Lecture-09-13 Photo Lithography

9.1. What are the different tones of a photo resist and how do they respond to UV light?

Ans: Photo resists can be of two types (two tones): Positive and Negative.

A *positive resist* is a type of photoresist in which the portion of the photoresist that is exposed to light becomes soluble to the photoresist developer. Example: Diazonaphtho-quinone/novolac (DQN) Resists.

A *negative resist* is a type of photoresist in which the portion of the photoresist that is exposed to light becomes insoluble to the photoresist developer. Example: SU 8, Kodak Thin Film Resist (KTFR).

9.2. Compare some of the Critical properties of Positive and Negative Photoresist.

Ans: Comparison of some of the critical properties are shown here:

Property	Positive Resist	Negative Resist
Adhesion to Silicon	Fair	Excellent
Developer Base	Aqueous	Organic
Minimum Thickness	0.5 μm	2.0 μm
Wet Chemical Resistance	Fair	Excellent
Step Coverage	Better	Poorer
Relative Cost	More	Less

9.3. What are the important process parameters that influence the film thickness in Spin Coating?

Ans: The important process parameters that influence the film thickness are: 1) Spin Speed (RPM); 2) Spinning Duration; 3) Dispensed solution Concentration and 4) Dispensed Solution volume.

Thickness increases with increase in Concentration and solution volume and reduces with increase in RPM and spinning duration. However, spinning duration has a far lower impact on thickness as compared to solution concentration.

9.4. What is the significance of Soft Baking in Photolithography?

Ans: Almost all of the solvents are removed from a photoresist coating during Soft Baking and therefore plays a very critical role in photo-imaging. The photoresist coating becomes photosensitive, or imageable, only after successful softbaking. Oversoft-baking will degrade the photosensitivity of resists by either reducing the developer solubility or actually destroying a portion of the sensitizer. Undersoftbaking will prevent light from reaching the sensitizer. Positive resists are incompletely exposed if considerable solvent remains in the coating. This undersoft-baked positive resists is then readily attacked by the developer in both exposed and unexposed areas, causing less etching resistance.

9.5. What is the role of Hard Baking in Photolithography?

Ans: Hard-baking is the final step in the photolithographic process. This step leads to hardening of the photoresist layer and improves adhesion to the wafer surface.

9.6. What is the role of the barrier layer in photolithography?

Ans: The patterns on the mask are first transferred on to the photo resist layer. After etching the photo resist layer, the barrier layer is also etched, which means that the pattern on the mask is now transferred in to the oxide layer. At the portions of the oxide layer that has been etched, there is direct access of the wafer surface to the surrounding. Subsequntly the photo resist layer is completely removed and one is left with only a patterned barrier layer. The barrier layer ensured selective contact during the doping reaction, thereby forming the P – N junctions on the wafer surface.

9.7. Why direct patterning of the barrier layer not possible in photolithography?

Ans: Because the oxide layer is not photo sensitive and therefore direct UV exposure of the oxide layer will not lead to any spatial variation of chemical/ structural properties within the UV layer. Thus, the patterns in the mask will not get transferred on to the oxide layer (and subsequently, to the wafer).

9.8. What is the numerical Aperture of a lens?

Ans: The numerical aperture (NA) of the lens used is a key aspect in determining the feature size in Photolithography. **NA= sinθ**

where θ is the largest angle incident on the wafer. The critical relationship between numerical aperture, light source wavelength, and feature size for optical lithography systems is given by the following equation: **R = kλ/NA**

R is the resolution or feature size. k is a proportionality constant that is determined by several factors, including antireflective coatings above or below the photoresist, the resist's own parameters, and the coherence of the illumination. λ is the light source wavelength. NA is the numerical aperture. As NA increases, the resolution decreases, decreasing the feature size; feature size is inversely proportional to numerical aperture

9.9. What are the major limitations of photolithography?

Ans: Photolithography has several major limitations. Some of which are:

1) It is not applicable for curved surfaces
2) It is diffraction limited
3) Photo sensitive polymers are necessary
4) The mask is expensive
5) Processing conditions are very harsh, so it cannot be used in biological samples.

9.10. How can Interference affect resolution in Photolithography ?

Ans: Interference is another property of light that presents a challenge to Photolithography. As the mask serves as a diffraction grating, the light that passes through the mask gets split into many separate light beams which start interfering with each other, creating an optical pattern on the wafer surface that differs from the pattern on the mask. Because interference increases as the pattern of holes and lines on the mask shrinks, interference restricts feature size.

9.11. What is Immersion Lithography? How is the numerical aperture improved in Immersion lithography?

Ans: In immersion lithography, the space between the projection lens and the wafer is filled with a liquid, which has higher refractive index than water. In that case, the effective NA increases to:

$$\mathbf{NA = n \times (\sin\theta)}$$

Since **n** > 1, immersion technology allows better resolution enhancement and higher numerical apertures (NA) over conventional projection lithography.