Micro-331 FS 2025

Guiding questions towards the answers to the SLT questions

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- SLT1 – MEMS/CR
- SLT2 – CVD
- SLT3 – PVD
- SLT4 – Lithography
- SLT5 – Dry etching
- SLT6 – Wet etching

SLT1 – MEMS & Cleanroom

- **1.1 Scale & MEMS vs. NEMS:**
    - *Hint:* Look at the mathematical scaling of Surface Area versus Volume as device size becomes very small.
- **1.2 Sensors in Automotive/Drones:**
    - *Hint:* Focus on the three distinct sensing needs: motion detection, sound, and frequency filtering.
    - *Mechanism:* For accelerometers and microphones, identify which part of the device *moves* relative to the fixed part and how that changes the electrical capacitance.
- **1.3 Accelerometers & Micromachining:**
    - *Hint:* To create movable parts, you must remove something. Review the role of the "buried oxide" layer in the release step.
    - *Comparison:* Think of Surface Micromachining as "building on top" and Bulk Micromachining as "digging into." Which is better for robust, heavy masses, and which allows for complex, multi-layer architectures?
- **1.5 Joule Heating:**
    - *Hint:* Recall the coefficient of thermal expansion (CTE). If you bond two materials with different CTEs together and heat them, what *mechanical* reaction must occur to relieve the stress?
- **1.6 Cleanroom Contamination:**
    - *Hint:* Dust isn't the only enemy. Consider invisible threats like chemical traces, humidity, and static electricity. Why is a particle of dust more critical in photolithography than in packaging?

SLT2 – Chemical Vapor Deposition (CVD)

- **2.1 CVD Principles:**
    - *Hint:* The trade-off is often between "simplicity/speed" and "quality/coverage." How does the Mean Free Path of gas molecules change between APCVD and LPCVD?
    - *Plasma:* Why would you introduce plasma if your substrate melts at low temperatures?
- **2.2 Growth Regimes (Arrhenius Plot):**
    - *Hint:* In the plot of Log(Rate) vs. 1/T, identify the two distinct slopes. In one regime, the system waits for gas to arrive (supply); in the other, it waits for the chemistry to happen (reaction). Which one dominates at high temperatures?
- **2.3 CVD vs. ALD (Silicon Nitride):**
    - *Hint:* Visualize CVD as a continuous "rain" of material and ALD as applying one "monolayer" at a time. How does this difference affect the ability to coat a very deep, narrow trench (conformality)?
- **2.4 Diamond & SiO2:**
    - *Hint:* Diamond requires removing graphite-like carbon during growth—what high-energy species performs this "cleaning" task?
    - *SiO2:* Compare an oxide grown *from* the silicon (consuming it) versus an oxide deposited *on* the silicon.
- **2.6 Electrodeposition:**
    - *Hint:* This process requires a conductive path and a liquid bath. Why is this method preferred for filling deep vias (TSVs) or making thick metal layers compared to the slow, gas-phase CVD?

SLT3 – Physical Vapor Deposition (PVD)

- **3.1 Thermal Evaporation:**
  - *Hint:* Compare the heating source: Resistive heating vs. E-beam. Which source concentrates energy locally enough to melt ceramics or Tungsten without melting the crucible?
  - *Planetary System:* Why do we rotate wafers in a "planetary" motion? Think about the directionality of the vapor source.
- **3.2 & 3.3 Sputtering (DC vs. RF/Magnetron):**
  - *Hint:* Think of sputtering as "atomic billiards."
  - *DC Limitation:* What happens electrically if you shoot positive Argon ions at an *insulating* target? The circuit must be completed.
  - *Magnetron:* How do magnets affect the path of electrons, and how does this improve ionization efficiency?
- **3.4 Step Coverage (PVD vs. CVD/ALD):**
  - *Hint:* Compare "Line of Sight" (PVD) vs. "Surface Reaction" (CVD/ALD).
- **3.5 Stress & Adhesion:**
  - *Hint:* Thin films rarely fit the substrate perfectly. Consider the mismatch in thermal expansion (extrinsic) and atomic lattice spacing (intrinsic). What post-process step effectively "relaxes" the material?

SLT4 – Lithography

- **4.1 Resolution:**
  - *Hint:* Look at the Rayleigh criterion formula. To get a better resolution, what must happen to the wavelength?
- **4.2 Masks vs. Direct Writing:**
  - *Hint:* Compare a stamp (Mask) to a pencil (Direct Laser Writing/EBL). Which one is faster for making 1,000 copies? Which one is cheaper if you need to change the drawing 10 times?
- **4.3 Etching vs. Lift-off:**
  - *Hint:* It comes down to the order of operations. Do you put the metal down *first* and cut it away (Etching), or do you put the stencil down *first* and fill the holes (Lift-off)?
- **4.4 E-Beam Lithography (EBL):**
  - *Hint:* Electrons have a much shorter wavelength than UV light. Why does this allow for smaller features, and why does scanning a single beam make the process slow?
- **4.5 Photoresist Contrast:**
  - *Hint:* Look at the slope of the contrast curve. Does a vertical slope (high contrast) result in vertical or sloped sidewalls on the wafer?

SLT5 – Dry Etching

- **5.1 Plasma Generation:**
  - *Hint:* Plasma involves ionizing gas. Consider the role of the blocking capacitor in creating a "self-bias." How does this bias help accelerate ions towards the wafer?
- **5.2 Isotropy vs. Anisotropy:**
  - *Hint:* Balance the *Chemical* component (F radicals) vs. the *Physical* component (Ion bombardment). Which one digs straight down, and which one eats in all directions?.
- **5.3 DRIE (Bosch Process):**
  - *Hint:* How do you dig a very deep, straight hole without the walls collapsing? Think of a cycle that alternates between "digging" (etching) and "reinforcing the walls" (passivation).
- **5.4 Selectivity:**
  - *Hint:* To stop an etch, you need a material that *doesn't* react with the gas. Compare the volatility of the byproducts. If the byproduct is solid/non-volatile, does etching stop or continue?
- **5.5 Dry Chemical Etching (XeF2 / HF Vapor):**
  - *Hint:* These are gas-phase processes *without* plasma. Without the directional energy of ions, what does the etch profile look like (isotropic or anisotropic)?

SLT6 – Wet Etching

- **6.1 Wet Etching Basics:**
  - *Hint:* Wet etching is generally purely chemical. What does this imply about the direction of the etch (under the mask)?
- **6.2 KOH & Anisotropy:**
  - *Hint:* Look at the atomic density of the silicon crystal lattice. Why is it chemically harder to attack the (111) plane than the (100) plane? Think about the number of "backbonds."

- **6.3 Etch Stops:**
    - *Hint:* You can't use a stopwatch for everything. How can doping (Boron) or electricity (Electrochemical) create a barrier that chemically prevents the etchant from working?
- **6.4 Stiction & Supercritical Drying:**
    - *Hint:* The danger zone is the "liquid-gas interface" where surface tension exists. Look at the phase diagram of CO_2—is there a path from Liquid to Gas that avoids crossing the phase boundary line?
- **6.6 Process Flow (Nanopore):**
    - *Hint:* Order matters. If you make the tiny 50nm pore *before* you release the membrane, how do you protect it during the harsh KOH etch? If you make it *after*, how do you handle the fragile membrane?