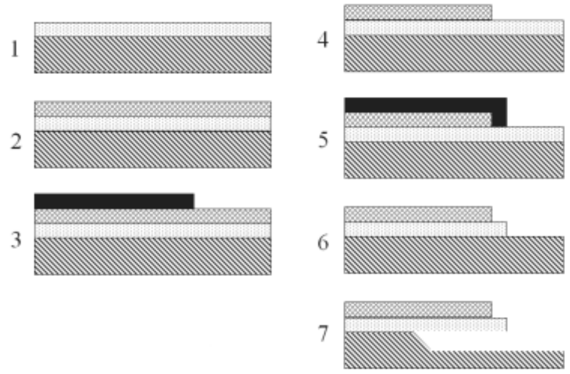
Started on	Monday, 14 November 2022, 13:39
State	Finished
Completed on	Monday, 14 November 2022, 13:52
Time taken	13 mins 17 secs
Marks	23.00/35.00
Grade	**6.57** out of 10.00 (**66**%)

Question **1**
Correct
Mark 1.00 out of 1.00

For the following Process Flow of the Bimorph structure assign the correct steps to the corresponding number (the images show a cross section AFTER the process to assign have been concluded):



3 Lithography 1 (heater) ✔
1 Silicon oxidation ✔
4 Cr etch and resist stripping ✔
6 Silicon dioxide etch and resist stripping ✔
5 Lithography 2 (cantilever) ✔
2 Cr layer deposition ✔
7 Silicon etch in KOH ✔

Your answer is correct.

The correct answer is:
3 → Lithography 1 (heater),
1 → Silicon oxidation,
4 → Cr etch and resist stripping,
6 → Silicon dioxide etch and resist stripping,
5 → Lithography 2 (cantilever),
2 → Cr layer deposition,
7 → Silicon etch in KOH

Question **2**

Not answered

Marked out of 1.00

Assuming that a Si wafer is immersed in a wet anisotropic etchant, which of the following is correct regarding the Si anisotropic etching process?

- A Si atom in a (111) plane has 2 backbonds and 2 dangling bonds
- A Si atom in a (100) plane has 2 backbonds and 2 dangling bonds
- A Si atom in a (111) plane has a higher etching rate than a Si atom in a (100) plane
- A Si atom in a (100) plane has 3 backbonds and 1 dangling bond
- A Si atom in a (111) plane has 1 backbond and 1 dangling bond
- The etch rate for Si atoms in (100) and (111) planes are temperature-independent

Your answer is incorrect.

A Si atom located in a certain plane is differently 'anchored' to the back of the substrate and has a different number of dangling bonds that are in contact with the etching solution. This can give rise to plane-dependent etching rates. A Si atom in (111) plane has 3 backbonds and 1 dangling bond whereas for a Si atom in (100) plane, there are 2 backbonds and 2 dangling bonds. Therefore, a (111) plane will etch much slower than a (100) plane in an alkaline etching bath. See "Anisotropic wet etching of silicon in alkaline baths" video from 7:20 to 8:15 for detailed explanations.

The correct answer is:
A Si atom in a (100) plane has 2 backbonds and 2 dangling bonds

Question **3**

Not answered

Marked out of 1.00

If a Si wafer is immersed in a wet anisotropic etchant (KOH), a Si atom in a [ ] plane has a higher etching rate than a Si atom in a [ ] plane because a Si atom in (111) plane has [ ] backbond(s) and [ ] dangling bond(s).

1	(111)	4	(100)	0	3	2	2

Your answer is incorrect.

A Si atom located in a certain plane is differently 'anchored' to the back of the substrate and has a different number of dangling bonds that are in contact with the etching solution. This can give rise to plane-dependent etching rates. A Si atom in (111) plane has 3 backbonds and 1 dangling bond whereas for a Si atom in (100) plane, there are 2 backbonds and 2 dangling bonds. Therefore, a (111) plane will etch much slower than a (100) plane in an alkaline etching bath. See "Anisotropic wet etching of silicon in alkaline baths" video from 7:20 to 8:15 for detailed explanations.

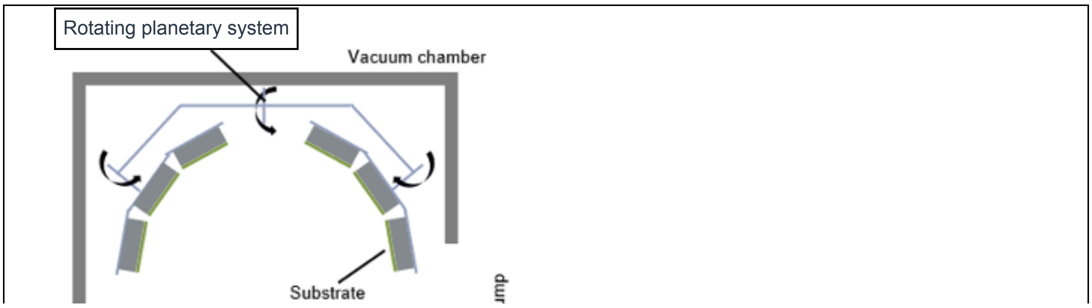
The correct answer is:
If a Si wafer is immersed in a wet anisotropic etchant (KOH), a Si atom in a [(100)] plane has a higher etching rate than a Si atom in a [(111)] plane because a Si atom in (111) plane has [3] backbond(s) and [1] dangling bond(s).

