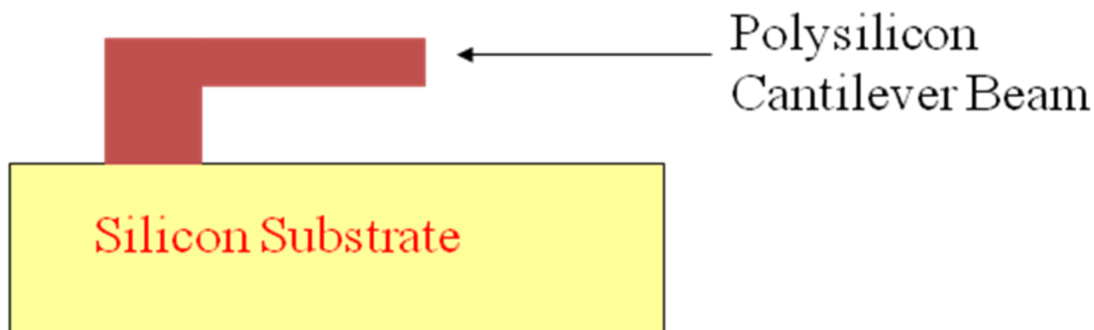
MEMS Fabrication, Continued

Surface Micromachining: The addition and subtraction of layers of materials on top of the substrate to realize a micromachined device

Example materials: metal films, polysilicon, polyimide, epoxies (SU-8)

Example:



Bulk Micromachining: Removal of the substrate material to realize a micromachined device

Example processes used: DRIE, wet etching

Example:

Wafer Bonding: The process of permanently attaching 2 wafers together

Wafer Bonding Processes:

(1) Gluing or adhesive bonding
(2) Eutectic bonding: solder
(3) Anodic bonding: Si to a special glass
(4) Si fusion bonding: high temp Si-Si bonding

Useful for fabricating complex MEMS devices

SOI Wafers

SOI: Silicon On Insulator: A type of wafer often used in making MEMS devices

SOI wafers consist of three layers

(1) A thick silicon base <Handle Layer> - Bottom Layer
(2) A thin silicon dioxide layer <Box Layer> - Middle Layer
(3) A thin silicon layer <Device Layer> - Top Layer

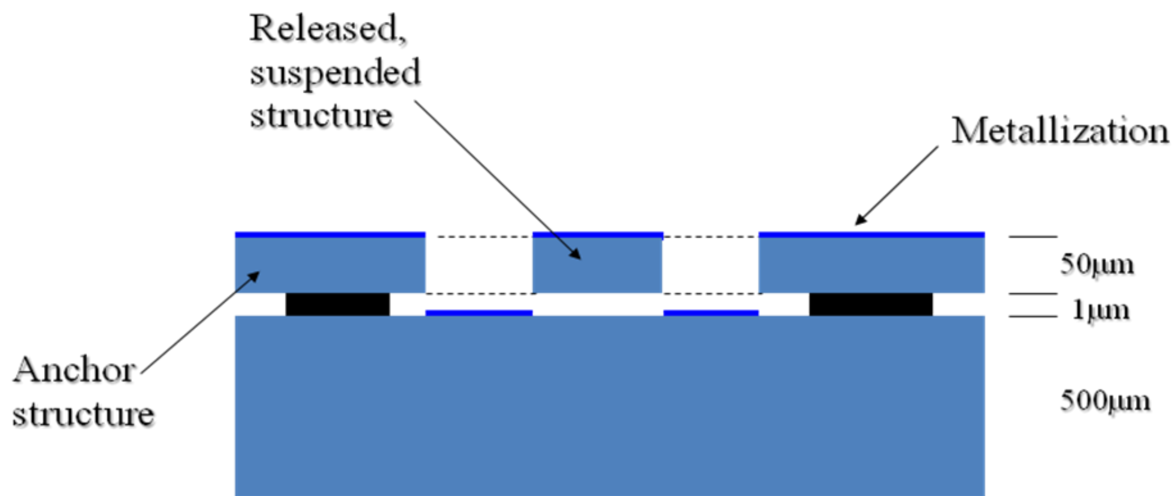
For MEMS applications: SOI wafers are manufactured by wafer bonding 2 wafers together and grinding and polishing one of them back to the desired Device Layer thickness

