Exercises for Module 2

of

Micro and Smart Systems NPTEL Course

(The following problems are taken from instructors' book entitled "Micro and Smart Systems", John Wiley, 2012.)

2.1 It is required to fabricate a polysilicon cantilever beamwhose dimensions are: length × breadth × thickness = 2000 μm × 10 μm × 2 μm. The sacrificial oxide thickness is 1 μm. Discuss the anchor pad size you would choose and explain whether it is possible to realize such a structure by surface micromachining. Give reasons for your answer.

2.2 In one of the designs of an accelerometer, the structure of the seismic mass (500 μm × 500 μm) and the four supporting springs (20 μm wide) were first obtained by etching a silicon layer of thickness 10 μm. The top view of this structure and the anchor pads are shown in Fig. 2.1. It was required to release the mass and the spring while keeping the oxide below the anchor pads (150 μm × 150 μm) intact. The oxide is only 1 μm thick. Suggest any modifications that would be necessary in the structure for its successful release.

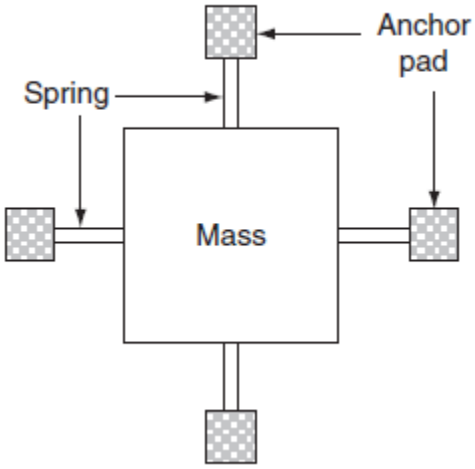

Fig. 2.1 Accelerometer layout for problem 2.2

2.3 A silicon wafer has been etched through square a window opening of size 10 μm × 10 μm in the oxide layer. Draw cross-sectional profiles and mark all dimensions of etched silicon for the following cases:

(a) The chemical is isotropic etchant, wafer is <100> silicon, etch depth is 5 μm.

(b) Etchant is 30% KOH solution, wafer is <100> silicon, etch depth is 5 μm.

(c) Isotropic etchant, wafer is <110> silicon, etch depth is 10 μm.
(d) Anisotropic etchant, wafer is <110> silicon, etch depth is 10 μm.

2.4 A (100) silicon wafer of thickness 300 μm is etched using a square window of size 500 μm × 500 μm in the oxide on silicon. The window sides are parallel to <110>. The etchant etches in only the <100> direction; the etch rate in the <111> direction is negligible. Draw the cross-section through the wafer, showing the dimensions, after the wafer is etched for a sufficiently long time to make a through hole in the wafer.

2.5 A (100) silicon wafer is 500 μm thick. A mask consists of rectangular window of unknown size. The sides of the window are parallel to <110>. After wafer etching a hole size of 50 μm × 80 μm is formed on the other side of the wafer. Find the size of the mask window. The undercut rate is negligible.

2.6 Repeat Problem 2.5, taking into account the undercutting if the etch rate in the <111> direction is only 50 times smaller than that in the <100> direction.

2.7 Thickness of a (100) silicon wafer is 410 μm. A square window of 1000 μm size is opened in the oxide on the front surface of the wafer with the mask edge aligned parallel to the <110> direction. The oxide on the back of the wafer is completely etched. This wafer is subjected to anisotropic etchant whose etch rate along the <100> direction is 50 μm/hour. Determine the diaphragm thickness and size when the etch duration is 4 hours. What is the wafer thickness outside the diaphragm at this stage?

2.8 In a bio-MEMS application involving microchannels (vertical cross-section: 20 μm × 20 μm), it is specified that the walls should make an angle of 90_ to the surface (vertical channel). Identify the type of silicon wafer that can be used for the purpose. Which chemical can be used for wet etching of this channel?

2.9 The etch windows shown in Fig. 2.2 are used in (100) silicon. What will be the substrate cross sections (along lines) after a complete etch in each case? Sketch the top view after the masking layer is removed. In Fig. 2.2(a), the length of the major axis (oriented at 45° to the [110] direction) of the ellipse is 100 μm. In Fig. 2.2(b) a projection of 50 μm × 5 μm in a square area of 150 μm × 150 μm is used.

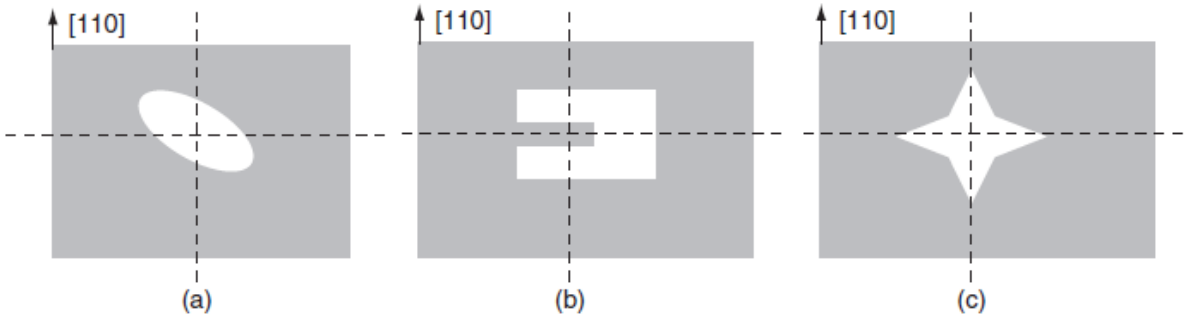

Fig. 2.2 KOH is the etchant in (a) and (b); HNA is used in (c). The masks are aligned as shown.

2.10 It is required to fabricate a device with a pair of interdigital electrodes by gold thin film. Its fingers are 5 μm wide and are separated by 5 μm. Identify a fabrication scheme that guarantees the high precision required in such situations. Explain the process steps. (Mention generic names of materials involved at each deposition stage and methods for deposition and etching.) Indicate the constraints of this method regarding choice of material and geometry.

2.11 Identify the best deposition/growth techniques for the following thin films: (a) 0.2 μm aluminum, (b) 0.1 μm BST, (c) high-purity silicon nitride, (d) 0.1 μm silicon dioxide for insulation layer, (e) 0.1 1 μm tungsten for conduction layer and (f) 1 μm PSG for sacrificial layer.

2.12 A chemical etches various crystalline planes of silicon with the following rates: Etch rates in <100> , <110>, and <111> directions are 51, 57, and 1.25 μm/hr, respectively. The (100) silicon substrate is 200 μm thick and has an etch window of 500 μm × 500 μm aligned to {110} directions. Draw and mark approximate dimensions of the etch profile after (a) 15 min and (b) 5 h of etching.

2.13 Isotropic etching is known to cause rounding off of etch profile. Anisotropic etching, though it yields better-defined shapes, can only form pyramidal openings. Determine (a) The approximate shape for a mask; (b) the type of etch; (c) etch-stop material and (d) a typical etchant required to form a triangular opening for a cavity formed on silicon by wet etching. Note: No restriction is imposed on the etch profile.