Biomedical Ultrasound Fundamentals of Imaging and Micromachined Transducers

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Lecture - 28

Welcome to this lab video on lithography demonstration. In this session, we'll walk through the entire process of photolithography, from preparing the wafer to developing the photoresist. The steps include using a mask aligner, spin coating the wafer, loading and aligning the mask, exposing the wafer using UV lithography, and then unloading the mask. We'll also cover the development of the photoresist and both soft and hard bake steps. These techniques, which you learned about in the theory class, will now be demonstrated in this lab session.

To begin with, lithography is one of the most critical steps in the fabrication process, as it defines the critical dimensions that will carry forward into subsequent steps like deposition and etching. Any errors during lithography will be propagated throughout the process, making precision essential at this stage.

For lithography, we use a light-sensitive material called photoresist, which changes its properties when exposed to UV light. This is why the process is referred to as photolithography—since UV light is the source that exposes the photoresist. After exposure, the areas of the photoresist that were exposed to UV light undergo a chemical change, allowing them to be dissolved during the development process. The result is that the pattern from the mask is transferred onto the substrate through the photoresist.

There are two main types of photoresists: positive and negative. With a positive photoresist, the features on the mask are exactly transferred to the wafer—the exposed areas are dissolved during development. In contrast, with a negative photoresist, the unexposed areas are dissolved, meaning the features from the mask remain intact on the wafer after development.

Please watch this lab video carefully and feel free to ask any questions you may have on the NPTEL forum. Enjoy the demonstration, and welcome to the TA class!

Today, we'll be using a positive photoresist for our lithography demonstration. The process begins with solvent cleaning of the sample to ensure it's free of contaminants. After cleaning, we'll perform a dehydration bake at 110°C for 10 minutes. This step is crucial to remove any residual moisture on the substrate. Following this, we'll spin coat the positive photoresist onto the sample.

Since the photoresist is a viscous liquid, we need to use spin coating at a specific rpm to form a thin, uniform layer.

After spin coating, we proceed with a soft bake to evaporate the solvent present in the photoresist and improve its adhesion to the substrate. Once the soft bake is complete, we'll move the sample to the lithography system, align the wafer with the mask, and perform the UV exposure. Following exposure, we will conduct a post-exposure bake, which enhances the chemical reactions that were initiated during the UV exposure.

Once the post-exposure bake is finished, we will develop the photoresist, which will dissolve the exposed regions, leaving the desired pattern. Now, let's briefly discuss the mask we'll be using. The mask is made of soda-lime glass with a thin layer of chromium deposited on it. There are two main types of masks: bright field and dark field. The mask we are using today is a bright field mask, where the features are opaque due to the presence of chromium, and the rest of the area is transparent. In contrast, a dark field mask has transparent features with the surrounding area being opaque.

For today's lab demonstration, we will be working with the bright field mask to transfer the desired pattern onto the wafer.

Now, let's proceed with the dehydration bake. I've placed the sample in the oven for dehydration at 110°C for 10 minutes. Prior to this, the sample was cleaned using a solvent cleaning process, where it was soaked in acetone, isopropyl alcohol, and DI water for 2 minutes each. After the cleaning, the sample was blow-dried to remove any remaining moisture. Now, it's set for dehydration bake to eliminate any further moisture.

While the sample bakes, let me talk about the PPE (Personal Protective Equipment) kit I'm wearing. Since I'll be handling photoresist, which is carcinogenic, I've put on this full PPE kit for safety. This includes a face shield and double gloves. The purpose of wearing double gloves is that if the outer pair gets contaminated with the photoresist, I can easily discard them without exposing my skin, thanks to the inner pair that remains clean.

Now, moving forward, I'm going to set up the spin coater for applying the photoresist. The sample has completed its dehydration bake, and it's time to move it to the spin coater. I've placed the wafer on the chuck and am aligning it to ensure it's centered and symmetrical from all sides. Once aligned, I'll switch on the vacuum, which will hold the wafer securely in place and prevent it from sliding.

Now that the wafer is fixed in position, I'm ready to apply the photoresist. I'll be using a positive photoresist stored in this bottle. With a dropper, I'll carefully pour the photoresist onto the center of the wafer, ensuring an even distribution before we begin the spin coating process.

