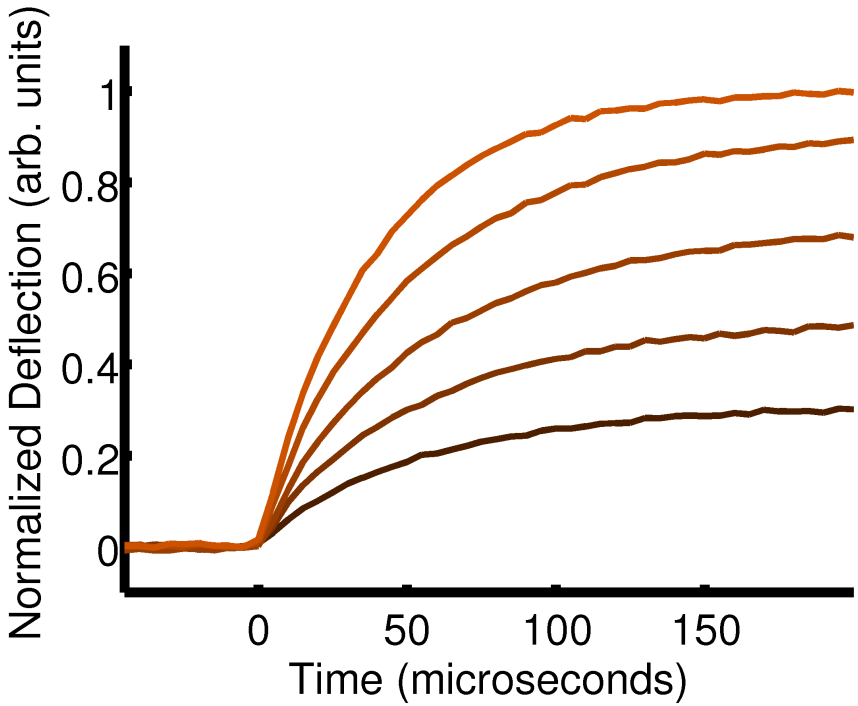


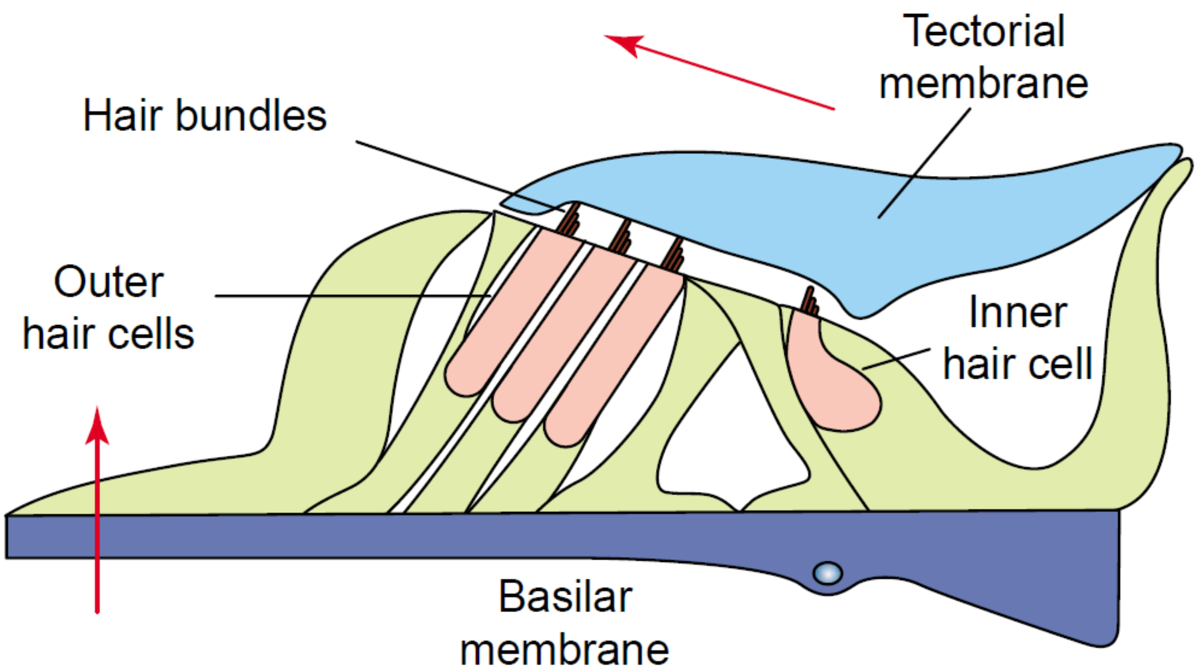
Worm Club Research Update

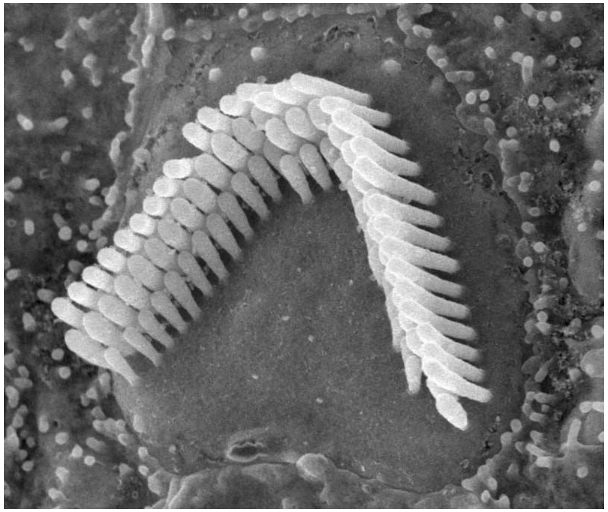
Joey Doll
May 9, 2011

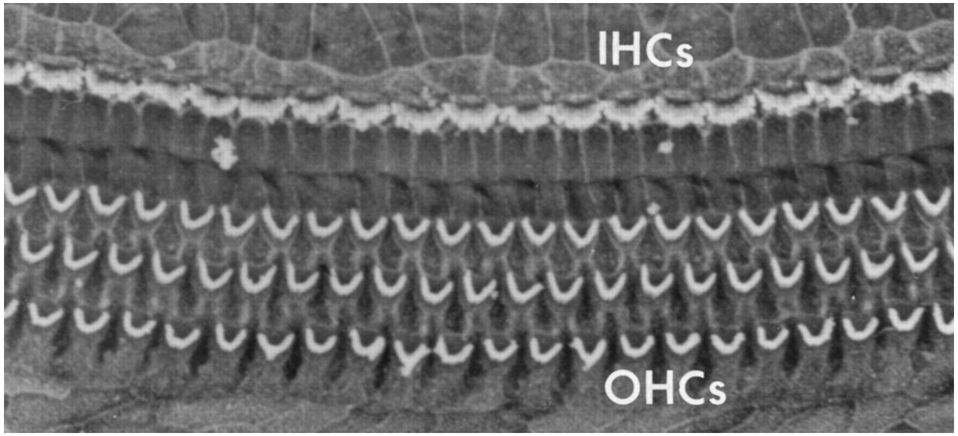
Today

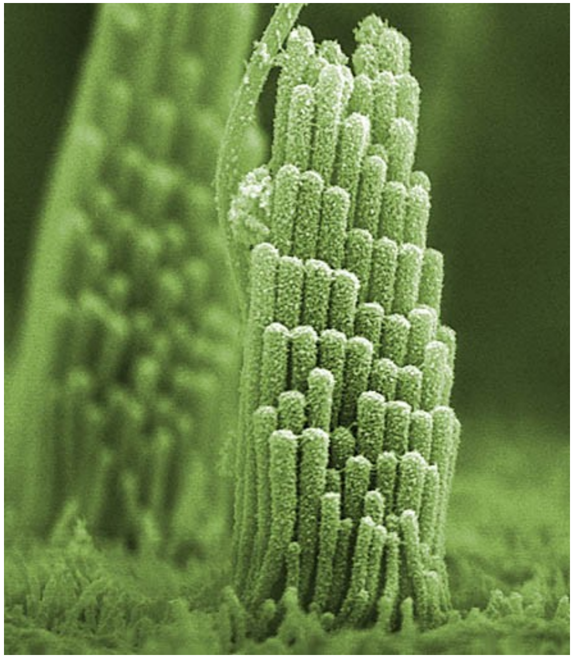
- Motivation and recap
- Progress update
- Debugging and fabrication tricks

