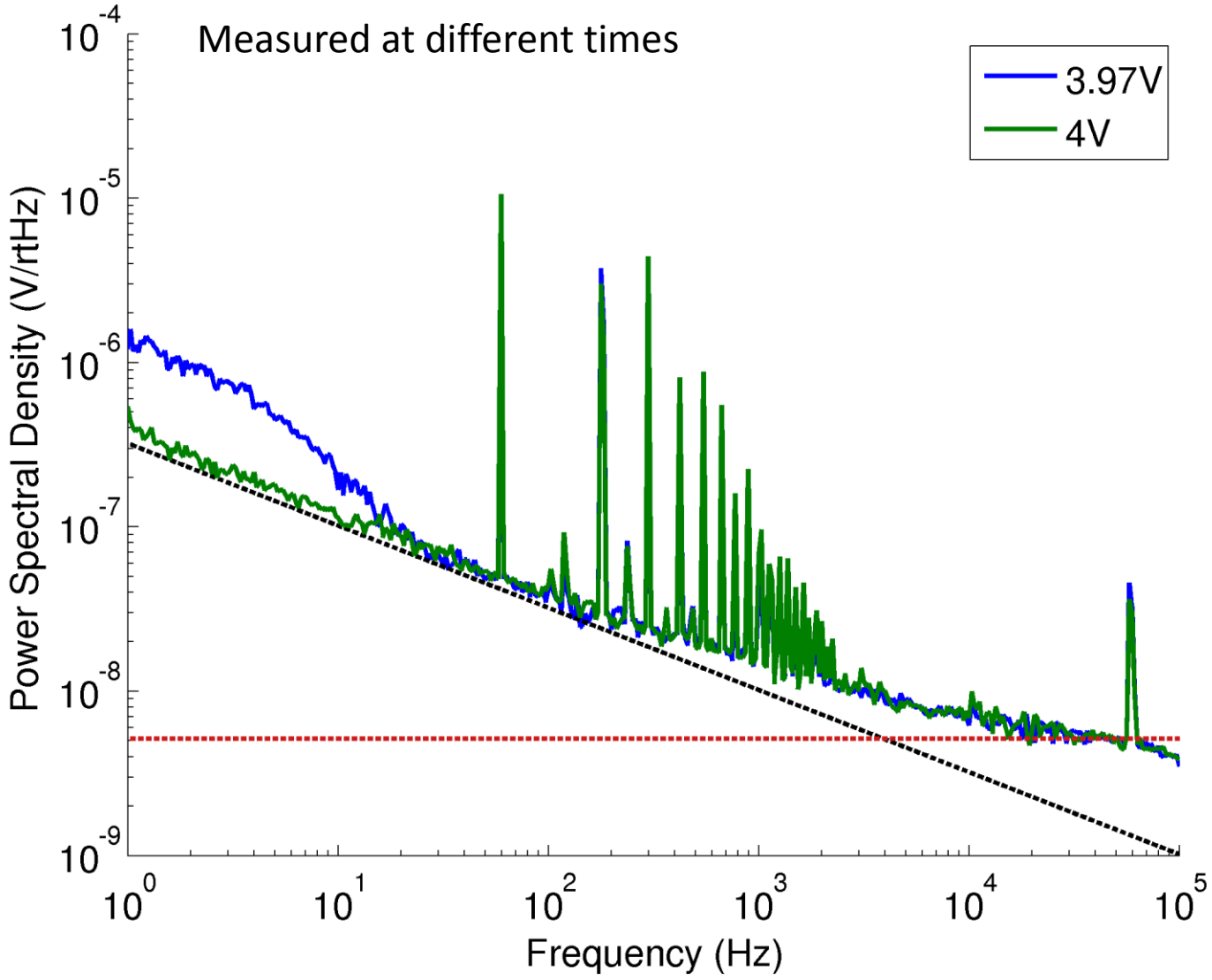
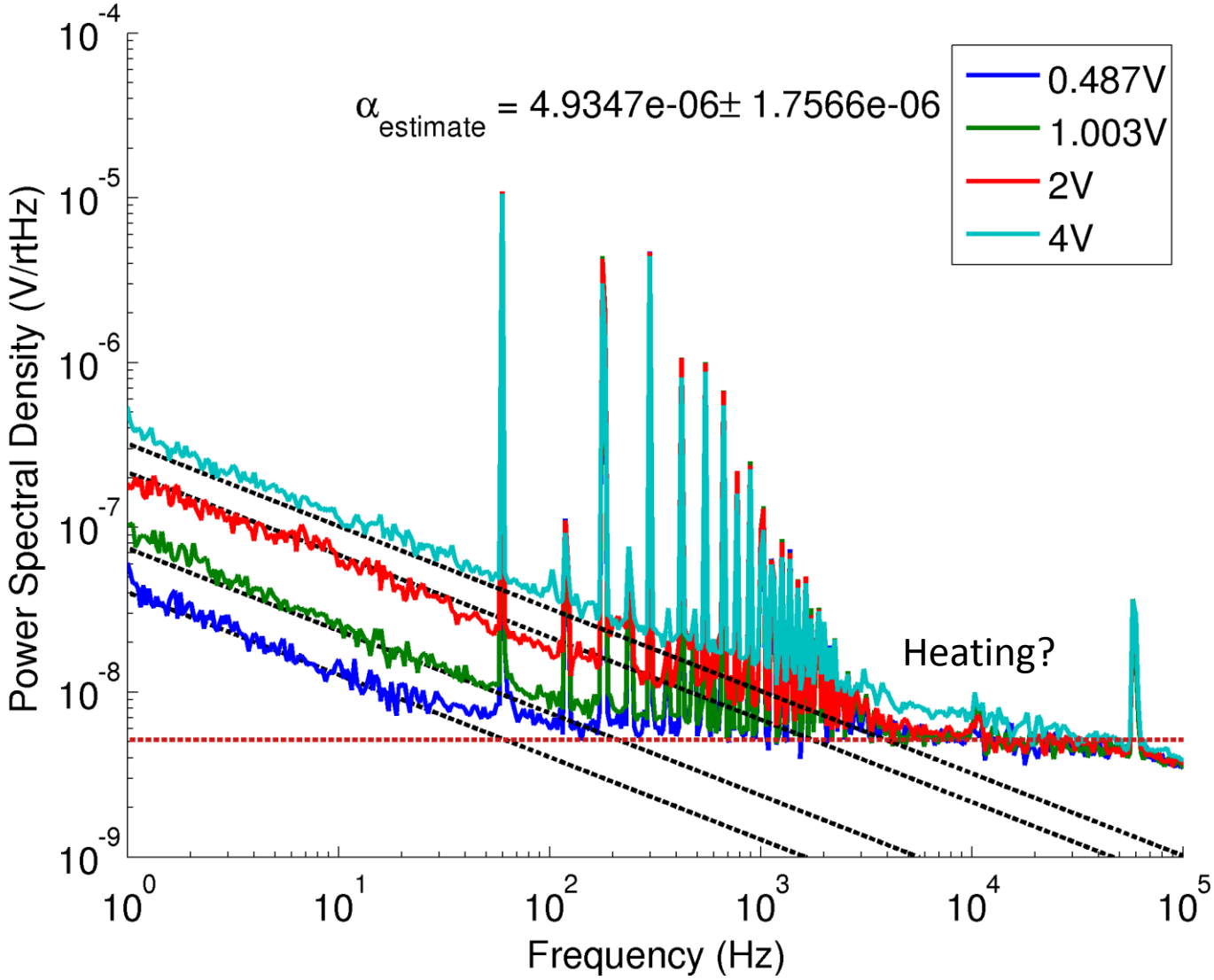
