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Recipe for Insulating a Noble Metal Alloy Electrical Contact: Stick it in an "Inert" Lubricant, Rub and Shake it

B.L. Nation, M.T. Dugger, and N. Argibay

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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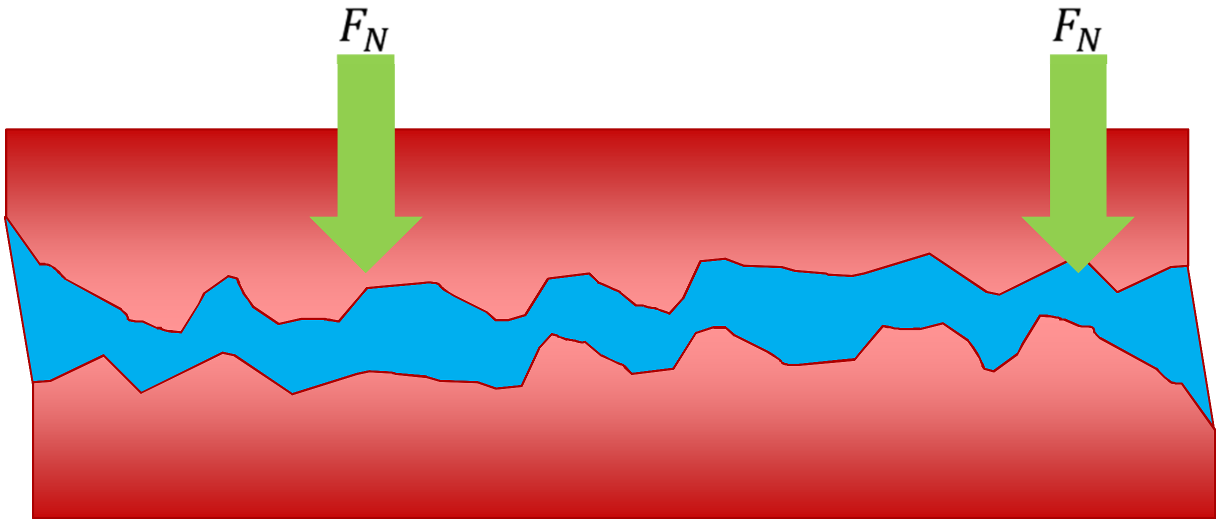
What is Tribology?

- *Tribos*- to Rub
- Study of Friction and Wear

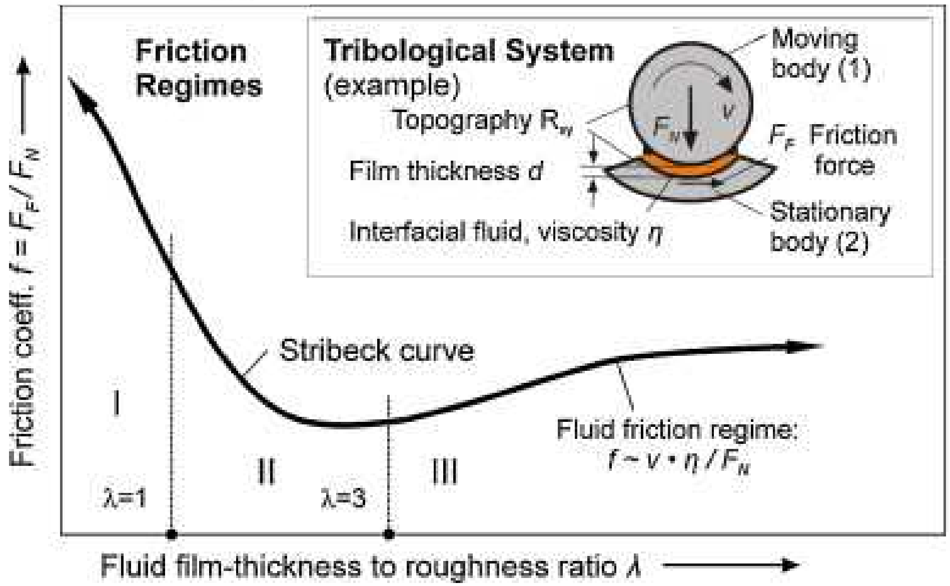
Why?

- Wasted Energy/Heat
- Component/Lubricant Lifetime
- Particle Generation

How Do Lubricants Work?



$$\mu = \frac{F_f}{F_N}$$



Friction regimes (sliding motion)

I Solid friction, $\lambda < 1$

Friction coefficients $f \approx 0{,}05 \ldots >1$

Friction mechanisms: elastic hysteresis, adhesion, microdeformation; interfacial shearing (boundary friction); fatigue