Structure of the Cochlea

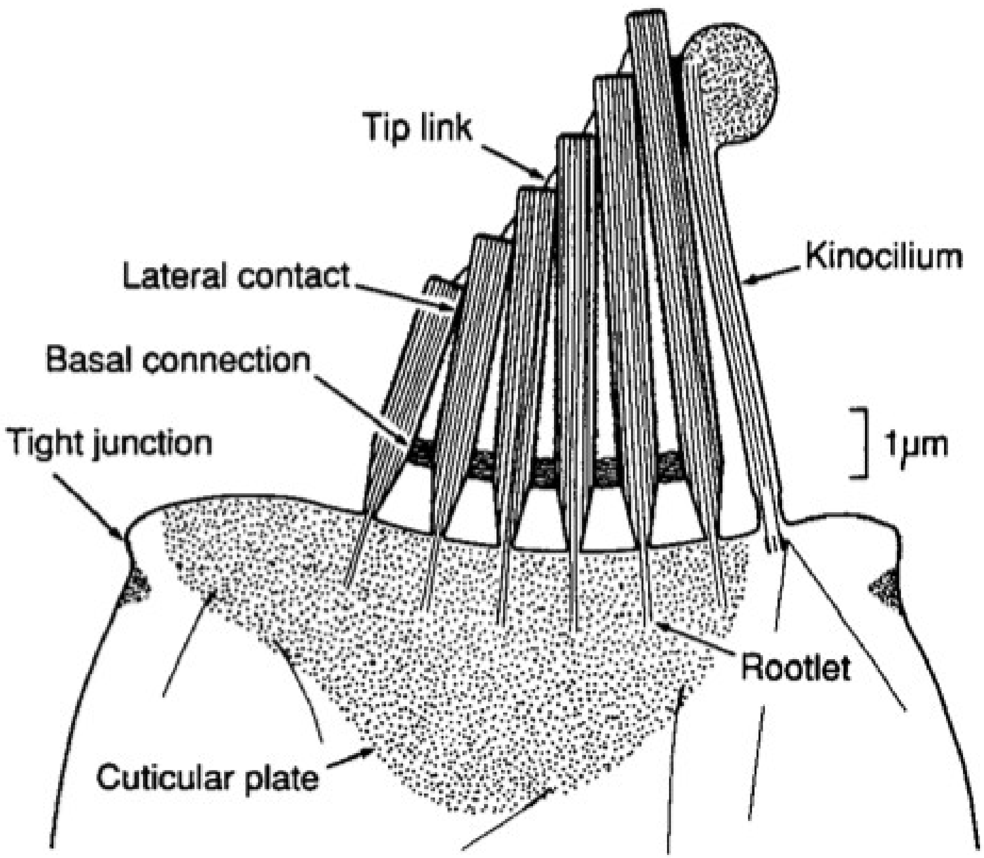


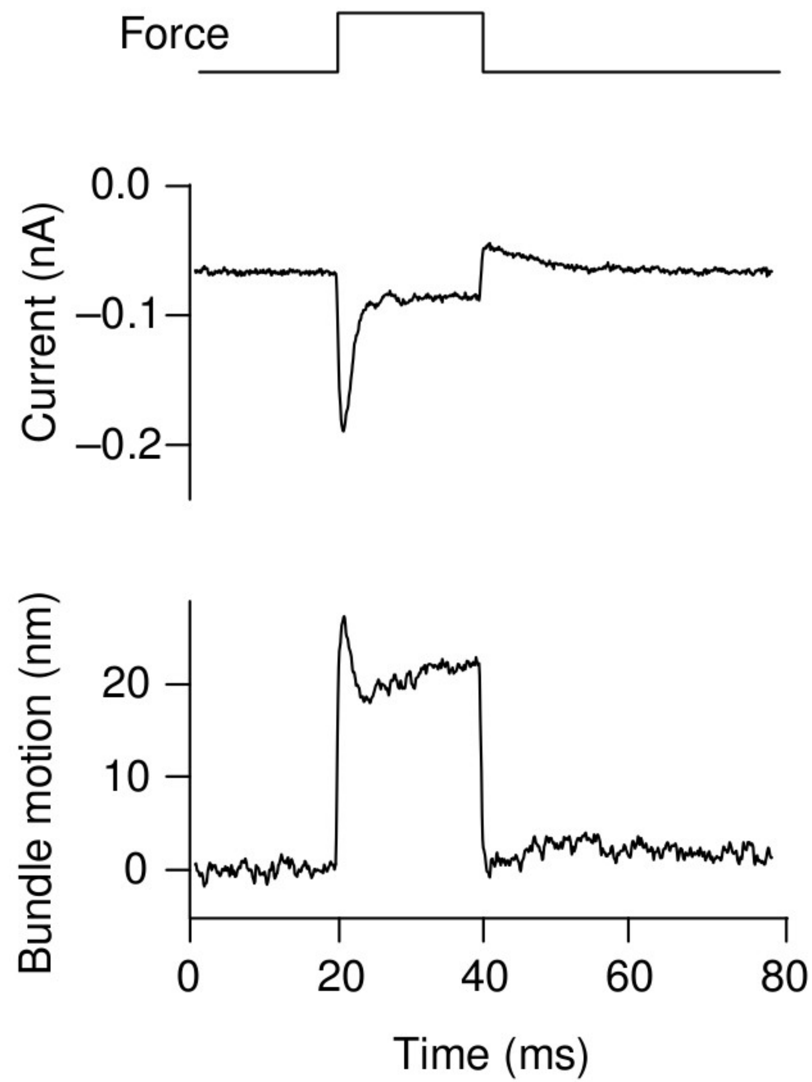




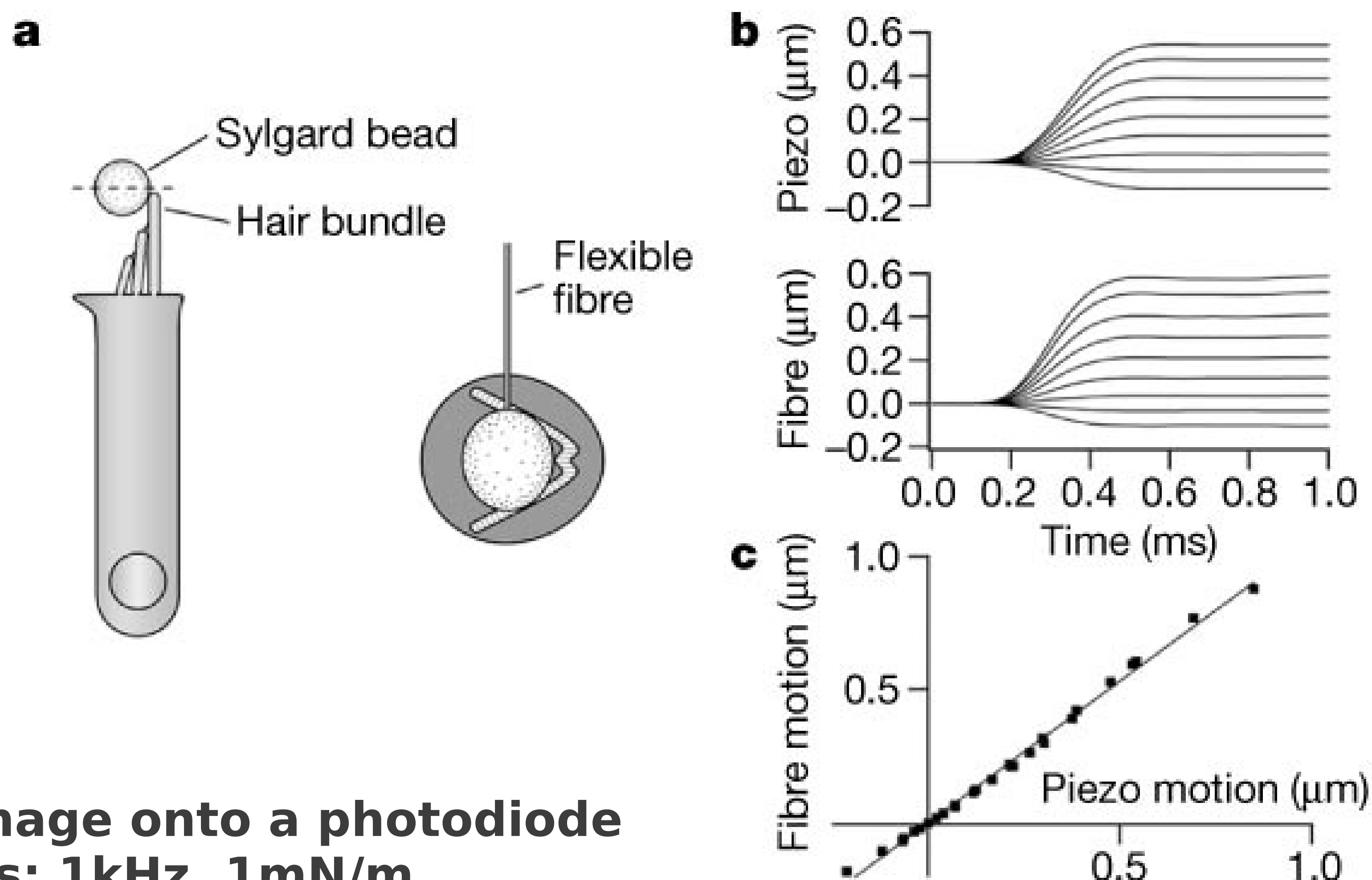


The Cochlear Hair Cell





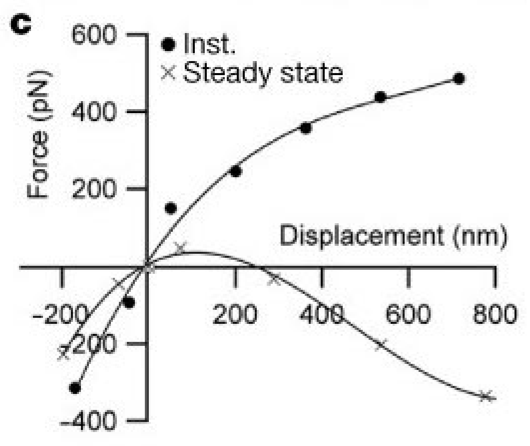
Current Experimental Methods



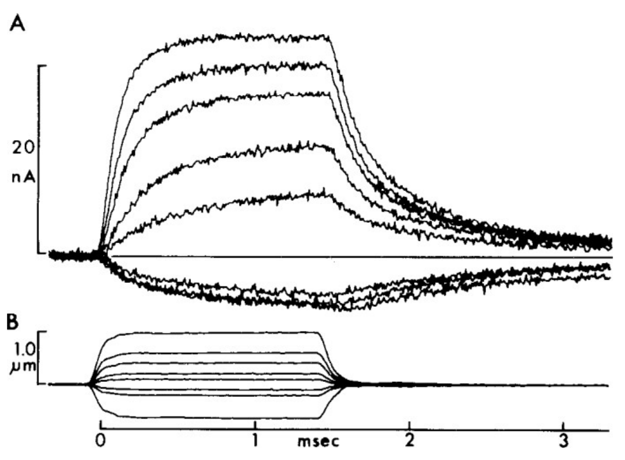
Project image onto a photodiode
Mechanics: 1kHz, 1mN/m
Kinetics: 5-10kHz, >50 mN/m

