Introduction to Contact Lithography (40 points)

Objective: The objective of this online lab is to demonstrate and overview the procedures necessary to perform contact lithography.

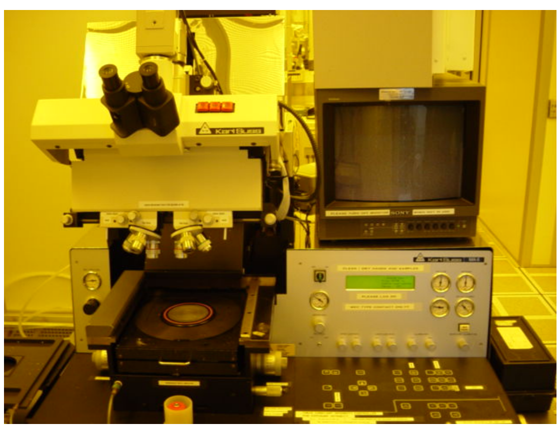
The student will watch a series of videos pertaining to each step of the photolithography process. These videos will provide detailed insight onto each step of the photolithography process. After watching the videos the student will be required to answer review questions on ANGEL.

Background: Lithography is essential for defining patterns on materials in nanofabrication. Advances in photolithography techniques have ultimately led to the miniaturization of electronic devices we are witnessing today. Photolithography is a central element to the semiconductor manufacturing industry; a modern day device will go through the photolithography process dozens of times prior to completion.

During the photolithography process an energy-sensitive chemical, called photoresist, is applied to the surface of a sample. This photoresist is then exposed to a particular energy source to produce a pattern within the material. When the process involves light as an energy source, it is called photolithography.

The small feature sizes involved in photolithography dictate an extremely clean processing environment; the videos in this lab show the photolithography process being conducted in a state of the art class 10 cleanroom.

In order to perform the photolithography process a variety of equipment is needed. Wet benches, hotplates, spin-casting stations, and an exposure tool are all necessary. The exposure tool used in this lab is the Karl Suss MA6BA6. This system is theoretically capable of printing features as small as ~0.5µm. The key concepts used for contact lithography can be related to e-beam lithography technology and stepper lithography technology. The minimum achievable feature sizes are ultimately dictated by the type of lithography technique employed.



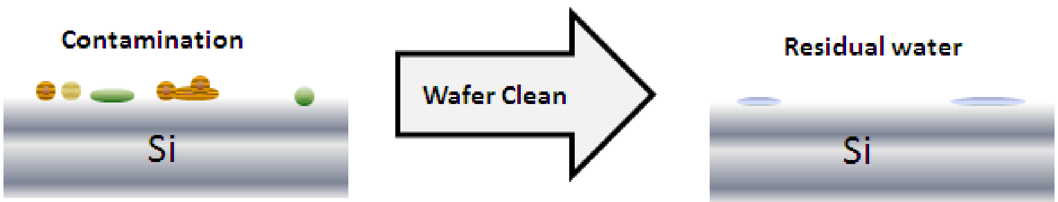
Karl Suss MA6BA6 Contact Aligner

Experiment: During this exercise features will be patterned onto a silicon wafer through the photolithography process. Read through the following steps and watch the clips for each stage of the lithography process in order to answer the lab questions on ANGEL.

Step 1: Wafer Clean

The wafer clean is an expensive but unavoidable processing step. Roughly 1/3 of the processing steps in advanced semiconductor manufacturing involve some type of wafer clean. Cleaning is necessary in order to remove the variety of types of contamination which may be present on the substrate. The most common sources of contamination include particles (dust, skin flakes, bacteria), metallics (Fe, Al, Cu, Na, Mg), organic contamination, and moisture.

Each type of contaminant will have a specific effect on the performance of a device. For instance, organic contaminants will cause a reduction in the integrity of the gate oxide. This is ultimately a concern to you because it would result in your electronic device failing sooner than expected. The wafer clean removes contamination as shown below.



