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Monolayer Degradation and Vapor Deposited Bound + Mobile Lubrication In MEMS

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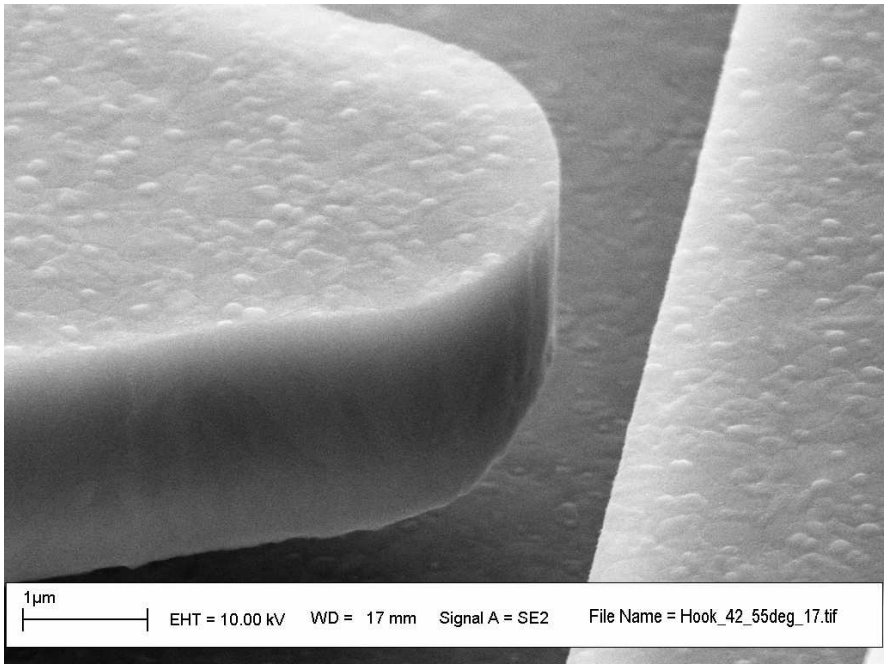
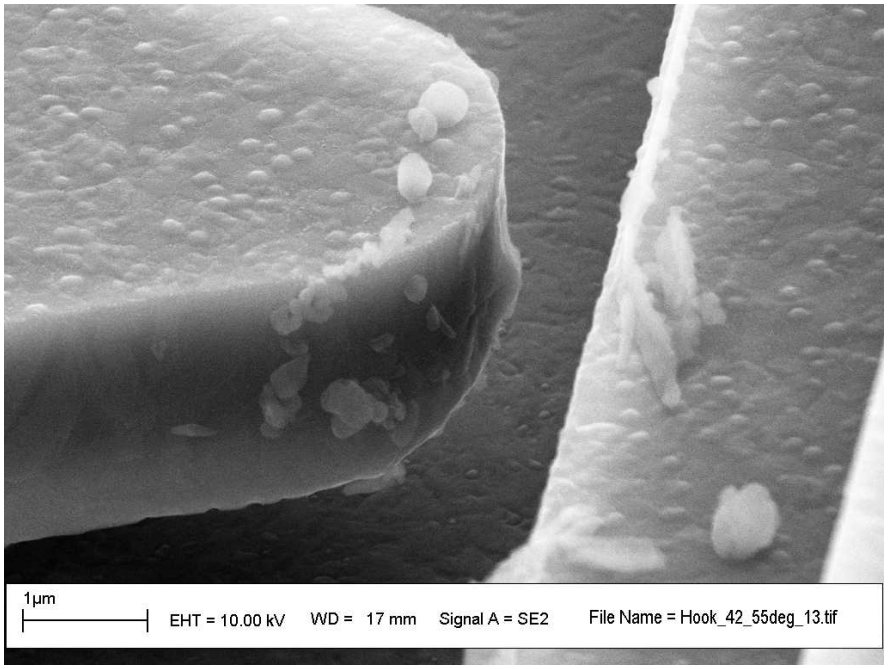
Tribological Issues in MEMS



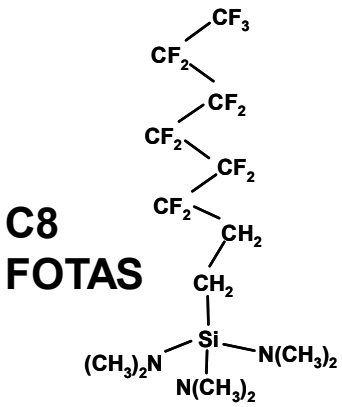


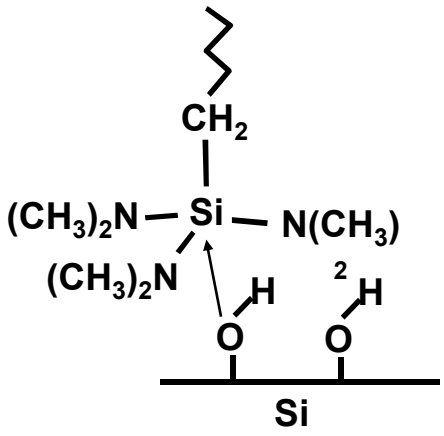
- Release related stiction
- Static failure
- In use stiction
- Wear / wear particles
- No current major production of MEMS with rubbing contacts

