

Microfabrication technologies


Dashboard › My courses › MICRO-331 › 2 November - 3 November › Graded quiz #5 on Dry Etching

Started on	Friday, 11 November 2022, 08:10
State	Finished
Completed on	Friday, 11 November 2022, 09:20
Time taken	1 hour 9 mins
Grade	11.3 out of 13.0 (87%)

Question 1

Correct

Mark 1.0 out of 1.0

 Flag question

Which of the following is true for a cryogenic deep dry Si etching process?

☐ There is no grass generation observed even with too much oxygen

☒ Etching and passivation steps are done simultaneously

☐ The loading effect is eliminated for this process

☐ The chuck temperature does not have a significant influence on the etching profile

Your answer is correct.


In cryogenic deep dry Si etching process, first the silicon wafer is brought to -110 °C. Hereafter, SF₆ gas is used for etching and O₂ gas is used for passivation. Both of these operations are performed simultaneously. See "Examples of etching processes for Si-based materials" video from 17:35 to 18:45 for more detailed explanations.

The correct answer is:
Etching and passivation steps are done simultaneously

Question 2

Partially correct

Mark 0.2 out of 1.0

 Remove flag

Which of the following statements are the limitations of IBE?

☒ Ions tend to have a lot of collisions during their trajectory, which reduces the etching quality

☒ Etching processes that consume or generate a significant quantity of gas are not possible

☐ The etching is slow compared to a standard dry etching process (e.g., CF₄ plasma etching)

☐ Long etching processes are quite instable as the operation pressure is too high

☐ Because of the low operation pressure, sputtered material accumulates on the sample surface

Your answer is partially correct.

You have correctly selected 1.


There are certain limitations of IBE which are a consequence of limited gas flow at an operating pressure of 0.1 mbar. In sensitive processes, to maintain the etch rate, a high ion flux is needed, which is difficult to obtain with a remote ion source. Additionally, etching processes that consume or generate a significant quantity of gas are not possible. See "Ion beam etching" video from 4:30 to 5:30 for more detailed explanations.

The correct answers are:
Etching processes that consume or generate a significant quantity of gas are not possible ,
The etching is slow compared to a standard dry etching process (e.g., CF₄ plasma etching)

Question 3

Correct

Mark 1.0 out of 1.0

 Flag question

Which of these equipments can be used for directional physical etching?

☒ A diode reactor

☐ An atomic layer chemical vapor deposition system

☐ A batch reactor

☐ A plug flow reactor

Your answer is correct.


Only the diode reactor is a viable directional physical etching tool, the rest of the answers are not related to this process. See "Types of dry etching equipment and plasma sources" video from 4:45 to 8:35 for more detailed explanations.

The correct answer is:
A diode reactor

Question 4

Correct

Mark 1.0 out of 1.0

 Flag question

Which of the following statement is correct for an Inductively coupled plasma (ICP) etching system?

☐ The plasma can only be activated when the pressure is set to an extremely high value

☐ There are two RF power sources: one for generation of the plasma and one for stabilizing the temperature inside the chamber

☐ A high voltage on the working electrode is needed, so that the plasma potential is kept at high values

☒ The electrical impedance of an ICP source is an inductor in series with a small resistor

Your answer is correct.


An RF current in the ICP plasma is generated by one RF power source. The other RF power source is used to generate the surface voltage bias. The electrical impedance of an ICP source is an inductor in series with a small resistor. A capacitive coupling is needed to initiate the discharge. See "Types of dry etching equipment and plasma sources" video from 9:40 to 12:25 for more detailed explanations.

The correct answer is:
The electrical impedance of an ICP source is an inductor in series with a small resistor

Question 5

Correct

Mark 1.0 out of 1.0

 Remove flag

Which of the following statements are true for a RF plasma? Assuming that the top electrode is connected to the ground and the bottom electrode is connected to the RF source.

☐ After a couple of RF oscillations, electrons tend to charge the top electrode

☐ After accumulation of electrons on the top electrode, the remaining electrons in the plasma are also pulled to the top and, after a while, an ion sheath is formed near the top electrode

☐ Due to the loss of electrons to the walls, the bulk of the plasma becomes slightly negative

☒ The current passing through the ion sheath is inversely proportional to the square of the thickness of the ion sheath

☒ DC self bias is formed on the bottom electrode thanks to the use of the capacitor in series with the RF source

Your answer is correct.


Electrons initially will be attacking more the electrode to which the RF is applied than heavy positive ions. Therefore, a negative charge is formed on the RF electrode side after a few cycles after ignition of the plasma. Few electrons are present in the dark ion sheath near the working electrode as a result of repulsion from the negatively charged electrode. An electrical field is created, which is the ratio of the total voltage drop across the ion sheath to the ion sheath thickness. See "Theoretical concepts of plasma generation" video from 3:40 to 12:00 for more detailed explanations.

