EXPERIMENT # 2: Lithography

Experiment # 2: Resist exposure and development

The purpose of this experiment is to familiarize the students with the photolithographic process, including resist spinning, baking, exposure, development and rinse.

Reading: Jaeger Section 2.1, Campbell Chapter 7 and 8, Instruction sheets

2.1 Negative (positive) photoresist is spun unto a silicon wafer using the following procedure:
The wafer is first placed unto the spinner chuck.
The spinner control box is turned on, as well as the vacuum switch on the south wall of the lithography area.
The spinner is turned on and the spinner speed is set to 3000 (6000) rotations per minute for 30 sec.
An eyedropper is used to suck up resist from the bottle, to squirt it unto the wafer without any delay, after which the spinner is started.
Spinning of the wafer causes the resist to be spread out uniformly over the wafer surface yielding a typical green or red (or both) colored (transparent) wafer.
The actual resist thickness is around 900 (2000) nm.
Radial streaks can be observed due to the presence of dust particles or when the resist was applied slowly, drop by drop.

2.2 The resist is subsequently baked on a hotplate adjacent to the spinner.
The hot plate is set at 100°C and the wafer is baked for 90s for positive resist.
The hot plate is set at 150°C and the wafer is baked for 60s for negative resist.
Remember where you put your wafer so that no switch occurs later.
Put the wafer in the wafer holder and close it.
Do not look at the wafer at this point; not only is there nothing to see on the wafer, the light of the microscope can also cause an unwanted exposure of the resist.

2.3 The exposure is done with the Suss MJB3 maskaligner.
The wafer is positioned on the wafer chuck with the wafer flat on the left, leaving the hole in the chuck partially covered.
Check that the wafer stage is parallel to the mask fixture and centered with respect to the hole in which it slides.
The wafer stage is then brought gently under the mask up to the stop, using a sliding motion.
No force is required to do this.
Please be aware that this a precision instrument which needs to be handled gently under all circumstances. Excessive force can damage the instrument.
The wafer is then raised towards the mask using the lever at the bottom left of the mask fixture. This process is monitored by looking into the microscope, while focusing on the features of the mask.
As the wafer comes in close proximity with the mask, one can observe a shadow of the mask on the wafer which disappears when full contact is made. There should be very little force required to bring the wafer in contact. As the lever is brought beyond the vertical position a beeping sound is heard. If no contact is made, or if a force is needed to bring the lever to its final position, get help from the TA to adjust to vertical position on the maskaligner. The resist is then exposed for typically for 30 seconds when exposing positive resist. The negative resist requires a shorter exposure time (3-6 sec). Multiple exposures can be obtained by partially covering the wafer during exposure. Cover half the wafer, expose 10 sec, rotate the cover by 90 degrees, expose again for 20 sec, remove the cover and expose again for 10 sec to obtain four areas on the wafer with a different exposure time, namely 15, 30, 45 and 60 sec.

The negative resist needs to be baked prior to development on the hotplate at 100°C for 60s.

**Exposure procedure:**

Exposure 1

- 15 s

Exposure 2

- Covered region
- 15 s

Exposure 3

- Covered region
- 30 s

Combined exposure

- 15 s
- 30 s
- 45 s
- 60 s

2.4a Development of negative resist. **Skip to 2.4b for development of positive resist.**

Development is done while the wafer is spinning. For this purpose we set the spinner speed to 700 rpm and increase the time to 2 min (maximum value).

Two squirt bottles are used, one containing the developing liquid, the other containing the rinse. Identify both before starting the developing.

Each are applied 20 sec by slowly squiring the liquid on the rotating wafer, first the developer to develop the resist and then the rinse to remove resist residue as well as to stop any further development.

When switching from developer to rinse, apply both at the same time during 2 seconds to prevent the wafer from drying.

After the rinse, the spinner speed is increased to 3000 rpm and the wafer is spun dry for at least 20 seconds.

2.4b Development of positive resist. **Skip to 2.5 when using negative resist.**

Development is done in a 1:4 mixture of AZ400 K developer and DI (de-ionized) water. Develop 60 sec while gently moving the wafer in the liquid.

Notice the red “cloud” after developing for about 30 sec. As the cloud disappears the developing is complete.

Rinse the wafer in DI water for 30 sec and blow dry the wafer (front and back).
2.5 There now should be a visible pattern on the wafer which can be further inspected under the optical microscopes.

**NOTE:** when using positive resist you have the option to develop a little more if needed. In the case you would like to have that option, make sure you use the red filter to avoid additional exposure during inspection.

When using the microscopes, always start using the lowest magnification (typically corresponding to the shortest objective).

As you adjust the focus, make sure that the front lens on the objective does not crash into the wafer.

Increase the magnification by going to the next objective on the revolving head and readjusting the focus.

Inspect your wafer and look for the smallest structure you can find.

Identify its size using the calibration and take a picture using the frame grabber.

When removing the wafer first go back to the shortest objective before moving the stage and picking up the wafer.

2.6 Reactive ion etching of resist is often used to remove undeveloped resist residue.

We will simulate this procedure by reactive ion etching of underexposed/underdeveloped resist.

The resist is partially removed in an oxygen plasma using the March RIE system.

The procedure will be supplied during the lab period.

Typical etch time is 2 - 3 min at a pressure of 1 Torr and a power of 100 Watt

**MASK LAYOUT**
Report questions:

2.a Briefly describe the different steps performed in the lab. Follow the instruction for report #1.

b) What is the difference between positive and negative resist? What are the advantages and disadvantages of each type of resist?

c) Why would the resist spun unto the wafer look green at times (transparent when using positive resist) if its color in the eyedropper is more like dark red?

d) Why do we bake the resist before exposure?

e) Why do we care about the position of the wafer and the wafer fixture before sliding it under the mask?

f) Why do we flood the wafer with nitrogen during exposure? Note that this only applies when using negative resist. Why?

g) Why do we use ultra-violet light to expose the resist? Does it have anything to do with the fact that the light in the cleanroom is yellow? Explain.

h) What part of the resist is removed after developing, is it the exposed or the non-exposed part? Does it depend on whether you use positive or negative resist?

i) What is the minimum feature size you found on the wafer? Provide the number of divisions, the calibration factor as well as the calculated size.

j) Paste the picture in the space below or on an added sheet and indicate the smallest feature. Provide the magnification of the objective as well as the calibration for this objective.

k) Describe the appearance of the resist in the partially developed regions. What is the minimum exposure time which yields full development? Estimate and plot the remaining resist thickness as a function of the exposure time.

l) Describe the RIE etch process and how it can be used to remove resist residue. Describe the change in appearance of the resist due to the RIE etch.