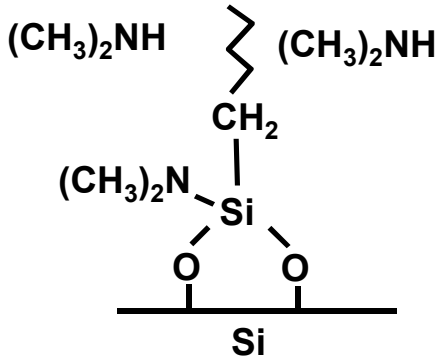
Stiction Solution

- Self Assembled Monolayers
- Liquid deposited chlorosilanes or vapor deposited aminosilanes
- Low surface energy reduces adhesive forces

Vapor-deposited aminosilanes: FOTAS: $CF_3(CF_2)_5(CH_2)_2Si(N(CH_3)_2)_3$



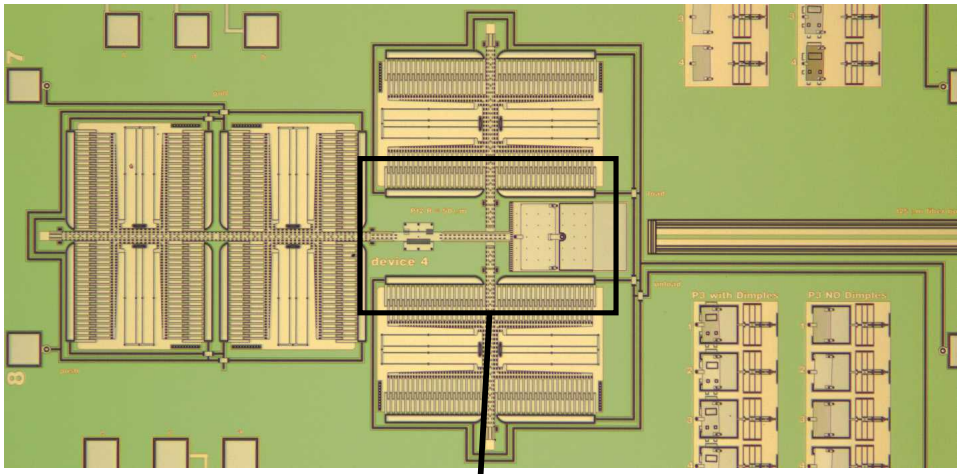


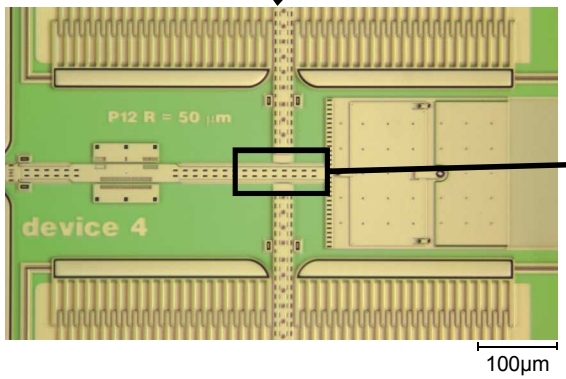


Static Friction In MEMS

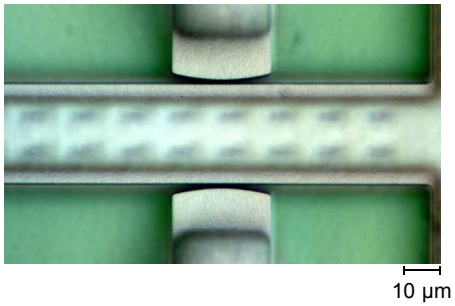
- Mechanical motion in MEMS usually stop start, gear actuation not fluid, reciprocating motion
- Static friction first obstacle to overcome in MEMS operation, will it work the first time
- Need to characterize static friction in MEMS sidewall contacts coated in SAM layer
- Examples include, weapons storage/dormancy and space applications, devices don't move for long periods of time