Cell Experiments

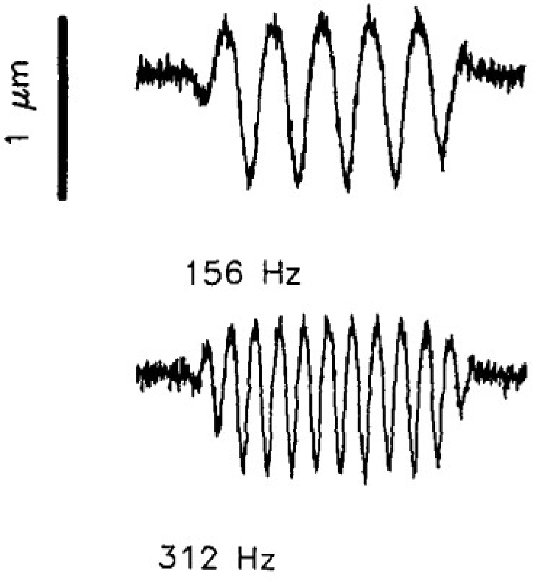
Mechanics



Kinetics



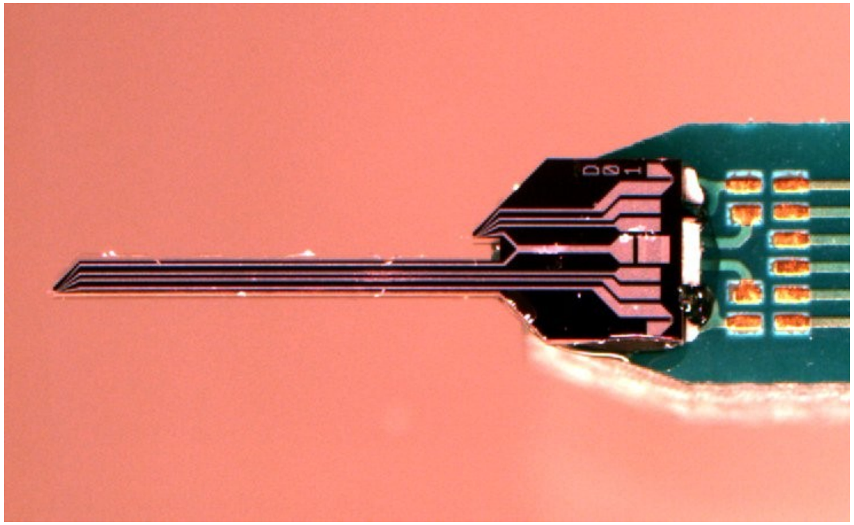
Somatic Motility

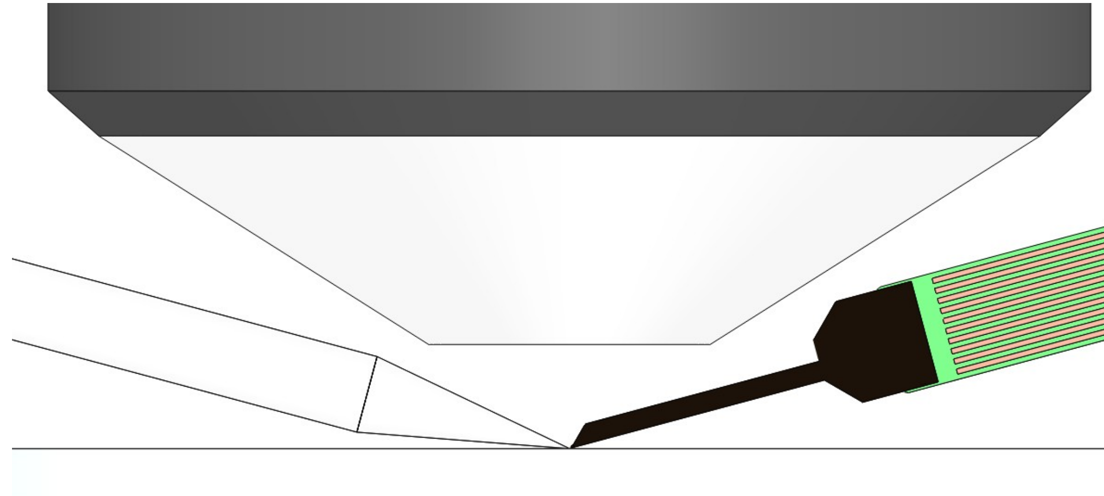


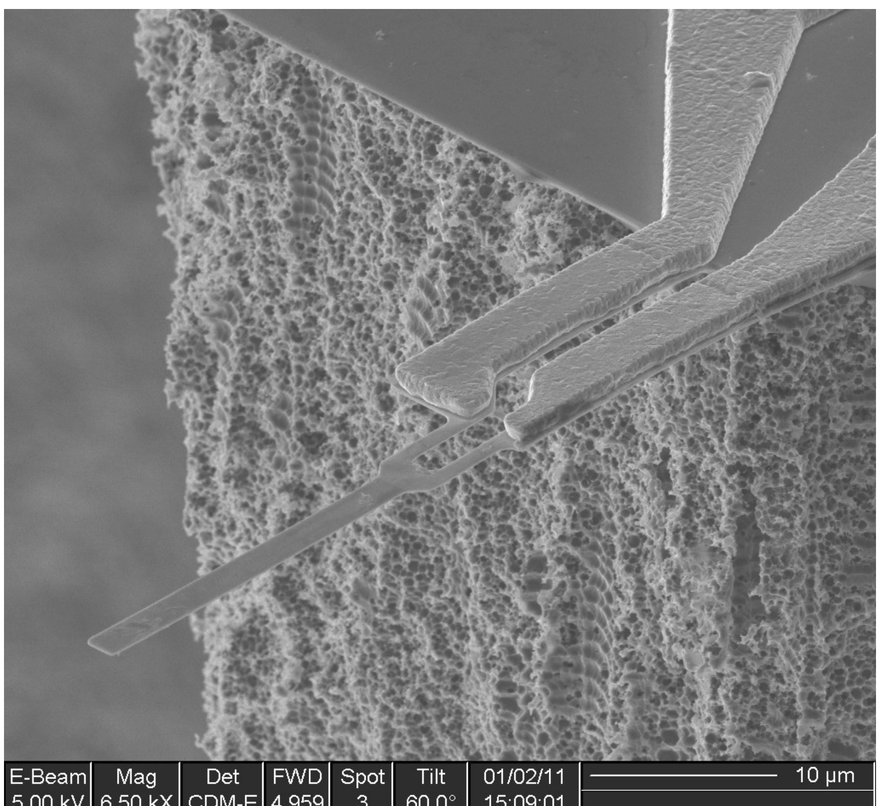
+ touch receptor neurons and other cells/molecules eventually

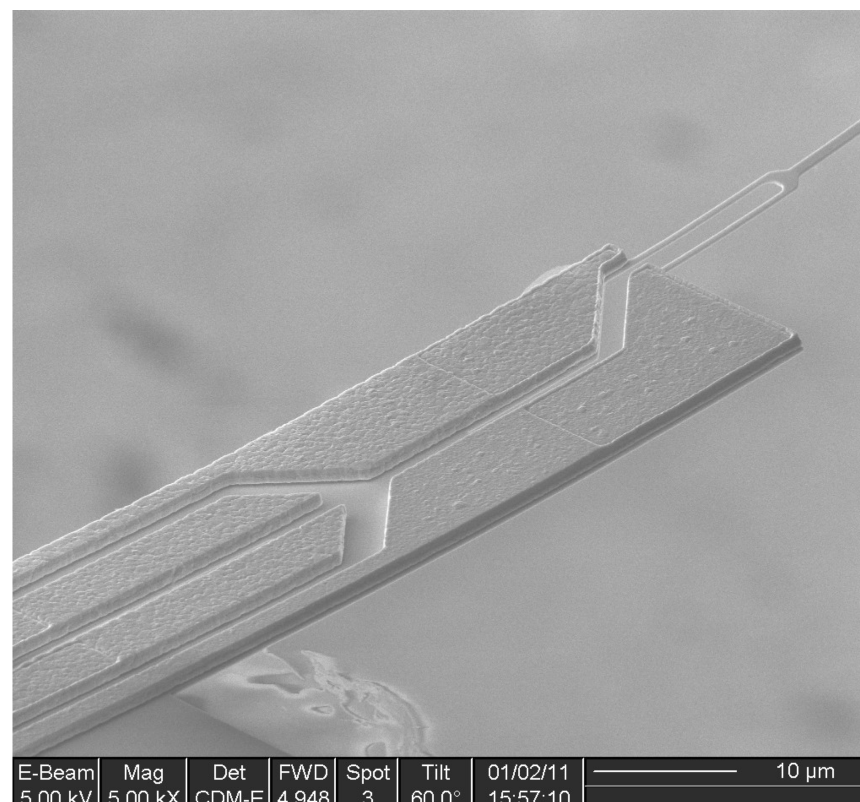
Device Designs

- Mechanics / Motility
  - 0.3 – 4 mN/m
  - 2 – 20 kHz in water (20 – 100 kHz in air)
  - 3 – 30 pN RMS force noise
- Kinetics
  - 10 – 50 mN/m
  - 60 – 200 kHz in water (200 – 500 kHz in air)
  - 30 – 80 pN RMS force noise
- Both types
  - 300 nm thick, 1-2 um wide, 30-200 um long
  - On-chip actuation (thermal and piezoelectric)



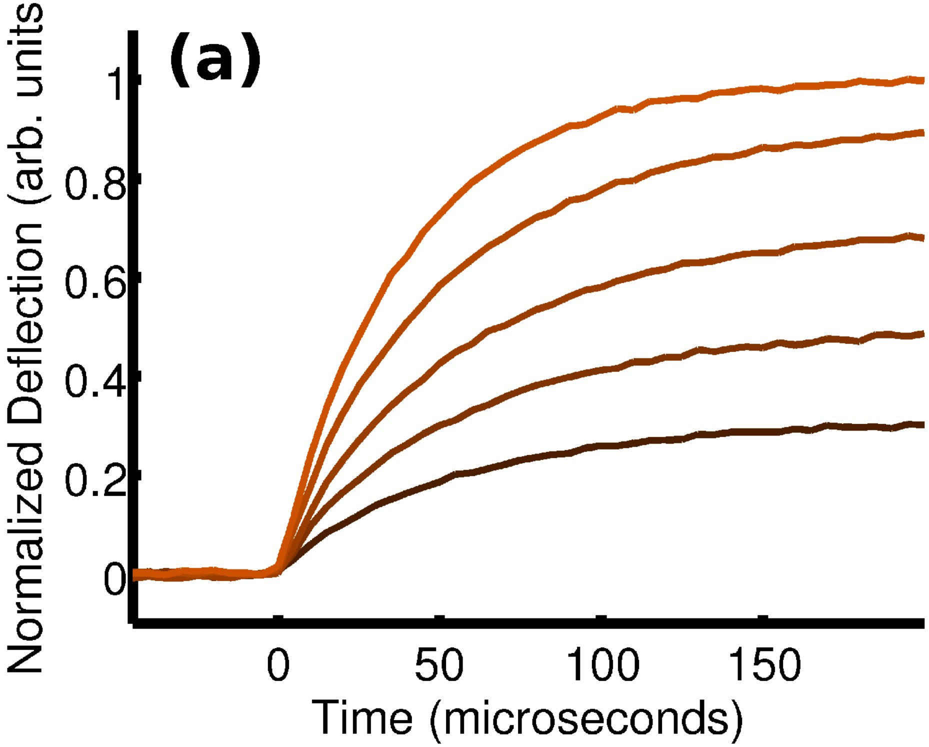



E-Beam 5.00 kV
Mag 6.50 kX
Det CDM-E
FWD 4.959
Spot 3
Tilt 60.0°
01/02/11 15:09:01
10 µm


