filename: LITHO

The fabrication of planar semiconductor devices and integrated circuits requires the formation of patterns on the surface of the circuit substrate. The process most commonly used to form these patterns is called photolithography. This technique uses a thin, photosensitive organic film, called photoresist, to transfer the pattern from a master mask to the IC substrate. Figure 1 illustrates the photolithographic process for two basic kinds of resist material, positive photoresist and negative photoresist. In this example the ultimate objective of the process step is the formation of openings to the silicon surface through a SiO_2 film, which could then serve as either a diffusion mask or a contact pattern. To begin the process the wafer is cleaned and dried, and the photoresist (PR) is applied. The PR is supplied in a viscous liquid form; it can easily be formed into a very thin (about 1 μm) and uniform layer by spinning a liquid-coated substrate at high speed. During the spin most of the solvents in the resist evaporate, but after spinning a pre-bake is performed to further dry and harden the film. As shown in the top segment of Fig. 1, the resist is exposed through a mask with the desired pattern on it. For a negative PR, the exposed areas are rendered insoluble by exposure to light. When immersed in a developer solution the unexposed regions are dissolved, leaving exposed regions covered by the resist. For a positive PR, the exposed regions are rendered soluble by exposure to light, and so after development only areas unexposed are still covered by resist. The resulting patterned substrate must then be placed in an etch (in this example, buffered HF), for which the resist serves as an etch mask. In this OP we are concerned with the application and development of the photoresist.

We use exclusively positive photoresists in our laboratory. There are a number of reasons for this, several of which will be discussed in lecture. Two important reasons are the somewhat simpler developing process (a slightly alkaline solution followed by a water rinse) and more durable film produced by positive resist. The characteristics of the resist we use are given in the data sheet on page IV-3.

Note that for these resists any area exposed to light will wash off in the developer, so care must be taken to avoid accidental exposure. Our Litho Room has yellow lights which do not expose the PR; the regular fluorescent room lights, **as well as an unfiltered microscope illuminator**, will expose the PR. Be careful not to expose a chip to these lights until it has been exposed with the mask aligner and developed.

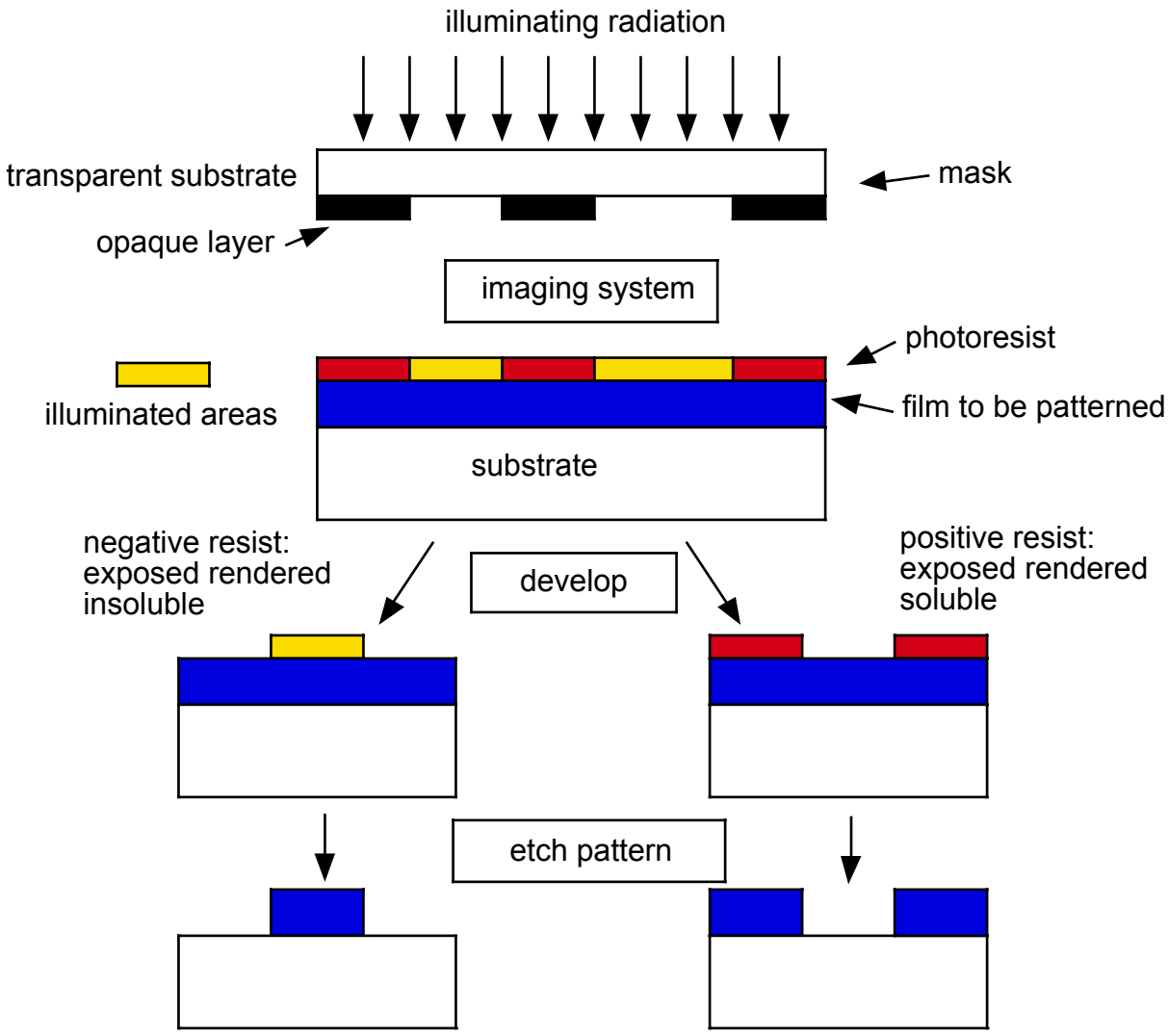

Figure 1: Basic lithographic process (adapted from Introduction to Microlithography, Thompson et al)