II Mixed friction, $1 < \lambda < 3$

Friction coefficients $f \approx 0{,}02 \ldots 0{,}1$

Friction is a coexistence of I and III

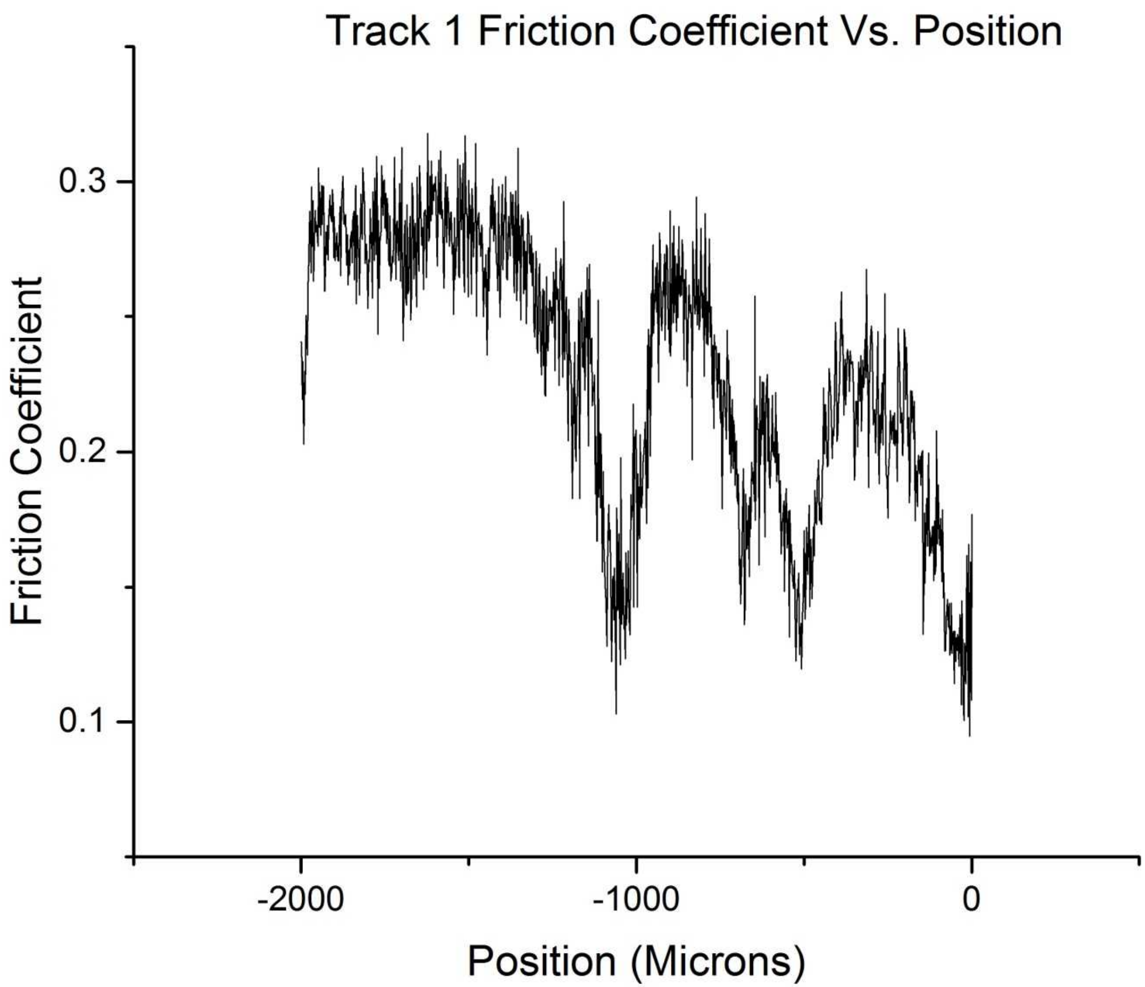
III Fluid friction, $\lambda > 3$

Friction coefficients $f \approx 0{,}001 \ldots 0{,}05$

hydrodynamics, elastohydrodynamics (EHD), rheology (fluid viscosity η) and pressure-viscosity coefficient α

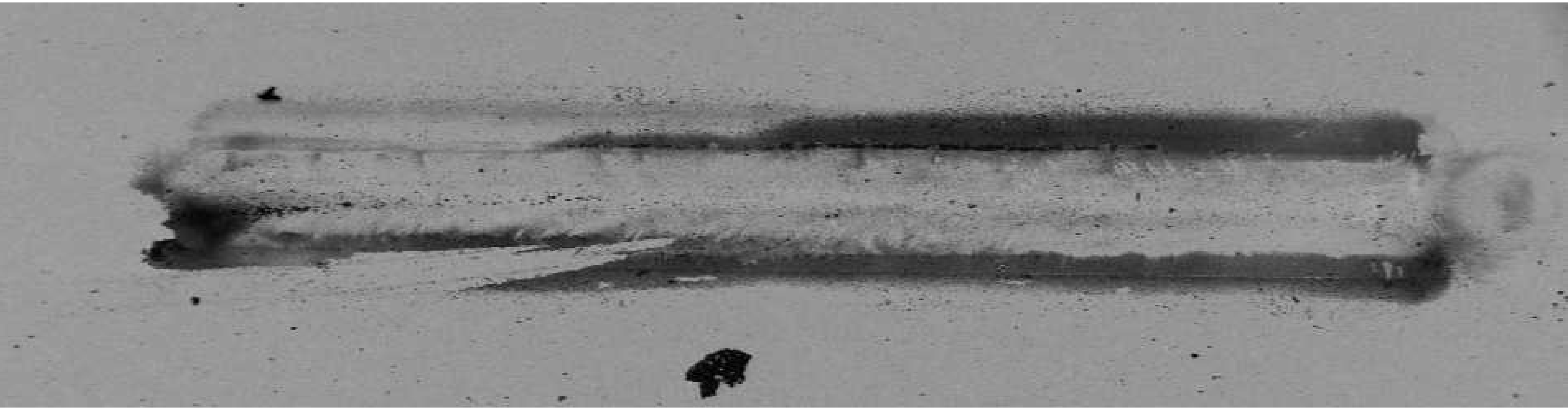
Friction Testing: Basics

Lubricar



The Problem

- Paliney 7 and Neyoro G contacts show increased electrical contact resistance (ECR) after submersion in Silicone Oils and multiple “connect”/”disconnect” cycles.
- Initial investigation found an insulating deposit that appears to be a Si-C-O compound and may be related to vibration in contacts
- Formation mechanism and prevention are key interests



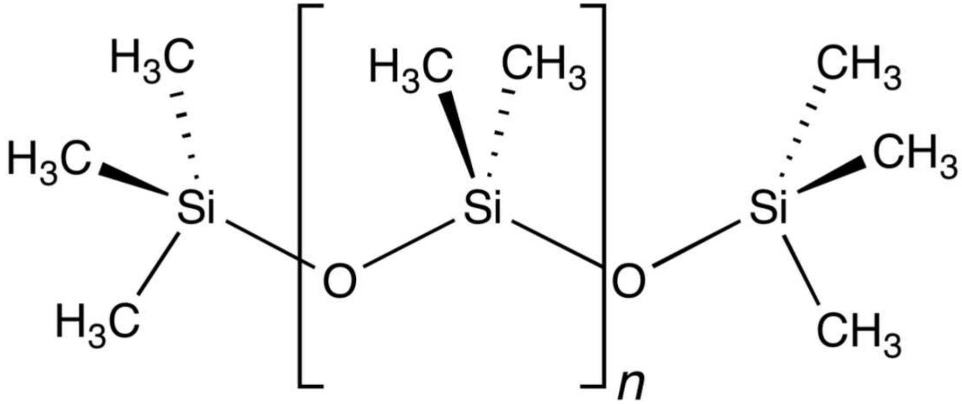
The Alloys

Alloy Name	Pd	Ag	Cu	Pt	Ni	Zn	Au
Paliney 7	34.8	29.4	23.3	5.4	N/A	1.6	5.4
Neyoro G	N/A	6.0	33	6.3	N/A	2.2	52.5

