ENGINEERING TRIPOS PART IIB

Monday 29 April 2013 2 to 3.30

Module 4M6

MATERIALS AND PROCESSES FOR MICROSYSTEMS (MEMS)

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Attachments: 4M6 Data Book (14 pages).

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
Single-sided script paper	Engineering Data Book CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

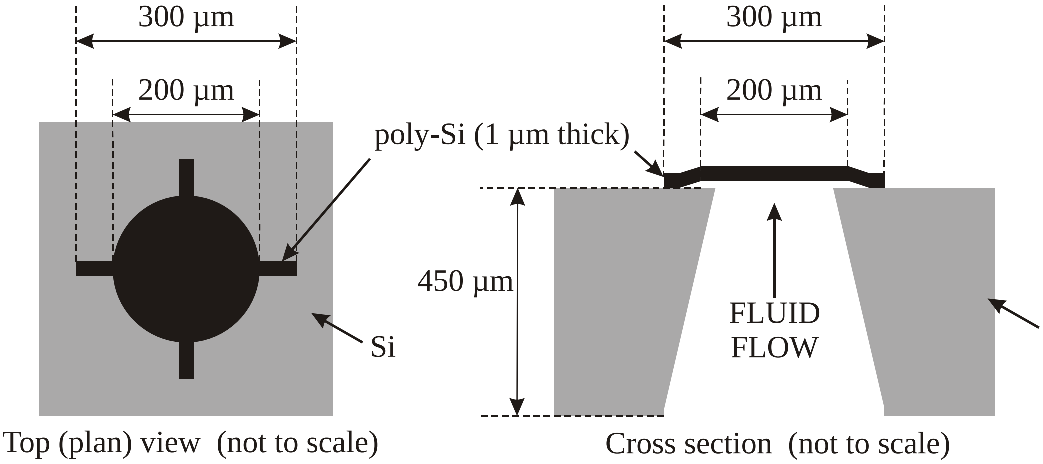
ajf02

1 Fig. 1 shows a simple microfluidic device which is designed to allow fluid to flow through it in one direction only (from bottom to top). It consists of a free-standing, circular plate of polycrystalline silicon (poly-Si) which is 200 µm in diameter and 1 µm thick. The plate is tethered to a 4” diameter silicon wafer substrate using four beams of 20 µm width and 50 µm length. The silicon substrate is (450±50) µm thick.

(a) Explain why polysilicon is a suitable material for the fabrication of the plate. [20%]

(b) Describe two methods by which the polysilicon layer can be produced. [30%]

(c) Describe a process flow for producing the microfluidic device shown in Fig. 1 starting from a bare silicon wafer. [50%]



Top (plan) view (not to scale) Cross section (not to scale)

Fig. 1

2 Reactive sputtering has been used to deposit a 5 μm thick layer of polycrystalline zinc oxide onto the surface of a silicon wafer. It is suspected that the surface of the zinc oxide film is rough. Zinc oxide is optically transparent in the visible spectrum.

(a) Describe a technique which would allow the surface roughness of the zinc oxide film to be quantified. [15%]

(b) With the aid of diagrams, describe two planarisation methods by which the surface roughness of the zinc oxide could be significantly reduced. Clearly explain the relative advantages and disadvantages of each technique. [40%]

(c) How could the thickness of the zinc oxide film be measured after planarization? Justify your answer. [20%]

(d) Metal electrodes are to be deposited onto the surface of the zinc oxide film to create a surface acoustic wave device. Photolithography will be used to pattern the electrodes. Why is it necessary to planarise the zinc oxide prior to photolithography being attempted? [25%]

3 (a) Explain the difference between the behaviour of a *positive tone photoresist* and a *negative tone photoresist* upon exposure to ultraviolet light. What might influence the choice of whether to use a positive or negative tone photoresist for a particular photolithography step in the fabrication of a MEMS device? [20%]

(b) Fig. 2 shows a layer of photoresist on a substrate which is being exposed to ultraviolet light through a mask, and which has not yet been developed. Draw cross-sectional diagrams after development for both positive tone and negative tone photoresist if:

(i) the photoresist has been *underexposed*;

(ii) the photoresist has been *correctly exposed*;

(iii) the photoresist has been *overexposed*. [30%]

(c) SU8 photoresist is to be used to create a microfluidic well on a silicon substrate, as shown in Fig. 3. The well is designed to be an open-topped cube with ideal sides of 10 µm. It is important that the bottom of the well is electrically isolated from the silicon substrate, and so a square pad of 20 nm thick silicon nitride is to be patterned to lie at the bottom of the well. The silicon nitride is to be patterned using a 2 µm thick AZ5214E photoresist. Both the SU8 and the AZ5214E will be exposed using the same mask aligner which has a 190 nm wavelength light source. Proximity printing will be used with a print gap of 5 µm.