SOI Wafer Illustration

Typical SOI MEMS Fabrication Process

(1) Photolithography on the device layer and Bosch process DRIE down to Box layer
(2) Dice wafer into individual die
(3) Remove most of the Box layer with timed liquid or vapor HF acid
(4) Replace liquid HF acid with alcohol solution
(5) Critical/triple point drying (liquid HF process only)
(6) Thin film metallization (Al, Ti-Au, Ti-Ni-Au)
(7) Mount in package and wire bond

Example SOI MEMS Device (cross-sectional view):



Polysilicon on Si Process

Alternative to SOI process

(1) Grow thin (≤1 μm) SiO_2 layer on the Si wafer
(2) Grow thin (≤5μm) polysilicon layer on the SiO_2 layer
(3) Pattern the polysilicon layer like the Device Layer in the SOI process

(4) Similar to rest of SOI process…

Note: the SOI Device Layer can be much thicker than the polysilicon layer and has some different material properties

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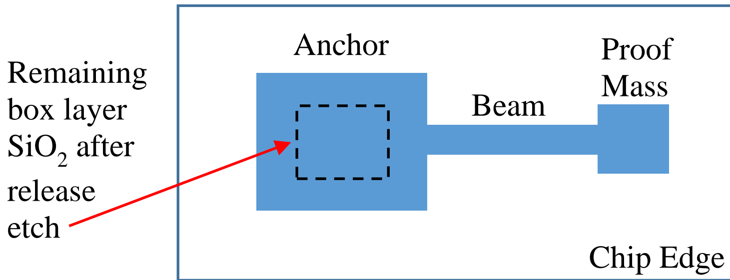
Realizing a MEMS Device with an SOI wafer

SOI wafer:

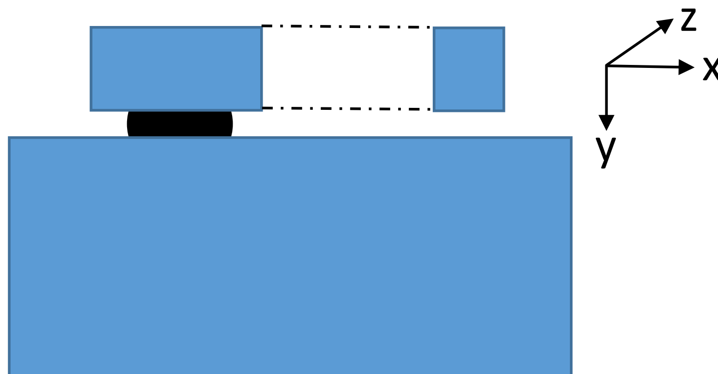
Layer	Material	Thickness
Device Layer	Si	100 μm
Box Layer	SiO_2	2 μm
Handle Layer	Si	500 μm

Example simple MEMS device in SOI process:

Top down view



Cross-sectional view



Anchor (rigid structure): does not bend/deform when subjected to external forces

Proof Mass (rigid structure)

Beam (flexible or elastic structure) does bend/deform when subjected to external forces. It will return to its original shape when those external forces are removed: it undergoes elastic deformation.

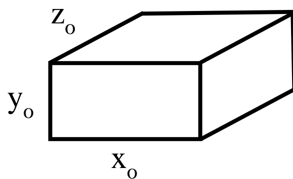
Beam ≡ Spring ≡ Flexure

Silicon (Si) is our primary structural material

Si material properties:
Density: $\delta = 2.3$ g/cm^3
Young's Modulus: E = ~165 GPa {111 to 190 GPa, type of Si and crystal plane dependent}
(note: 1 Pa = 1 N/m^2)

E ≡ stress/strain

Proof Mass



Volume = V $= x_o y_o z_o$

Mass = m = δV, [m] = kg

Note: Be careful of unit conversions: μm to m, etc.

Associated with mass in inertial force, F_I

$$F_I = ma$$