Version AJF/2

EGT3
ENGINEERING TRIPOS PART IIB

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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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 4M6 Data Book (14 pages)
Engineering Data Book

10 minutes reading time is allowed for this paper.

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

1 (a) Describe each of the following processes for producing a metal layer on a substrate. Your answer should clearly explain the physical or chemical mechanism leading to formation of the layer, and hence how the process is controlled.

(i) *Immersion plating.* [15%]

(ii) *Electroless plating.* [20%]

(iii) *Electroplating.* [20%]

(b) Fig. 1 shows the cross section of a silicon wafer that has been coated with a 5 µm thick layer of a photoresist. The photoresist has been patterned so that it contains circular holes of 5 µm diameter which expose the silicon substrate. The holes are in a regular array with a centre-to-centre pitch of 25 µm. Three such wafers are produced, and each is subjected to one of the three processes described in part (a) to form a copper layer on its surface. In the case of the wafer subjected to electroless plating, the substrate is dipped into a sensitising solution prior to growth of the copper layer. For each of the three wafers, sketch the cross section of the wafer after growth of the copper layer. Annotate your diagrams to highlight the key differences in the copper layer that will result. [30%]

(c) Would you choose a positive or negative tone photoresist to produce the layer of photoresist in part (b)? Justify your answer. [15%]

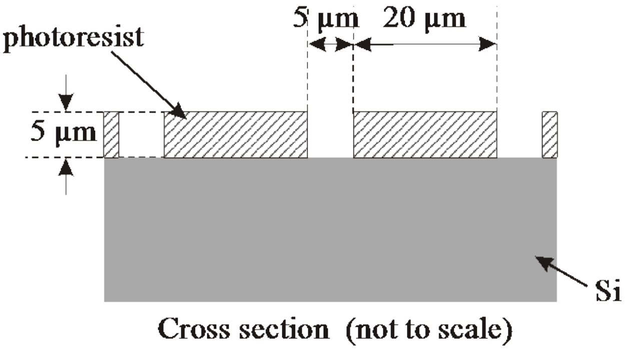


Fig. 1

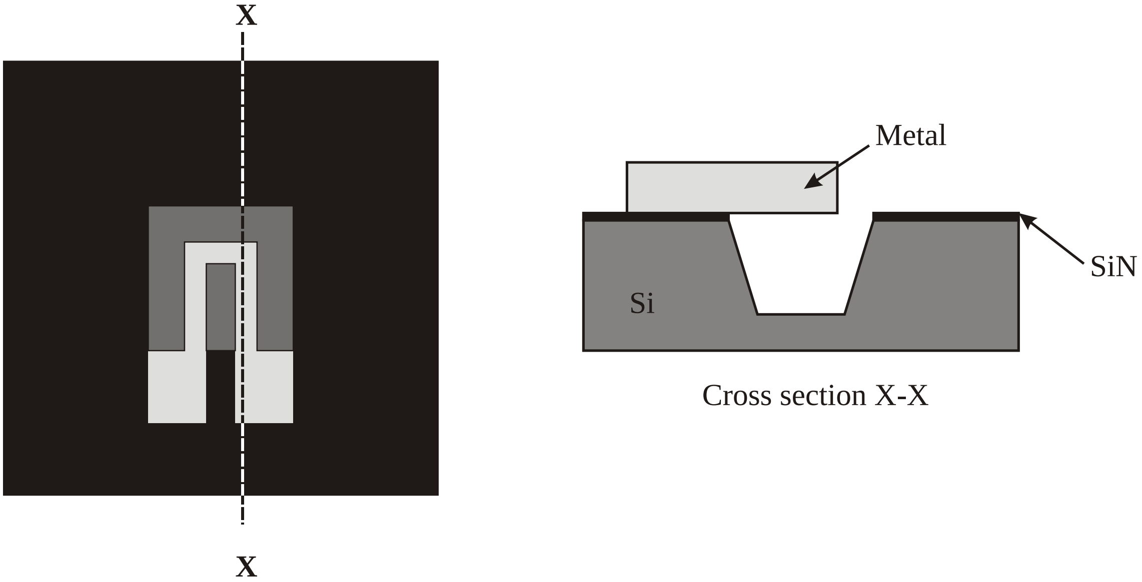
2 (a) What factors must be considered when selecting a particular material in the design of a MEMS device? [25%]

(b) Fig. 2 shows a simple thermal actuator made from a 3 μm thick metal film on a silicon substrate that has been coated in a 200 nm thick layer of silicon nitride. Application of a potential difference to the two contact pads at either end of the U-shaped actuator results in a current flow which in turn causes heating of the metal and expansion.