E-Beam 5.00 kV
Mag 5.00 kX
Det CDM-E
FWD 4.948
Spot 3
Tilt 60.0°
01/02/11 15:57:10
10 µm

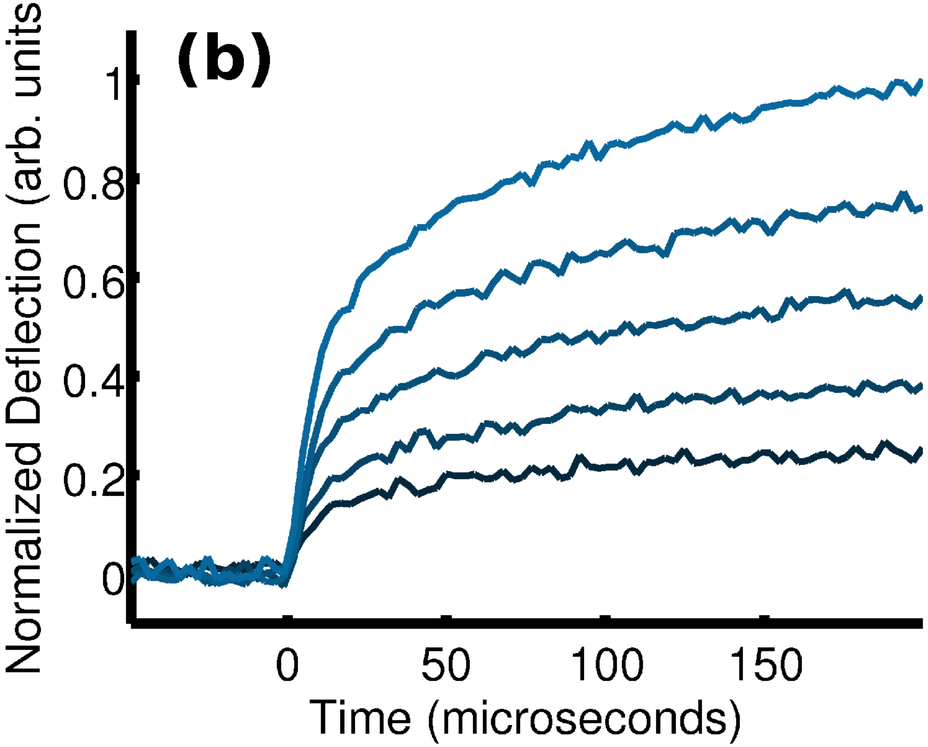
Thermal Actuator Step Response

Air



Tau = 57 ± 10 microseconds

Water

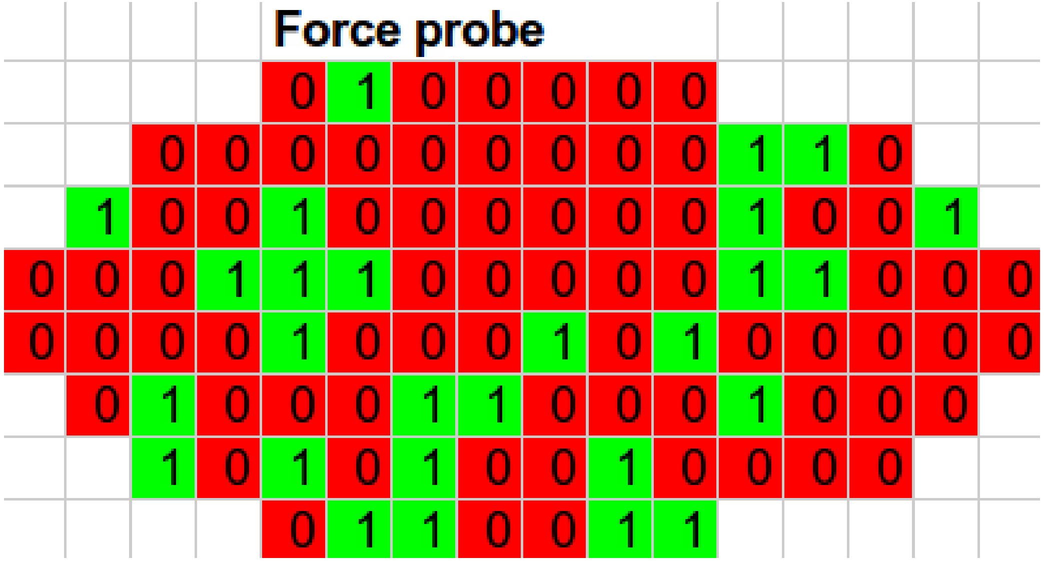


Tau1 = 7.9 ± 1.2 microseconds
Tau2 = 96 ± 11 microseconds

1) Measured using a 50kHz split photodiode detector with Anton, Tony and Robert Fettiplace
2) Anton is building a faster 500kHz photodiode detector
3) Time response limited by heater time constant – piezoelectric will be faster

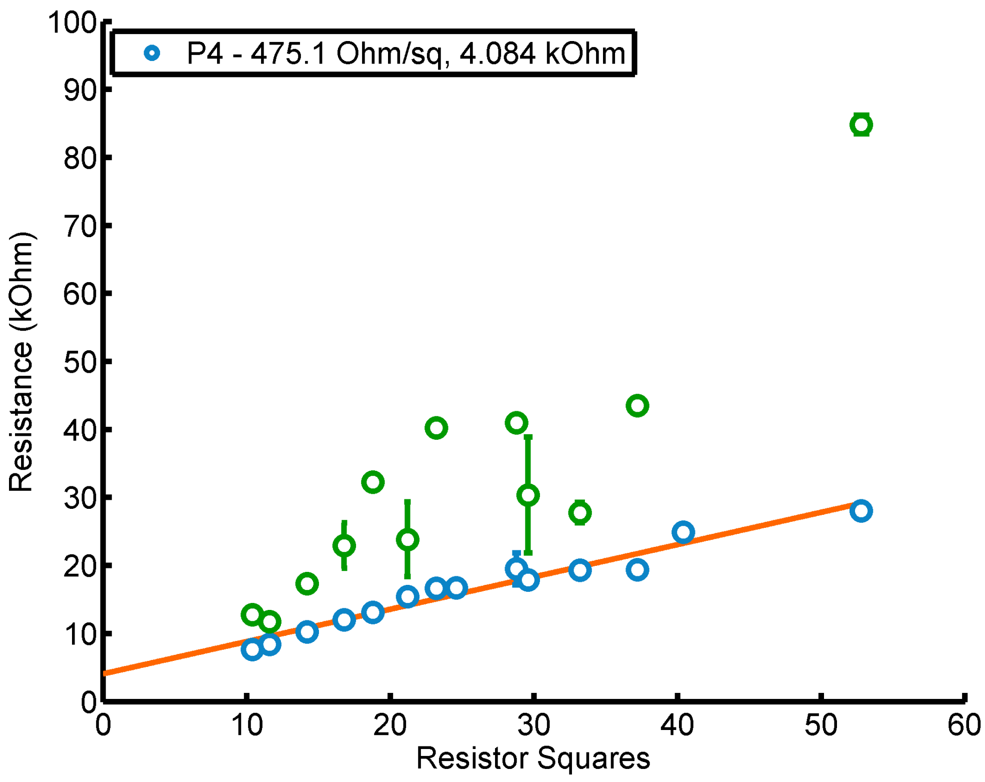
Debugging a Cantilever Process

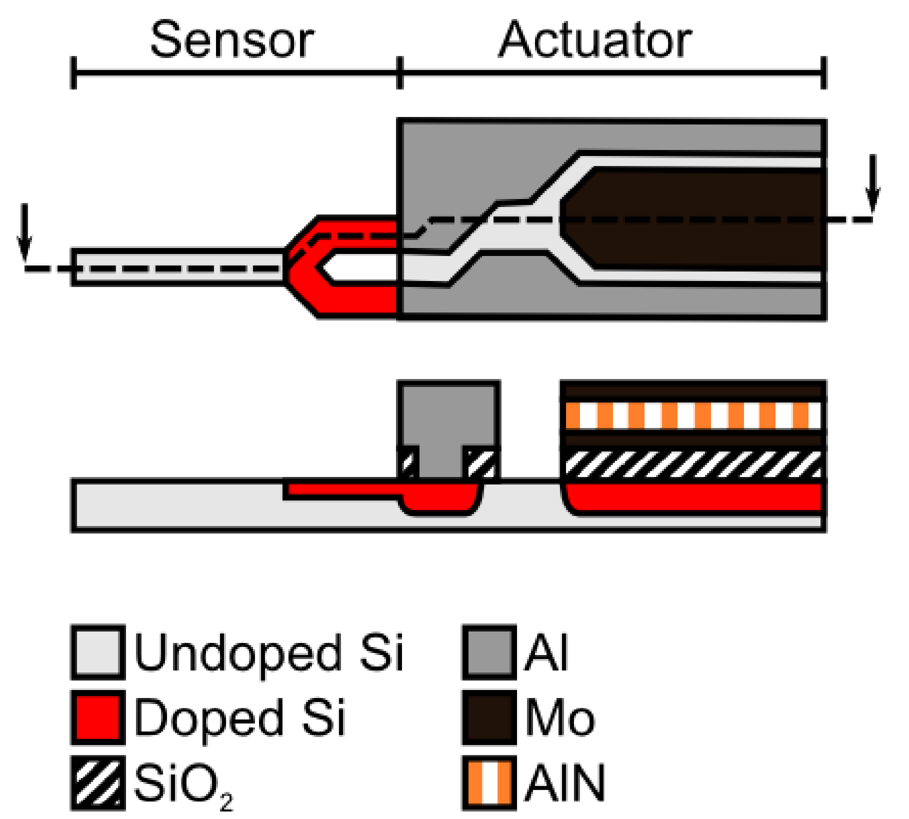
- Shallow doping and surface damage
- Cracking and low yield
- Polymer goop
- Passivation



