# Measurement Challenges in Micro-tensile and Micro-fatigue Reliability Studies

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# Microsystems Reliability

***How does the _____ affect the _____ of _____ ?***

**Factors Affecting Reliability:**

- Surface Roughness
- Humidity
- Temperature
- Environment
- Coatings
- Microstructure
- Deposition Layers
- Stress Concentrations
- Processing Steps
- Component Stresses
- Applied Current
- …etc.

**Properties of Mechanical Reliability:**

- Strength
- Fracture Toughness
- Creep
- Fatigue
- Adhesion
- Friction
- Wear
- Resonant Performance
- Device Performance
- …etc.

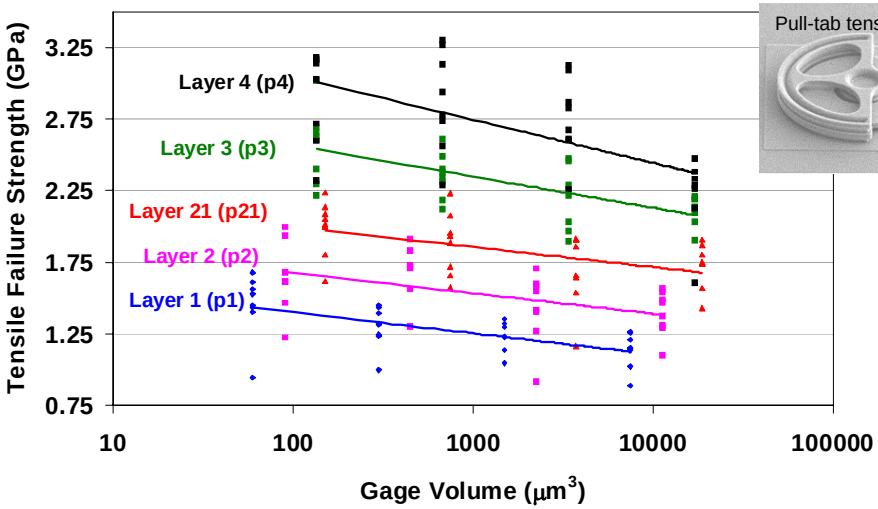
**MEMS Materials at Sandia:**

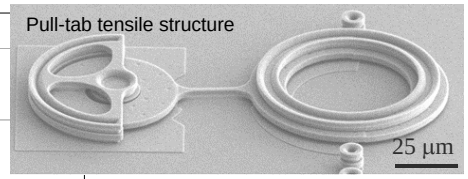
- SMM polysilicon
- SMM amorphous diamond
- Silicon-On-Insulator
- LIGA Ni (sulfamate)
- LIGA Ni-Co
- LIGA Ni-Fe
- LIGA Ni-Mn
- …etc.

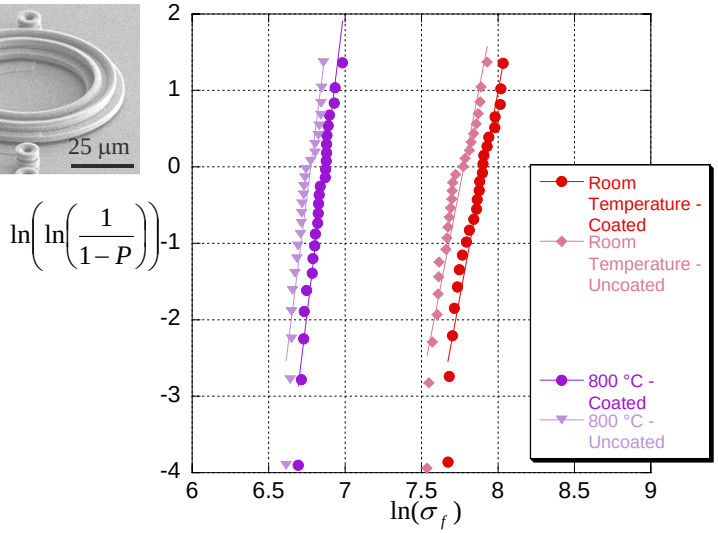
**This very incomplete matrix of environments, properties and materials requires ~700 reliability studies!!!**
**WE MUST FOCUS EFFORTS ON EXPECTED PROBLEM AREAS**