MEMS Friction Tester

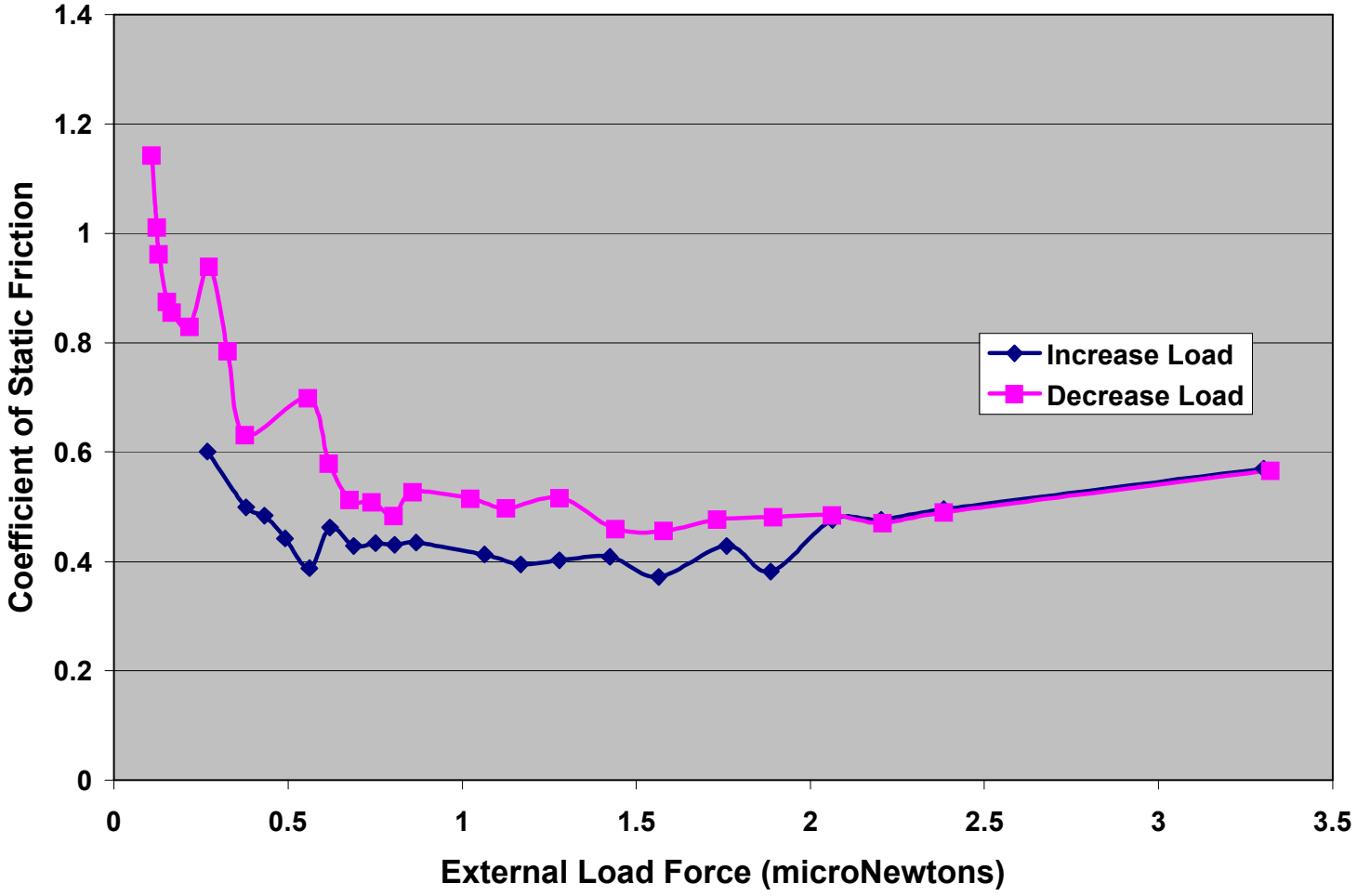


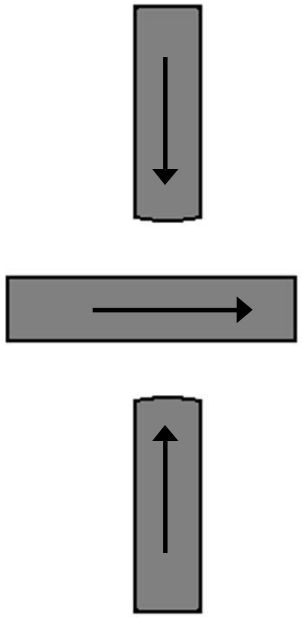


Pinch Contacts

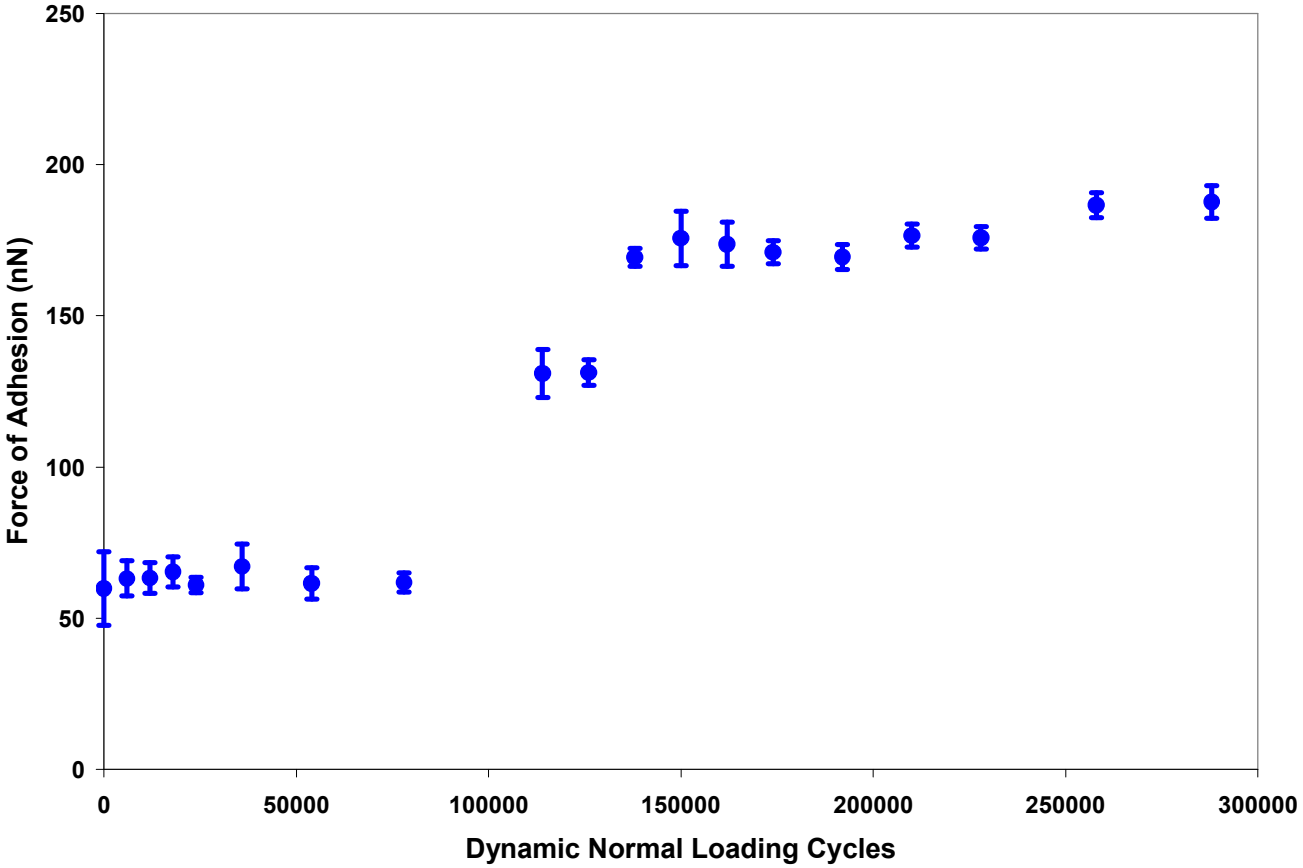


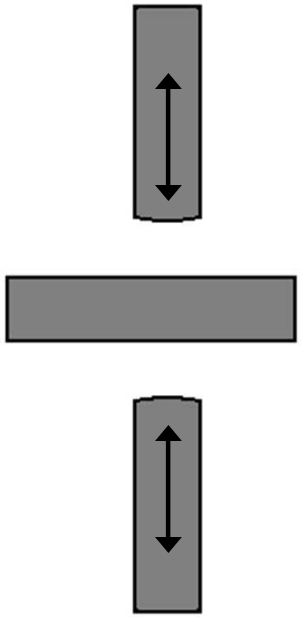
Static Friction FOTAS



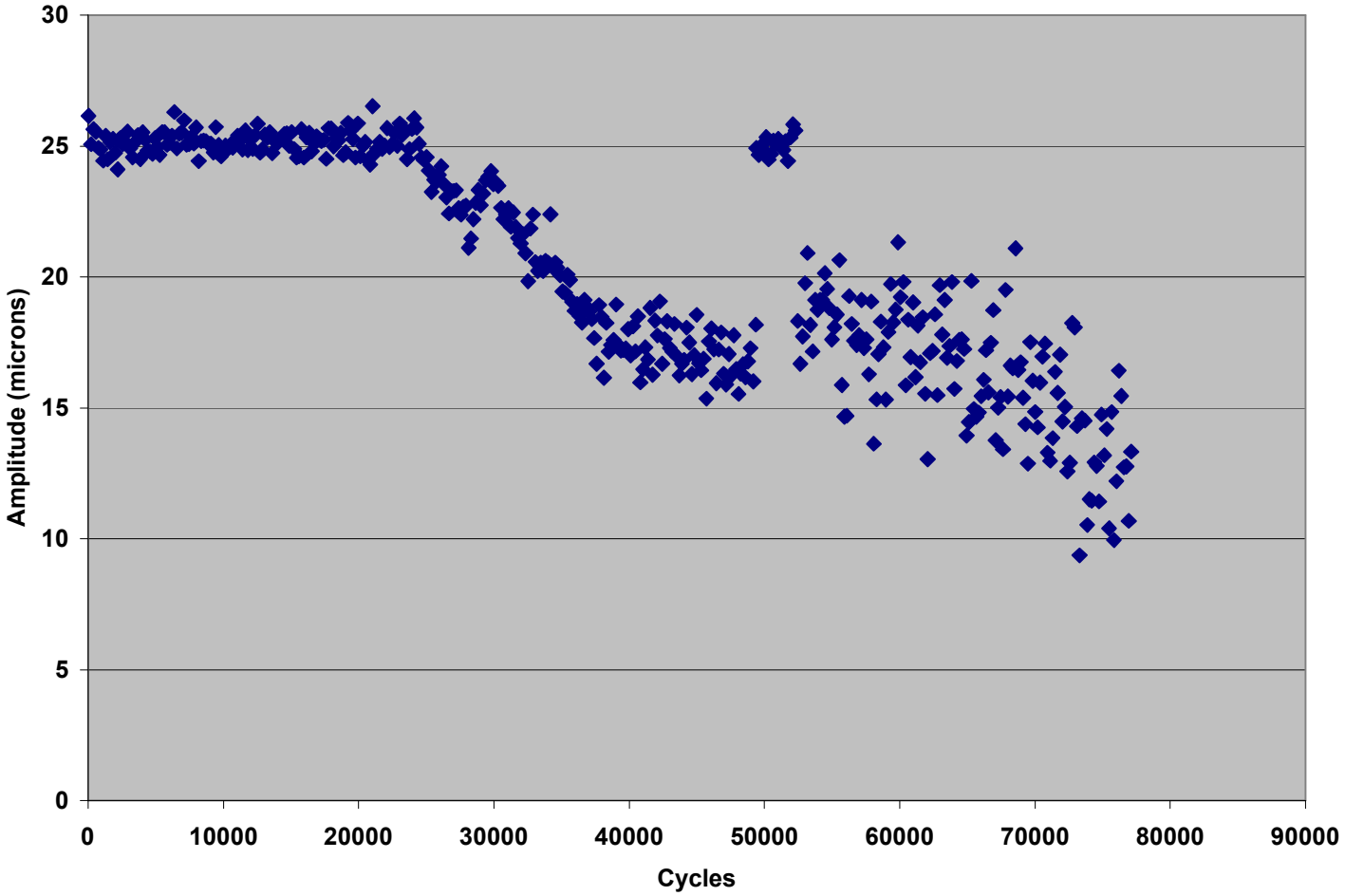


