ECE 30

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Agenda

- Young's Modulus and 3 point Flexure
- Photolithography
- DRIE
- How an Accelerometer Works

Harmonic Motion

Harmonic Osscilators are described by a cosine function.

$$x = Acos(\omega t)$$

We describe ω in terms of the frequency and period of the osscilator.

$$f = \frac{1}{T}$$

Where f is the frequency and T is the period of the osscilator.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Derivation:

$$F = -kx \tag{1}$$

$$F = ma \tag{2}$$

$$a = \frac{dv}{dt} = \frac{d^2x}{dt} \tag{3}$$

$$\frac{d^2x}{dt} = \frac{-kx}{m} \tag{4}$$

$$x = Acos(\omega t) \tag{5}$$

$$\frac{dx}{dt} = -A\omega sin(\omega t) \tag{6}$$

$$\frac{d^2x}{dt} = -A\omega^2 cos(\omega t) \tag{7}$$

$$-A\omega^2 cos(\omega t) = \frac{-kAcos(\omega t)}{m} \tag{8}$$

$$-Am\omega^2 cos(\omega t) = -kAcos(\omega t) \tag{9}$$

$$m\omega^2 = k \tag{10}$$

$$\omega^2 = \frac{k}{m} \tag{11}$$

$$\omega = \sqrt{\frac{k}{m}} \tag{12}$$

To get the period we have to multiply by 2π. This is because the period of an unmodified cosine function is 2π and the constant ω multiplies with this 2π period.

Young's Modulus

Measures the resistance of a solid to elastic deformation.

Imagine a beam which is L units long, y units tall and z units across. We elastically deform the object by ΔL.

$$\text{Stress} = \frac{F}{A} \tag{13}$$

$$\text{Strain} = \frac{\Delta L}{L} \tag{14}$$

$$Y = \frac{F/A}{\Delta L/L} \tag{15}$$

All materials have a Young Modulus.

- Steel $= 20 \times 10^{10} N/m^2 = 140 GPa$

$$1\frac{N}{m^2} = 1Pa$$

3 Point Flexure

Two points are fixed
One point is flexed

Start with a beam of length L. Fix the ends and apply a force F on the middle. The crosssection is d high and b across.

Measuring from the bottom surface of the beam it will bend down a distance δ.

It can be shown:

$$\delta = \frac{F}{y}\frac{L^3}{4bd^3}$$

Photolithography

- A very pure silicon wafer is grown in a lab.
- We then coat the waver in a photoresist material.
- We then take a mask which blocks light.
- The light is passed through the mask and focused down to a microscopic structure.
- The light passing through the mask develops the photoresist, removing it from the surface.
- In additive lithography we then deposit material into the gaps in the photoresist.
- In subtractive lithography we etch into the material through the gaps left in the photoresist using an ionized gas which reacts with the silicon but not the resist.
- At the end we remove the photoresist and are left with a silicon structure.

DRIE

- We begin with two silicon wafers with an insulator between them.
- We etch into the silicon the anchor points
- We take some glass and deposit metal onto it
- We then flip the silicon over and bond it to the glass deposits using Anodic bonding
- We then etch away the back of the silicon until we remove the full insulator

Deep Reactive Ion Etch system.

- Gas is let into a chamber
- We apply current to ionize the gas
- The gas is pushed onto the wafer
- The back of the wafer is covered with ionized super cold helium.
- The gases are then pumped out the bottom of the chamber.
- The etching and masking phases repeat to create deep features into the material.