The correct answers are:
The current passing through the ion sheath is inversely proportional to the square of the thickness of the ion sheath,
DC self bias is formed on the bottom electrode thanks to the use of the capacitor in series with the RF source

Question 6

Partially correct

Mark 0.7 out of 1.0

 Remove flag

Which of the following statements are true for a dry etching equipment?

☒ An electrostatic chuck can be used to clamp the wafer by electrostatic forces

☒ A scrubber gas treatment is necessary to adjust Ar flow in the chamber

☐ Optical end point detection is used to monitor the stability of the fixation of the wafer on the electrostatic chuck

☒ There are at least two electrodes that are needed to maintain the gas in the plasma state

☐ A load chamber is utilized to load the desired gas for the etching process

Your answer is partially correct.

You have selected too many options.


In a typical example of a dry etching equipment, the load chamber is used as a wafer holder and this wafer is translated into the reactor without breaking the vacuum in the chamber. An electrostatic chuck is utilized to clamp the wafer in the chamber. A scrubber gas treatment is used to eliminate toxic side products. Optical End Point Detection (EDP) is utilized to provide information on the materials that are etched away. See "Deep dry etching of silicon; dry etching without a plasma" video from 9:35 to 11:45 for more detailed explanations.

The correct answers are:
An electrostatic chuck can be used to clamp the wafer by electrostatic forces ,
There are at least two electrodes that are needed to maintain the gas in the plasma state

Question 7

Correct

Mark 1.0 out of 1.0

 Flag question

In a CF₄ plasma to which hydrogen gas is added, an etched hole can be protected by the deposition of a fluorocarbon polymeric layer. How can the selectivity of dry etching be enhanced?

☒ By decreasing the temperature

☐ By decreasing the H₂ concentration

☒ By increasing the monomer concentration

☐ By decreasing the pressure

Your answer is correct.


A dry etching process can be selective, which means that it will only etch the target, not the mask material. Selectivity can be enhanced by tuning the polymerization point of the gas. More polymerization will lead to extra masking material that gets deposited so that the mask can withstand the etching longer. Increasing the monomer concentration, increasing H₂ concentration, decreasing the temperature and increasing the pressure are some of the valid methods to increase the selectivity. See "Dry etching in a gas plasma; etching anisotropy" video from 13:20 to 14:15 for more detailed explanations.

The correct answers are:
By decreasing the temperature,
By increasing the monomer concentration

