Topic 2: AZ1512 HS photoresist thin films coating and UV exposure

Objective

In this laboratory, students will learn:

- How to deposit a uniform thin film of photoresist AZ1512HS (HS for high sensitivity) on 4-inch silicon wafers.
- How to use UV light to transfer different patterns from a photomask to this photoresist film.
- How to use the Filmetrics instrument, including its usage and the principle it employs to determine the thickness of AZ 1512HS photoresist.

Experiment

AZ 1512HS is a positive photoresist (PR) sensitive to the UV spectrum from 310 to 440 nm (covering the i, h, and g lines). After UV exposure, positive photoresist becomes soluble in the developer. The resist is compatible with all common developers used for positive photoresists, like AZ 726 MIF and AZ 351. During this experiment, different parameters affecting the process of the photoresist, such as spin speed and dose exposure, will be tested. These parameters depend on various factors, including the nature of the substrate, resist, photomask, and exposure tool. Consequently, the optimal values must be determined empirically. Any alterations in the substrate surface, resist thickness or bake conditions, or mask pattern can affect the optimal dose, requiring additional characterization. A diverse range of test exposures should be developed for each process layer. It is also crucial that testing is conducted using the same substrate and resist processing conditions as those intended for the final product.

1.Operating precautions

- Hotplate Safety: When working with hotplates, do not touch them to avoid burns.
- Volatile Chemicals: Both photoresist (PR), hexamethyldisilizane (HMDS) and the developer are volatile substances. Therefore, it is essential to perform the coating and developing processes only in a fume hood to ensure proper ventilation and safety.
- Caustic developer: Be aware that the developer used in the process is caustic. Handle it with care and follow safety protocols.
- Light Exposure Safety: Do not look directly into the light source while exposing the photoresist to prevent eye damage.

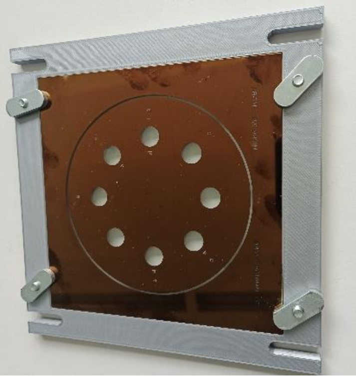
2.Operating Procedure:

- Upon entering the lab, students must wear lab coats, nitrile gloves, and eye protection during UV exposure.
- Begin by turning on all the equipment needed for your experiments. Be sure to follow the operating instructions provided in the lab.
- Each group will be provided with four 4-inch wafers, ensuring that each student receives one wafer.
- **Wafer identification**

  - Record the ID number of each wafer and determine the type of doping and crystal orientation.
- **HMDS coating**
  - The wafers have already been HMDS treated (this step will be experimented in another Topic)
- **Photoresist Coating**:
  - Place the wafer on the spinner chuck and center it precisely using the alignment tool. Apply suction using the vacuum pump button.
  - Set the spinner control to the proper speed (each student selects one speed between 2000 and 5000 RPM), while keeping all the other parameters constant.
  - Spread
  - The spin coating program is:

Step	Spin speed (RPM)	Time (s)	Purpose
1	700	10	Spread resist
2	Your choice	60	film thickness

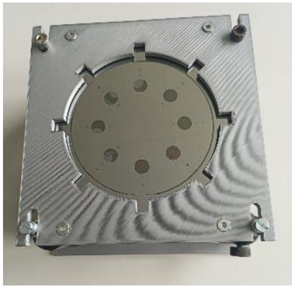
  - Soft-bake at 100°C for 1 minute: This step is crucial as it removes solvents from the photoresist and improves its adhesion to the wafer.
  - Remove the wafer and allow it to cool for 1 minutes.
  - **UV Exposure:**
  - Measure the light intensity of the UV source
  - Check if the photomask is clean before proceeding.
  - Expose the wafer:
    - Prepare the holder and the photomask for the exposure process
    - Carefully position the wafer on the specific holder.
    - Place the mask on its holder and secure it with screws so that it does not fall off when turned over



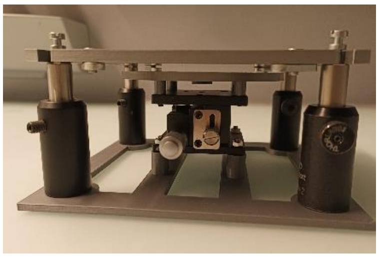
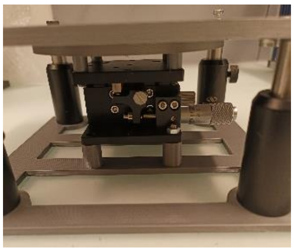
    - Lower the wafer chuck and gently place the wafer on the holder, ensuring it is well centered.