Watch the wafer clean video at the link below:

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=976fee4b-a841-4a91-afd6-f

This video demonstrates the cleaning process. The cleaning process is performed in an industry grade class 10 cleanroom space which has been dedicated for the photolithography process; for this reason the cleanroom space appears yellow.

As you can see, there may still be some residual water on the wafer's surface following the cleaning process. This necessitates a dehydration bake.

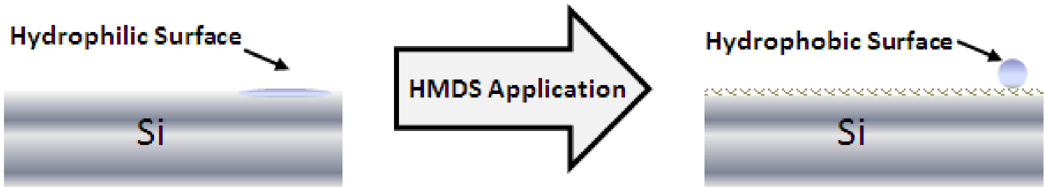
Step 2: Dehydration Bake

In order to remove any residual water, we need to perform a dehydration bake. As shown below the dehydration bake will remove any residual water on the wafer's surface. Watch the dehydration bake video at the link below:

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=e5abcebf-aa54-4bee-901a-9

Step 3: HMDS Application

In reality, the surface of our silicon wafer forms a thin layer of oxide due to the reaction of the wafer's surface with the oxygen in the ambient atmosphere. This is a high quality oxide that is only a few nanometers thick. The presence of this oxide makes the surface of our wafer hydrophilic. This is a problem since our photosensitive material will adhere best to a hydrophobic surface. For this reason, we coat our wafer with a thin layer of hexamethyldisilizane (HMDS). This material will render the surface of the wafer hydrophobic such that our photosensitive material will wet the surface of the wafer. The image below shows how the HMDS affords a water repellant wafer.

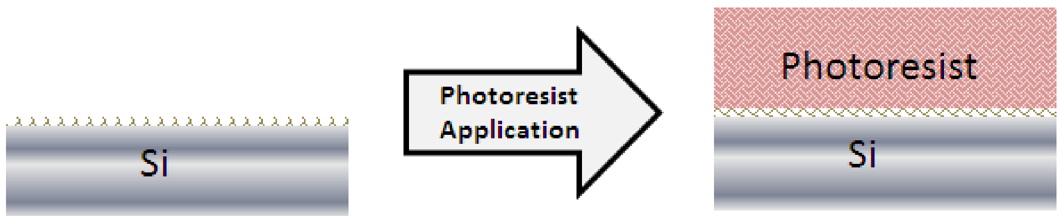


Watch the HMDS video at the link below which shows how a thin layer of HMDS is applied to the surface of our silicon wafer through the spincasting process:

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=f7aa74ad-d508-46a9-9b80-6

Step 4: Photoresist Application

Following the HMDS application we immediately coat our photosensitive material. This material is called photoresist. The particular type of photoresist used during a particular lithography process will vary with application. In this instance we have used a positive type of photoresist. A positive photoresist will be rendered soluble in developer in the select areas of the material exposed to UV light, in other words, “what shows goes”. The photoresist layer is typically relatively thick, as shown below. The layer of photoresist coated in the following video is roughly 1.3 μm thick.



Photoresists are highly engineered materials which require very precise processing conditions. For this reason all of the processing parameters must by closely monitored while performing the photolithography process.

Watch the photoresist application video at the link below which shows how similar the photoresist application is to the HMDS application. This video will go into more detail on the composition of this special type of photosensitive material.

