Started on	Sunday, 13 November 2022, 18:40
State	Finished
Completed on	Sunday, 13 November 2022, 18:52
Time taken	12 mins 8 secs
Marks	12.00/16.00
Grade	**7.50** out of 10.00 (**75**%)

Question **1**

Correct

Mark 1.00 out of 1.00

Consider the thermo-mechanical micro-actuator case study: what is the critical step to ensure the chromium tracks are well aligned with the SiO_2 cantilevers?

a. The SiO_2 etching in BHF

b. The second photolithography ✔

c. The chromium deposition

d. The first photolithography

Your answer is correct.

The second photolithography step is critical. Indeed it is this step which defines which areas of the SiO_2 layer will be protected during the subsequent buffered hydrofluoric acid etch. If there is a misalignment with the chromium tracks during the second photolithography step, then the SiO_2 layer will be etched where the chromium tracks are located and this will lead to the failure of the device. The chromium deposition on top of the SiO_2 layer has no influence on the alignment. Indeed, a full layer of chromium is deposited on top of a full layer of SiO_2. The first photolithography has no influence on the alignment as wherever we pattern the chromium tracks they will be on top of the full SiO_2 layer. Finally, the SiO_2 etching step has no influence on the alignment as at this stage, everything which is not protected is etched. See the video about the thermo-mechanical micro-actuator between 07:53 and 08:40 for detailed explanation.

The correct answer is:
The second photolithography

Question **2**

Correct

Mark 1.00 out of 1.00

Device reliability is important when fabricating devices for commercial use, where long lifetime is required. However, reliability issues cannot always be determined immediately after fabrication. Which of the following failure modes that are originating from the fabrication can be detected during or shortly after the fabrication of a device?

a. Particle contamination ✔

b. Corrosion due to environmental humidity

c. Fatigue due to cyclic loading of a device

d. Strain-induced stress causing failure by temperature variations

Your answer is correct.

Particle contamination on the device can be detected immediately after its fabrication by thorough inspection. The other listed answers are very common failure-modes which restrict MEMS devices from operating long-term.

The correct answer is:
Particle contamination

Question **3**
Correct
Mark 1.00 out of 1.00

In the case study of the thermo-mechanical micro-actuator, one step involves etching the 1.5 µm thick SiO_2 layer in order to create a 204 µm long x 80 µm wide patterns. The etching time of this step is 20 minutes. What is the required etching time in minutes to create a 524 µm long x 80 µm wide patterns in the same SiO_2 layer?

Answer: 20 ✔

The etching time of the SiO_2 layer doesn't depend on the pattern geometry but on the SiO_2 layer thickness only. Indeed, in the case of SiO_2 etching, we want to etch the SiO_2 vertically and not laterally, contrarily to Si etching in KOH for the release of the cantilevers. SiO_2 etching is isotropic/the same in every direction which means there will also be some undesired lateral under etching. However, as the thickness of the SiO_2 layer is 1.5 µm only, the 1.5 µm lateral under etching in the 80 µm wide by 204-524 µm long cantilever is negligible. See the video about the thermo-mechanical micro-actuator between 08:40 and 11:53 for detailed explanation.

The correct answer is: 20.00

Question **4**
Incorrect
Mark 0.00 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 incorrect.

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 **5**
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 ✔ .

an underlying PDMS layer | a cavity etched through the entire wafer thickness

Your answer is correct.

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 **6**

Correct

Mark 1.00 out of 1.00

Match the corresponding Contamination causes in microfabrication with their consequences:

Unwanted chemicals	Non-uniform processes ✔
Metallic ions	Semiconductor materials contamination ✔
Small particles	Failure of microstructures ✔

Your answer is correct.

Small particles effects: small feature size of microstructures makes them prone to failure, if microparticles are present during microfabrication.

Metallic ions effects: electrical properties of semiconductor circuits in a sensitive way depend on embedded impurities; Mobile Ion Contaminants (MICs) are metallic ions that are very mobile in semiconductor materials, are present in most chemicals, and can result in device failure long time after fabrication.

Unwanted chemicals effects: trace chemicals and process water can result in unwanted surface etching, creation of compounds that cannot be removed from the surface, or cause non-uniform processes

The correct answer is:
Unwanted chemicals → Non-uniform processes,

Metallic ions → Semiconductor materials contamination,

Small particles → Failure of microstructures

Question **7**

Partially correct

Mark 0.50 out of 1.00

The signal-to-noise-ratio (SNR) and sensitivity of capacitive accelerometers have been greatly enhanced over the past 20 years, mostly by... (More than one option could be correct.)

