Instructions: *Attempt all parts of a particular question together.*

1. **(a)** A Si crystal is to be grown by the Czochralski's method, and it is desired that the ingot contain 10^{16} phosphorus atoms/cm^3. Find the weight of phosphorous added to 5 kg Si in crucible. For P in Si, distribution coefficient is 0.35. The atomic weight of phosphorous is 31 g/mole and density of Si is 2.33 g/cm^3.

   (b) Figure-1 shows a thin oxide film deposited on a flexible substrate (PDMS). Explain the processes and their purpose to be undertaken to get the final device (as shown in figure). Illustrate your answer and steps with process structural diagrams.
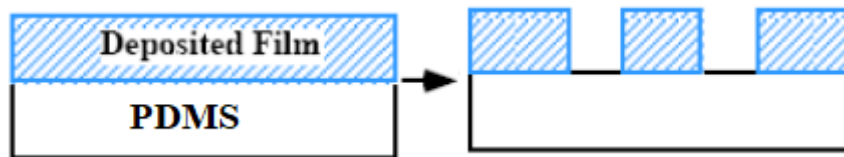
   [6 + 10 = 16 marks]

Figure:1

2. **(a)** Draw the phase diagram for the IGZO system and indicate the following compounds on it: $InGaZnO_4$, In_2GaO_x, $GaZnO_x$.
   (b) For fabricating a flexible sensor using inkjet printing, printable ink need to be created using copper paste. At 30°C can you use this ink assuming drop diameter of 0.3 cm for Drop-on Demand (DoD) printing? Comment on your answer with proper justification.
   [Data for Cu paste at 30°C: density = 9 g/cm^3, surface tension = 1.159 N/m, viscosity = 0.46 Pa-Sec]

   [8 +8 = 16 marks]

3. **(a)** A flexible device is to be fabricated using film-on-substrate (FoS). The thicknesses of film and substrate are 10 μm and 70 μm, respectively. Substrate is made up of some epoxy polymer whose properties are to be determine experimentally. So this substrate is taken in pellet form having thickness and diameters of 10 mm and 4 mm, respectively and undergone a compression analysis. Initially, sample was pre-loaded with 100 g and after loading it with 800 g, thickness of the sample reduces to 8 mm. Calculate the flexural rigidity in the direction normal to the thickness of FoS, taking its Poisson's ratio to be 0.4. What is the minimum bending radius of this system without undergoing fracture?
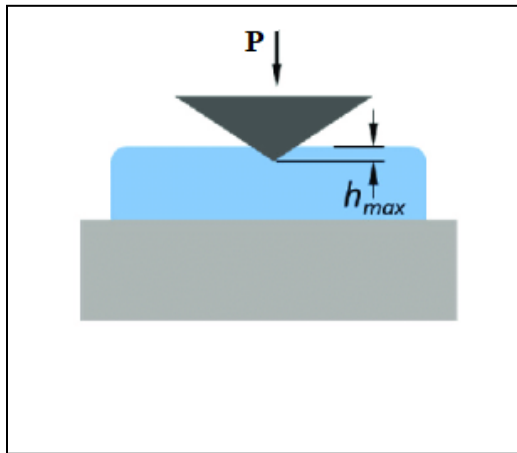
   (b). Explain why zinc oxide (ZnO) is generally highly n-type and why to obtain p-type ZnO is a challenge? Name two dopants used for making p-type ZnO.
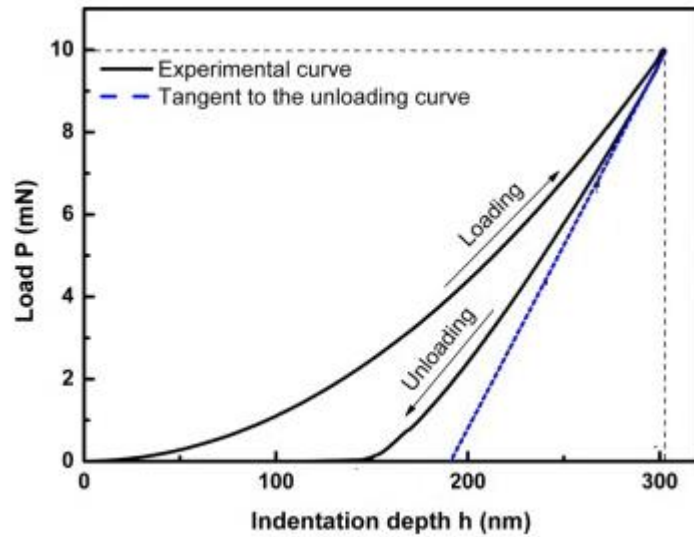
   [10+6 = 16 marks]

4. A flexible sensor is developed using conducting polymer on substrate, as shown in figure 2(a) . In order to measure the hardness of sample (film) a nano-indendation method is used where the tip of pyramidal indenter is made up of diamond. The angle at the apex of the tip is 65^0. Figure 2(b) shows the load versus indentation depth plot. Calculate the stiffness, Young's modulus and hardness of the sample (in GPa)

[Data given: Young's modulus of diamond $= 4000$ GPa, Poisson's ratio of diamond $= 0.07$, Poisson's ratio of film $= 0.5$]

[12 marks]

(a)   (b)

Figure 2

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