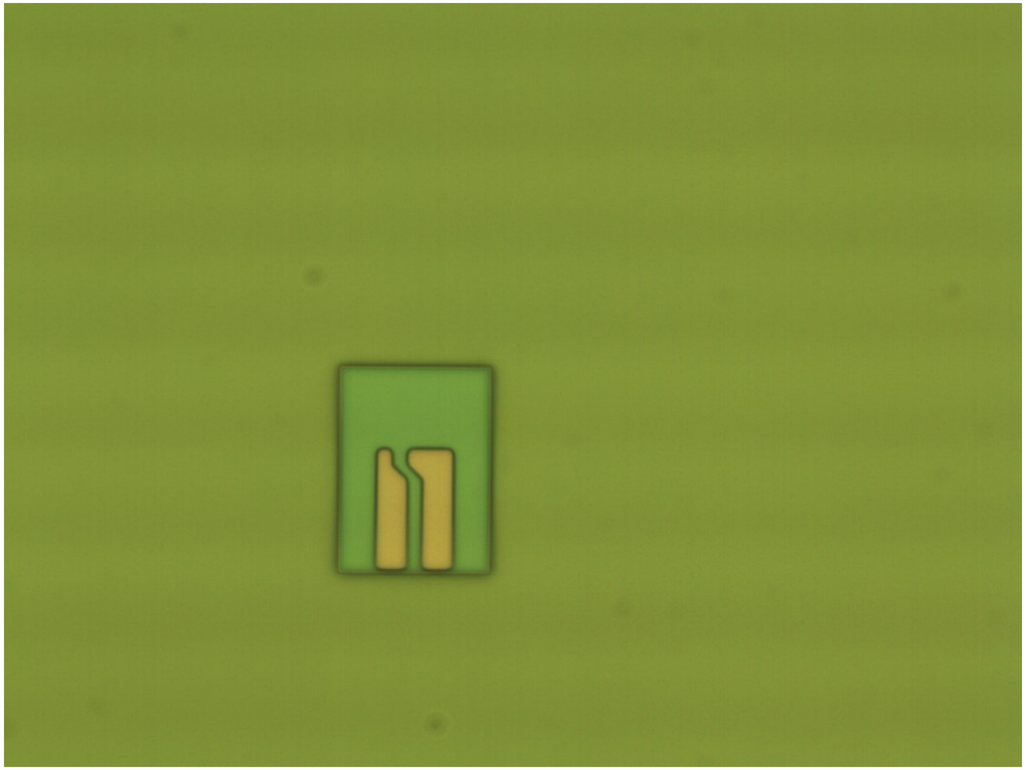
Shallow Doping and Surface Damage

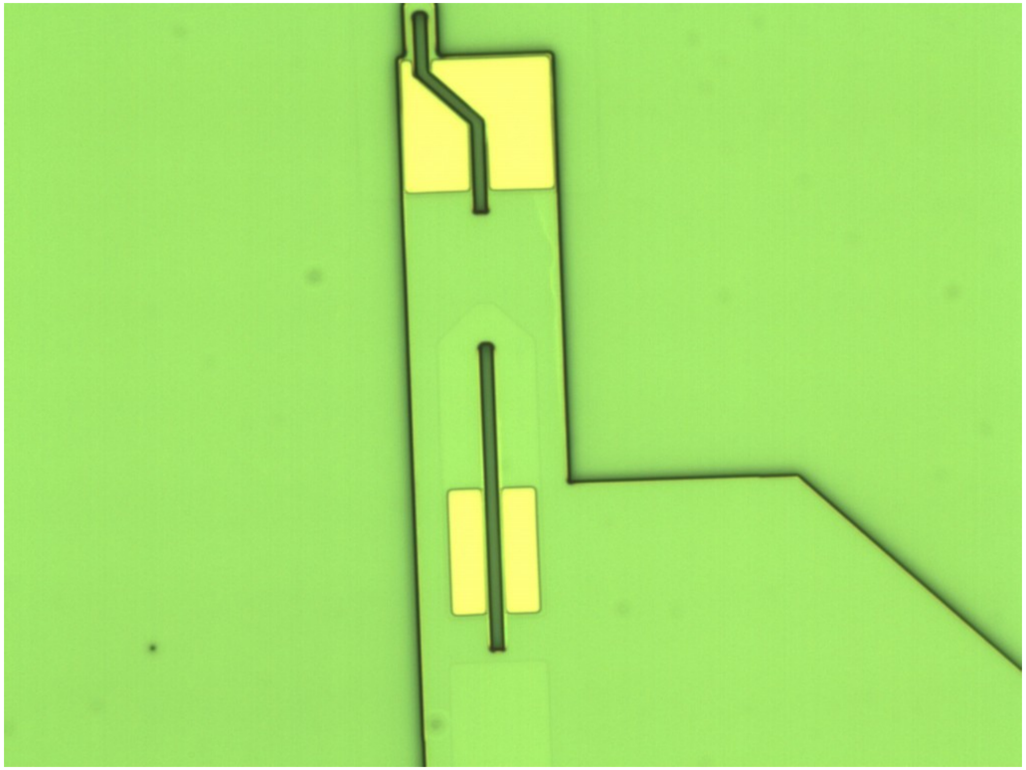
1) Increased piezoresistor depth (15nm → 50nm)
2) Added an extra contact doping step (150nm deep)
3) New tool for release: plasma → HF vapor





