Substrate and Substrate Cleaning:

1. **Q: What is a substrate in the context of semiconductor fabrication?** A: A substrate is a base material on which semiconductor devices are built. It provides a foundation for the device components.
2. **Q: Why is substrate cleaning important in semiconductor manufacturing?** A: Substrate cleaning removes contaminants and impurities from the substrate surface, ensuring proper adhesion and functionality of subsequent layers.
3. **Q: Name two common methods for substrate cleaning.** A: Wet cleaning (using chemicals and solvents) and dry cleaning (using plasma or gas-phase processes).

Thin and Thick Films:

4. **Q: Define thin film and thick film in semiconductor processing**. A: Thin films have nanometer to micrometer thickness and are used for precise layers, while thick films have micrometer to millimeter thickness and are used for larger-scale structures.
5. **Q: Provide an example of a thin film application in semiconductor devices.** A: Thin film transistors (TFTs) in liquid crystal displays (LCDs).

Etching:

6. **Q: What is etching, and how is it used in semiconductor fabrication?** A: Etching is the process of selectively removing material from a substrate to create patterns or features. It's used to define structures on the substrate.
7. **Q: Differentiate between wet etching and dry etching.** A: Wet etching uses liquid chemical solutions, while dry etching uses plasma or gas-phase processes to remove material.
8. **Q: What are the two main categories of etching processes, and how do they differ?** A: The two categories are wet etching and dry etching. Wet etching uses liquid chemicals, while dry etching employs plasma or gas-phase reactions.
9. **Q: How does the etch rate depend on the concentration of etchant in wet etching?** A: The etch rate generally increases with higher etchant concentration.
10. **Q: Explain the principle behind isotropic etching.** A: Isotropic etching removes material uniformly in all directions from the exposed surface, creating rounded or tapered features.
11. **Q: What is an anisotropic etch, and why is it preferred in certain applications?** A: Anisotropic etching removes material at different rates in different crystallographic directions, resulting in well-defined vertical sidewalls.
12. **Q: In the context of dry etching, what is reactive ion etching (RIE)?** A: Reactive ion etching uses chemically reactive ions in a plasma to etch material selectively.
13. **Q: How does RIE achieve anisotropic etching compared to traditional wet etching?** A: RIE uses directional ions to etch vertically, while wet etching can cause isotropic etching due to the solution's uniform attack.
14. **Q: Describe the process of deep reactive ion etching (DRIE) and its applications.** A: DRIE involves alternating etching and passivation steps to create deep, high-aspect-ratio features. It's used in micro-electromechanical systems (MEMS) and through-silicon vias (TSVs).
15. **Q: What is the purpose of a hard mask in etching processes?** A: A hard mask protects the underlying material during etching and provides a pattern for the etching process.
16. **Q: Compare the advantages of wet etching and dry etching techniques.** A: Wet etching is simple and inexpensive, while dry etching offers better control, precision, and selectivity.
17. **Q: How does plasma etching differ from chemical etching?** A: Plasma etching uses ions and reactive species in a plasma to chemically react with the material, providing greater control and directionality.
18. **Q: Explain the principle of undercutting in etching processes.** A: Undercutting occurs when etching removes material beneath the protective mask, leading to an undesirable shape change.
19. **Q: What is the purpose of an etch stop layer, and how does it work?** A: An etch stop layer prevents the etching process from damaging underlying layers. It works by being chemically resistant to the etchant used.

20. **Q: Describe the Bosch process in dry etching and its applications**. A: The Bosch process involves cyclic etching and passivation steps to create high-aspect-ratio structures. It's used in MEMS and microfluidics.
21. **Q: How does wet etching differ from chemical mechanical polishing (CMP)?** A: Wet etching removes material through chemical reactions, while CMP involves mechanical and chemical forces to achieve planarization.
22. **Q: In the context of photolithography, explain how etching is used to transfer patterns onto a substrate**. A: After exposing and developing a photoresist pattern, etching removes exposed or unprotected material, transferring the pattern to the substrate.

Epitaxy:

23. **Q: Define epitaxy in semiconductor processing.** A: Epitaxy is the process of depositing a crystalline layer on a crystalline substrate with matching crystal orientation.
24. **Q: What is the difference between homoepitaxy and heteroepitaxy?** A: Homoepitaxy involves depositing the same material on a substrate, while heteroepitaxy involves depositing different materials with matching crystal structures.