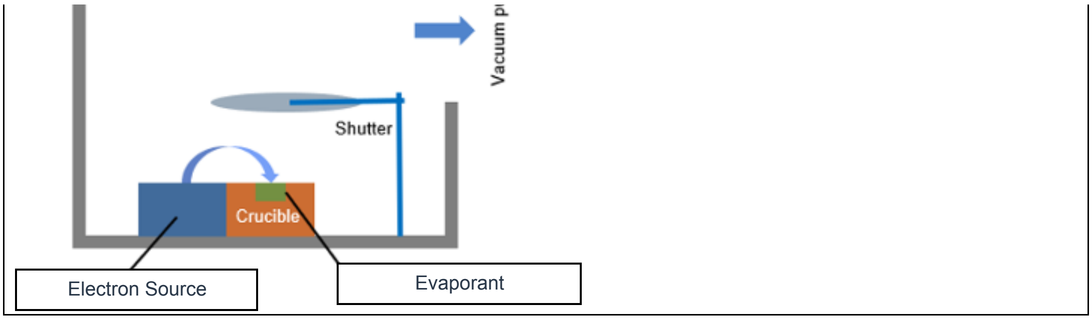
Question **4**

Correct

Mark 1.00 out of 1.00

Below is a schematic drawing of an evaporation tool. Some components are not labelled. Drag and drop the corresponding part into the figure.





RF Capacitor

Magnetron source

Quartz Crystal Resonator

Your answer is correct.

Question **5**

Partially correct

Mark 0.50 out of 1.00

What is correct in saying about the deposition rate of a thin film in a CVD chamber?

Multiple answers are possible

- [ ] When using LPCVD process one can get an appreciable throughput thanks to the possibility of stacking multiple wafers simultaneously in the reactor
- [x] If gas pressure is increased at constant temperature, a deposition which is in the reaction controlled regime can never shift to the mass-controlled regime ✖
- [ ] A lower gas flowrate results in a higher gas concentration near the heated substrate
- [x] As the activation energy of the reaction decreases, the deposition rate decreases ✖
- [x] Local variations in the gas concentration occur less at lower pressure, in which case more uniform deposition rates can be achieved ✔

Your answer is partially correct.

You have selected too many options.
At atmospheric pressure, local variations in the gas concentration are common and would result in uneven deposition rates across the surface of the substrate. These variations can be reduced by lowering the pressure in the reactor. If the gas pressure is lowered, fewer molecules are available for deposition, but these can be transported from further away, so that the deposition rate increases; also deposition shifts to the reaction-controlled regime. See "Basic principles of CVD and CVD reactors" video from 06:58 to 09:41 for detailed explanations.

The correct answers are:
Local variations in the gas concentration occur less at lower pressure, in which case more uniform deposition rates can be achieved ,

When using LPCVD process one can get an appreciable throughput thanks to the possibility of stacking multiple wafers simultaneously in the reactor

Question **6**

Correct

Mark 1.00 out of 1.00

Which of the following statements are true considering the properties of electron guns?

- [x] The purpose of a suppressor in an electron gun is to limit the emission of electrons to the tip apex region. ✔
- [x] The tip of Schottky field emitters are coated with ZrO_2 to reduce the working function. ✔

The more anodes in an electron gun, the better the resolution.

Your answer is correct.

See video “Electron beam lithography: tool overview” – slides about the electron gun.

The correct answers are:
The purpose of a suppressor in an electron gun is to limit the emission of electrons to the tip apex region. ,

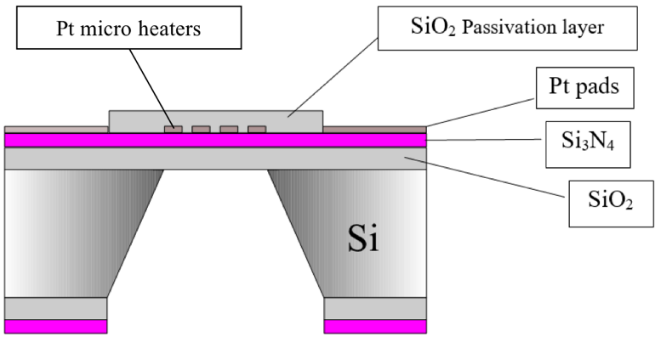
The tip of Schottky field emitters are coated with ZrO_2 to reduce the working function.

Question **7**

Not answered

Marked out of 1.00

We aim at fabricating a micro hotplate as shown below. The step by step fabrication consists of wet oxidation of 650 nm SiO_2, deposition of 200 nm Si_3N_4, deposition and patterning of 100 nm Pt layer (which serves as a micro heater), deposition of SiO_2 passivation layer, removal of the passivation on top of Pt pads, and finally back side etching of the wafer. After completion of each step, we need to inspect the device. For the inspection and measurement steps listed below, match the most appropriate characterization technique (each of the option can only be picked once).