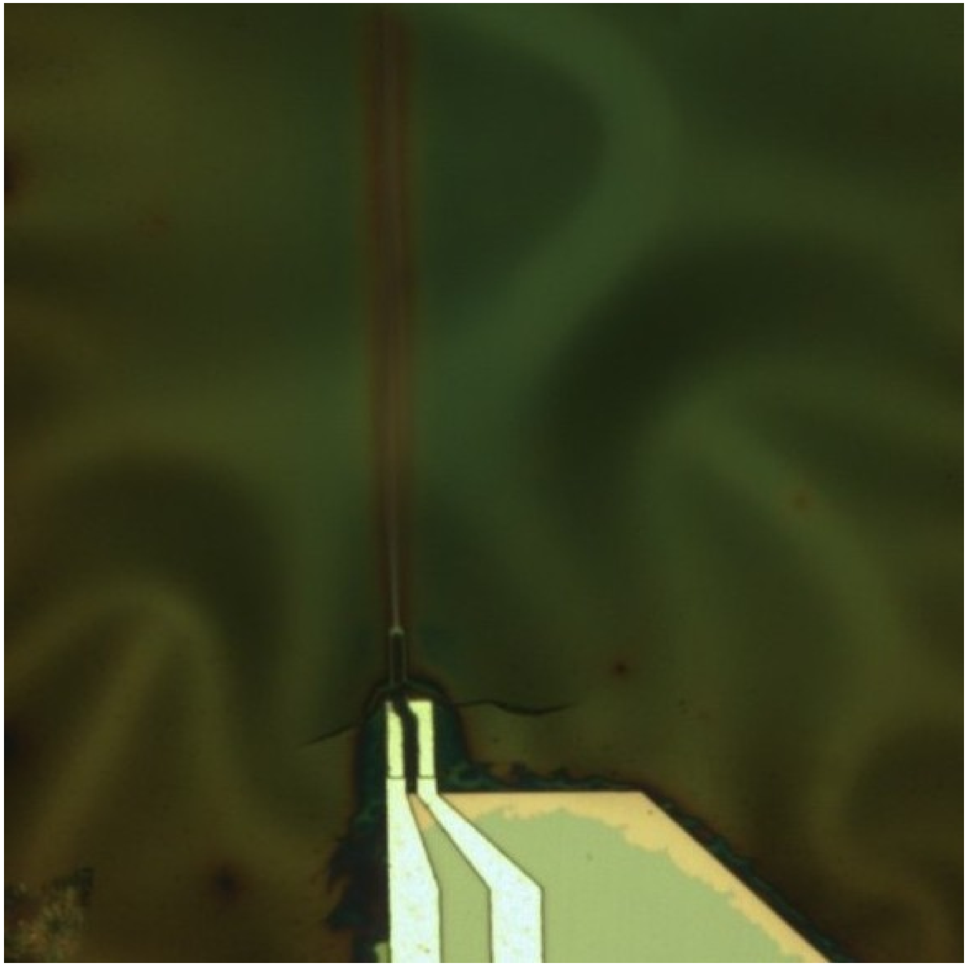
Shallow Doping and Surface Damage



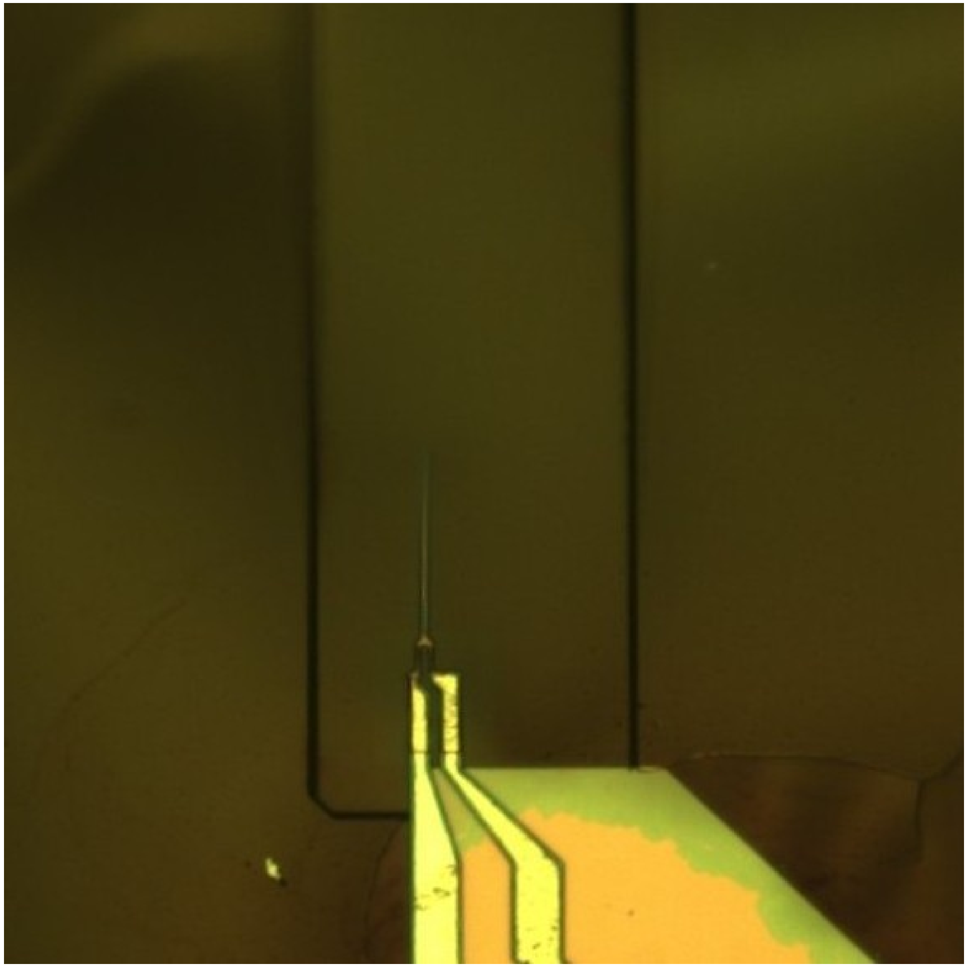


Recycled another image on the reticle
(steppers are the greatest)

Cracking and Cantilever Yield

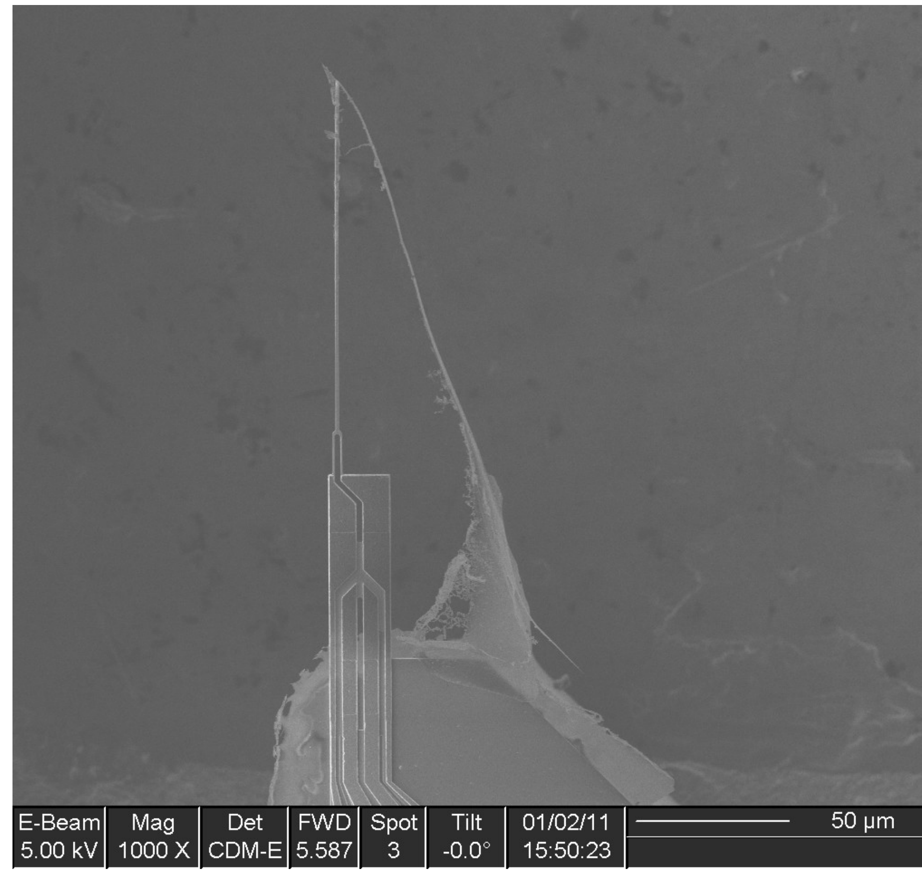


30 ± 15% (10-50%)
(n = 8 wafers)



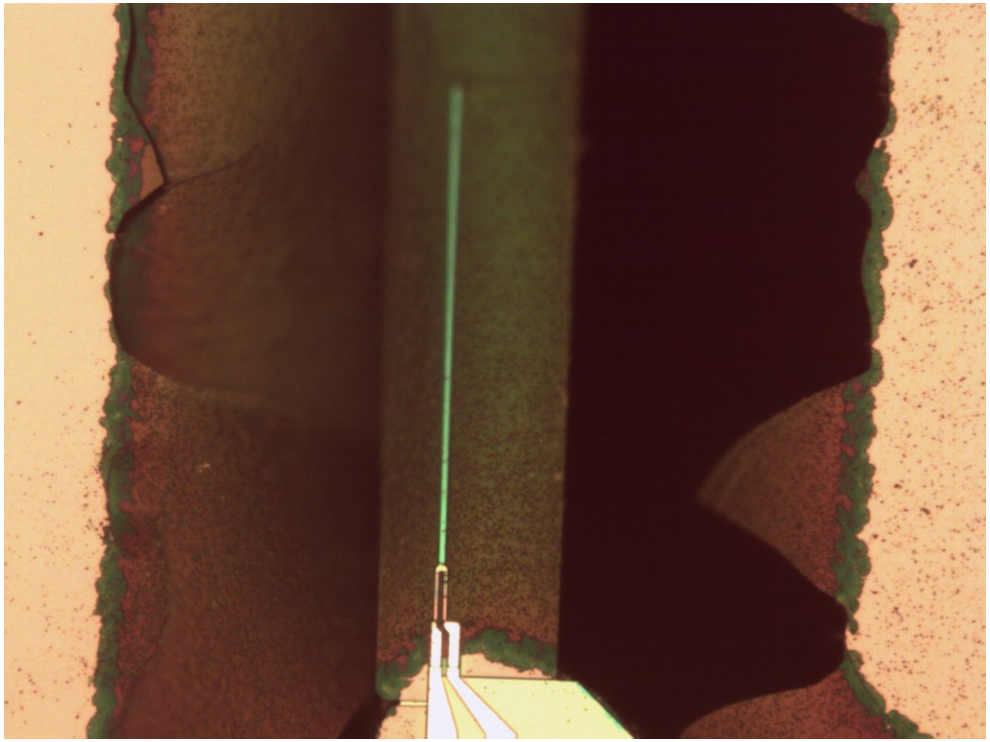
70 ± 17% (51-91%)
(n = 4 wafers)

Polymer Goop

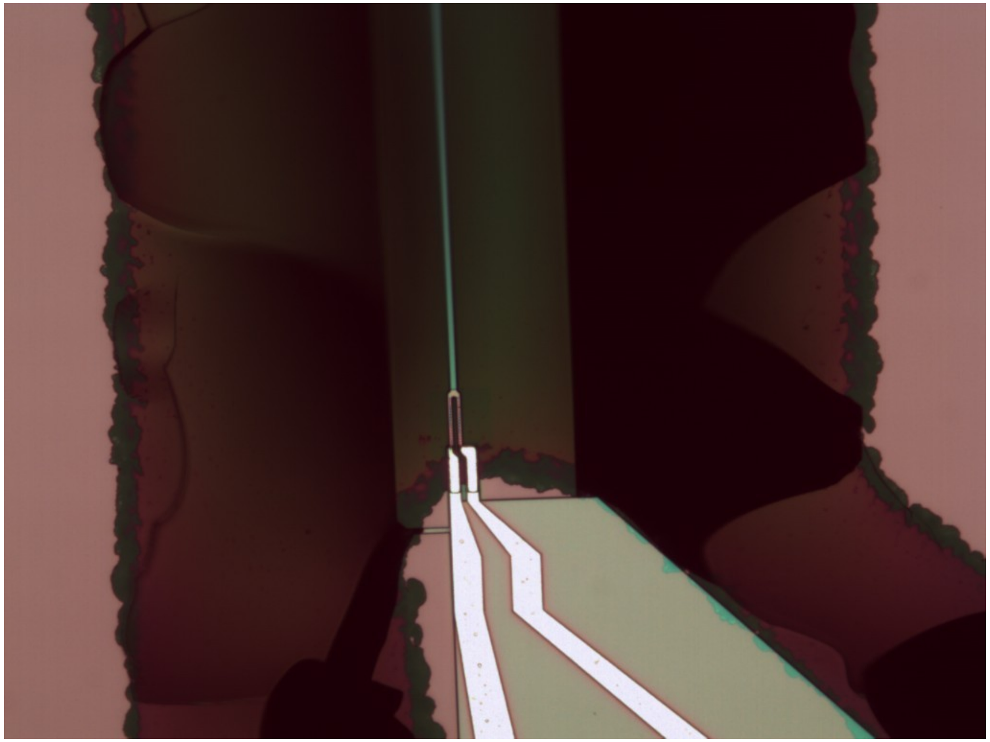


Polymers oxidize in oxygen plasma, right?