# MEMS Mechanical Reliability Capabilities: SMM Si

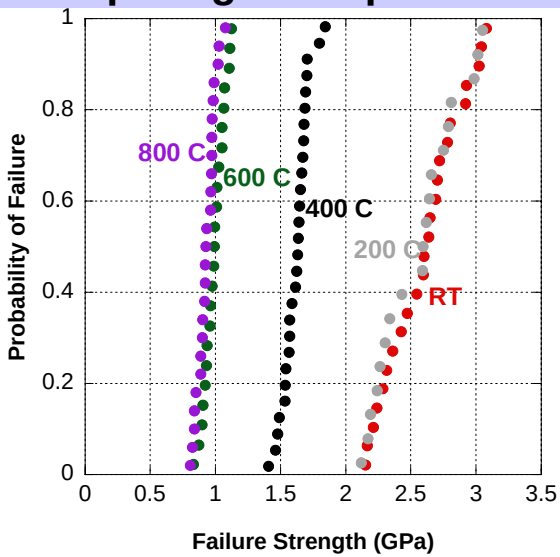
## Failure Strength / Statistics



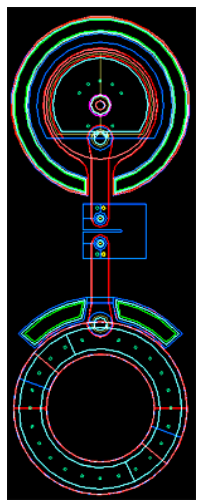



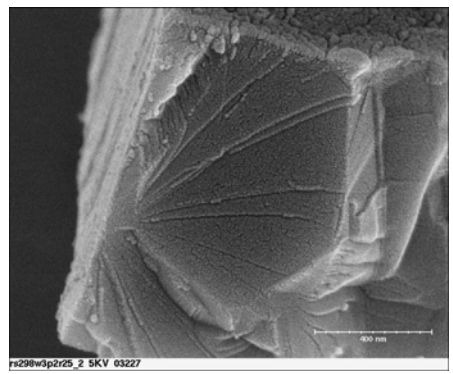

## Creep / High-Temp Behavior




## Fracture Toughness

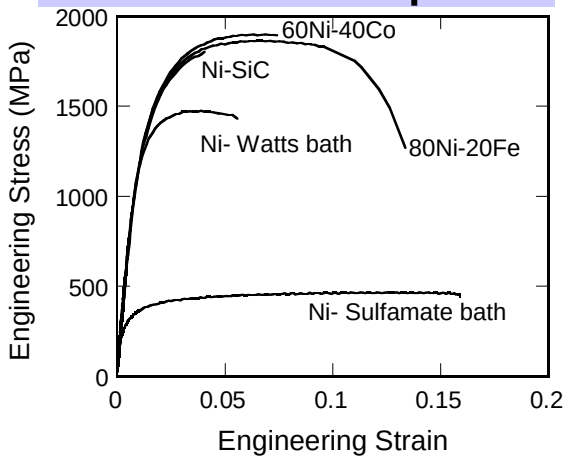


## Fractography



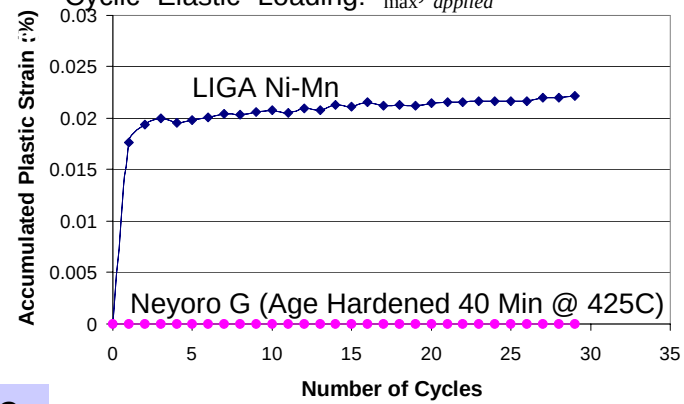
# MEMS Mechanical Reliability Capabilities: LIGA