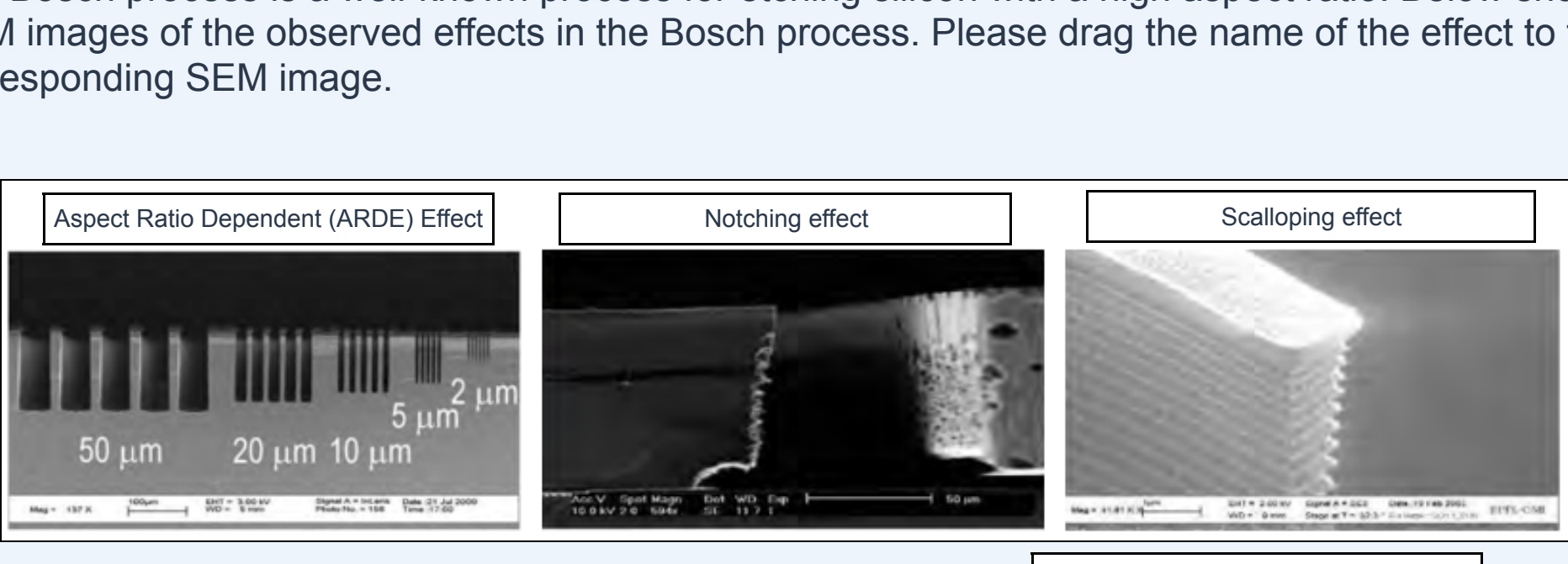
Question 8

Correct

Mark 1.0 out of 1.0

 Flag question

The Bosch process is a well-known process for etching silicon with a high aspect ratio. Below shows SEM images of the observed effects in the Bosch process. Please drag the name of the effect to the corresponding SEM image.



Your answer is correct.

The "Scalloping effect" means the non-even surface of the sidewall of the etched silicon trenches because of the pulsed nature of the Bosch process, which originates from the alternating etching and polymerization cycles.


The "Aspect Ratio Dependent (ARDE) Effect" means the etch rate depends on the hole or trench width. If there is a wider mask opening, the etching goes deeper than if there is a narrow mask opening, and this is related to the fact that the gas has easier access into a larger hole than in a small hole, and etching is more favored in that way.

The notching effect means when reaching the embedded oxide layer, due to its insulating properties, it can be charged by the ions from the plasma so that further incoming ions are deflected and they give enhanced etching in side direction.

Question 9

Correct

Mark 1.0 out of 1.0

 Remove flag

Our goal is to anisotropically etch 295 nm of Al with 1000 nm thick photoresist as a mask. Assume a constant etching rate of 400 nm/min for Al and an etching selectivity (Al/PR) of 2. How thick does the photoresist "remain" after etching 295 nm of Al? Please give your answer in "nanometer".