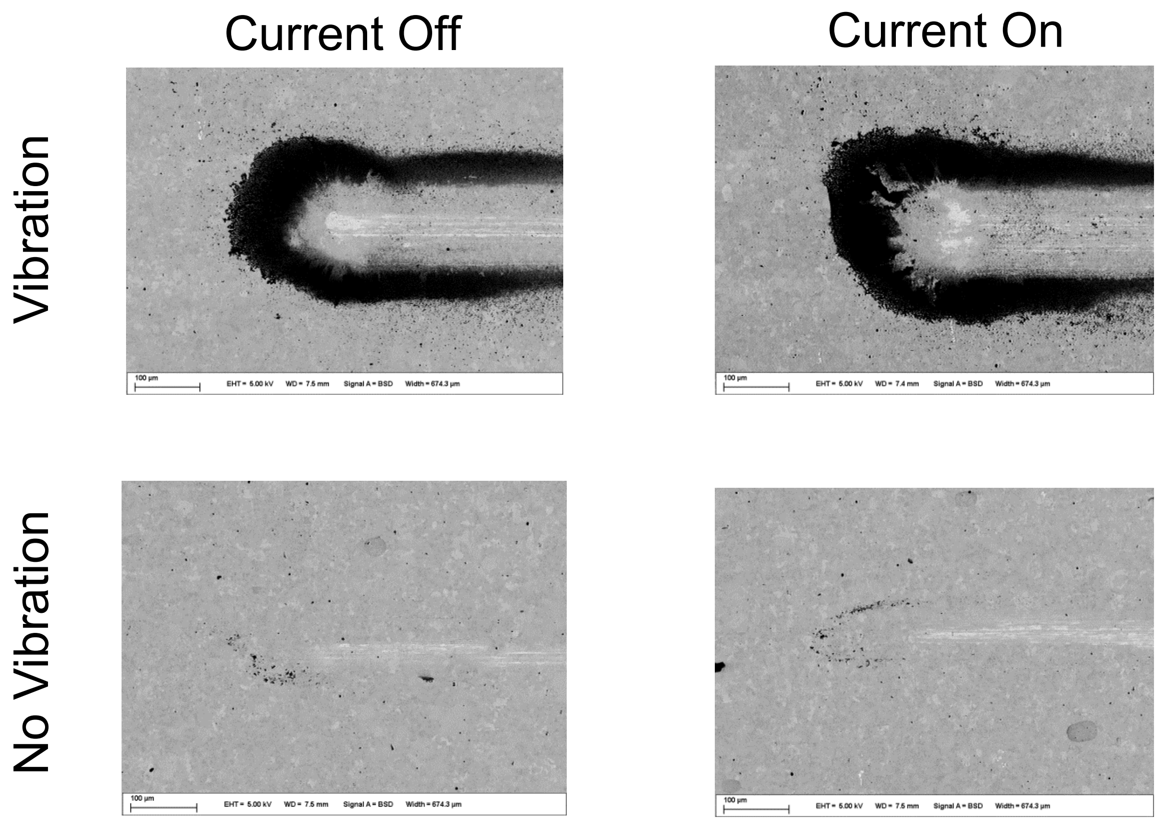
The lubricant

Chemical Formula: $SiO(CH_3)_2$ Chemical Name:Poly(dimethylsiloxane)

Property	Xiameter PMX-200 Silicone Oil
Pour Point, C	-65
Viscosity at -40 C, cS	400
Viscosity at 25 C, cS	20
Viscosity at 40 C, cS	15.1
Viscosity at 100 C, cS	6.1
Surface Tension, mN/m	20.6
Specific Gravity at 25 C	0.949
Refractive Index	1.4
Flash Point, C	204
Thermal Conductivity, W/m.K	0.142
Dielectric Strength, V/mil	375
Thermal Expansion Coeff., cc/cc.C	1.07E-03