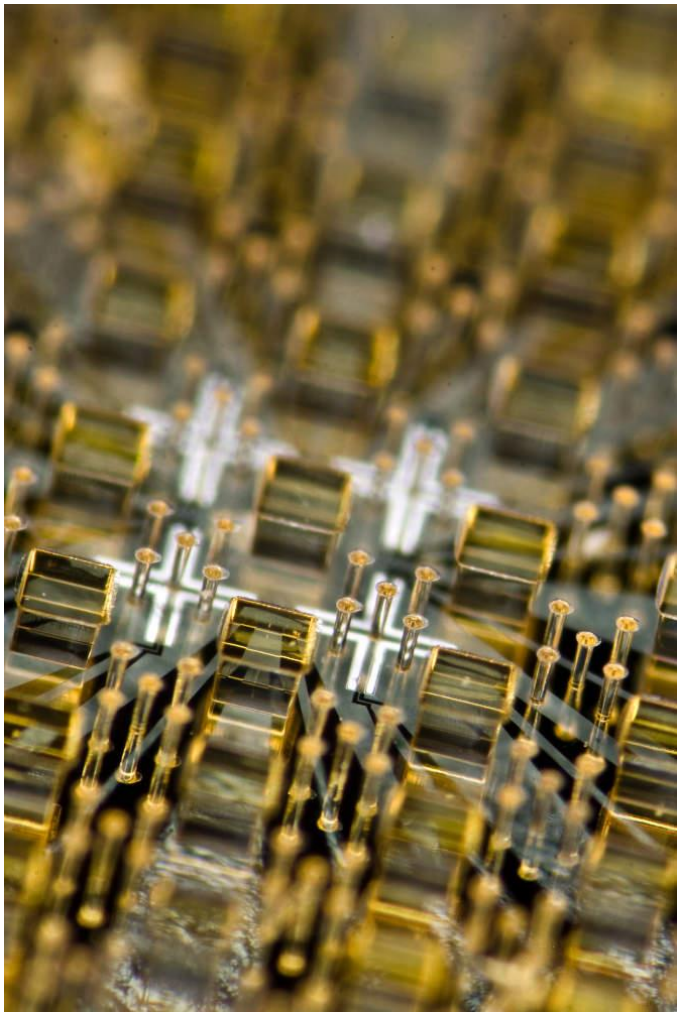


