Topic 3: One-layer and two-layer lift-off

In this session, students will engage in hands-on activities to explore two methods for creating photoresist lift-off profiles: single-layer and double-layer lift-off. They will acquire key techniques for preparing silicon surfaces, followed by the application of photoresist using spin coating. Students will also learn to perform UV exposure and execute the development process to complete the lift-off procedure.

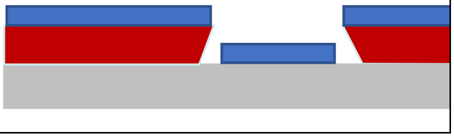
I. Liftoff of aluminum

Liftoff processing in microfabrication is a crucial technique for creating intricate patterns and structures at the micro and nanoscale. This method is especially useful when working with materials that are difficult to etch using traditional techniques. The process begins by depositing a sacrificial photoresist layer onto a substrate, followed by defining the desired pattern through precise lithographic techniques. A thin film of the target material—often a metal—is then deposited uniformly over the substrate. Finally, the sacrificial photoresist is dissolved using a compatible solvent, such as acetone, causing the material on top of the photoresist to liftoff. This leaves behind the carefully defined microstructures or patterns on the substrate.

Resist Stripping and Metal Lift-Off Procedure

Your task is to perform the last step of stripping the resist in a solvent until all the metal on the resist is lifted-off.

- Get a sample from your TA. The sample has been previously patterned using a negative photoresist, followed by metal deposition, as outlined in the process flow:

Step	Process description	Cross-section after process
01	**Substrate**: Glass wafer • *Teply O_2 plasma treatment,*	
02	*Photolith PR coat* • *2 um AZ nLOF 2020 coating in ACS200,*	
03	*Photolith expo+ develop* • *4.7 sec exposure with MJB4 (94mJ/cm^2)* • *Developing in ACS200,*	
04	*Metal deposition* • *20/700 nm Ti/Al in EVA760, 450 mm WD, dep. rate: 5 A/s*	

- Place the sample into a small glass container.
- Fill the beaker with enough acetone to fully submerge the sample.

- The photoresist and aluminum should gradually lift away. This operation can take time; if the aluminum has not completely lifted off, use a swab and gently wipe the wafer (avoid touching your patterns), or place the sample in an ultrasonic bath for assistance.
- Once the lift-off is complete, clean the sample by rinsing it with isopropyl alcohol (IPA) to remove any remaining acetone. Dry the sample with nitrogen (N_2) gas
- Finally, examine the sample under an optical microscope to verify the result..

For the smooth conduct of the session, the group will form two pairs. One student from each pair will study the negative layer, while the other will study the double layer

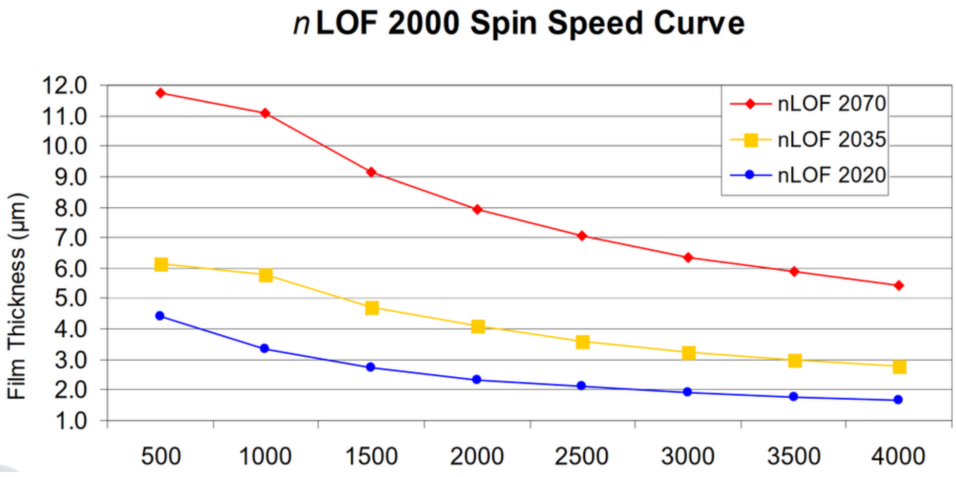
II. One layer liftoff: AZnLOF 2070 negative photoresist