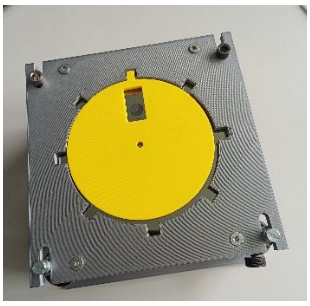
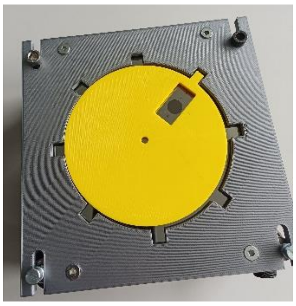
- Place the mask holder on the four rods and secure it with screws so that the assembly remains stable.



- Raise the wafer until it is in contact with the mask. Do not apply too much force to avoid breaking the wafer.

- Position a circular shadow mask on top of the photomask. This shadow mask allows you to select only one transparent window on the photomask at a time.

- For each position of the shadow mask, set the exposure timer and press "expose."
- Repeat this step for all the 8 positions of the photomask.

Caution: Do not look directly at the UV light while exposing the wafer to avoid eye damage.

- For each wafer complete the corresponding table and any observations made during the process:

Wafer ID #			Light Intensity (unit)		Spin speed (unit)			
position	1	2	3	4	5	6	7	8
Exposure time (unit)								
Dose (unit)								

- **Develop**
    - Develop the wafers one at a time to ensure precise control over the process.
    - Carefully place the wafer in the developer bath and start the timer.
    - The recommended development time is approximately 20 seconds.
    - Once the development time is complete, remove the wafer from the developer bath and immediately rinse it in a water bath to wash away any residual developer. Thorough rinsing is required
    - After rinsing, remove the wafer from the water bath and dry it using a nitrogen gun. This step is crucial to prevent water spots and ensure a clean surface for subsequent processes.

Advice: You can often observe the patterns as they develop. While the development time is predetermined, you can utilize both your eyes and a timer to gauge the appropriate development duration. The ideal moment is when the most exposed area (zone 8) is fully developed, revealing a clear view of the silicon surface.

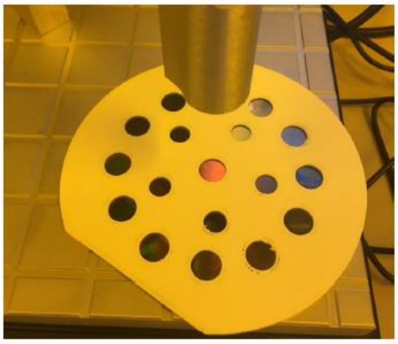
I. Reflectance thickness measurement

This technique is used to determine the thickness of a thin film or coating by analyzing the reflectance properties of light. As light interacts with a thin film, its reflectance changes, which can be utilized to calculate the film's thickness.

AZ 1512HS photoresist measurement

1. Turn on the filmetrics

2. Start calibration measurement (Assistant)
3. Place your wafer on the sample stage under the F20 fiber optic detector.
4. Place on top of the wafer a shadow mask having specific circular holes where the film thickness should be taken consistently and accurately. (see figure).



- Spin curve
  - Measure the photoresist thickness at six central positions on each wafer to calculate the average thickness and evaluate uniformity.

Wafer ID			Spin speed (rpm)			
area	Center	A	B	C	D	E
Thickness (unit)						
GOF						
Thikness average (unit)						

  - Plot a graph of the average photoresist thickness versus spin speed.
  - Discuss your results.

- Contrat curve
    - How do you calculate the exposure dose?
    - Measure the film thickness in the 8 external areas and complete the corresponding table.
    -

<table>
<tr><td colspan="3">Wafer ID
#</td><td colspan="2">Light Intensity
(unit)</td><td colspan="4">Spin speed
(unit)</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td>Position</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>Exposure time (unit)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Dose (unit)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Thickness (unit)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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- Plot a graph of normalized photoresist thickness versus dose (using a logarithmic scale for the dose). This will help visualize the relationship between thickness and exposure dose.
- From the plotted curve, identify and extract the sensitivity or dose to clear of the photoresist. The later indicates the exposure dose required to completely clear the photoresist.
- Analyze the extrapolated slope of the linear region of the curve to determine the gamma of the photoresist.
- Compare the four curves obtained from different experiments or conditions, focusing on differences in sensitivity, dose to clear, and gamma values.
- Plot a graph of photoresist sensitivity as function of its thickness.
- Each graph and photo must have its own caption, including a brief description and analysis.
- List all the equipment you used during your session.
- How does positive photoresist function in photolithography?
- What materials are photomasks typically made of?