- ☐ a. …implementing thin gaps
- ☐ b. …highly doping the Si
- ☐ c. …packaging them in vacuum
- ☑ d. …using combs ✔

Your answer is partially correct.

You have correctly selected 1.
SNR and sensitivity are proportional to the readout capacitance. Using combs enables to drastically increase the readout capacitance by increasing the capacitive readout area without increasing the inertial mass size. Implementing thing gaps enables to drastically increase the readout capacitance, which is inversely proportional to the capacitive gap. Si must be conductive enough, i.e. it needs to be doped. But highly doping does not provide any benefit. Finally, accelerometers have to avoid any oscillations, hence they need to be damped, i.e. operation in vacuum has to be avoided.

The correct answers are:
…using combs,

…implementing thin gaps

Question **8**
Partially correct
Mark 0.50 out of 1.00

What is the purpose of the chromium layer in the thermo-mechanical micro-actuator? More than one option could be correct.

- a. To be electrically conductive
- b. To have a different thermal expansion coefficient compared to SiO_2 ✔
- c. To give a metallic appearance to the wafer
- d. To ensure a good adhesion of the photoresist

Your answer is partially correct.

You have correctly selected 1.
The purpose of the chromium layer is to be electrically conductive in order to apply a current through the patterned chromium tracks. It is this current which heats up and actuates the thermo-mechanical micro-actuator. Chromium is also chosen because of its large difference of coefficient of thermal expansion with SiO_2. Indeed, the radius of curvature of the bi-morph cantilever is proportional to this difference. See the video about the thermo-mechanical micro-actuator between 00:54 and 02:25 as well as between 04:25 and 05:47 for detailed explanation. The metallic appearance that chromium gives to the wafer is not a required property in the case of the thermo-mechanical micro-actuator. The device would work perfectly well without it. Finally, chromium doesn't help the photoresist adhesion.

The correct answers are:
To be electrically conductive,

To have a different thermal expansion coefficient compared to SiO_2

Question **9**
Correct
Mark 1.00 out of 1.00

Why is the thermo-mechanical micro-actuator bending after the KOH release before actually applying any current for joule heating? Because of…

- a. …the electrical current going through the chromium track
- b. …the repulsive electrostatic force between the cantilever and the silicon substrate
- c. …the capillary forces created by the liquid KOH during the release step
- d. …the difference in residual stress between the chromium and SiO_2 layers ✔

Your answer is correct.

The initial bending of the cantilever is due to residual stresses resulting from the various fabrication steps. The origin of these stresses will be discussed in a subsequent video in this chapter. See the video about the thermo-mechanical micro-actuator between 09:48 and 11:54 for detailed explanation. Applying electrical current changes the radius of curvature of the micro-actuator but the initial upward bending already exists without any current. Capillary forces can be problematic in microfabrication, especially during drying steps. However in this specific case, capillary forces would tend to make the cantilever collapse on the wafer. They are not responsible for the initial upward bending. Finally, there exists no electrostatic force between the cantilever and the silicon substrate.

The correct answer is:
…the difference in residual stress between the chromium and SiO_2 layers

Question **10**
Correct
Mark 1.00 out of

To confine the acoustic waves generated at resonance, …

- a. …FBAR-BAW use a cavity etched through the entire wafer thickness, whereas BAW SMR use

1.00

Bragg mirrors

b. …FBAR-BAW use an underlying air gap, whereas BAW SMR use Bragg mirrors ✔

c. …FBAR-BAW use an underlying air gap, whereas BAW SMR use an underlying PDMS layer

Your answer is correct.

FBAR stands for thin-Film Bulk Acoustic Resonator. FBAR have an underlying air gap, which is actually a surface-micromachined local cavity whose height (gap) is in the order of few hundreds of nm (there is one cavity per resonator). This cavity confines the acoustic waves. SMR stands for Solidly-Mounted resonator. SMR are not free-standing structures, hence their name. The acoustic waves confinement is provided by underlying Bragg mirrors.