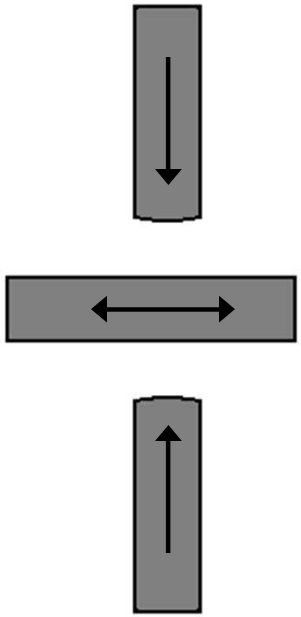
Normal Contact Degradation





Dynamic Degradation

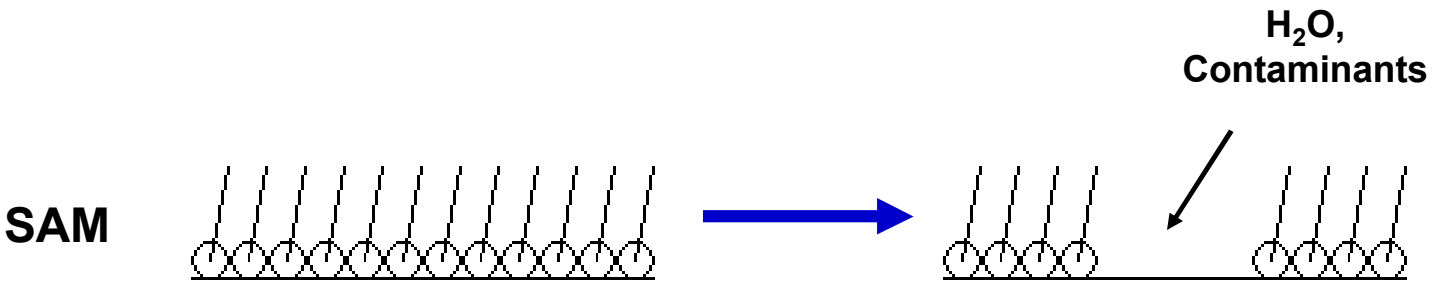




Monolayer Degradation

Degradation of Self-Assembled Monolayers

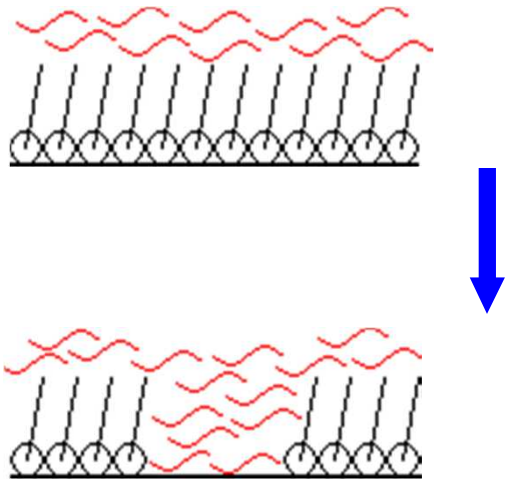