Answer: ✓

The correct answer is: 852.50

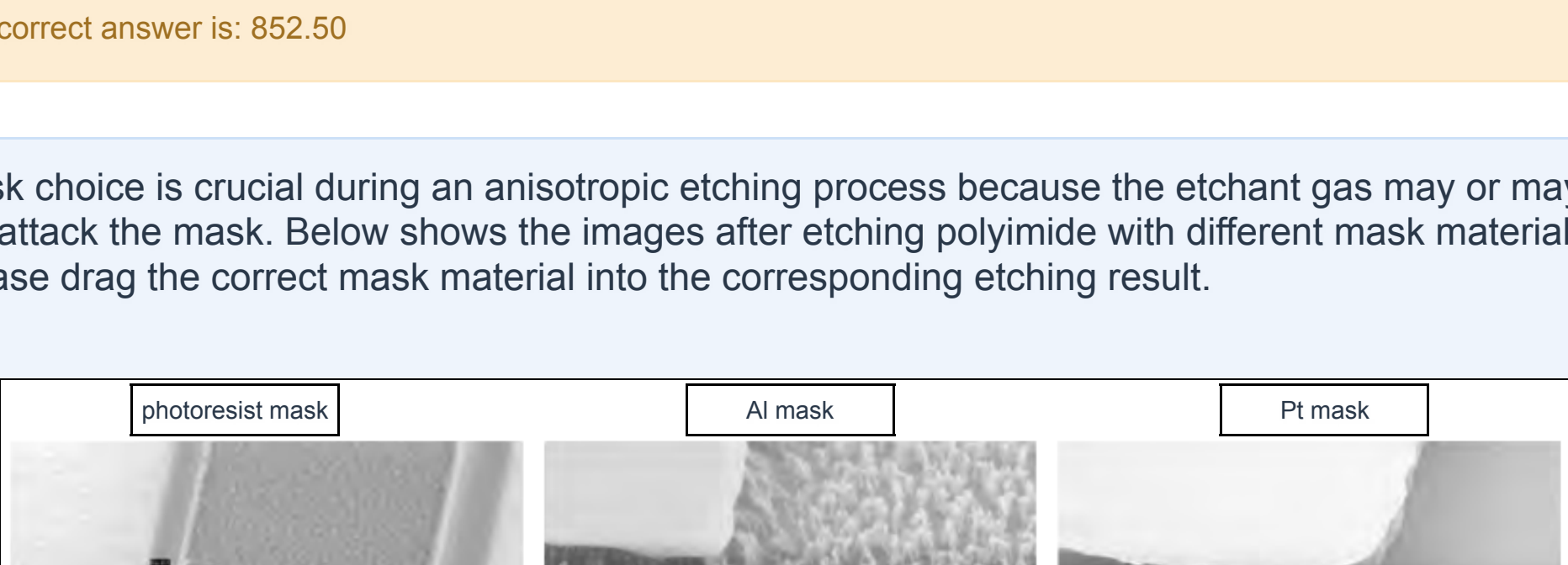
Question 10

Correct

Mark 1.0 out of 1.0

 Flag question

Mask choice is crucial during an anisotropic etching process because the etchant gas may or may not attack the mask. Below shows the images after etching polyimide with different mask materials. Please drag the correct mask material into the corresponding etching result.



Your answer is correct.

Question 11

Partially correct

Mark 0.5 out of 1.0

 Remove flag

Al re-deposition during polyimide etching occurs when an Al mask is used. It results in 'grass' formation at the bottom of the substrate. How can this problem be solved?

☐ The wafer can be placed in an oxygen plasma chamber to remove this layer

☒ A reduced gas pressure can be used so that diffusion distances in the etching chamber are enhanced

☐ An erodible mask can be used on top of the Al mask

☐ A thin SiO₂ layer can be predeposited on the surface of the Al mask to avoid this accumulation

Your answer is partially correct.

You have correctly selected 1.

When an Al mask is used during polyimide etching, because of the etching that occurs of the Al mask, Al atoms are re-deposited on the bottom of the etched features. Generally, this kind of re-deposition phenomena can be reduced when one uses a plasma at a lower pressure, which exhibits a higher mean free path of the sputtered material reaction products, so that these can be better removed from the etching area. See "Examples of etching processes for organic films and metals" video from 2:35 to 3:35 for more detailed explanations.

The correct answers are:
A reduced gas pressure can be used so that diffusion distances in the etching chamber are enhanced,
A thin SiO₂ layer can be predeposited on the surface of the Al mask to avoid this accumulation

Question 12

Correct

Mark 1.0 out of 1.0

 Flag question

Sometimes, in Cl plasma etching, a corrosion phenomenon is observed in Al etching under the form of chlorine-containing residues remaining on the film sidewalls. Which chemical compound is at the origin of this corrosion?

☐ Nitrogen gas that is gently blown on the wafer surface to create AlN gas

☐ Diluted acetone in which the wafer is dipped before etching

☒ HCl that is formed on the Al surface

☐ PGMEA that is used as a developer

Your answer is correct.

Sometimes a corrosion phenomenon is observed on the etched Al structures. This is believed to originate from Cl-containing residues that remain on the etched side walls. If these residues are combined with moisture absorption, HCl and AlCl₃ molecules are formed. The problem is even more severe for Al-Cu alloys. Corrosion can be prevented by rinsing well the wafer in de-ionized water after the removal from the Cl plasma. Also, one can apply a plasma etching step in O₂ to remove residual photoresist and Cl atoms and at the same time, restore a thin passivating Al₂O₃ layer. Another possibility is to expose the etched structure to a fluorine plasma during which the Cl atoms are replaced by F atoms. See "Examples of etching processes for organic films and metals" video from 8:45 to 10:10 for more detailed explanations.

The correct answer is:
HCl that is formed on the Al surface

Question 13

Correct

Mark 1.0 out of 1.0

 Flag question

Which of the following statements are true related to the pulsed deep dry etching process of Si (Bosch process)?

☒ C₄F₈ is used in the sequence as the passivation gas

☐ Ar is used in the sequence as the chemical etching gas

☐ The etching rate can be decreased by adding Ar in between etching and passivation steps

☐ A loading effect is observed when there are only wide mask openings on the wafer

☒ The scalloping effect can be reduced by decreasing the duration of the gas pulses

Your answer is correct.

In deep dry etching of Si (Bosch process), SF₆ gas is used for etching and C₄F₈ gas is used for polymerization. These gases are activated in the chamber alternatively to reach a desired etching depth with vertical side walls. Depending on the area opening of the mask, etching rates might be area-dependent. The etching gas has easier access into a large hole than a small hole and the reaction products can also be better removed. This phenomenon is known as "loading effect". Ar gas does not play any role in the etching process. See "Deep dry etching of silicon; dry etching without a plasma" video from 2:00 to 6:00 for more detailed explanations.

The correct answers are:
C₄F₈ is used in the sequence as the passivation gas ,
The scalloping effect can be reduced by decreasing the duration of the gas pulses

Finish review