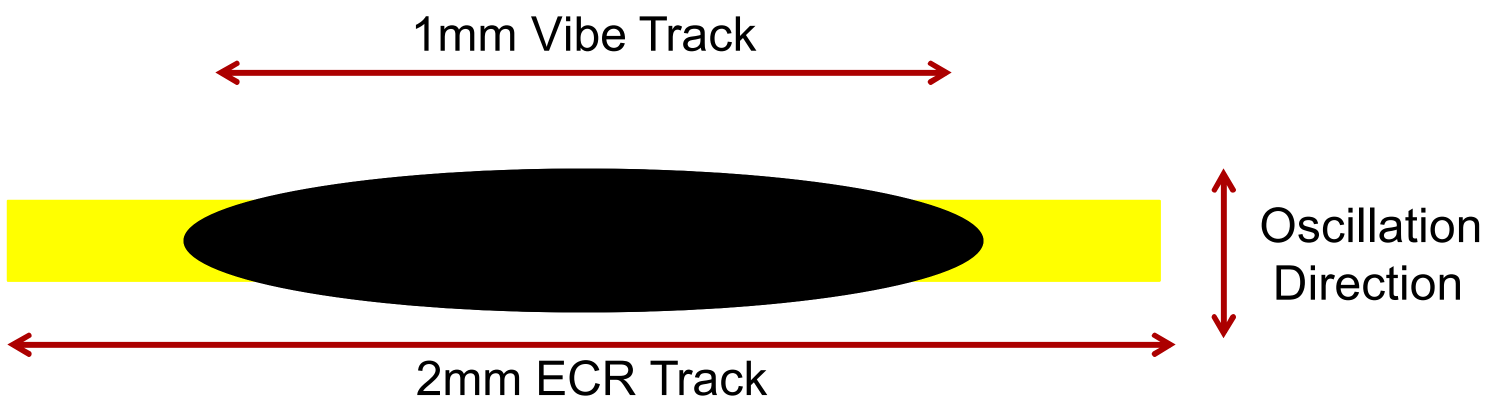
Vibration Matters



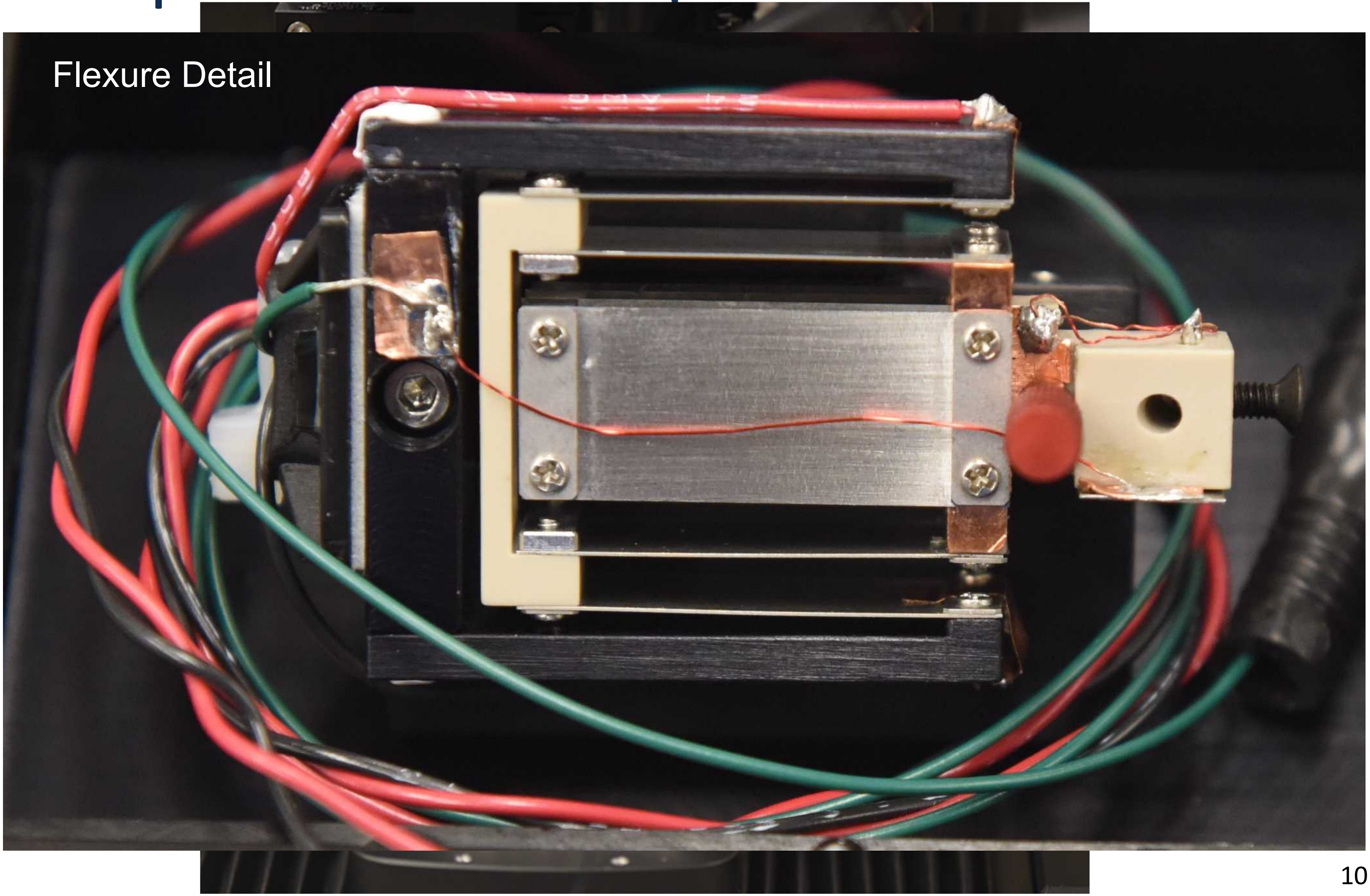
Current not required for degradation

Testing Profile

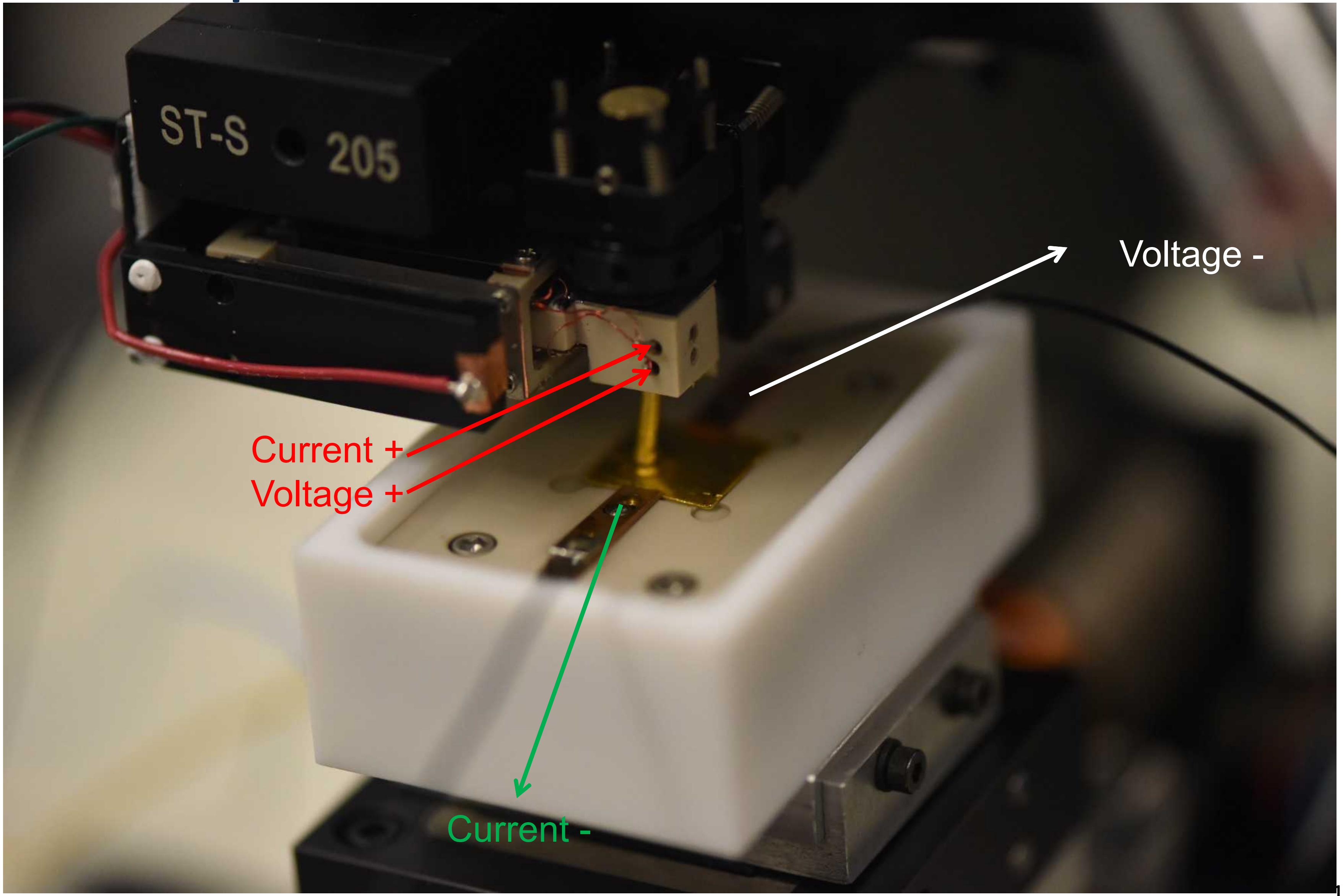
- Standard Testing Procedure:
  - Slow ECR measurement (100 microns/second) over 2mm track for 3 cycles
  - Turn Off ECR, Fast 1mm (2mm/second) Vibe Track for 100 cycles in center of 2mm track
  - Slow ECR measurement (100 microns/second) over 2mm track for 20 cycles
  - Create map of Friction and ECR vs. Cycle and Position along track



