Introduction

- MEMS
  - Micro – scale on which the devices exist
  - Electro – devices have electrical input/output
  - Mechanical – devices have mechanically moving parts
  - System – integration of components
- Why develop MEMS?
  - Sensors (Analog Devices – Accelerometer (Airbag Sensor))
    - Small package
      - Lightweight
      - Higher sensitivity
        » Small forces – sub-mN
        » Small displacements – sub-μm
  - Actuators (Texas Instr. Micromirror Device)
Types of MEMS

- Bulk Micromachining
  - Removal of bulk Si from wafer to define a device
  - Examples
    - SCREAM
    - SCALPEL

Conceptual Design for Thin Film Tester
Load Cell Fabrication

Load Cell Force Calibration

UNM The University of New Mexico

Moving Vernier
Stationary Vernier
Fix-Fix Beams
Si Cleave Line
Si

Load Frame
1500 μm Long Fix-Fix Beams

Loading Tip
1000 μm Diameter Sapphire Sphere

Vernier
δ = 4.75 μm
Sphere Hanging by Epoxy
Epoxy
Sapphire Sphere
Gold Nanofilm Characterization

- Analysis of Au Film
  - Au film sputtered on Si (100) substrate
  - Stoney’s Formula
    - ~10 MPa residual compressive stress
  - XRD
    - Main orientation (111)
    - ~2.5 MPa residual compressive stress
  - TEM
    - Average grain size ~57nm

- Average grain size ~57nm
Experimental Setup


Gold Nanofilm Data

The force-displacement relationship for gold nanofilms is shown, with different symbols representing different films. The theoretical membrane theory line is also indicated.
Fracture

- Au Film
  - 100 nm thick
  - (111) Texture
  - 10 MPa compressive residual stress

Creep of Au Films

Creep Behavior of 100 nm Thick Au Film at Room Temperature

Thickness = 100 nm
Diameter = 500 μm
Average Grain Size = 57 nm
Indenter Diameter = 300 μm
Max Applied Load = 761 μN
Temperature = 20 °C
Types of MEMS

- **Surface Micromachining**
  - Selective deposition and removal of thin films from a substrate (Si) to create a multi-level device
  - SUMMIT™ Process (Sandia)
  - DMD Process (Texas Instruments)

**Stiction**

- **Stiction** - Unintended structural collapse due to secondary forces

**Causes**
- During etching of sacrificial layers
- Application of surface treatments
### Experimental Concept

- **Stiction failed cantilever (s-shaped failure)**
  - Fixed end of beam raised incrementally
  - Crack length \( s \) is measured before and after increment
    - Arrest value for the critical strain energy release rate is found

### Experimental Setup

- Linear stage for course z-motion
- Piezoelectric actuator for fine z-motion
- Interferometric objective
- Microcantilever
- Substrate
- Linear stages for x-y motion
Microcantilevers Used in this Work

- SUMMiT IV™ from Sandia
- Beam dimensions: 30 μm wide and 1500 μm long

‘Wet’ Experimental Results

- Wet experiments in IPA vs. DI
  - $G_{IPA} < G_{DI}$
  - poly-Si substrate
  - Hydrophilic gold
  - Hydrophobic gold

Surface Tension Effect

$$\sigma_{DI} = 73 \text{ mJ/m}^2 ; \sigma_{IPA} = 21.7 \text{ mJ/m}^2$$
Types of MEMS

- **LIGA** – Lithographie Galvanoformung und abformung
  1. Deposit PMMA onto a substrate
  2. Develop PMMA
  3. Deposition of metal onto primary substrate
  4. PMMA removed
  5. Injection molding of another plastic
     - **Forms**
       - Freestanding metal structure
       - Plastic injection-molded structure
       - Investment-cast metal structure from injection-molded structure
       - Slip-cast ceramic part from injection-molded structure

LIGA Dynamometer