Ideally, we should cover about 70% of the sample surface area with the photoresist, which will take a couple of minutes to achieve. Using the dropper, I'm applying the photoresist carefully to ensure even coverage. Now that I'm almost finished, I'll place the lid on the spin coater and start the spin coating process.

I've set the spin coater to run at 3000 rpm for 40 seconds, which will result in a photoresist layer that is 1.2 microns thick. With the spin coating process complete, I'll remove the lid, switch off the vacuum, and carefully take the sample out. The next step is to carry out a soft bake, so I'll place the sample in the oven at 110°C for one minute to ensure the solvent evaporates and the photoresist adheres well to the substrate.

Once the soft bake is done, it's time to move to the next step: operating the mask aligner tool. First, I'll unlock the mask holder by releasing the lock that secures the plate to the tool. Now, I'll load the mask by placing it in the holder.

One important point to note is the orientation of the mask. The chrome side, which is opaque, should be placed face-up when loading it onto the holder. If I flip it over, the glass side will face me, but for proper alignment, I need the chrome side facing upward. This is because when the mask plate is flipped upside down, the chrome side will be close to the sample, ensuring that the light doesn't diffract excessively, allowing us to achieve the desired critical dimensions. After confirming the mask is properly positioned, I'll activate the vacuum to secure it in place.

Once the indicator turns green, it means the mask is securely held by the vacuum, confirming that I've properly loaded the mask. Now, it's time to load the substrate. I'll carefully place the sample onto the sample holder and align it correctly. Using the software, I'll secure the sample in place by activating the vacuum to ensure it doesn't move during the process. Once the substrate is locked in place, I'll close the mask holder, ensuring both the mask and sample are properly positioned in the tool.

Next, I'll use the Z movement knob to bring the substrate very close to the mask. This movement allows me to adjust the position of the substrate up or down. As I carefully move the sample toward the mask, I'll press the wedge lock. The wedge lock is crucial because it ensures that if there's any tilt in either the mask or the sample, they will both be leveled and brought into the same plane, aligning them perfectly. Since I'll be using proximity lithography, I'll slightly increase the distance between the mask and the sample before proceeding to the alignment stage.

At this point, the microscope will come into view, and I’ll be able to see the patterns on the mask. On the screen, I can see the devices on the left and right sides of the mask. Since this is the first lithography step and I don’t have any alignment markers on my sample, I can skip straight to the exposure process.

To begin the exposure, I’ll press the “Expose” button. The UV lamp, which operates at a 365-nanometer wavelength (eye line), will move into position above the mask and sample. When I press the circular button, the UV light will be exposed to the sample and mask. The lamp provides 22 millijoules of energy per second, and I’ve calculated the exposure time to be 4.5 seconds based on this energy output.

Now, I will press the "Expose" button, which will initiate the UV light exposure on the sample. After 4.5 seconds, the UV lamp will return to its initial position, signaling that the exposure is complete. Next, it's time to remove the sample and proceed with the post-exposure bake. To do this, I will first release the wedge lock, increase the distance between the mask and the sample, unlock the mask holder, and finally break the sample vacuum. Now, I can carefully take the sample and prepare it for the post-exposure bake.

I’ll place the sample in the oven for post-exposure bake at 110°C for one minute. After the bake, I’ll remove the sample and place it on a lint-free cloth. At this point, the pattern should have successfully transferred onto the photoresist. The next step is development, where the exposed areas of the photoresist will dissolve in the developer solution, leaving the pattern from the mask on the photoresist.

For the development process, I’ve prepared two Petri dishes: one on the left containing the developer solution, and the other on the right with DI water, which will act as a stopper for the developer. I’ll submerge the sample in the developer solution and gently agitate it for around 25 seconds. As the development process progresses, the exposed photoresist will begin to dissolve. After 25 seconds, I’ll immediately transfer the sample into the DI water to halt the development.

To ensure all the exposed photoresist is washed away and stop further development, I’ll rinse the sample under running DI water. Afterward, I’ll blow-dry the sample with nitrogen. This completes the lithography process, and the sample is now ready for further processing, such as deposition or wet etching.

That concludes today’s lab demonstration. Thank you for watching!