Monolithic Copper Integrated Circuitry supporting Multi-layer Micro-Electro-Mechanical Systems

North Carolina State University, CuMEMS Project Team
B. Duewer, A. Glaser, D. Nackashi, J. Wilson, D. Winick

Primary Objectives:
Enhance UMC Copper market, and deliver to the design community a process suitable for monolithic implementations of complex microsystems (aka, MEMS) and complete systems-on-a-chip (SoC)

System Application
• Beam steering and adaptive optics
• Precise free-space wavefront modulation
• Analog height (phase) + Binary tilt (amplitude)

“Smart” Micromirrors (surface: Metal 6)
• Circuitry directly under each element
• C0-ramp capacitive position sense
• Compare & calibrate to master or ext. ref.
• D2A HV drive & Mechanical failure detect

Microsystem Demonstration of Arrayable Smart Sensor/Actuator Elements

Performing Mechanical Characterization
Resonance frequency of many MEMS designs is strongly correlated to Young’s modulus.
For future MEMS design in copper, the Young’s modulus of the mechanical films must be determined.
The procedure chosen uses an electrostatic actuator known as a comb motor. An AC signal is supplied to the comb fingers while the shuttle is held at ground potential.

On The Chip:
Mechanical Parameter Extraction Structures
Element Array with Distributed Control
Process Monitoring Structures
Global I/O Control and Instruction Processing

Upper-layer Metals become Mechanical
• Sacrificial etch --> free structures
• Replicated tests on each mechanical layer
• Intermediate lift-off --> stacked tests

Element Stackup (exploded view):

Electrostatic potential, driven across the air gap and a series stabilizing capacitor, acts to pull the mirror downward. Flexure beams provide a restoring force.

Extracted Parameters
• Latent Stress (ε)
• Young’s Modulus (E)
• Poisson’s Ratio (P)
• Residual Strain

Measurement Techniques
• Active --> Optical Blur, Micrometer Reticle
• Passive --> Monochromatic Interferometry

Double clamped beams with identical cross sectional areas have a critical length, above which the beams begin to bend and buckle. The transition beyond this length is abrupt, therefore easily observed among an array of beams with identical cross sectional areas varying only in length. At that critical length, the associated compressive strain in the beam is given above. The beams vary in length from 5 to 200 microns, allowing the determination of strain fields between 0.132 and 8.225*10^-5.

Guckel ring, likewise, determine any stress that is tensile.