Piezoresistor Noise

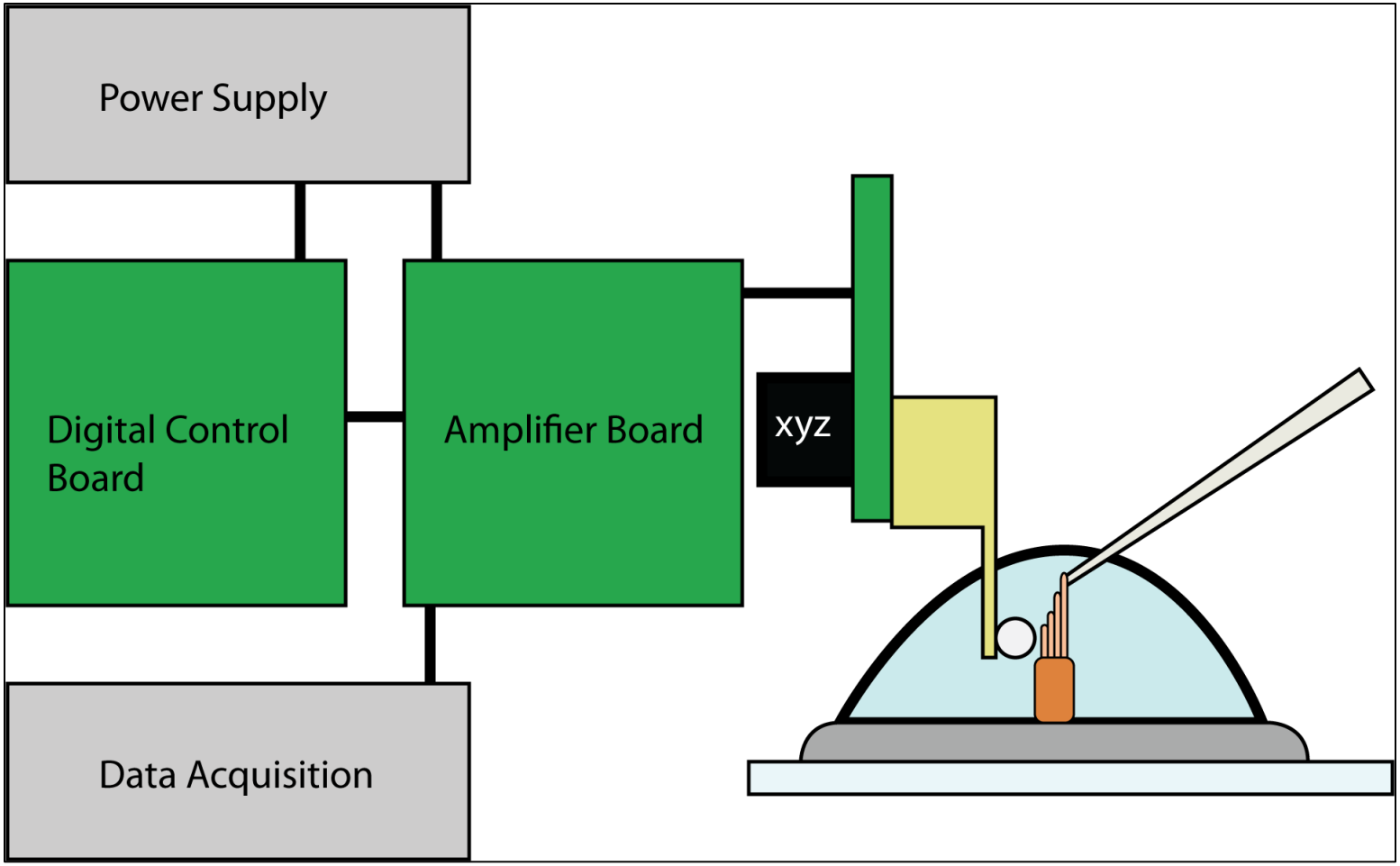


Next Steps

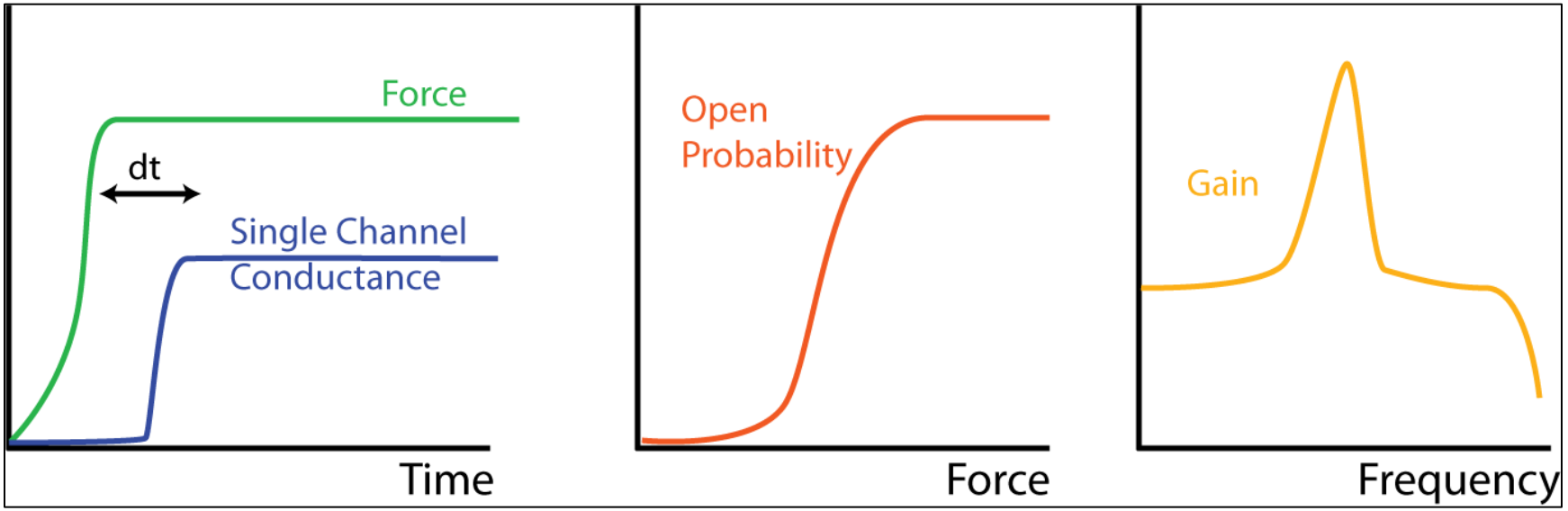
- Writing
  - Cantilever optimization
  - Aluminum nitride on Ti
- Device characterization
- System integration
  - Circuit board
  - Control
- Experiments



Experiment Setup



Neuron Experiments



Conclusions

- Fabrication was pretty successful
  - Curving from high dopant concentration
  - AlN/Ti etch process could be improved
- Noise characteristics are looking good
  - Alpha on par with lowest ion implantation results (large grain of salt)