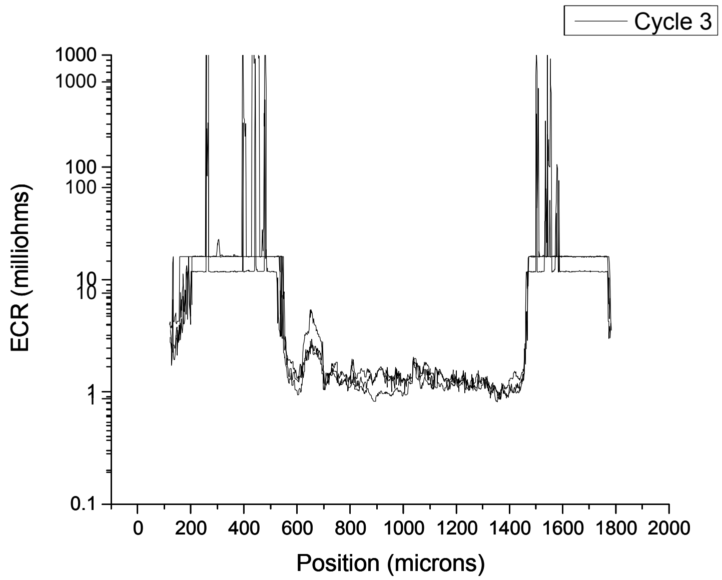
Experimental Setup



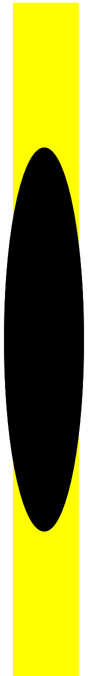
Oil Cup Detail/ 4-wire ECR

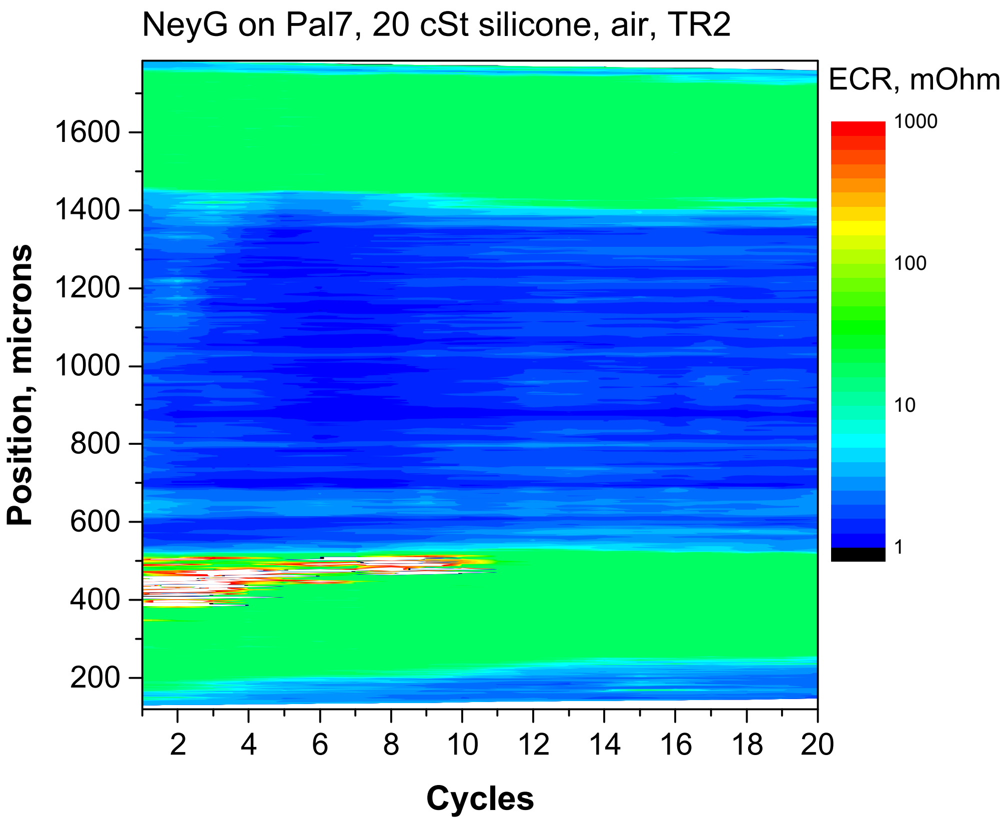


Example Track



Example Results

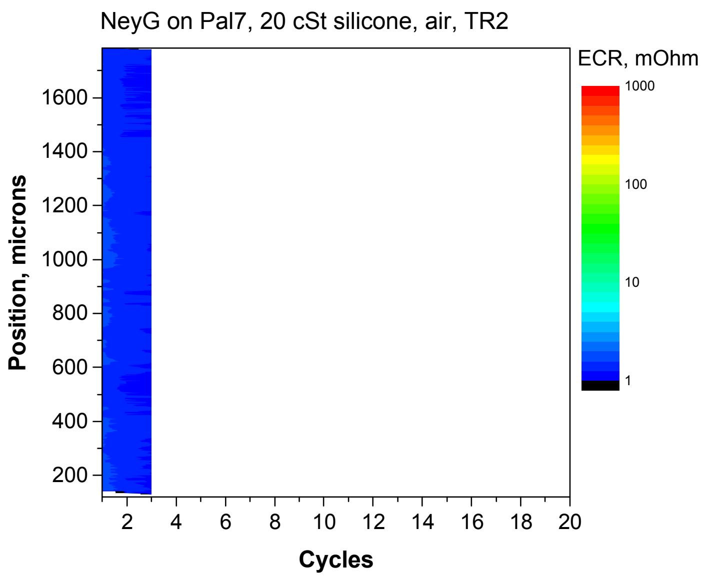


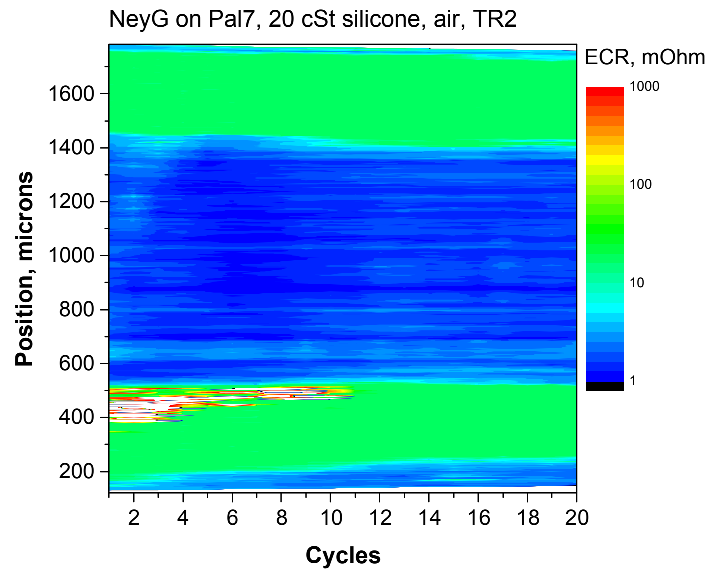


Results