The operating procedure for processing the positive resist we use is given on the next page. Several important features should be noted:

- Pre-bake: dries and hardens film; time, temperature, humidity affect photospeed of resist
- Exposure: check Mask Aligner log book for current time
- Development: there is a large development latitude so time is not critical; make sure to fully rinse chips HPH_2O before drying
- Flood Exposure: required to make removal of post-baked resist easier; during exposure positive PR liberates N_2, which if the exposure intensity is too high, can cause resist lift-off from substrate; this is the reason for the 5 sec/pause/5 sec/etc exposure used here

- Post-bake: required to harden PR and to improve adhesion of PR to substrate for later wet etch steps

References

Photoresist: Materials and Processes, W.S. DeForest, McGraw Hill 1975, ISBN 0-07-016230-1

Introduction to Microlithography, eds. L.F. Thompson, C.G. Willson, M.J. Bowden, American Chemical Society, 1983, ISBN 0-8412-0775-5.

Operating Procedure OP-L

1. Dehydration bake: Bake out the sample in the Post-bake oven for 5 mins. (The Post-bake oven is set at a temperature 125˚ C).

2. Place chip on spinner chuck. Carefully open the Adhesion Promoter bottle and using the eyedropper, put a drop or two of Adhesion promoter at approximately the center of the sample. (When replacing the dropper, DO NOT spill any Adhesion fluid on to the threads of the bottle top.) Start the spinner (step on foot pedal). If necessary, adjust controller for spin rate of approximately 4000 rpm. Set timer for 30 sec.

3. Apply Photoresist: At the end of spin-cycle, repeat Step 2 using the positive photoresist (AZ1350J or equivalent). We are using a syringe-like dispenser with a particulate filter to remove any large "boulders" that could contaminate your film. See TA's for instructions on proper use of these dispensers. Don't be afraid to use too much photoresist, since the excess will spin off.

4. Pre-bake: At the end of the spin cycle, remove the sample and do a 10 min pre-bake in the pre-bake oven at 95˚.

5. Expose: The sample is now ready for alignment and exposure: use OP-O, align the sample with the

appropriate Mask on the Micro-Tech Mask Aligner. Having aligned the sample with the Mask, do a 15 sec. exposure to UV light. CHECK FOR NEW EXPOSURE TIME IN LOG BOOK. At the end of the exposure, remove the sample, replace the mask in the appropriate container. The sample is now ready for development.

6. Develop: The development station is located on the left side of the sink. The station has 3 beakers marked Developer, H2O, and H2O. (The three beakers should be set up by the T.A.). Using a pair of tweezers, dip the sample into the developer for 60 sec. Remove the sample at the end of the 60 sec. and rinse in the water in the next two beakers. Carefully blow sample dry. Inspect.

7. Flood expose under UV lamp for approx. 5 sec., pause, 5 sec., pause, 5 sec., for a total of 15 sec.

8. Post Bake: in the post bake oven, perform bake at 125˚C for 10 min. The sample is now ready for any subsequent processing.

Resist Developer make-up:

1. AZ Developer:high purity water, in ratio 1 : 1.
2. Approximately 80-100 ml will develop about 4 chips.

Basic Photolithography

1) CLEAN YOUR SUBSTRATE!!!!
Photoresist does NOT like to stick to DIRTY or WET substrates. Immediately prior to PR application a dehydration bake is a good idea: 125o, approx 5-10 min.

2) SPIN ON PHOTORESIST
Make absolutely sure your sample COMPLETELY COVERS THE VACUUM CHUCK. First apply adhesion promoter (a couple of drops) and spin dry (check the spin speed during this step). Now apply a few drops of photoresist in the center of the chip.

Spin: 4,000 to 5,000 rpm, 30 sec.

3) PREBAKE: 95˚C, 10 min.; the time is important.

4) EXPOSE: note: the UV lamps take approx. 15 min to warm up. Microtech aligner: approx. 15 sec. Check log book for current exposure.

Turn the aligners OFF when you finish. DO NOT TURN OFF THE UV LAMP unless everyone is done for the day. THE LAMPS MUST COOL 30 min. AFTER THEY ARE TURNED OFF BEFORE THEY CAN BE RESTARTED.

5) DEVELOP:
AZ Microposit Developer, diluted 1:1 with DI water.
Time: normal process: approx. 60 sec.

DEVELOPER SHOULD BE USED ONLY IN BEAKERS LABELED FOR IT. NEVER PUT DEVELOPER IN BEAKERS LABELED FOR WATER. After use dispose of developer in sink; don't be stingy in how much you use-developer is cheap. RINSE ALL BEAKERS THOROUGHLY AFTER USE.

6) RINSE thoroughly in DI, blow dry.

7) FLOOD EXPOSE: approx. 5 sec., pause, 5 sec.

8) POST BAKE: 125˚C, 30 min.