(i) What is the figure of merit for the selection of the metal if the force exerted by the actuator is to be maximised? [10%]

(ii) If there is a new requirement that the speed of actuation has to be maximised, qualitatively explain what additional material properties of the metal would be desirable. [15%]

(c) Construct a process flow for the fabrication of the thermal actuator starting from a bare, Si (100) wafer if nickel is chosen as the metal material. [50%]



Cross section X-X

Plan view

Fig. 2

3 (a) Explain what is meant by a *stringer* with reference to MEMS device manufacture. Under what circumstances are stringers likely to be formed? Use diagrams to illustrate your answer. [20%]

(b) With the aid of a diagram, describe the process of *chemical mechanical polishing* (CMP). Explain the relative advantages and disadvantages of CMP compared with alternative planarization techniques. [30%]

(c) It is desired to produce a series of parallel beams of silicon nitride that are 50 µm wide and 500 nm thick at a very well-defined 10 µm above the surface of a silicon wafer. The beams are at a centre-to-centre pitch of 100 µm. The height of the beams above the silicon substrate are defined by a set of silicon supports that run perpendicular to the silicon nitride beams, as shown in Fig. 3. The supports are 10 µm wide and at a centre-to-centre pitch of 100 µm. Describe a process flow for the fabrication of this structure starting from a bare Si (100) wafer. [50%]

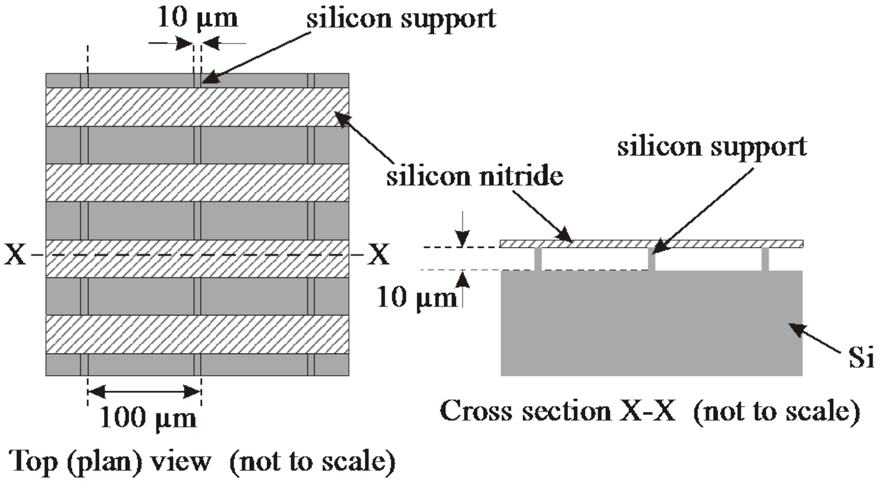


Fig. 3

4 There is much interest in the possibility of using MEMS sensors to allow health workers to perform blood tests in GP surgeries and people's homes with immediate results. This could allow faster and more appropriate treatment of patients at lower cost.

(a) It would be preferable if the sensor device itself that is in contact with the blood could be disposible. Explain the opportunities and challenges associated with using common MEMS fabrication techniques that are based on microelectronic device fabrication to economically produce such devices. Use examples of real MEMS devices to illustrate your explanation. [35%]

(b) It is likely that such a device will need to be sterilised. Describe three different techniques which could be used. [15%]

(c) What factors should be taken into account when deciding on the complexity of the disposible part of such a biosensor? [20%]

(d) Many biosensors operate by detecting the attachment of a complementary biological molecule to a functionalised surface so that the device is specifically sensitive. For example, the surface may be functionalised with an antibody molecule that will only bind to a complementary antigen. Describe the method of microcontact printing for patterning a small surface area with a biological molecule. [30%]

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