Polymer Goop

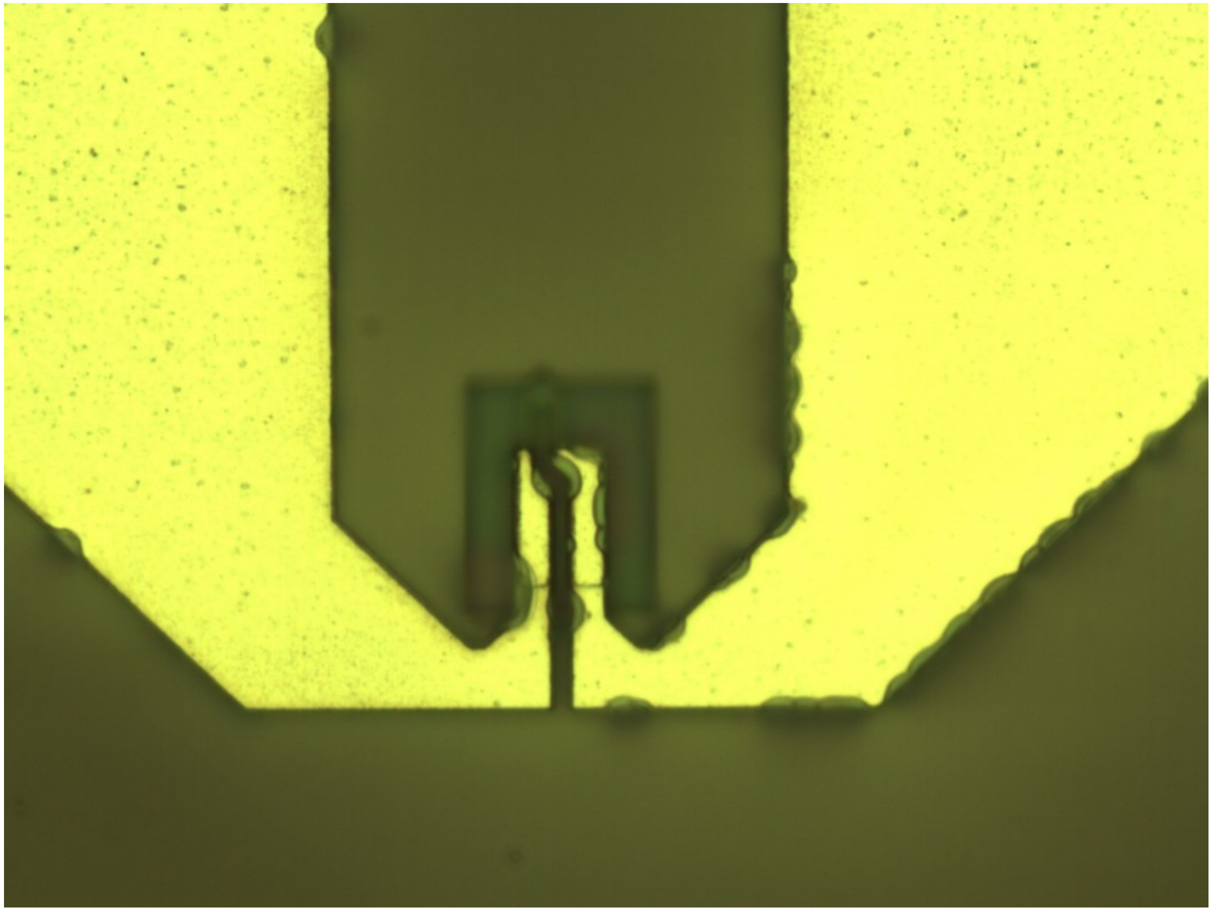


After 60min O2 plasma
(apparently not)



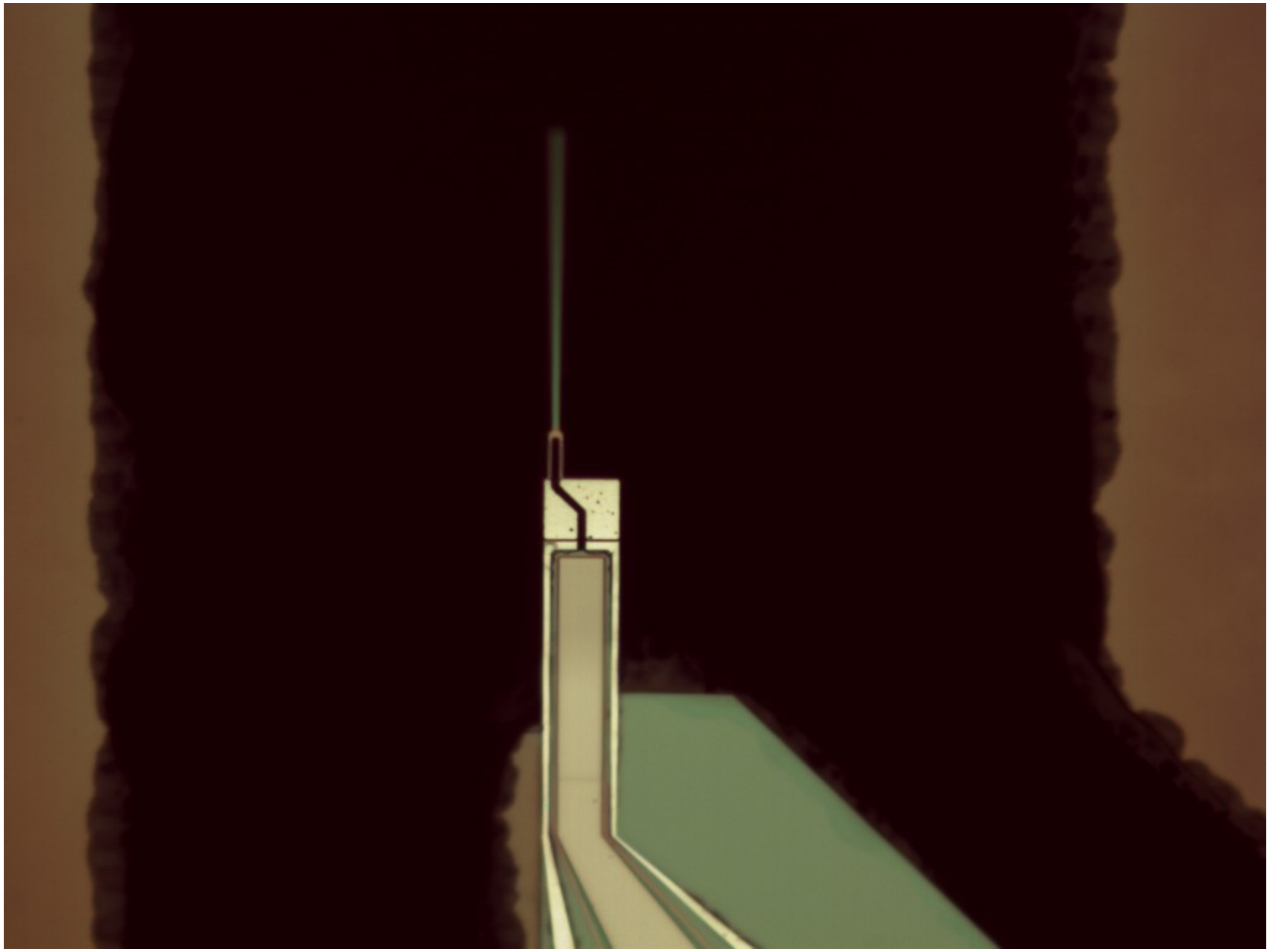
After 2min O2/CF4/SF6 plasma
(addition of fluorine allows
the fluorocarbons to oxidize)

Polymer Goop



Related: Coat everything in LTO before etching
(to prevent corrosion during hot water release
and for protection from the fluorine)