- Thermal
- Mechanical
- Allows hydroxylation of surface
- Device adheres or wear causes device to be unpredictable

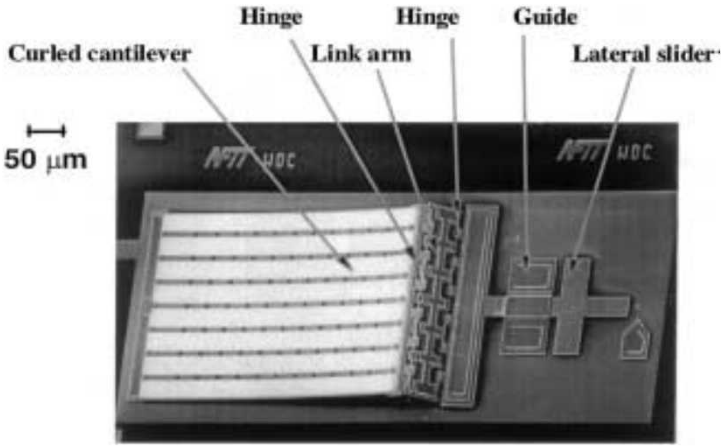


Solutions to Degradation & Wear

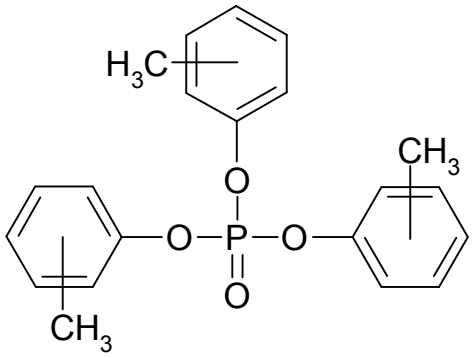
- Add renewable mobile lubricant to device on top of bound antistiction layer
- Bound plus mobile used in magnetic recording industry past 50 years
- Application to MEMS by Zabinski et. al. Tribology Letters 2002
- Proof of concept, large contact area/forces, not sidewall contact