## Stress-Strain Response

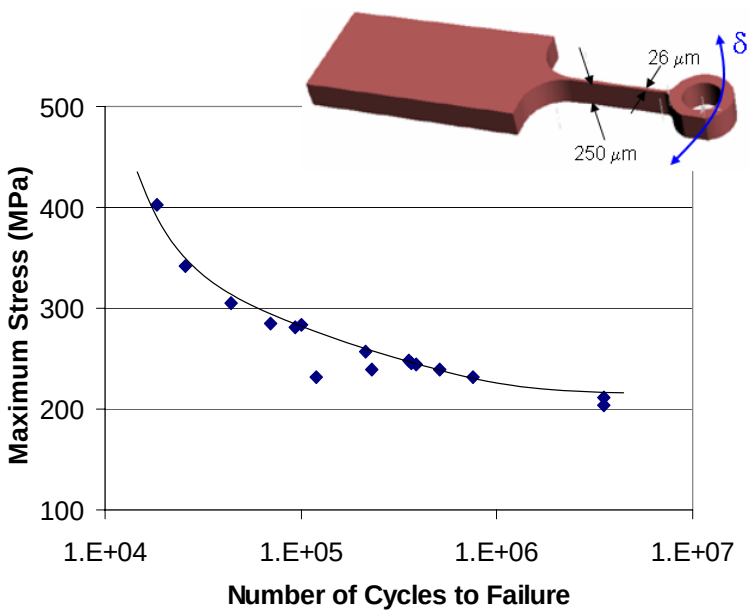



## Microplastic Ratchetting

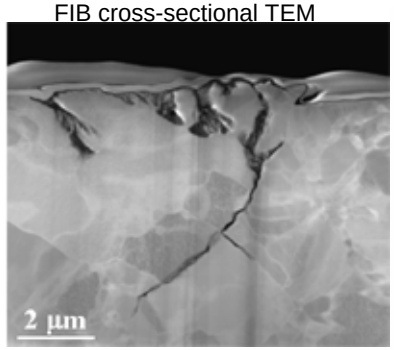
Cyclic "Elastic" Loading: $\varepsilon_{max,\ applied} = 0.2\%$ $R=0$