Miller Indices:

25. **Q: Explain Miller indices as used in crystallography.** A: Miller indices represent the orientation of crystal planes in a lattice structure. They help define directions and planes within crystals.
26. **Q: Calculate the Miller indices for a plane that intercepts the x-axis at 2 units, the y-axis at 3 units, and the z-axis at 1 unit.** A: (213)

Baking:

27. **Q: Why is baking used in semiconductor processing?** A: Baking removes moisture and contaminants from wafers, enhancing the quality of subsequent processing steps.
28. **Q: What is the purpose of a pre-bake step before applying photoresist?** A: Pre-bake removes solvent and reduces air bubbles from the photoresist, ensuring uniform coating.

Deposition Techniques:

29. **Q: Explain the sol-gel deposition technique**. A: Sol-gel involves converting a solution (sol) into a solid (gel) film through chemical reactions, used for thin film deposition.
30. **Q: Describe the spin-coating method.** A: Spin-coating involves depositing a liquid material onto a spinning substrate, creating a uniform thin film.
31. **Q: How does sputtering work for thin film deposition?** A: Sputtering involves bombarding a target material with ions to release atoms that deposit onto a substrate.

Lattice and Crystals:

32. **Q: Define a lattice in crystallography.** A: A lattice is a repetitive 3D arrangement of atoms or points in space.
33. **Q: How is the lattice constant defined?** A: The lattice constant is the distance between equivalent points in adjacent unit cells of a crystal lattice.

Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD):

34. **Q: Explain the difference between PVD and CVD**. A: PVD involves depositing material from a physical source, while CVD involves depositing material from a chemical reaction.
35. **Q: Describe the steps of the CVD process.** A: CVD involves introducing precursor gases, which react to deposit a solid film on a substrate.

Spray Pyrolysis:

36. **Q: What is spray pyrolysis?** A: Spray pyrolysis is a deposition technique where precursor solutions are atomized and sprayed onto a heated substrate to form a thin film.
37. **Q: State an advantage of using spray pyrolysis.** A: Spray pyrolysis is suitable for large-area deposition and can be used for various materials.

Photo Mask:

38. **Q: What is a photo mask in semiconductor lithography?** A: A photo mask is a template with patterns used to define structures on a substrate during lithographic processes.
39. **Q: How is a photoresist used in conjunction with a photo mask**? A: A photoresist is coated on the substrate, exposed to light through the mask, and developed to transfer the mask pattern onto the substrate.

Diffusion:

40. **Q: Define diffusion in semiconductor processing.** A: Diffusion is the process of introducing dopants into a semiconductor substrate to modify its electrical properties.
41. **Q: Explain the difference between n-type and p-type diffusion**. A: N-type diffusion introduces donor atoms to increase electron concentration, while p-type diffusion introduces acceptor atoms to increase hole concentration.

NMOS and CMOS Fabrication:

42. **Q: Differentiate between NMOS and PMOS transistors in terms of doping**. A: NMOS transistors use n-type source and drain regions, while PMOS transistors use p-type source and drain regions.
43. **Q: Outline the steps for fabricating a basic NMOS transistor.** A: Steps include oxidation, photolithography, diffusion, gate oxide growth, polysilicon deposition, and metallization.

Ion Implantation:

44. **Q: What is ion implantation?** A: Ion implantation is a process of introducing dopant ions into a substrate using an accelerated ion beam.
45. **Q: How does ion implantation affect the electrical properties of a semiconductor?** A: Ion implantation introduces controlled doping, altering the conductivity and behavior of the semiconductor.

Oxidation and Isolation:

46. **Q: Describe the purpose of oxidation in semiconductor processing.** A: Oxidation forms a thin insulating layer (oxide) on a semiconductor surface, protecting and isolating underlying layers.
47. **Q: Explain local oxidation of silicon (LOCOS).** A: LOCOS is a technique to selectively grow silicon dioxide to isolate active regions on a semiconductor substrate.

Integrated Circuits (IC) and Packaging:

48. **Q: What is an integrated circuit (IC)?** A: An integrated circuit is a compact arrangement of interconnected electronic components on a semiconductor substrate.
49. **Q: Describe flip-chip packaging.** A: Flip-chip packaging involves directly bonding the active side of a semiconductor die to a substrate, enhancing electrical performance.