Bound + Mobile



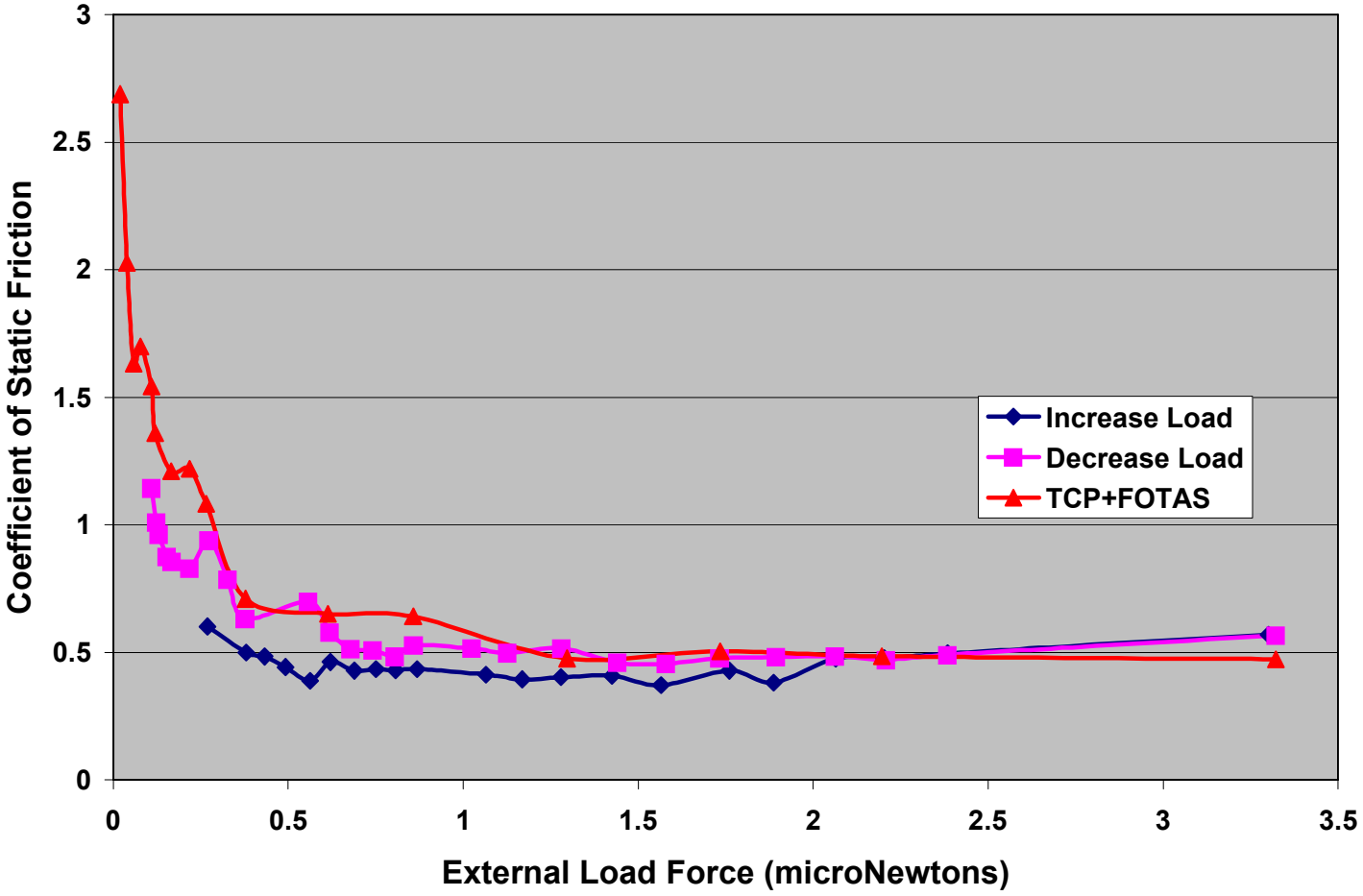


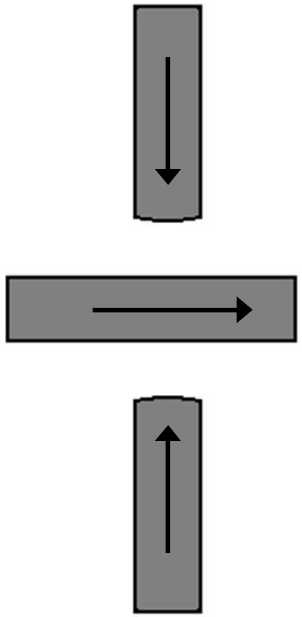
TCP Mobile Layer



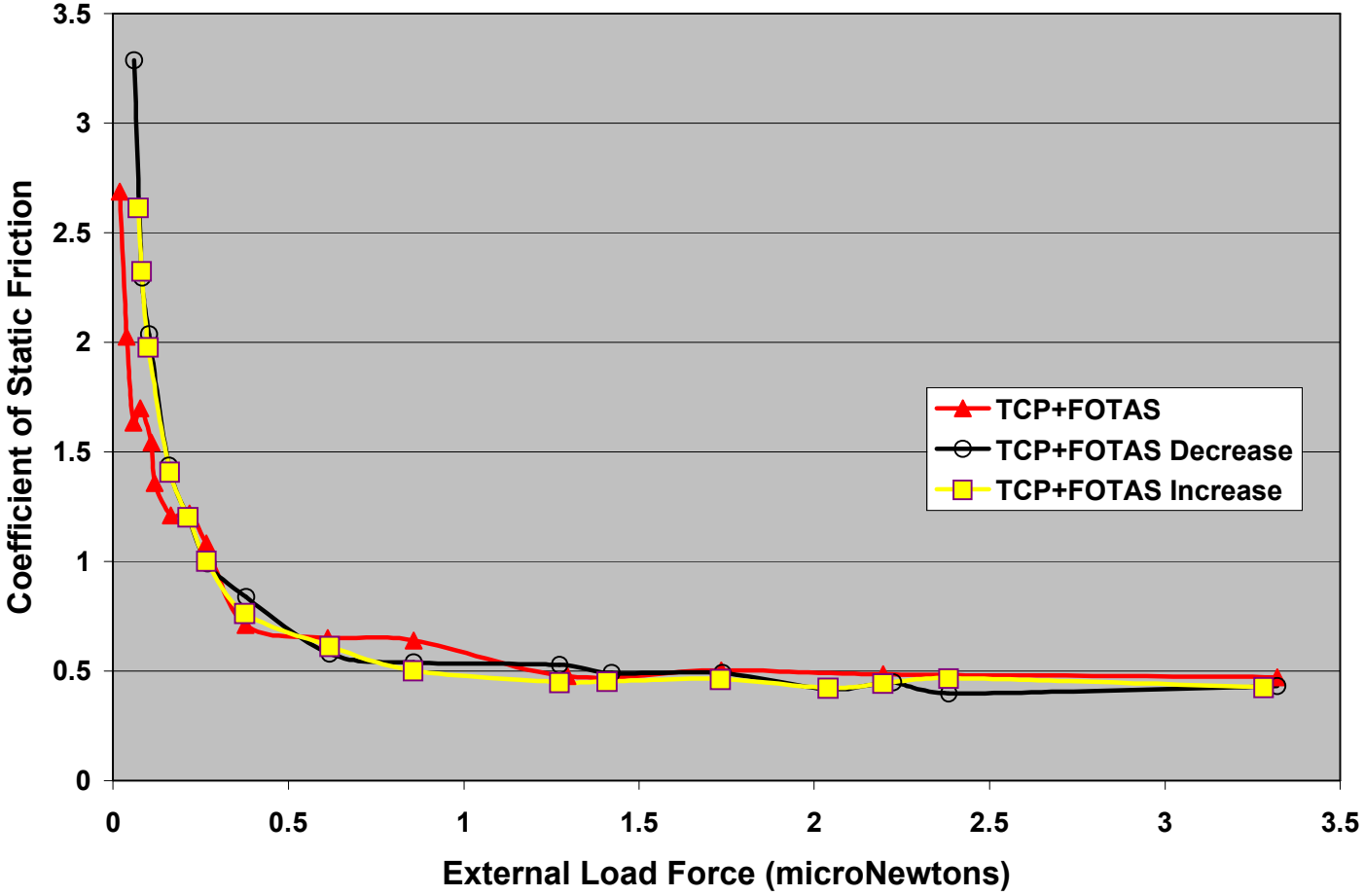
- Tricresyl Phosphate, known high temperature lubricant additive
- Studied in our lab extensively in past, QCM
- Help build a framework for testing lubricant criterion
- Brendan Miller's talk will address specifics

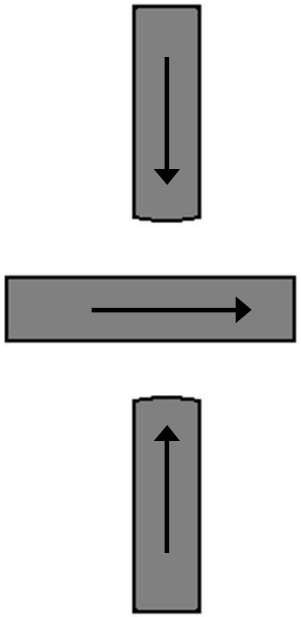
TCP + FOTAS


Coefficient of Static Friction
External Load Force (microNewtons)
Increase Load
Decrease Load
TCP+FOTAS
0
0.5
1
1.5
2
2.5
3
3.5



TCP + FOTAS Hysteresis





Conclusions/Future

- Monolayers degrade very quickly upon rubbing contact, even degrade with very small motion
- Devices fail because of increase in adhesion and generation of wear particles
- Mobile lubricants should exhibit specific properties, limited adhesion, low static friction, simple delivery to device
- TCP showed an increased adhesion at low loads
- High loads approached same values, possibly lower at highest loads
- Future Work includes kinetic friction, device lifetimes, and testing other vapor deposited lubricants

NC STATE UNIVERSITY

- Degradation Work Funded by SANDIA National Labs MESA Project
- Bound Plus Mobile Work Funded by AFOSR Extreme Friction MURI

NNSA National Nuclear Security Administration

Sandia National Laboratories

Device Failure