(i) Calculate the resolution that will be achieved for each of the SU8 and AZ5214E photoresists. [20%]

(ii) If the mask aligner permits the positioning of the mask relative to the sample with an accuracy of 1 µm, calculate the minimum acceptable size of the square silicon nitride pad, marked *x* in Fig. 3. [30%]

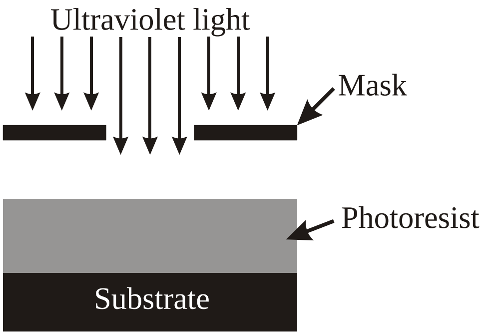
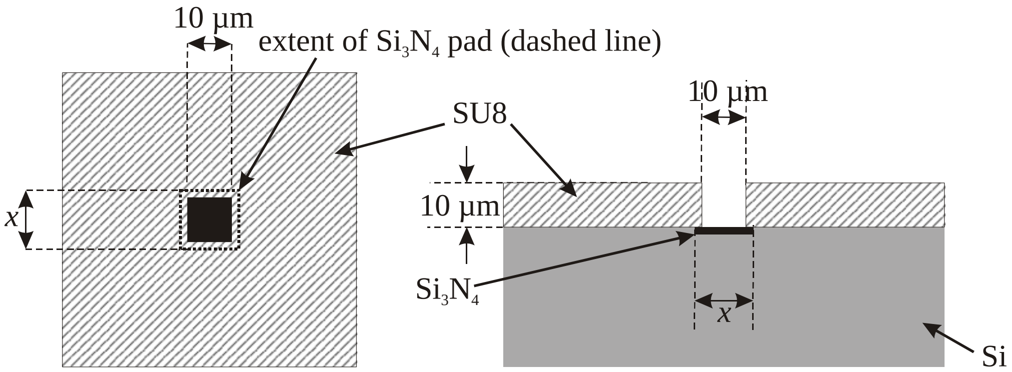


Fig. 2



Top (plan) view (not to scale)

Cross section (not to scale)

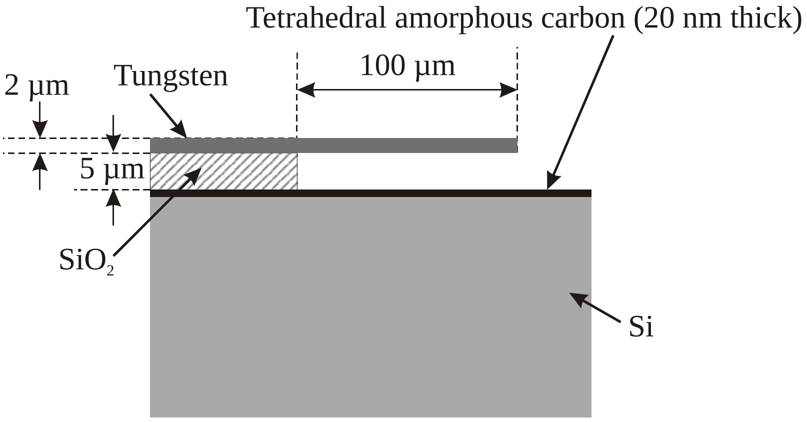
Fig. 3

4 (a) With the aid of a schematic diagram, describe how tetrahedral amorphous carbon can be deposited using a *filtered cathodic vacuum arc*. What is the key parameter for ensuring that the material is diamond-like in nature? Why is it difficult to produce layers of tetrahedral amorphous carbon that are over 200 nm thick? [40%]

(b) Fig. 4 shows a radio frequency MEMS switch. The switch consists of a tungsten cantilever which is 100 µm long, 10 µm wide and 2 µm thick. It is mounted on a layer of silicon dioxide which is 5 µm thick, which defines the height of the tungsten cantilever above a silicon substrate. The switch is activated by applying a d.c. bias to the cantilever with respect to the silicon substrate, which causes the cantilever to be pulled towards the substrate. There is a 20 nm thick layer of tetrahedral amorphous carbon on top of the silicon.

(i) Design a process flow for the fabrication of this device starting from a bare silicon wafer. It does not affect the device if there is a layer of tetrahedral amorphous carbon between the silicon dioxide support and the silicon. [40%]

(ii) Why has the silicon been coated with tetrahedral amorphous carbon in this device? What alternative materials could be used in place of the tetrahedral amorphous carbon, but which would serve the same purpose? [20%]



Cross section (not to scale)

Fig. 4

END OF PAPER

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Module 4M6 – NUMERICAL ANSWERS

3 (c) (i) 2.1 μm, 1.6 μm
(ii) 19.4 μm