Lecture Outline

- Reading: Senturia, Chpt. 3; Jaeger, Chpt. 2, 3, 6
- Example MEMS fabrication processes
- Oxidation
- Film Deposition
  - Evaporation
  - Sputter deposition
  - Chemical vapor deposition (CVD)
  - Plasma enhanced chemical vapor deposition (PECVD)
  - Epitaxy
  - Atomic layer deposition (ALD)
  - Electroplating

Making Mechanical Devices

- How best does one make a mechanical product?
- Assembly line production?
  - Pick and place parts
  - Used for many macroscopic mechanical products
  - Robotic automation greatly reduces cost
- Problem: difficult to do this with MEMS-scale parts (but not impossible, as we'll soon see ...)
- Solution: borrow from integrated circuit (IC) transistor technology
  - Use monolithic wafer-level fabrication methods
  - Harness IC's batch methods, where multiple devices are achieved all at once
**Polysilicon Surface-Micromaching**

- Uses IC fabrication instrumentation exclusively
- Variations: sacrificial layer thickness, fine- vs. large-grained polysilicon, in situ vs. POCl$_3$-doping

**Silicon Substrate**

- Nitride Isolation Oxide
- Interconnect Polysilicon
- Structural Polysilicon

Hydrofluoric Acid Release Etchant

**Silicon Substrate**

300 kHz Folded-Beam Micromechanical Resonator

**Electroplating: Metal MEMS**

- Use electroplating to obtain metal structures
- When thick: call it "LIGA"
- Pros: fast low temp deposition, very conductive
- Cons: drift, low mech. $Q$ but may be solvable?

**Silicon Substrate**

- Photoresist

**Silicon Substrate**

- Aluminum Release Etchant

**Silicon Substrate**

- Electrode

**Silicon Substrate**

- Suspended Nickel Microstructure

**Silicon Substrate**

- Nickel

- Ti/Au

- $\text{Si}_3\text{N}_4$

- Isolation

**Bulk Micromaching and Bonding**

- Use the wafer itself as the structural material
- Adv: very large aspect ratios, thick structures
- Example: deep etching and wafer bonding

**Silicon Substrate**

- Glass Substrate

**Silicon Substrate**

- Metal Interconnect

**Silicon Substrate**

- Movable Structure

**Silicon Substrate**

- Electrode

**Silicon Substrate**

- Movable Structure

Micromechanical Vibrating Ring Gyroscope

1 mm

[1 mm Micromechanical Vibrating Ring Gyroscope: Najafi, Michigan]

Microrotor (for a microengine)

[1 mm Micromechanical Vibrating Ring Gyroscope: UC Berkeley]