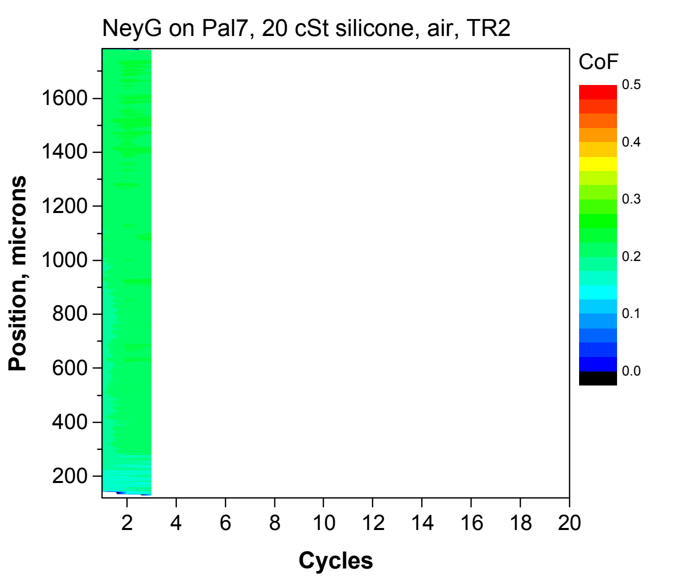
Before Vibration | **After Vibration**

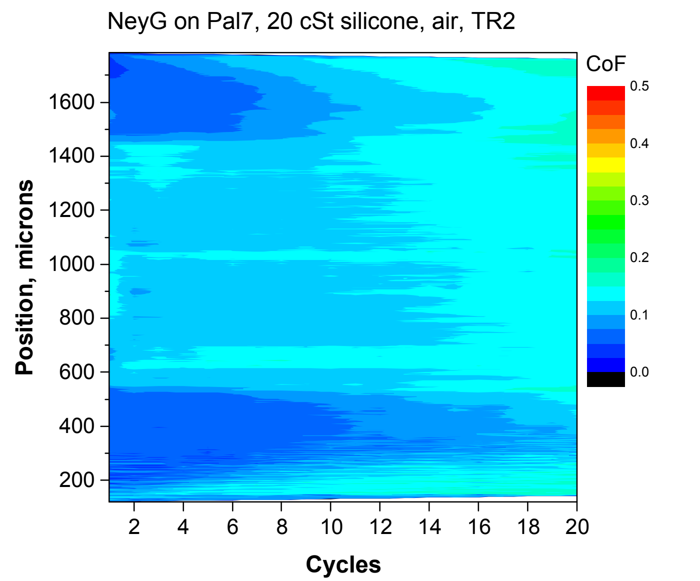
ECR





Friction





Gold Vs. Gold

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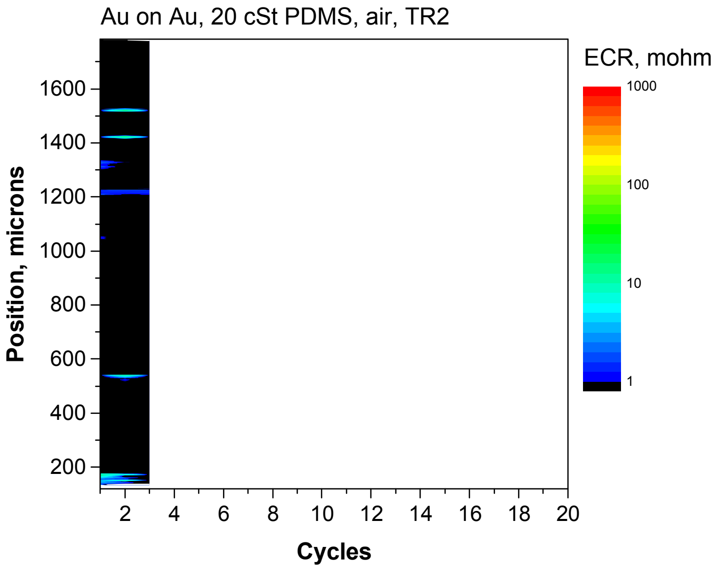
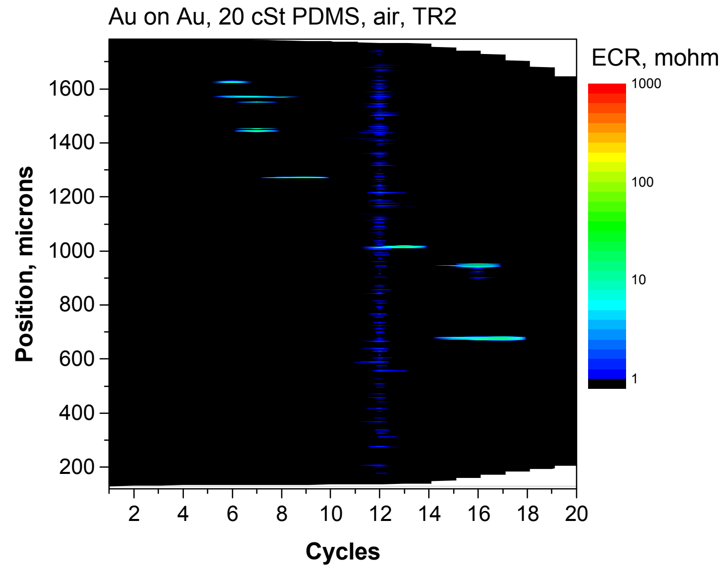
Before Vibration