Sheet resistance measurement of Pt after the metal deposition	Choose...
Check lateral dimensions of micro heater after stripping the resist	Choose...
Check the thickness of the Pt layer after dry etching and stripping the resist	Choose...
Check if the contact pads are fully exposed from the passivation layer	Choose...
Check the interface between metal, Si_3N_4 and SiO_2	Choose...

Your answer is incorrect.

After Pt deposition, the film remains unpatterned, we use Van der Pauw 4-point measurement to obtain the sheet resistance of the metal film.

After Pt micro heater patterning, we can use an optical microscope to measure the lateral dimension of the micro heater and a mechanical profilometer to measure the thickness of the Pt film (be careful of possible Si_3N_4 loss due to Pt dry etch) before passivation film deposition.

After passivation opening on top of the Pt pads, we can use a prober station to do 2-point I-V curve measurement to check if the electrode pads are freed from the passivation cover, which means no insulating passivation film remaining on top of the pads.

Finally, we can use FIB to make local cross sections and inspect the interfaces.

For further information, please see video “Optical microscopy”, “Electrical characterization”, “Mechanical surface profile measurement” and “Focused ion beam”.

The correct answer is:
Sheet resistance measurement of Pt after the metal deposition → Van der Pauw 4-point measurement,

Check lateral dimensions of micro heater after stripping the resist → Optical microscopy,

Check the thickness of the Pt layer after dry etching and stripping the resist → Mechanical profilometry,

Check if the contact pads are fully exposed from the passivation layer → 2-point I-V measurement in prober station,

Check the interface between metal, Si_3N_4 and SiO_2 → Focused ion beam analysis

Question **8**

Correct

Mark 1.00 out of 1.00

The presence of shear stress in the gas flow near a heated substrate is an important phenomenon inside a CVD reactor and it is caused by the [different velocites] ✔ of the gas flowing [in the boundary layer] ✔

[different temperatures]

[outside the boundary layer]

Your answer is correct.

Shear stress is due to variable gas flow velocities at differing distances from the substrate. Due to the no-slip condition, the speed of a gas at the substrate is zero, but far enough from the substrate, the speed is basically equal that of the applied flowrate. This is causing variable flow speeds in the boundary layer. See "Theoretical concepts of gas flow in CVD reactors" video from 02:28 to 03:50 for detailed explanations.

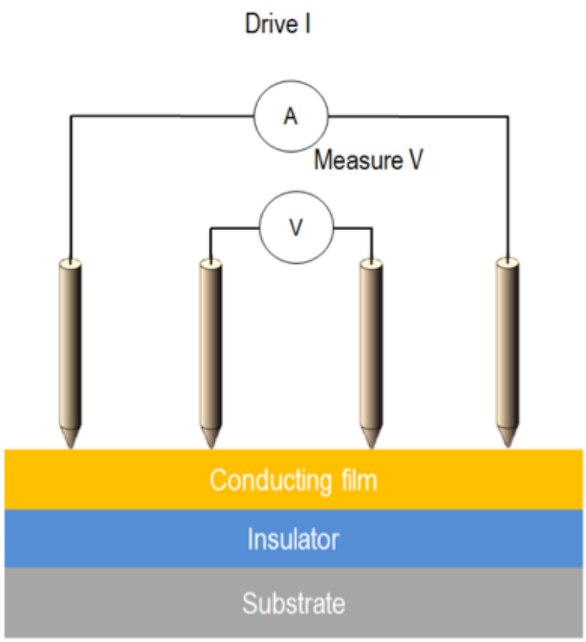
The correct answer is:
The presence of shear stress in the gas flow near a heated substrate is an important phenomenon inside a CVD reactor and it is caused by the [different velocites] of the gas flowing [in the boundary layer]

Question **9**

Not answered

Marked out of 1.00

Why is 4-point probe measurement (see the following picture) more suitable to evaluating small electrical resistances rather than simpler 2-point approaches?



- ○ The voltmeter has low series impedance, so the current forced to pass through it is high enough to overcome the contact resistance
- ○ The current source has low series impedance, so the voltage drop caused by the contact resistance becomes negligible
- ○ The current source has high series impedance, so the contact resistance becomes negligible in such a configuration
- ○ The voltmeter has high series impedance, so both the current passing through and the voltage drop

caused by the contact resistance are negligible

Your answer is incorrect.

The voltmeter has high series impedance, the current passing through this impedance is negligible, so that the voltage drop caused by the contact resistance is also negligible. Therefore, 4-point measurement can evaluate a small resistance more accurately than 2-point measurement.

The current source has very low series impedance (ideally zero), so the contact resistance (at the interface of the probe and the film) are not negligible with respect to that.

For more information, please see video “Electrical characterization” at 01:34.

The correct answer is:
The voltmeter has high series impedance, so both the current passing through and the voltage drop caused by the contact resistance are negligible

Question **10**

Correct

Mark 1.00 out of 1.00

Mask-based versus direct write photolithography

Mask-based lithography is a better-suited method compared to direct writing when the design [has already been] ✔ optimised and the structures need to be fabricated [many times] ✔ .