The End Result

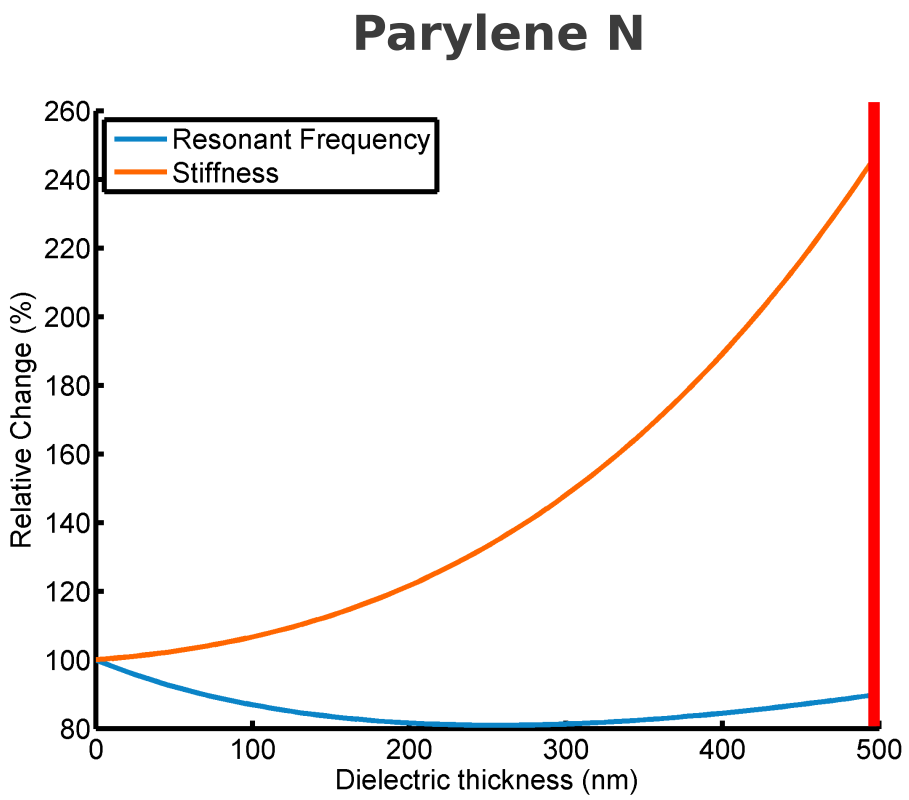


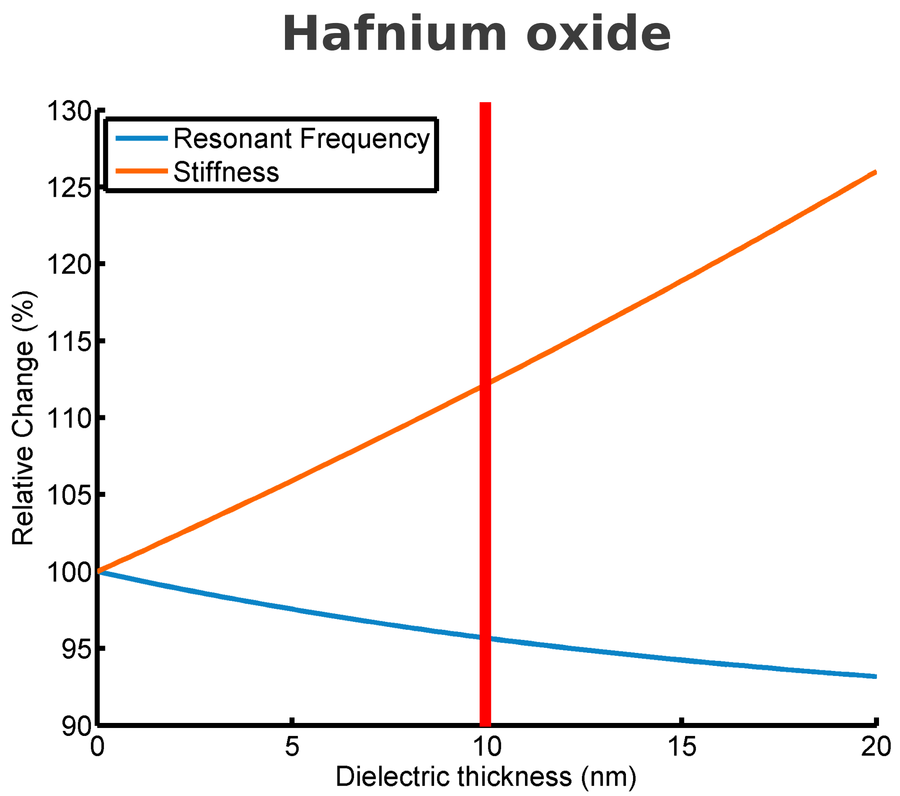
Poly-on-insulator
Piezoelectectric actuator

Passivation

- Devices need to be insulated
  - Electrochemical corrosion
  - Shunt resistance
- Parylene
  - Somewhat conformal
  - >500nm thick to coat all exposed surfaces
  - Polymer → soft and squishy, water permeable
- Atomic layer deposition (ALD) metal oxides
  - Conformal and pinhole free for >4nm
  - Ceramic → hard, not very water permeable

Passivation

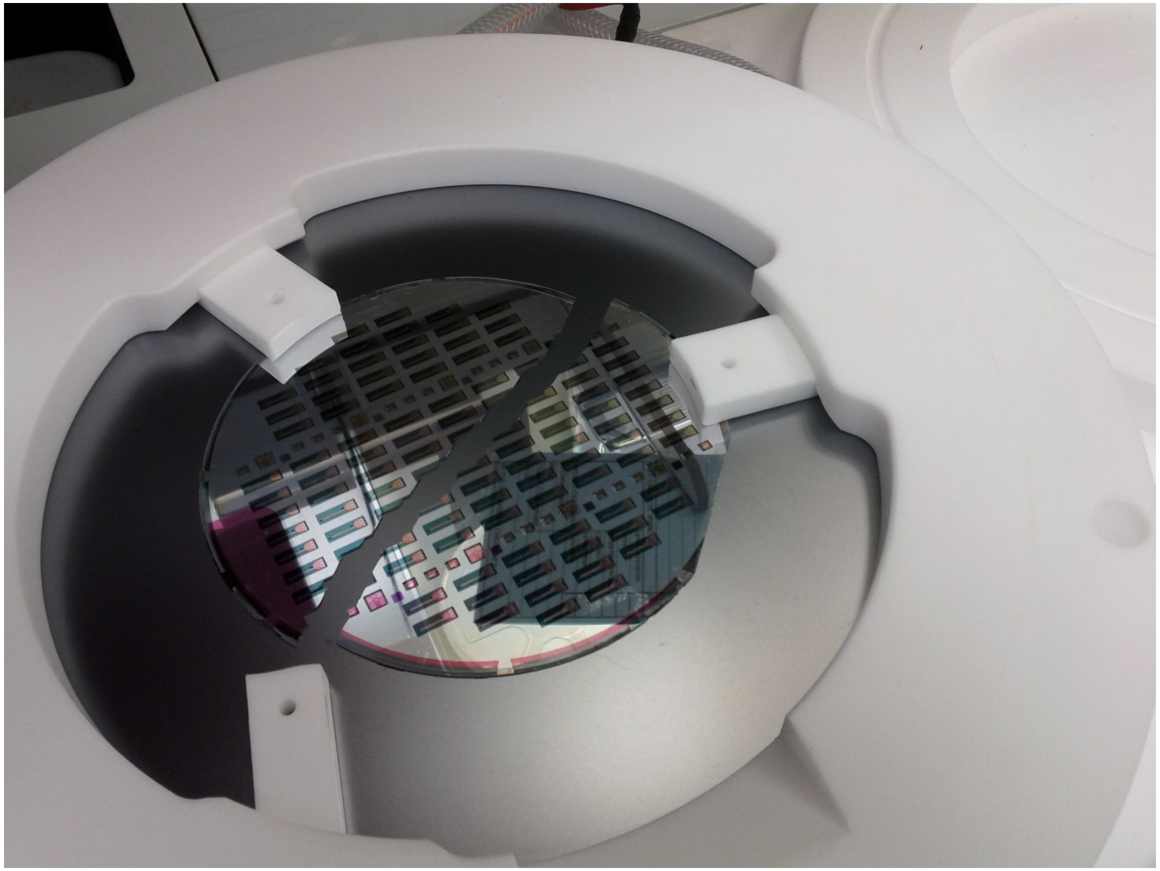




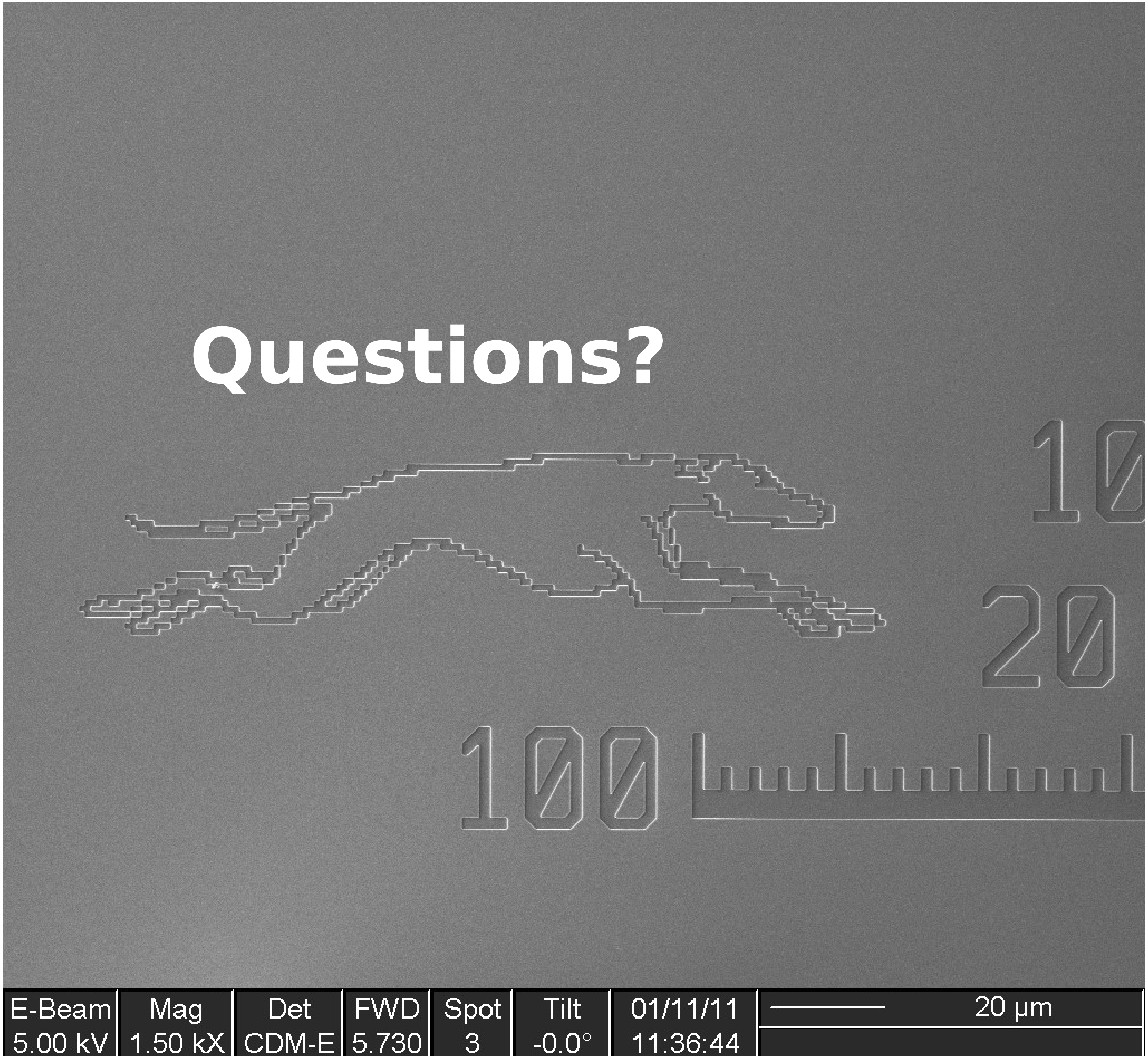
(Detailed ALD electrochemistry experiments are ongoing with Alex H.)

Conclusions

- Just finished releasing 8 wafers
  - 2 PE wafers done
  - ~3 good wafers
- Shipping the last batch to Michigan
  - 5 wafers today
  - 4 wafers Thurs



Questions?


10
20
100
E-Beam
5.00 kV
Mag
1.50 kX
Det
CDM-E
FWD
5.730
Spot
3
Tilt
-0.0°
01/11/11
11:36:44
20 µm