Microfabrication Terms, Continued

**Stiction**: “Static Friction”, when two micro-structures come into contact, they tend to stick together

Due to several forces acting on small masses:
1. Electrostatic forces between charged surfaces
2. Capillary forces from a high surface tension during a wet etch release can pull micro-structures together, that are then held together by Van der Waals forces
3. Spot welding

Stiction is a MAJOR problem in MEMS devices

**Triple Point Drying**: (TPD) a drying process to avoid stiction by going from liquid to solid to gas, avoiding stiction problems due to surface tension from going from liquid directly to gas.

**Critical Point Drying**: (CPD) a drying process to avoid stiction by going from liquid to supercritical liquid to gas. Supercritical liquid to gas has almost no surface tension.

TPD or CPD is performed in a special temp/pressure chamber

**Example TPD Process**
1. Liquid etchant is replaced with liquid water
2. Water is frozen: ice
3. Ice is sublimated (solid directly to gas)

**Example CPD Process**
1. Liquid etchant is replaced with alcohol
2. Alcohol is replaced with liquid CO₂
3. Liquid CO₂ to supercritical CO₂
(4) Supercritical CO₂ to gaseous CO₂
(5) Replace CO₂ with atmospheric gases

Both TPD and CPD are fairly harsh processes that can damage fragile microstructures.

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**Dicing:** A process by which wafers are cut into individual die

Uses an automated diamond saw and water jet cooling

Care must be taken to protect fragile micromachined structures during dicing

The final release etch is usually done after dicing to protect fragile structures and to prevent stiction from the water

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**Thin Film Metallization:** Sputtering and Electron Beam Deposition

**Sputtering Deposition:** Sputtering is used to remove atoms from a sputtering target, which migrate across a low pressure chamber and deposit on a substrate.

**E-Beam Deposition:** A focused electron beam is used to evaporate material from a target, which migrates across a low pressure chamber and deposits on a substrate

Typically 2 or 3 layers deposited:
(1) Adhesion layer, Ti or Cr
(2) A barrier layer, Ni
(3) A top layer, Au
**Wire Bonding:** The process of attaching tiny wires between pads on the die and pads on the package the die is attached to/in.

**Typical wire bonding wire:** 25µm diameter Au wire

- Al, Ti-Au, Ti-Ni-Au “can be” wire bonded
- Ti-Ni-Au “can be” soldered

**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:

![Cantilever Beam Diagram](image)

**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:
**Polysilicon on Si Process**

Alternative to SOI process

1. Grow thin ($\leq 1\, \mu m$) SiO$_2$ layer on Si wafer
2. Grow thin ($\leq 5\, \mu m$) polysilicon layer on SiO$_2$ layer
3. Pattern the polysilicon layer like the Device Layer in SOI process
4. Similar to rest of SOI process…

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