[still has to be] [a few times]

Your answer is correct.

. Direct laser writing should mainly be considered when it comes to fabricating masks, or when we are doing some prototyping.

The correct answer is:

Mask-based versus direct write photolithography

Mask-based lithography is a better-suited method compared to direct writing when the design [has already been] optimised and the structures need to be fabricated [many times].

Question **11**

Not answered

Marked out of 1.00

Which characterization method is best suited for the following cases? (each of the option can only be picked once)

Method to perform compositional analysis	Choose...
Method to measure the surface roughness below 1 nm	Choose...
Method to inspect patterned thin film micro-structures	Choose...
Non-invasive thickness measurement of an unpatterned dielectric film deposited on a full wafer	Choose...

Your answer is incorrect.

Please see video “Optical thin film thickness measurement”, “Mechanical surface profile measurement”, “Optical surface profile measurement” and “Scanning electron microscopy”.

The correct answer is:
Method to perform compositional analysis → Energy dispersive X-ray analysis,

Method to measure the surface roughness below 1 nm → Atomic force microscopy,

Method to inspect patterned thin film micro-structures → Scanning electron microscopy,

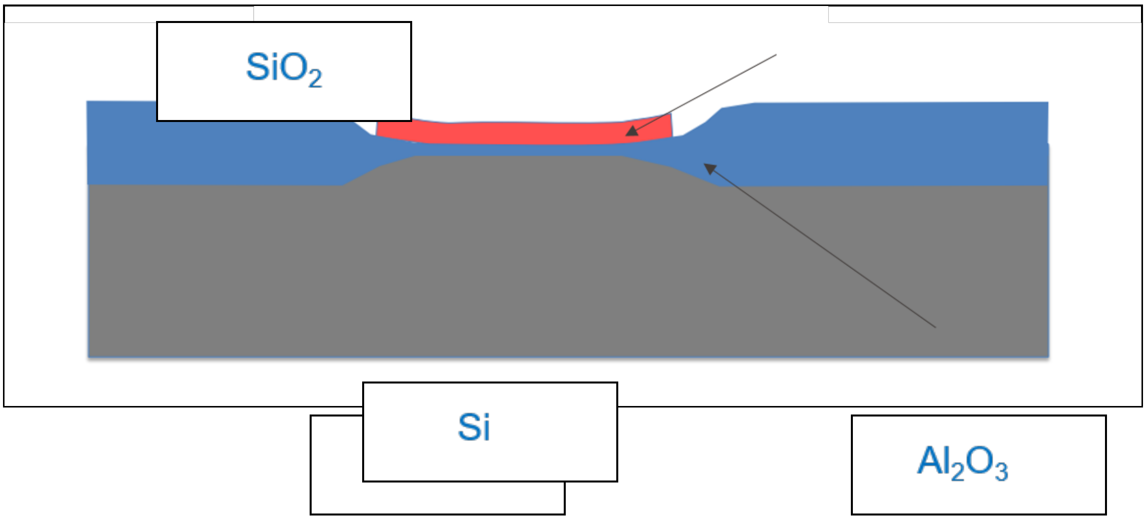
Non-invasive thickness measurement of an unpatterned dielectric film deposited on a full wafer → Optical thin film interference

Question **12**

Correct

Mark 1.00 out of 1.00

Local oxidation of silicon (LOCOS) is an important process step in the fabrication of a transistor (e.g. FET MOS). The structure shown in the schematic drawing below was fabricated using such a LOCOS process. Drag and drop the items onto the image.



Your answer is correct.

The drawing illustrates the LOCOS process (local oxidation of silicon) which is a thermal oxidation process where SiO_2 is formed in selected areas on a silicon wafer by using a Si_3N_4 mask.

