Experiment 15, Part B. Photolithography using Chemically Amplified Crosslinkable Epoxy Resin Resist.

The following directions are an adaptation of the SU-8 Resist Guidelines provided by the supplier.

You will be using Nano SU-8 photoresist from Micro-Chem, with the SU 8-50 or -100 formulation. This photopolymer can be used to make relatively thick photoresist films ranging from 1 micron up to 200 microns.

Unlike the hydroxystyrene photoresists discussed in class, which were positive resists for which exposure led to heightened solubility, SU-8 is a negative resist. Within the regions that are exposed through the mask, the photoacid generator is activated. The generated acid leads to an accelerated crosslinking process between epoxy resin oligomer in the photoresist, leading to a fully crosslinked, insoluble solid. The remaining regions can be dissolved away in the appropriate solvent.

1) Select a clean silicon wafer which has been pre-treated with a solvent rinse with acetone or toluene, a "piranha" clean process (soak in H_2SO_4 and H_2O_2 at high temperature) followed by a water rinse, and ethanol rinse, and a bake at 200°C. These wafers will already be prepared and available to you in the lab.

2) Determine the desired thickness of your photo resist pattern. Finer features will be better defined in thinner layers of photoresist. You may want to try one or two different thicknesses. Based on the desired thickness, select an appropriate spin speed using the table below:

Product Name	Viscosity (cSt)	Thickness (µms)	Spin Speed (rpm)
		40	3000
SU-8 50	12250	50	2000
		100	1000
		100	3000
SU-8 100	51500	150	2000
		250	1000

Table 1. Thickness vs. spin speed data for selected SU-8 resists.

3) Place your wafer on the vacuum chuck of the spin coater and make sure that it is well secured. Dispense approximately 3 ml of photoresist for 3 inch wafers, or 5 ml for a 5 inch wafer onto the middle of the silicon wafer.

4) Spread Cycle: Ramp to 500 rpm at 100 rpm/second acceleration. Hold at this speed for 5-10 seconds to allow the resist to cover the entire surface.

5) Spin Cycle: Ramp to final spin speed at an acceleration of 300 rpm/second and hold for a total of 30 seconds.

6) After the resist has been applied to the substrate, it must be soft baked to evaporate the solvent and densify the film. SU-8 is normally baked on a level hot plate, although convection ovens may be used. The following bake times are based on contact hot plate processes. Bake times should be optimized for proximity and convection oven bake processes since solvent evaporation rate is influenced by the rate of heat transfer and ventilation.

For photolithography, the smoothness of the thin film is critical, because contact mask processes rely on close contact between the film and the mask. For best results, ramping or stepping the soft bake temperature is recommended. Lower initial bake temperatures allow the solvent to evaporate out of the film at a more controlled rate, which results in better coating fidelity, reduced edge bead and better resist -to-substrate adhesion. Refer to Table 2 for TWO STEP contact hot plate process recommendations.

Product Name	Thickness (µms)	Pre-bake @65°C	Softbake @95°C
	40	5	15
SU-8 50	50	6	20
	100	10	30
	100	10	30
SU-8 100	150	20	50
	250	30	90

Table 2. Recommended soft bake parameters

Once the coated silicon wafers are baked, measure the film thickness using ellipsometry or a profilometer (see lab TA for directions). This should be done for each of your samples before exposure.

7) Exposure of substrates to mask under UV:

This resist is designed to respond to UV light between 350 nm (below which the resist begins to absorb much of the light) and 400 nm.

You will need to place your contact mask in close contact with your wafer – you can do so by clamping the mask to the wafer or by using a solid piece of *UV-transparent* glass or clear polymer slab to hold the mask onto the substrate.

Expose your substrates at a range of times, and try to determine optimal conditions for developing your features.

8) Following exposure, a post expose bake (PEB) must be performed to selectively cross-link the exposed portions of the film. This bake can be performed either on a hot plate or in a convection oven. Optimum cross-link density is obtained through careful adjustments of the exposure and PEB process conditions. The bake recommendations below are based on results obtained with a contact hot plate.

Product Name	Thickness (μms)	PEB 1 @65°C	PEB 2 @95°C
	40	1	4
SU-8 50	50	1	5
	100	1	10
	100	1	10
SU-8 100	150	1	12
	250	1	20

Table 4. Recommended post exposure bake parameters

9) You will use the commercial developer for this product, which consists of a combination of solvents for the uncrosslinked SU-8 resist.

Recommended develop times are given in Table 5. for immersion processes. These proposed develop times are approximate, since actual dissolution rates can vary widely as a function of agitation rate, temperature and resist processing parameters. Following the developer process, the substrate should be rinsed with isopropyl alcohol and dried with a nitrogen or air stream.

Rinse tip: If a white film is produced during rinse, this is an indication that the substrate has been under developed. Simply immerse or spray the substrate with SU-8 developer to remove the film and complete the development process. Repeat the rinse step

Examine your patterned sample(s) using an optical microscope. Observe the feature sizes in the photopattern and in your mask. Answer the followinq questions to turn in at the end of class.

Questions for Experiment 15b:

What film thicknesses were used in the spincoated photoresists that you made, and at what rpm?

How well formed were the features you created using your homemade mask? What are the largest and smallest features that were imaged?

Is feature size consistent with the size of features on the mask

Is there any correlation between film thickness and fidelity of the features? Explain.

What exposure and development times were appropriate for your masked features? Do these parameters vary with larger or smaller features?

What is the role of the post expose bake? What is risked if the bake time is decreased significantly? Are there any potential issues if bake time is greatly increased?

How important do you think film shrinkage upon crosslinking would be in this process – explain.