Mathematical Problems:

50. Q: Calculate the aspect ratio of a photoresist pattern with a height of 2 micrometers and a width of 10 micrometers. A: Aspect Ratio = Height / Width = 2 / 10 = 0.2

51. Q: If a silicon wafer with a diameter of 150 mm is cut into square substrates, how many 5 mm x 5 mm substrates can be obtained? A: Area of wafer = π * (150 mm / 2)^2 = 17671.89 mm² Area of one substrate = 5 mm * 5 mm = 25 mm² Number of substrates = Area of wafer / Area of one substrate = 706.88
52. Q: Calculate the lattice constant of a crystal with a unit cell volume of 100 Å^3 and a cubic structure. A: Volume of cube = a^3, where 'a' is the lattice constant. 100 Å^3 = a^3 Lattice constant (a) = ∛100 Å^3 ≈ 4.76 Å
53. Q: If the resistivity of a semiconductor material is 3.5 Ω-cm and its cross-sectional area is 0.02 cm², calculate the resistance. A: Resistance (R) = Resistivity * (Length / Area) Assuming Length = 1 cm, R = 3.5 Ω-cm * (1 cm / 0.02 cm²) = 175 Ω

XRD Data Analysis - Thin Film Thickness Calculation:

1. **Q: How can you use the Bragg equation to calculate the lattice spacing of a crystalline material from XRD data?** A: The Bragg equation, $n\lambda = 2d \sin(\theta)$, relates the wavelength of X-rays (λ), lattice spacing (d), diffraction angle (θ), and order of diffraction (n).
2. **Q: Explain the principle of XRD-based thin film thickness calculation using the Bragg-Brentano geometry**. A: In the Bragg-Brentano geometry, the angle of diffraction is used to determine the lattice spacing, which, in turn, helps calculate the thin film thickness.
3. **Q: How can you calculate the thickness of a thin film using the full width at half maximum (FWHM) of a diffraction peak?** A: FWHM is related to crystallite size and lattice strain, which can be used to calculate the thickness of a thin film using appropriate equations.
4. **Q: Describe the rocking curve method for thin film thickness determination in XRD analysis.** A: The rocking curve method involves measuring the intensity of a diffraction peak while varying the angle of incidence. A broader peak indicates a thicker film.
5. **Q: Explain the concept of a standard reference material in XRD thin film analysis**. A: Standard reference materials with known lattice parameters are used to calibrate XRD instruments and validate thickness calculations.

UV/Vis Data Analysis - Band Gap Energy Calculation:

6. **Q: How does the absorption spectrum of a semiconductor provide information about its band structure?** A: The onset of absorption in the UV/Vis spectrum corresponds to the energy needed to promote electrons from the valence band to the conduction band, giving insights into the band gap.
7. **Q: Describe how to determine the band gap energy from a Tauc plot of UV/Vis absorption data.** A: The Tauc plot involves plotting $(\alpha h\nu)^2$ against photon energy ($h\nu$) and extrapolating the linear portion to find the band gap energy (Eg).
8. **Q: What is the relationship between the absorbance spectrum and the band gap energy of a semiconductor material?** A: The onset of the absorption edge in the absorbance spectrum corresponds to the band gap energy, where electrons are excited from the valence to the conduction band.

9. **Q: Explain the Urbach tail and its significance in UV/Vis absorption spectra.** A: The Urbach tail is a low-energy tail in the absorption spectrum, caused by localized states in the band gap. It provides information about defects and disorder in the material.
10. **Q: How can you determine the optical band gap energy from the wavelength at which the absorption coefficient is maximum?** A: The absorption coefficient is proportional to photon energy, and the optical band gap energy can be estimated from the peak absorption wavelength.
11. **Q: Describe the method of using the Tauc plot for indirect band gap materials.** A: For indirect band gap materials, the Tauc plot involves plotting $(\alpha h\nu)^2$ against $h\nu$ and extrapolating the linear portion to determine the indirect band gap energy.
12. **Q: How does the Kubelka-Munk function relate to UV/Vis absorption measurements?** A: The Kubelka-Munk function transforms the diffuse reflectance spectrum into an absorption-like spectrum, making it useful for non-transparent or scattering materials.
13. **Q: Explain the significance of the absorption edge and the Urbach energy in determining band gap and electronic properties.** A: The absorption edge indicates the energy required for electron excitation, while the Urbach energy characterizes the disorder or imperfections affecting the band structure.
14. **Q: How does the band gap energy of a semiconductor material relate to its color appearance?** A: The color of a material is related to the energy of absorbed or emitted light, which is influenced by the band gap energy.
15. **Q: Discuss the importance of sample preparation and baseline correction in UV/Vis absorption measurements.** A: Proper sample preparation and accurate baseline correction are crucial for obtaining reliable absorption spectra, which in turn affect band gap energy calculations.