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=d2d3c8e3-f0f1-415b-b641-1

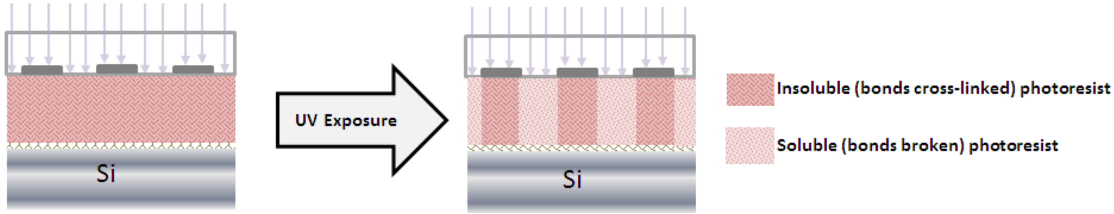
Step 5: Spinner Bowl Clean

In a real laboratory environment it is necessary to clean up after coating the HMDS and the photoresist. The chemical used to perform this cleaning process is an abrasive solvent, thus, certain PPE is required. Watch the spinner bowl clean video which shows how to clean up the laboratory work station after applying the HMDS and the photoresist.

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=cb45ef6d-5d0f-434e-a580-1

Step 6: UV Exposure

Following the photoresist application the next step is to make this photosensitive material selectively react by exposing certain areas of the photoresist to high energy UV light. This is done using a special type of tool known as a contact aligner. Here, a photomask is brought into contact with our sample. The photomask can be thought of as a type of stencil which transfers a pattern into our photoresist material as shown below.

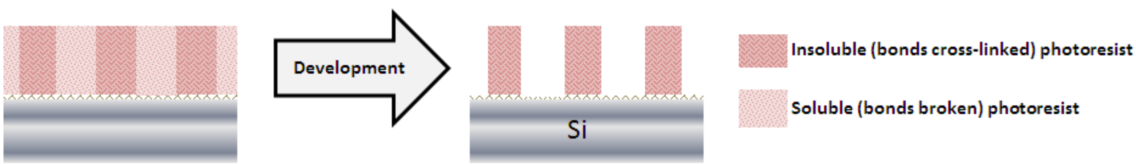


Watch the UV exposure video at the link below which shows how the UV exposure step is carried out in a real cleanroom environment. This video will go into more detail on the photomask and the fundamental physics governing the resolution of contact lithography.

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=6c848a4e-a6f2-47e4-a47c-f

Step 7: Development

Next, the wafer is developed. During this step the areas of the photoresist which reacted with the UV light are washed away in the developer.



Watch the development video at the link below which shows the development process in action. This video will detail the parameters and type of developer used to develop the reacted photoresist.

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=79820a18-71e5-4b19-b2e9-d

Step 8: Photolithography Recap

The photolithography process involves a variety of steps. Watch the photolithography recap video at the link below which recaps the entire process from start to finish.

http://www.engr.psu.edu/mediaportal/flvplayer.aspx?FileID=184cad7e-7757-4da2-b6b8-7

Questions (2 pts each) to be answered on ANGEL (NO HARD COPY REQUIRED)

1. What sequence of chemicals is used to clean the wafer prior to performing photolithography?
2. Why is DI water used during the cleaning process?
3. What are the time and temperature used for the dehydration bake?
4. What is the purpose of HMDS?
5. What type of spin-casting dispense technique is used to apply the HMDS to the wafer?
6. What type of photoresist was used in this lab?
7. What are the names of the sensitizer, solvent, and resin that makes up this type of photoresist?
8. What is the purpose of the photoactive compound in the photoresist?
9. What processing condition dictates the resist thickness?
10. When is the soft bake performed?
11. What chemical is used to clean the spinner bowl? What PPE does this require?
12. Generally, what process tool creates the photomask?
13. What side of the photomask is in contact with the PR and why?
14. What UV wavelength is our photoresist exposed to and what is the length of this exposure time?
15. What is the full chemical name of the chemical developer?
16. Research the MSDS for Microposit CD-26. What are the ingredients and in what percentages are they found in this material? What are the environmental precautions for disposal?
17. Which two parameters have the biggest influence on resolution in contact lithography?
18. Once the photolithography process is complete, what is the next step?
19. Describe the basic mechanism by which positive photolithography transfers a pattern, and comment on the chemical interactions of the resist throughout the entire process.
20. The photomask used for your positive lithography process features Cr bars which are 50 um wide. However, your profilometry data shows that the photoresist bars transferred to your substrate are only 40 um wide. What could have caused this?