Important Reminder:

- **Bring your laptop** to the lab session in order to plot your curves and collect your data.
- **Prepare in advance an Excel table** for the following:
    1. **Contrast Curve**: Normalized thickness as a function of dose (on a semi-logarithmic scale).
    2. **Thickness Curve**: Thickness as a function of spin speed.

Make sure the tables are set up before the session so that you can quickly input the data and create the necessary graphs during the lab.

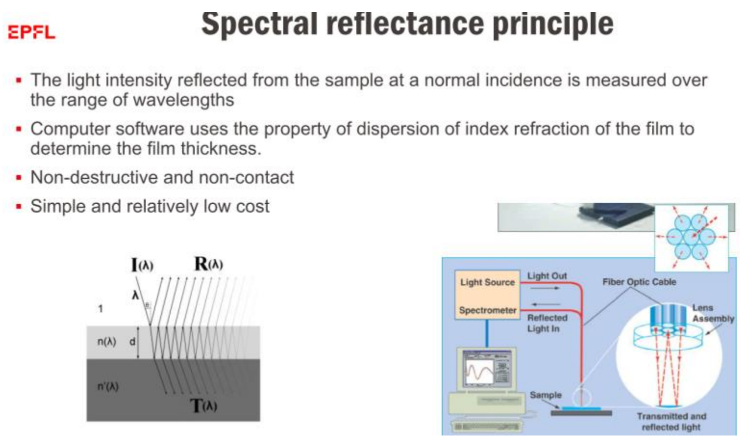
Filmetrics F20.

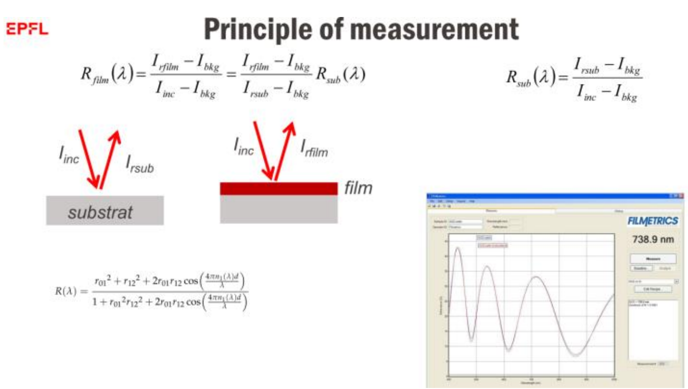
a. Principle:

Filmetrics uses the Spectral Reflectance optical technique for measuring the thickness of thin films. This method is simple, accurate, non-destructive, and requires minimal sample preparation. Spectral reflectance measures the amount of light reflected from a thin film across a range of wavelengths, with the incident light perpendicular to the sample surface. The amplitude and number of reflectance peaks in the spectral data are related to the film's thickness, optical constants, and roughness.

To determine a film's properties, the reflectance spectra are calculated based on trial values of thickness, as well as the n (refractive index) and k (extinction coefficient) model parameters. These values are adjusted until the calculated reflectance matches the measured reflectance. Initially, the software uses saved refractive index data as a first approximation. The software includes a wide range of material data for various layers, with each specific material represented by its refractive index dispersion.

However, when selecting silicon dioxide films, the software will use a specific refractive index for all silicon dioxide, even though different fabrication processes may result in different densities. This approximation can present challenges when there are differences between the refractive index data and the real material, making it difficult to achieve a good fitting.





b. Operating procedure

- Turn on the computer
- Turn on the spectrometer and the lamp
- Open the Filmetrics software
- Edit the film stack
    - Click on "Edit Recipe."
        - The "Edit Recipe" dialog box will be opened. Check to see that the film stack matches that of the current sample. Different films can be selected using either the drop-down menu next to the material or through the "Search" function. A new layer of material can be added by clicking the "+" button. An existing layer can be deleted by clicking the "x" button. Note that the "substrate" and "medium" always need to be defined. Once the changes have been made, the recipe can be saved by clicking on the save icon.
- Baseline Measurement: A baseline measurement should be performed before measuring any sample. Obtain a baseline measurement by clicking on the "Baseline" button on the main screen. A dialog box will appear. Follow the steps on the screen to perform a baseline measurement.
- Place the sample on the stage and click on the "Measure" button on the main page. The software will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the calculated reflectance will coincide with the measured reflectance.
- Analysis of Results After testing the sample, the measured and calculated reflectance spectra will be displayed on the graph, and the measured film thickness will be listed in the results box in bold numbers. Report the calculated thickness and the reflectance spectra.
- The accuracy of this method, determined by how well the measured reflectance spectrum matches with the calculated spectrum, is affected by the purity of the film material, the accuracy of the refractive index data, the condition of the substrate surface, and the accuracy in locating the wavelength maxima. This can be judged by the goodness-of-fit (GOF) value, which is a number between 0 and 1. A GOF close to 1 indicates a good match between measured and theoretical spectra.