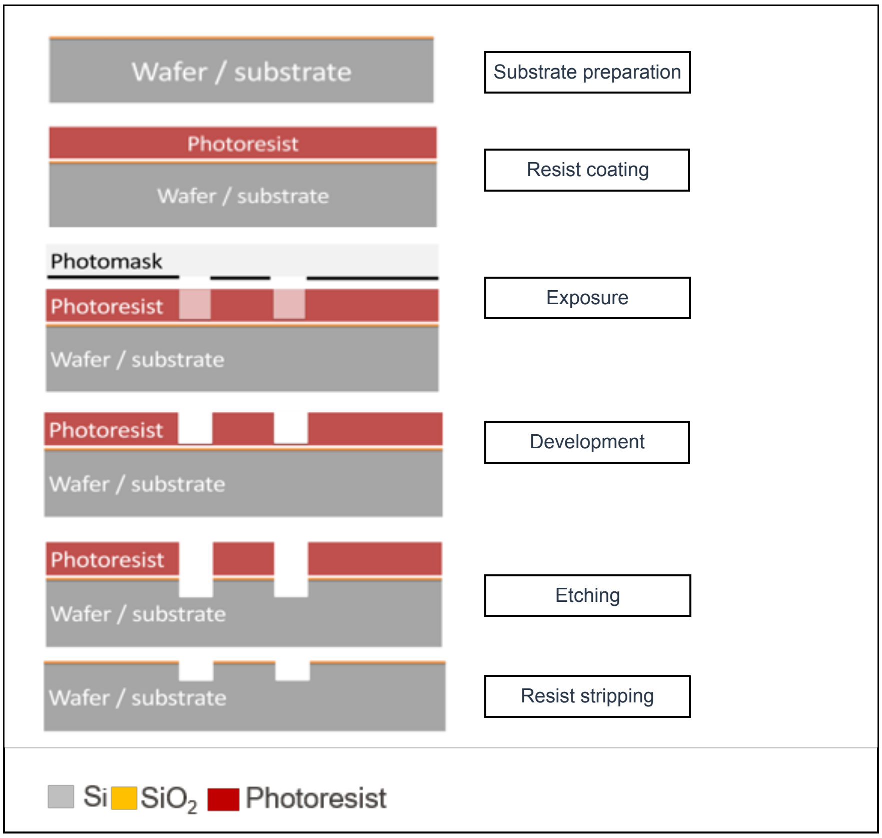
Question **13**

Correct

Mark 1.00 out of 1.00

The image below shows a schematic drawing of a typical process flow for a photolithographic process.

Drag and drop the text items to the right side of the corresponding image to name each step. Beware of the distractors.



Lift-off | Ion implantation

Metal evaporation

Your answer is correct.

The process flow for lithography consists of substrate preparation, resist coating, resist exposure, resist development, patter transfer and resist stripping. In the case of this schematic drawing the pattern transfer is performed by etching as shown in the fifth step.

Question **14**

Correct

Mark 1.00 out of 1.00

PVD can be used to deposit uniform thin films of a variety of materials. The most prominent methods are evaporation and sputtering. What is the advantage of sputtering over evaporation?

- ○ With sputtering the substrate is less prone to damage.
- ◉ Sputtering eases the deposition of refractory materials such as Hafnium carbide (HfC). ✔
- ○ Higher film purity can be achieved with sputtering.
- ○ Stencil lithography is better suited for use in a sputter tool.

Your answer is correct.

Due to the fact that mechanical and not thermal energy is used to eject atoms from the target, sputtering enables the deposition of refractory oxides, nitrides and carbides. Because of the plasma, sputtering requires higher pressure than evaporation; 10^{-1} to 10^{-3} Torr for sputtering instead of 10^{-6} to 10^{-7} Torr for evaporation as mentioned in the slide about film growth and control parameters in the fifth video of the sputtering section. As a result, film purity is lower with sputtering than with evaporation. Energetic sputtered atoms and plasma secondary electrons collide on the substrate which generate heat and might create surface damages. Finally, because of the random angle of incidence of sputtered atoms, this technique is not well suited to perform stencil lithography.

The correct answer is:
Sputtering eases the deposition of refractory materials such as Hafnium carbide (HfC).

Question **15**

Correct

Mark 1.00 out of 1.00

If the gas pressure in a CVD reactor is increased at constant temperature, a deposition which is in the [mass-transfer controlled] ✔ regime can never shift to the [reaction controlled] ✔ regime

laminar flow | turbulent regime

Your answer is correct.

By lowering the pressure the mean free path of the gas molecules is increased, meaning that there will be gas molecules coming further from the substrate that can be used in the reaction. This causes the deposition at lower pressure to remain in the reaction-controlled regimes for a larger range of temperatures. This means that at a given temperature a process that is in the reaction-controlled regime can shift to the mass transfer controlled regime by increasing the pressure but not viceversa.

The correct answer is:
If the gas pressure in a CVD reactor is increased at constant temperature, a deposition which is in the [mass-transfer controlled] regime can never shift to the [reaction controlled] regime

Question **16**

Correct

Mark 1.00 out of 1.00

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

- ☐ 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
- [x] The scalloping effect can be reduced by decreasing the duration of the gas pulses ✔
- [x] C_4F_8 is used in the sequence as the passivation gas ✔
- [ ] A loading effect is observed when there are only wide mask openings on the wafer

Your answer is correct.

In deep dry etching of Si (Bosch process), SF_6 gas is used for etching and C_4F_8 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:
C_4F_8 is used in the sequence as the passivation gas ,

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

Question **17**

Correct

Mark 1.00 out of 1.00

When depositing thin film by PVD techniques, it is important to measure the film thickness *in-situ* during the process. How do modern evaporation equipment perform this real-time monitoring?

- ○ By using an ellipsometry system to measure the changes in the light reflected from the substrate’s surface.
- ○ By measuring the change of the substrate’s mass through a weight sensor under it.
- ◉ By measuring the changes in the oscillation frequency of a quartz crystal resonator. ✔
- ○ By using a profilometer to scan the substrate’s surface.

Your answer is correct.