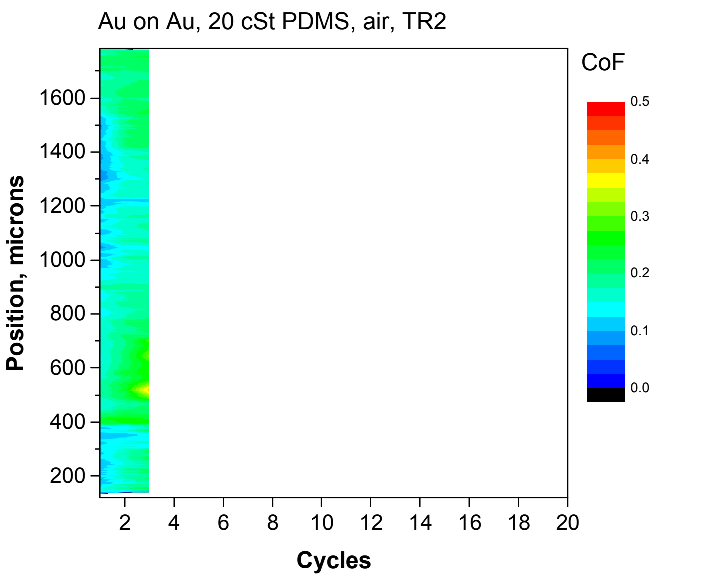
After Vibration

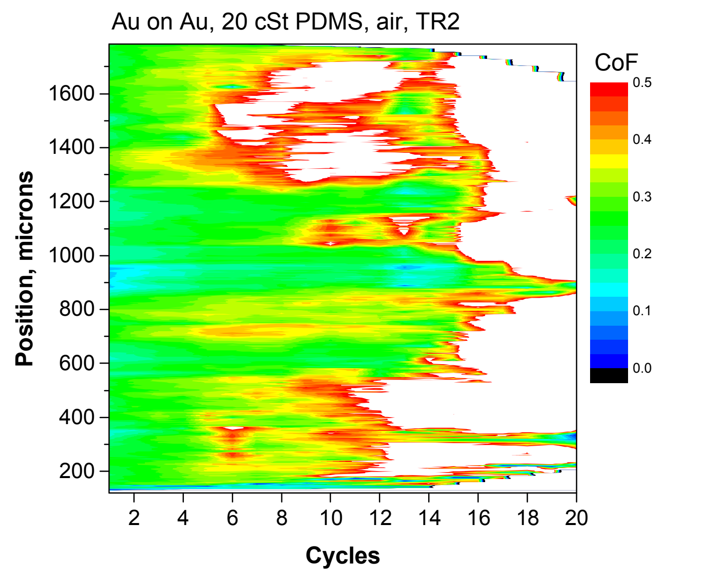
ECR





Friction

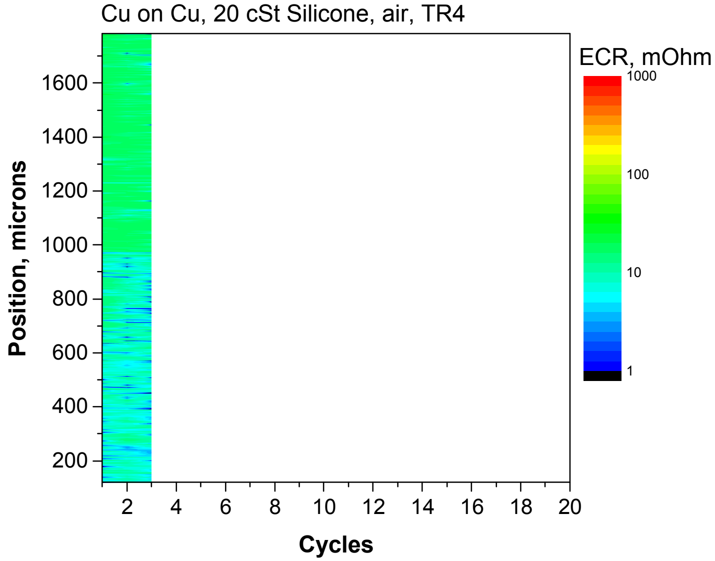


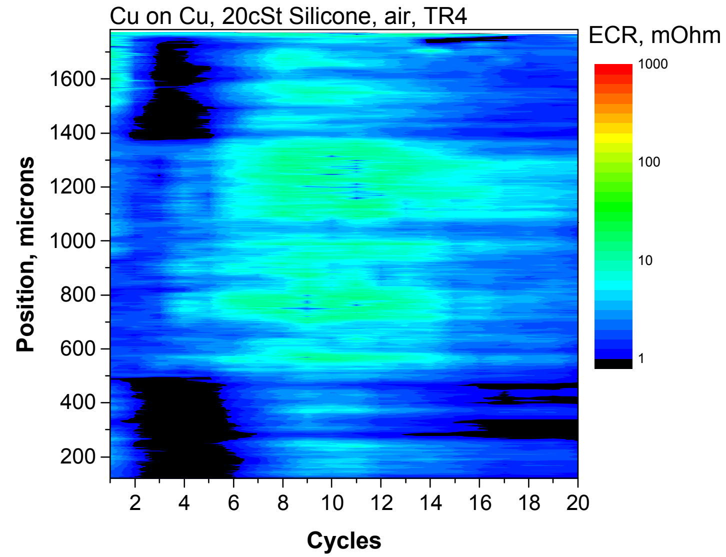


Copper Vs. Copper

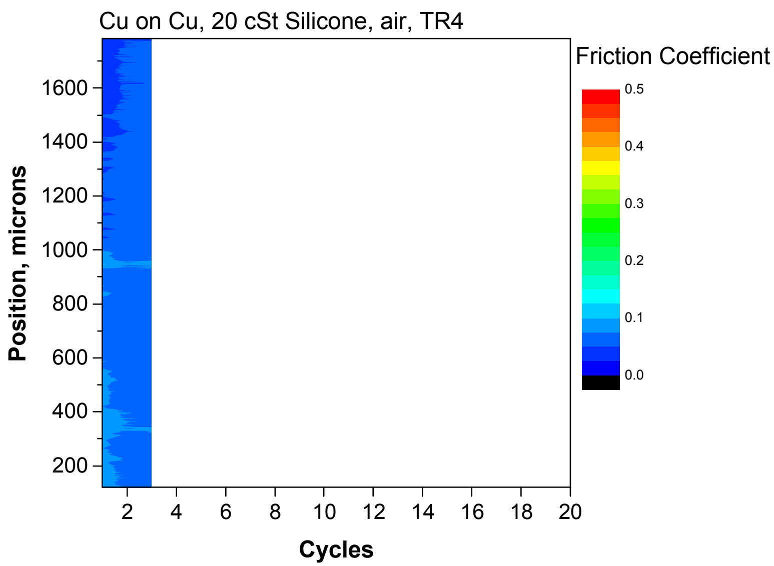
Before Vibration | After Vibration

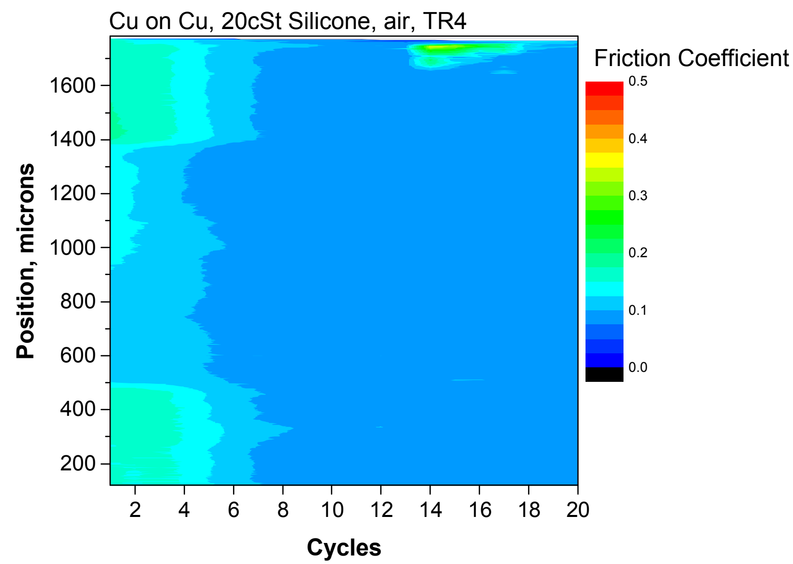
ECR



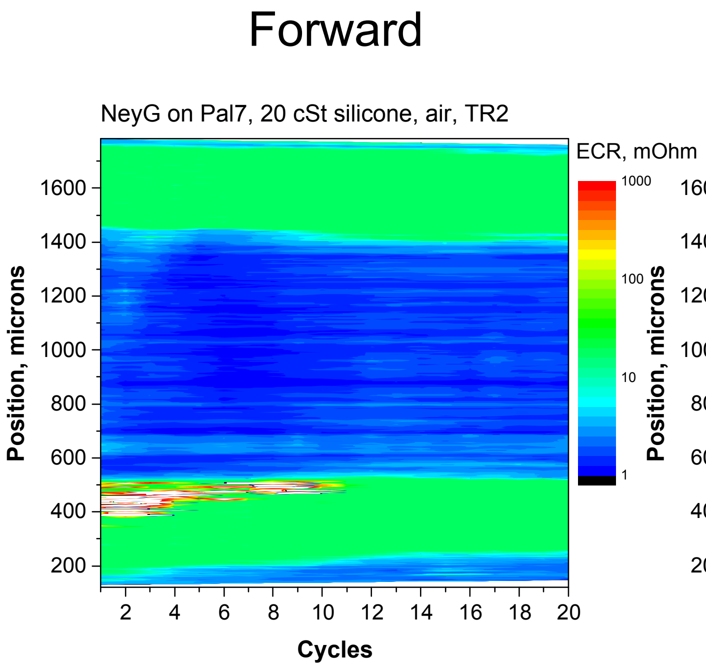


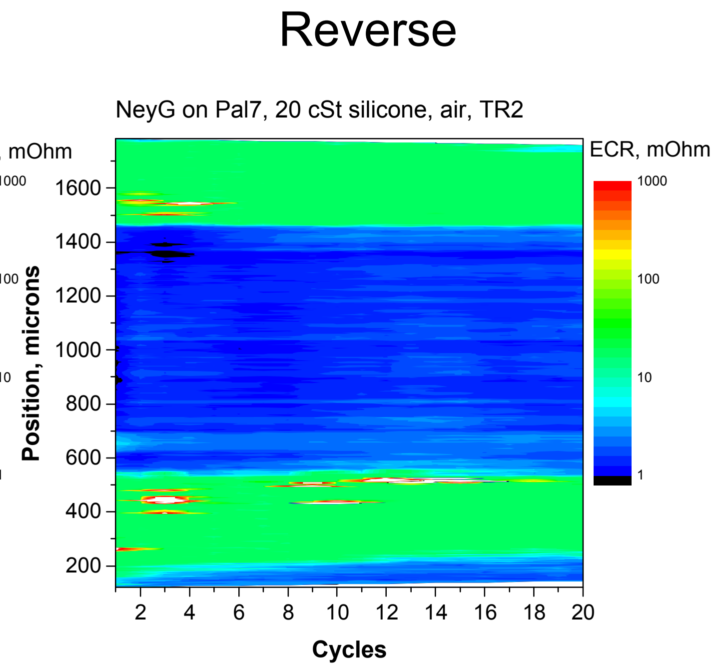
Friction



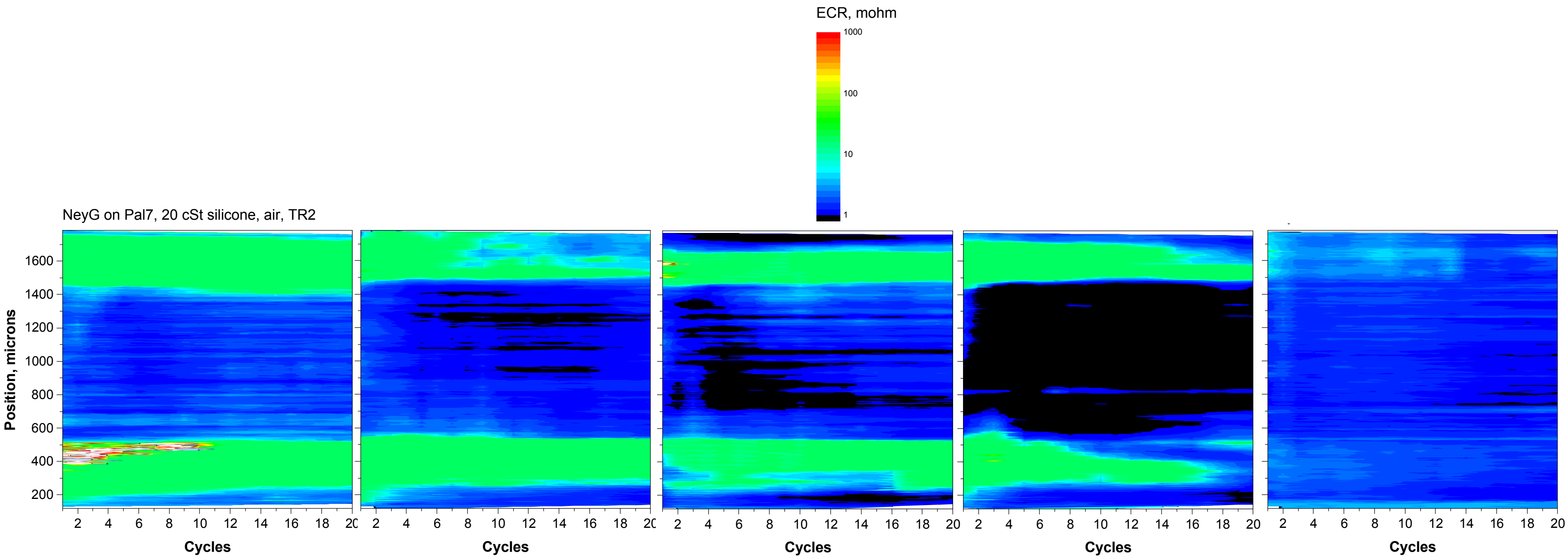


Directionality of ECR

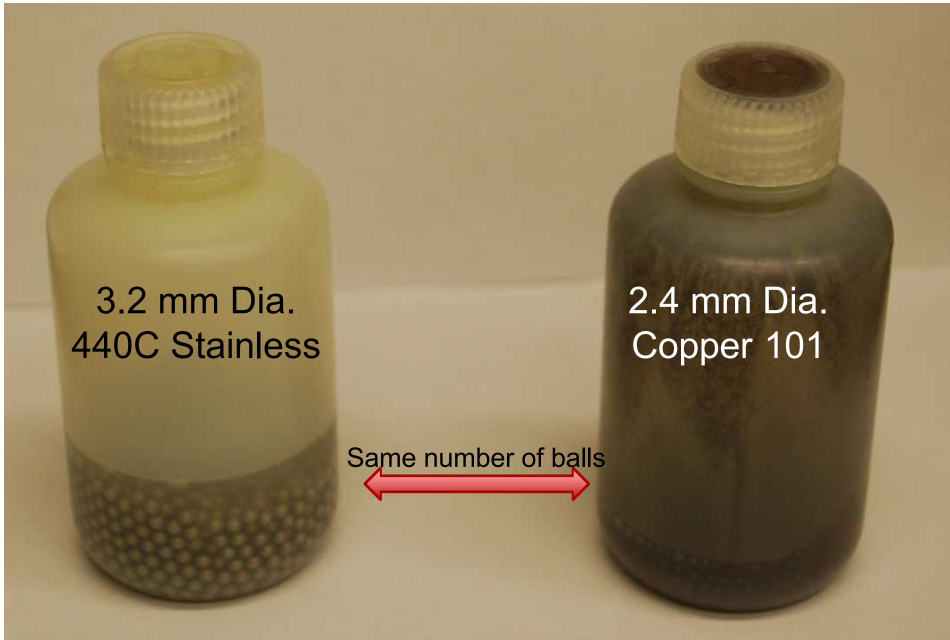




Depletion of Oxygen?



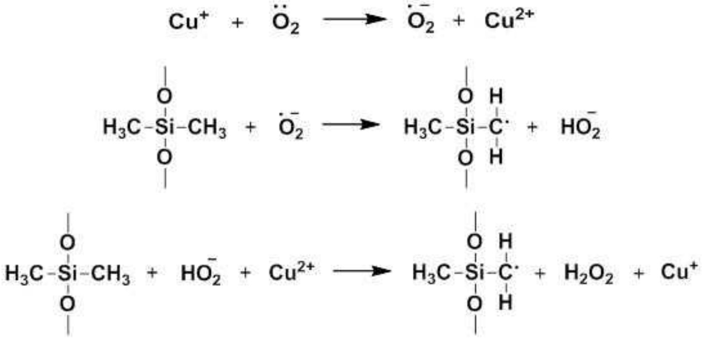
Mechanism Investigation



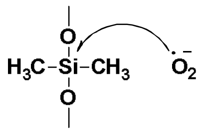