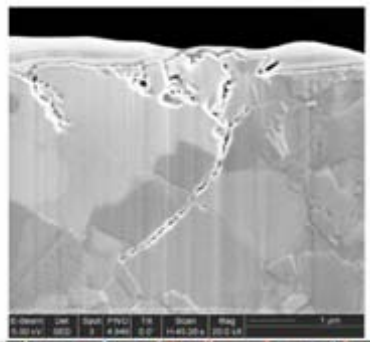



## Fatigue

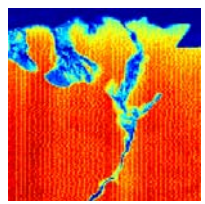


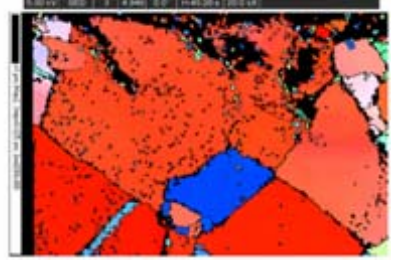

FIB cross-sectional TEM



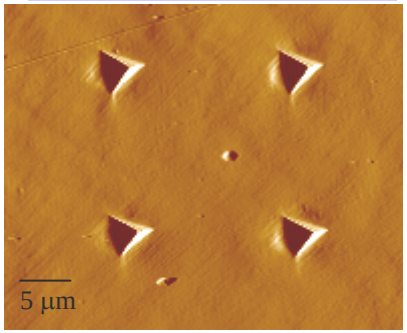
Nickel spectral map

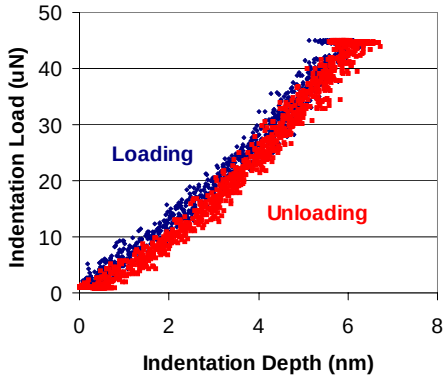


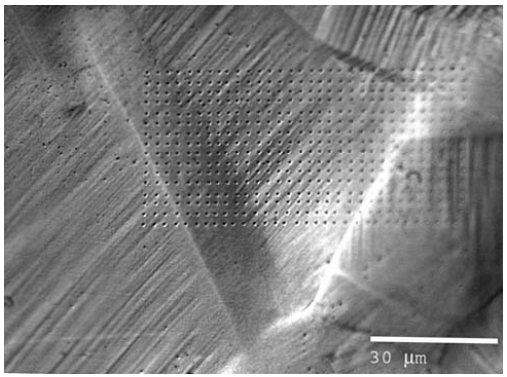


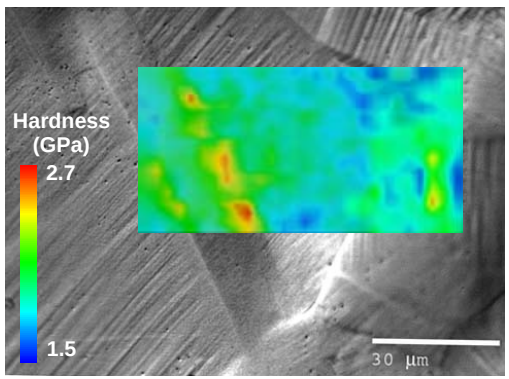
# MEMS Mechanical Reliability Capabilities (cont'd)

## Nanoindentation



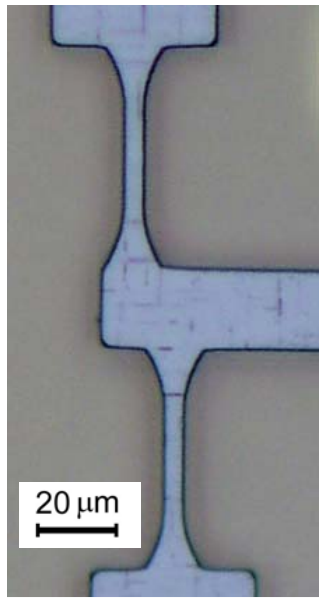



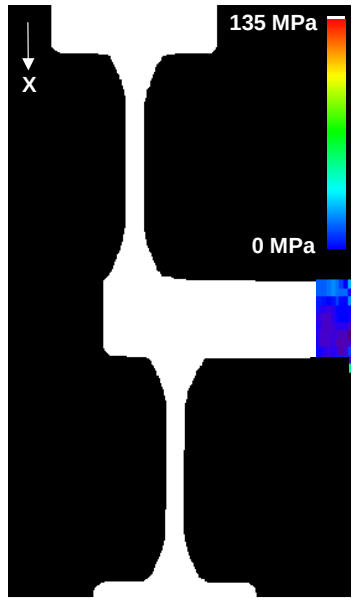
4-point bend in Nanoindenter XP

## Synchrotron Microdiffraction

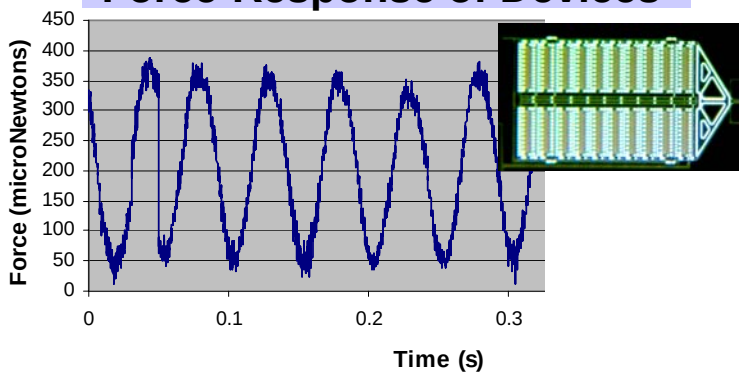
Optical Micrograph




$\sigma_{xx}$




## Force-Response of Devices



# *Nanomaterials Measurement Challenges*

- **Spatially-Resolved (<1 μm) Non-contact Temperature Measurement**
- **Accurate in-plane length measurements (accuracy ~10 nm)**
- **Micro-Force standards (< 5 μN)**
- **Improvements in Spatially-Resolved Characterization Techniques (high-res SEM, SIMS, In-situ TEM, Microdiffraction, microRaman, etc.)**