In modern evaporation tools, thickness of the deposited layers is monitored using quartz crystal resonators as explained in the slide about other equipment specs. Ellipsometry is a powerful tool to measure the thickness of deposited films as well as other thin films properties such as refractive index, electrical conductivity and roughness among others. However it is not possible to integrate an ellipsometry system inside an evaporation chamber. Integrating a weight sensor in the substrate holder would make the substrate clamping system a lot more complicated and the mass measurement itself would also be difficult; we would need to detect the addition of a few nanometer of material onto a 500 µm thick substrate. Finally using a profilometer to scan the substrate surface is not possible as it would alter the deposition of the material and be complex to implement

The correct answer is:
By measuring the changes in the oscillation frequency of a quartz crystal resonator.

Question **18**

Not answered

Marked out of 1.00

A mixture of 40 wt% [ ] with 49 wt% [ ] is called buffered oxide etch or buffered HF (BHF). The use of BHF produces a slower and less aggressive etch so that [ ] masks can be used and there is no need for the preparation of an expensive [ ] mask

| H2SO4 | HCl | SiO2 | photoresist | Au | HF | NH4F |

Your answer is incorrect.

A mixture of 40 wt% NH_4F with 49 wt% HF is called buffered oxide etch or buffered HF (BHF). Compared with pure HF bath, BHF bath is less aggressive so that photoresist masks can be used and an expensive Au mask is not needed. Photoresist would be very strongly degraded in pure(=49%) HF baths.

The correct answer is:

A mixture of 40 wt% [NH4F] with 49 wt% [HF] is called buffered oxide etch or buffered HF (BHF). The use of BHF produces a slower and less aggressive etch so that [photoresist] masks can be used and there is no need for the preparation of an expensive [Au] mask

Question **19**

Correct

Mark 1.00 out of 1.00

Resolution enhancement in electron beam lithography (EBL)

The resolution in EBL is limited by forward scattering of the electrons and it can be improved by using a [thinner] resist and by [increasing the acceleration voltage] .

increasing the size of the electron source

thicker

decreasing the acceleration voltage

Your answer is correct.

When hitting the resist, the electron beam broadens because of forward scattering. The thinner the resist layer, the smaller the impact of this broadening in the final structures. On the contrary, the acceleration voltage needs to be increased to decrease the forward scattering.

The correct answer is:

Resolution enhancement in electron beam lithography (EBL)

The resolution in EBL is limited by forward scattering of the electrons and it can be improved by using a [thinner] resist and by [increasing the acceleration voltage].

Question **20**

Correct

Mark 1.00 out of 1.00

In a so-called lift-off process, a thin gold (Au) film is deposited by PVD on a patterned resist layer. Which of the following proposition is correct?

- ○ An e-beam evaporator should be used because the boiling point of gold is too high for a resistive-heating evaporator.
- ◉ An evaporator with a large source-substrate distance should be used for line of sight deposition. ✔
- ○ Using a rotating planetary system is required in order to have good step coverage.
- ○ Sputtering is better suited than thermal evaporation for an application such as lift-off.

Your answer is correct.

Using an evaporator with a large source-substrate distance makes the deposition more directional, and thus avoids depositing gold on the walls of the photoresist as discussed in the slide about lift-off process in the second video of the thermal evaporation section. A resistive-heating evaporator can very well evaporate gold. The main advantage of using an e-beam evaporator is the purity of the deposited film and is not related to the gold boiling point. Sputtering is not directional and is thus not well suited for lift-off deposition. Using a rotating planetary system enables good step coverage. However, for the specific case of lift-off process, we don’t want good step coverage as we want to avoid having material deposited on the walls of the photoresist.

The correct answer is:

An evaporator with a large source-substrate distance should be used for line of sight deposition.

An evaporator with a large source-substrate distance should be used for line of sight deposition.

Question **21**

Correct

Mark 1.00 out of 1.00

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

- A diode reactor ✔
- An atomic layer chemical vapor deposition system
- A plug flow reactor
- A batch 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 **22**

Correct

Mark 1.00 out of 1.00

What can be correctly said about the laminar regime of the boundary layer?

- Inertial forces suddenly set in when the substrate temperature rises
- Inertial forces are much larger than viscous forces
- The mean free path of gas molecules is no longer a relevant parameter for CVD deposition
- The gas flow is more likely to be laminar in a smaller reactor ✔

Your answer is correct.

The Reynolds number is proportional to the horizontal coordinate x along the reactor and thus increases when the reactor size increases. This is why the gas flow in the reactor is more likely to be turbulent in a larger reactor. When the reactor size is getting smaller, the gas flow is more likely to be laminar throughout the chamber. See "Theoretical concepts of gas flow in CVD reactors" video from 06:01 to 07:05 for detailed explanations.

The correct answers are:
The gas flow is more likely to be laminar in a smaller reactor ,

The mean free path of gas molecules is no longer a relevant parameter for CVD deposition

Question **23**

Correct

Mark 1.00 out of 1.00

To confine the acoustic waves generated at resonance, FBAR-BAW use [an underlying air gap] ✔ , whereas BAW SMR use [Bragg mirrors] ✔ .

[a cavity etched through the entire wafer thickness]

[an underlying PDMS layer]

Your answer is correct.