AZnLOF 2000 series is a negative photoresist designed specifically for liftoff processing. The resist produces a negative (undercut) profile to reduce deposition of the material on sidewalls. This design feature facilitates better access for solvents during the liftoff process, allowing for more efficient removal of the film after deposition.

1. Get two silicon samples from your TA.
2. photoresist coating.

- The program of the controller.
  - Step 1 : to spread the photoresist over the entire sample
  - Setp 2 : to get the desired thickness

Step	Spin speed (RPM)	Time (s)
1	700	10
2	3000	60



- From this curve, what is the expected thickness of the deposited film?
- Measure the thickness of the film using Filmetrics. Compare the two values and make a conclusion.

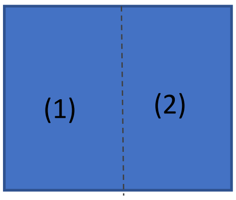
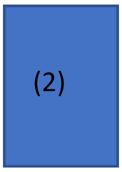
3. Bake your sample on the Hotplate 100°C for 90s.
4. Lithographic Exposure: For the exposure of AZ nLOF 2070, we will test two different exposure times. One student from each pair will select a sample to process according to the conditions outlined in the following table.

	t_{exp} (s) for UV P.259 Lamp	t_{exp} (s) for X-cite lamp
Sample 1	18	20
Sample 2	22	25

5. A post-exposure bake (PEB) is essential for the AZ nLOF 2070 resist. While the bake time remains consistent regardless of the resist thickness, it significantly influences the final results of the photoresist profile.

$$T_{PEB} = 105°C, \text{ for } 90 \text{ s}$$

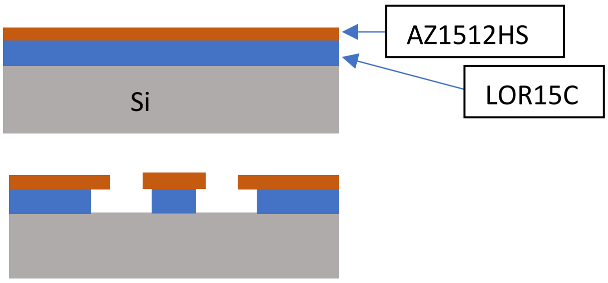
6. Substrate Development

Step 7-1: Develop the complete sample for 1 min40 sec. or stop when the surface of the silicon substrate is visible. Step 7-2: Rinse in water and dry with N_2. Step 7-3: Observe under an optical microscope one pattern. Step 7-4: Cleave the sample into 2 pieces. For each part, add an additional time for development as indicated below. Keep one part as a reference sample t_{dev} = 1min40s	
Step 7-5: For the second part, add an additional time for development (20 s) Repeat steps 7-1 to 7-3. Observe the same structure at the same size and magnification.	