Since 440C has higher mass and lower thermal conductivity we can rule out shear and thermal degradation because it did not produce reaction product

Suspected Pathway

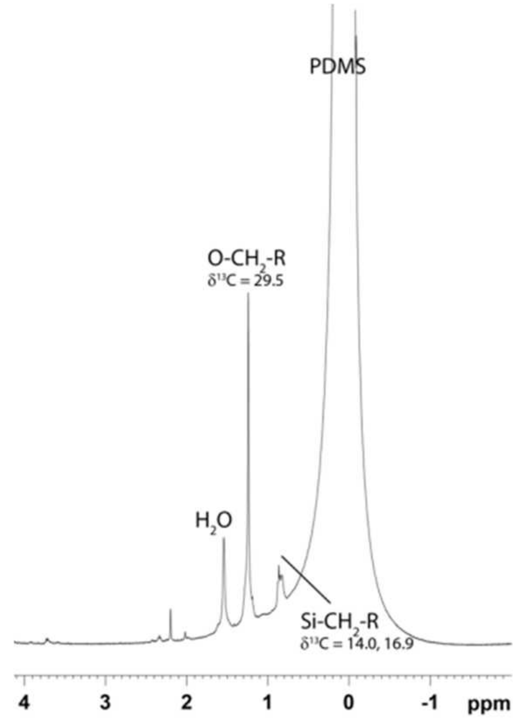
Methyl Oxidation



Direct Attack



NMR of Deposit



Conclusions

- Degradation of silicone oils is driven by:
  - Copper content in Paliney 7
  - Freshly abraded copper surface in wear track
  - Presence of oxygen in silicone oil
  - Generation of radicals and polymerization
- Degradation can be observed by:
  - Measuring contact resistance change before and after production
  - Decreased friction
- Future Work
  - Investigate Alternative Fluids (MAC, PAO, PFPE)
  - Conduct Low Oxygen Testing