The correct answer is:
To confine the acoustic waves generated at resonance, FBAR-BAW use [an underlying air gap], whereas BAW SMR use [Bragg mirrors].

Question **24**

Correct

Mark 1.00 out of 1.00

Lithography normally uses a binary mode of illumination (either light or no light). Grayscale lithography is a variation where 3D structures can be obtained in resist.

In order to obtain 3 different heights in the patterned photo-resist structure after development, lithography can be performed both by direct write laser and using a photomask.

Select one:

- (•) True ✔
- ( ) False

Although more cumbersome, there are ways of exposing parts of a wafers with different energies without necessarily having to use direct laser writing. The mask used in mask-based lithography can be fabricated with different thicknesses of chromium, which result in different transmission coefficients. It is also possible to code the grayscale values in spatial modulations of the patterns that form the mask.

The correct answer is 'True'.

Question **25**

Correct

Mark 1.00 out of 1.00

Let us assume we have a 162 µm wide x 511 µm long pattern in a SiO_2 layer on top of a silicon wafer. What is the required etching time in minutes to release such a pattern in KOH in order to create a cantilever? We assume the wafer orientation is (100), the same as in the bi-morph example, and that the patterns are oriented at 45° from the flat as in the bi-morph example.

Answer: 222 ✔

The etching rate of silicon (100) plans is about 20 µm/h. To release the cantilever from the silicon wafer, 162*0.5 µm silicon must be under etched from each side of the cantilever. This represents an etching time of 162*0.5/20 h or 162*0.5/20*60 minutes. See the video about the thermo-mechanical micro-actuator between 09:47 and 11:53 for detailed explanation.

The correct answer is: 243.00

Question **26**

Partially correct

Mark 0.50 out of 1.00

Which of the following propositions about sputtering are correct?

- [ ] Sputtering can be used to deposit polymers.
- [ ] At fixed process parameters, sputtering yield is constant independently of the material.
- [x] Sputtering can be used to deposit metals, alloys, refractory oxides and nitrides. ✔
- [ ] The stress of deposited film by sputtering can be controlled by tuning the substrate temperature.
- [x] Sputtering has better step coverage than evaporation due to higher operating pressure. ✔

Your answer is partially correct.

You have correctly selected 2.

Because of the plasma, sputtering requires higher pressure than evaporation; 10^{-1} to 10^{-3} Torr for sputtering instead of 10^{-6} to 10^{-7} Torr for evaporation as mentioned in the slide about film growth and control parameters in the fifth video of the sputtering section. As a result, the mean free path in a sputtering chamber is a few mm only and atoms ejected from the target will collide with many gas particles/ions before depositing with random incidence angles on the substrate. This leads to a better step coverage than with evaporation. Sputtering can be used to deposit metals, alloys, refractory oxides and nitrides because mechanical energy is used to remove atoms from the target. Nothing prevents the use of sputtering with polymers. PTFE is listed in the slide about advantages of sputtering in the third video of the sputtering section. As discussed in the slide about film growth and control parameters in the fifth video of the sputtering section, temperature of the substrate can be used to control stresses in thin films. In the slides about ions-target interactions in the fourth video of the sputtering section, we can see the sputtering yield is different for each target of material.

The correct answers are:
Sputtering has better step coverage than evaporation due to higher operating pressure.,

Sputtering can be used to deposit metals, alloys, refractory oxides and nitrides.,

Sputtering can be used to deposit polymers.,

The stress of deposited film by sputtering can be controlled by tuning the substrate temperature.

Question **27**
Correct
Mark 1.00 out of 1.00

For cleanroom use water has to be de-ionised to give a very high resistivity, 18 M ✔ Ω cm in VLSI areas

k G T m

Your answer is correct.

The correct answer is:
For cleanroom use water has to be de-ionised to give a very high resistivity, 18 [M]Ω cm in VLSI areas

Question **28**
Incorrect
Mark 0.00 out of 1.00

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?

- [x] A thin SiO_2 layer can be predeposited on the surface of the Al mask to avoid this accumulation ✔
- [ ] A reduced gas pressure can be used so that diffusion distances in the etching chamber are enhanced
- [x] The wafer can be placed in an oxygen plasma chamber to remove this layer ✖
- [ ] An erodible mask can be used on top of the Al mask

Your answer is incorrect.

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 SiO_2 layer can be predeposited on the surface of the Al mask to avoid this accumulation

Question **29**
Incorrect
Mark 0.00 out of 1.00

Which of the following is a commonly used application of HF etching?

- (•) To remove the residual organics from the wafer surface and to improve adhesion of the surface ✖
- ( ) To thermally and mechanically stabilize the structures on the wafer
- ( ) To form free standing structures
- ( ) To make the wafer surface more hydrophilic especially for possible PDMS molding processes

Your answer is incorrect.

Your answer is incorrect.

This type of etching is used for locally removing a SiO_2 layer to define free-standing structures like used for micro-actuators. See "HF bath for SiO2 and glass wet etching" video from 0:10 to 1:20 for detailed explanations.