8. Keep the samples in a box for characterization next topic 5.

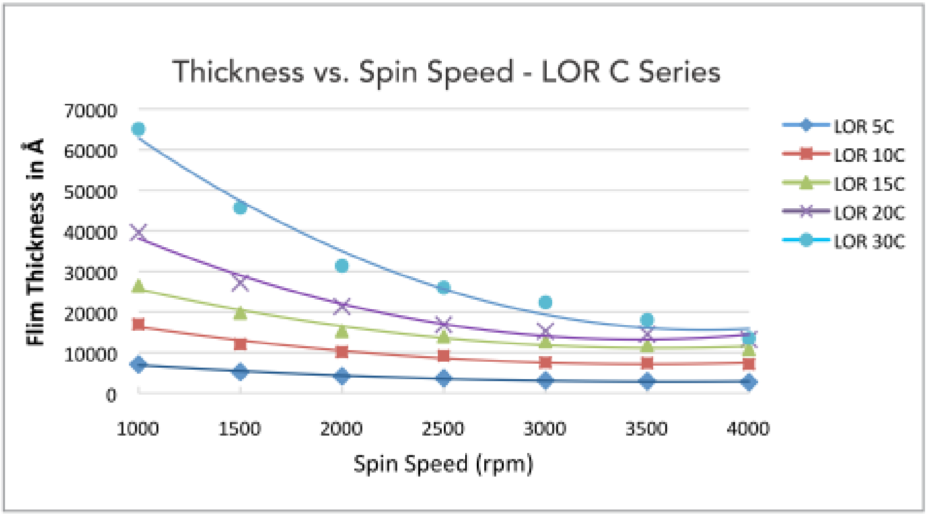
III. Two-layer liftoff: LOR15C and AZ1512HS

Two layers of resist are commonly applied on top of each other to achieve well-defined edge shapes, as demonstrated in the figure below. In this experiment, AZ 1512HS resist and Lift-off resist LOR15C are used. Due to their distinct chemical properties, the two resists remain chemically independent, ensuring the LOR resist layer dissolves faster than the exposed AZ 1512HS resist. This creates an undercutting beneath the top photoresist layer (PR)



1. Get two silicon samples from your TA.
2. Spin Coating: LOR 15C

Step	Spin speed (RPM)	Time (s)
1	700	10
2	2500	60



- From this curve, what is the expected thickness of the deposited film?

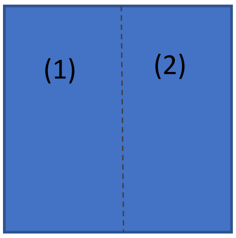
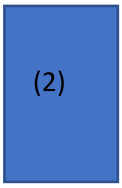
3. **Soft Bake / Pre-Bake:** The bake time and temperature will determine how quickly the LOR resist dissolves in the photoresist developer. For this experiment, the temperature will be set at T_{PEB} = 160°C for two different t_{PEB} .
   The second student in each pair will process the double-layer samples according to the conditions outlined in the following table.

	t_{PEB} (min)
Sample 3	3
Sample 4	5

4. Allow the LOR 15C film to cool to room temperature (RT) for 1 minute.
5. Measure the thickness of the film using Filmetrics. Compare this value to the one extracted from the curve.
6. Spin Coating: AZ1512HS.

Step	Spin speed (RPM)	Time (s)
1	700	10
2	4000	60

7. Soft Bake : 100^{o}C for 2 min.
8. UV exposure: t_{exp}=8 s
9. Substrate Development:

Step 9-1: Develop the complete sample in AZ726 MIF for 1 min10 s, or stop when the surface of the silicon substrate is visible. Step 9-2: Rinse in water and dry with N_2. Step 9-3: Observe under an optical microscope one pattern. Step 9-4: Cleave the sample into **2** parts. For each part, add an additional time for development as indicated below. Keep one part as a reference sample t_{dev} = 1min	
Step 9-5: For the second part, add an additional time for development (20 s) Repeat steps 9-1 to 9-3. Observe the same structure at the same size and magnification.	

Under the microscope, you should observe an undercut along the edges of the pattern, which will appear as a shadow or double line. If the undercut is not visible, additional development time may be necessary. A longer development time will result in a more pronounced undercut.

Questions:

- How does negative resist work?
- Does LOR 15C be patterned directly with UV light through a photomask?
- What is the difference between spin coating on a circular wafer and on a square one?
- Can I reproducibly control the undercut?
- What is the purpose of the lift-off process in the fabrication of microdevices?
- What would be the result of the lift-off process if LOR were omitted?
- Explain why “lift-off” is considered a surface micromachining process.