Admin:
- Current Enrollment: EE147 247A
  - CE
  - 16
  - 19
  - 6
  - 41
- Room Capacity: 52
- We can accommodate all students.
- First HW: ~ Friday
- Check out course web, piazza.

ROBOTIC VEHICLE SENSOR REVENUE FORECAST

Accelerometer
IMU
Inertia Measurement Unit
- Accelerometer 3x
- Gyro 3x
- Compass 3x
9-axis IMU

Accelereometer

Spring constant = k
m
Δx

Spring
proof
mass
capacitor
(Readout circuit)
\[ F = m \cdot a = k \cdot \Delta x \]
\[ \uparrow \quad \Rightarrow \text{Hook's law} \]
\[ \text{acceleration} \]
\[ \Rightarrow a = \frac{k}{m} \cdot \Delta x \quad \text{or} \quad \Delta x = \frac{m}{k} \cdot a \]
\[ \uparrow \quad \text{maximize displacement.} \]

**Readout def:**

\[ g = g + \Delta g \]

\[ C = \frac{EA}{g} \quad \text{Air} \]
\[ \varepsilon = \varepsilon_0 \]
\[ = 8.854 \times 10^{-12} \quad \frac{F}{m} \]
\[ \uparrow \quad \text{MKS} \]
\[ C' = \frac{EA}{g + \Delta g} \]

\[ \Delta C = \left| \frac{dC}{dg} \right| \cdot \Delta g \]
\[ = \frac{EA}{g^2} \cdot \Delta g = \frac{EA}{g} \cdot \frac{\Delta g}{g} \]

\[ \frac{\Delta C}{C} = \frac{\Delta g}{g} \]

**Physics \rightarrow Technology \rightarrow Design \rightarrow Simulation**

\[ \text{Design Rules} \]

\[ \downarrow \quad \text{Fabrication} \]

\[ \text{Test} \]
IC → CMOS → 70 Photolithography → <$1K/8''

Read Chap 1. + Chap 2 of Jaeger

MEMS select Si-based MEMS (low $/high vol)

[Silicon-on-insulator (SOI)] ←
Polysilicon surface-micromachining
CMOS
Silicon nitride

SiO₂: buried oxide (BOX) ~ μm thick

Si device layer ~ 105 μm

Deep Reactive Ion Etching (DRIE)

→ Cookie Cutting Process
$\frac{H}{W} = \text{Aspect ratio}$

DRIE produce high aspect ratio $> 20$

$> 100$

conventional KOH

\text{(111) crystal plane}

\text{CROSS-SECTION}

\text{SOI MEMS, \rightarrow Single-mask process}

\text{lithography}

Process

Φ Lithography \rightarrow create patterns

Negative: Photosensitive coating

Development

camera
Example of resolution:
- Berkeley Nanolab: 250 nm resolution
- Most university lab: 1 \mu m
- TSMC/EUV: 5 nm

Photoresist (PR)

Exposed Area
Called Reticle: 2 cm x 2 cm

Lithography machine usually called a "stepper": step-and-repeat
Contact Aligner: 1-to-1 contact alignment with a low-cost mask. This can include UV lasers or inkjet printing on transparency. The resolution is approximately 1 μm.

New Maskless Aligner: Digital Micromirror Device (DMD) with a 1" x 1" size. This device can project images with a magnification of 5-10x, resulting in a resolution of ~1 μm.

SOI MEMS: DRIE etches Si only, stopping at SiO2.
“Release” Etching
49% HF (often diluted)
→ high etch rate for SiO₂
> μm/min
Almost don’t etch Si
< μm/min
“Selectivity” = ratio of etching rate
very high

Design Rules (Highly simplify) (Assume 250 nm Litho resolution)

1. Line width > 300 nm
2. Spacing > 300 nm
3. Fixed structures (Anchored) > 20 μm
4. Released structures < 8 μm
< 4 μm
> 8 μm

2×8=16 μm