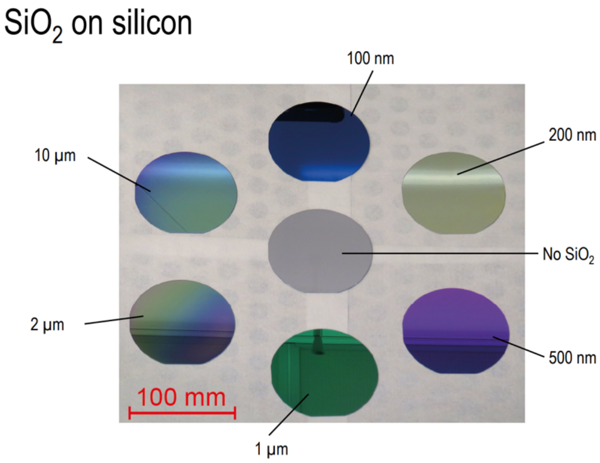
The correct answer is:
To form free standing structures

Question **30**

Incorrect

Mark 0.00 out of 1.00

What is the reason for the color change of silicon wafers coated with SiO_2 thin films having different thicknesses?



- Reflectivity of the thin film changes with the thickness for different wavelengths
- Refractive index change of SiO_2 due to the variation of its film thickness
- Interference of the light reflected from the thin film's lower and upper boundaries
- Optical absorption spectrum of the thin film varies with different thickness

Your answer is incorrect.

It is the interference between the light reflected by the upper and lower boundaries of the transparent thin film, which leads to the spectrum change and finally the color change from the observer's view.

The refractive index of SiO_2 does not change significantly with the thickness to change the color. However, different SiO_2 deposition processes might result in different refractive index and therefore lead to different color of SiO_2 thin film with the same thickness.

It is mainly the intensity in the optical absorption spectrum that changes with the thickness of a thin film, thus does not change the color.

The reflectivity for different wavelengths does not change significantly with the thickness of a thin film, thus does not change the color either.

For further information, please see video “Optical thin film thickness measurement” at 00:44.

The correct answer is:
Interference of the light reflected from the thin film's lower and upper boundaries

Question **31**

Correct

Mark 1.00 out of 1.00

In a CF_4 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?

- [x] By decreasing the temperature
- [ ] By decreasing the pressure
- [x] By increasing the monomer concentration

By increasing the monomer concentration

By decreasing the H_2 concentration

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 **32**

Correct

Mark 1.00 out of 1.00

Bulk acoustic wave (BAW) resonators are the key element of modern GHz-range ladder filters that are used today in smartphones etc. They are basically…

a. …low-pass filters

b. …high-pass filters

c. …band-pass filters

Your answer is correct.

Ladder filters are band-pass filters used to select a particular band of the GHz telecom frequency spectrum.

The correct answer is:
…band-pass filters

Question **33**

Not answered

Marked out of 1.00

What is the best possible resolution of a Scanning Electron Microscope (SEM) in general, and what determines this limitation?

≈6 pm, because of diffraction limit

≈3 nm, because of the system's focusing ability

≈50 nm, because of the system's focusing ability and forward scatterning

≈3 pm, because of diffraction limit

≈12 pm, because of the system's focusing ability and backward scattering

Your answer is incorrect.

Although the calculation of the diffraction limit would lead to a resolution of approximately \lambda /2=6 pm, a SEM's resolution is limited by the system's focusing ability and electron scattering resulting in the best resolution of a few nm in case of conducting samples.

For further information, please see video "Scanning electron microscopy" at 01:11.

The correct answer is:
≈3 nm, because of the system's focusing ability

Question **34**

Our aim is to have silicon trenches with depth of 354 μm and width of 27 μm by using photolithography and

Correct

Mark 1.00 out of 1.00

the Bosch process. In a given recipe in the Bosch process, we have a constant silicon etching rate of 5 µm/min. Calculate how long in "minutes" the Bosch process lasts to achieve an etch depth of 354 µm?

Answer: 70.8 ✔

The correct answer is: 70.8

Question **35**

Not answered

Marked out of 1.00

Which of the following is true for the mask material selection for Si etching in an HNA bath?

- One has to dip the wafer first in a concentrated acetone solution which is followed by dipping in a HNO_3 bath
- Photoresists can be used as masking material, as they withstand strong oxidizing agents like HNO_3
- Wet etching of SiO_2 is performed by clamping the Si wafer on a metallic chuck
- For very deep etching, a Au or Si_3N_4 mask is required

Your answer is incorrect.

If one is at the temperature where the Si etching rate is 50 µm/min, the SiO_2 etching rate is in between 30 to 80 nm/min, so that SiO_2 can be used as a mask material. For very deep etching, Au or Si_3N_4 masks are required, as regular photoresists cannot withstand strong oxidizing agents like HNO_3 in a HNA bath. See "Isotropic wet etching of silicon in the HNA bath" video from 9:30 to 10:20 for detailed explanations.

The correct answer is:
For very deep etching, a Au or Si_3N_4 mask is required

EPFL

Contact EPFL CH-1015 Lausanne +41 21 693 11 11