The correct answer is:
…FBAR-BAW use an underlying air gap, whereas BAW SMR use Bragg mirrors

Question **11**

Correct

Mark 1.00 out of 1.00

What is the advantage of performing microfabrication processes in a cleanroom environment?

a. Because of the downward laminar flow, cleanroom operators are automatically protected from dangerous fumes

b. Precise temperature control provides maximum comfort for operators

c. Downward laminar flow of filtered air reduces the risk of dust particles contamination on the wafers ✔

d. A governing organization takes care of the maintenance of the tools and machines which enables operators to focus on their process flow

Your answer is correct.

The downward laminar flow ensures cleanliness of the environment in the whole working area and is crucial to the success of most processes. Under no circumstances does the laminar flow protect users from dangerous fumes.

The correct answer is:
Downward laminar flow of filtered air reduces the risk of dust particles contamination on the wafers

Question **12**

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

[T] [G] [m] [k]

Your answer is correct.

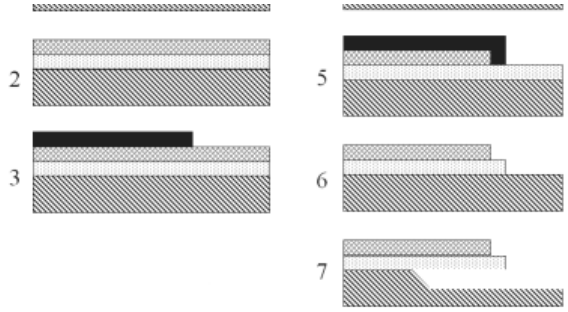
The correct answer is:
For cleanroom use water has to be de-ionised to give a very high resistivity, 18 [M]Ω cm in VLSI areas

Question **13**

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):



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

Your answer is correct.

The correct answer is:
6 → Silicon dioxide etch and resist stripping,

2 → Cr layer deposition,

4 → Cr etch and resist stripping,

3 → Lithography 1 (heater),

5 → Lithography 2 (cantilever),

7 → Silicon etch in KOH,

1 → Silicon oxidation

Question **14**

Incorrect

Mark 0.00 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: 40.5 ✖

The correct answer is: 243.00

Question **15**

Correct

Mark 1.00 out of 1.00

Packaging is an important part of modern MEMS microphones as they are often exposed to adverse environment. A MEMS microphone package contains the MEMS microphone die itself as well as the ASIC die. What other functions does the package fulfill? More than one option could be correct.

- ☑ a. The package protects the 2 dies ✔

b. The package affects the acoustic performance ✔

c. The package is under vacuum

d. The package provides electromagnetic shielding ✔

Your answer is correct.

The package physically protects the dies and their bonding wires. It also prevents them from direct contact with external environment. There is a metallic layer in the inner part of the lid that acts as cap of the package, in order to provide some electromagnetic shielding. It also plays a great role on the acoustic performance as the back-volume is part of the SNR calculation. It is of course not in vacuum since both membranes have holes, i.e. the back-volume is at ambient pressure.

The correct answers are:
The package protects the 2 dies,

The package affects the acoustic performance,

The package provides electromagnetic shielding

Question **16**

Incorrect

Mark 0.00 out of 1.00

What is the purpose of the SiO_2 layer in the thermo-mechanical micro-actuator? More than one option could be correct.

a. To oxidize the surface of the silicon wafer ✖

b. To create an electrically insulating layer below the chromium tracks ✔

c. To give distinct colors to wafers with different thicknesses

d. To form the structural material of the thermo-mechanical micro-actuator

Your answer is incorrect.

The goal of the SiO_2 layer is to create the shape of the cantilever when patterning it in buffered hydrofluoric acid; it thus acts as the structural material of the cantilever. In addition, SiO_2 layer also create an electrically insulating layer below the chromium tracks. If an electrically conductive layer existed below the chromium tracks, a short circuit between the contacts pads would exist and no current would flow through the chromium tracks. SiO_2 layers with different thicknesses give distinct colors to the wafers and when growing, SiO_2 layer oxidizes the surface of the wafer. These are two facts but they are not purposes of the SiO_2 layer. See the video about the thermo-mechanical micro-actuator between 00:54 and 02:25, 03:02 and 04:25 as well as between 08:40 and 09:47 for detailed explanation.

The correct answers are:
To create an electrically insulating layer below the chromium tracks,

To form the structural material of the thermo-mechanical micro-actuator

◀ Rehearsal Quiz for the Exam (no grading)

Jump to...

Rehearsal Quiz for CVD ▶