BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
COMPREHENSIVE EXAMINATION (Open +closed Book)
2022-23 I SEM
PHYSICS OF ADVANCED MATERIALS PHY F414
TIME 180 mins 120 MARKS DATE: 23.12.2022

- Part A (40 marks) and B (40 marks) (closed book) are given together and to be completed in 2 hrs. Part C (40 marks) will be given once you return parts A+B.

Part A (Quiz/short answer type) (Closed book) 40 marks

Write precise answers in sequence from the first page of the answersheeet A

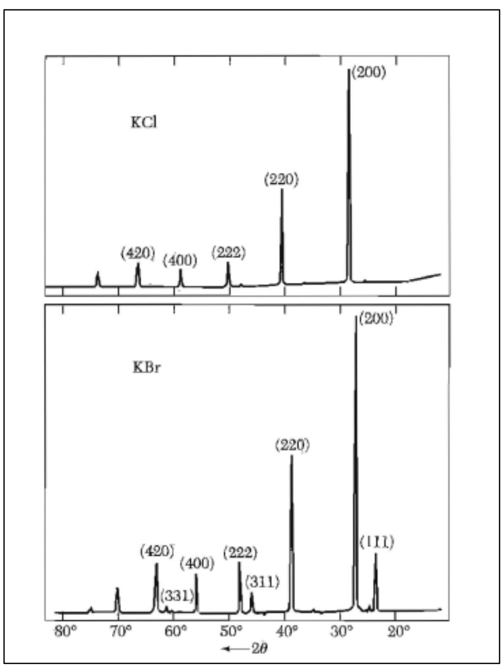
1. How will you differentiate between a normal ionic conductor and a semiconductor? **[3]**
2. Give examples, one each for type I, II, and III superionic conductors. **[3]**
3. Show that all reflections are allowed for a simple cubic (primitive) structure. **[3]**
4. Suppose a Si wafer 0.1 cm thick originally contains one P atom for every 10 million Si atoms, and is treated so that for every 10 million of atoms of Si there are 400 P atoms at the surface.Calculate the concentration gradient in (i) atom%/cm and (ii) atom/cm^3/cm if lattice parameter = 5.43 A **[5]**
5. 100 keV B implants on a 200 mm dia Si wafer a dose of 5 x 10^{14} ions/cm^2. Calculate the peak concentration and required ion beam current for 1 min of implantation. Given: projected range = 0.31 micron and projected straggle = 0.07 micron. **[5]**
6. Why in most of the magnetic materials we find transition metals? Give an example of transition metal-based magnetic material. **[3]**
7. For BCC and FCC Compute the radius of the interstitial atom that will just fit into interstitial sites in terms of the atomic radius R. **[5]**
8. Draw a flow chart for the preparation of BJT fabrication processing steps. **[3]**
9. In a vapour phase epitaxy, what the is stagnant layer problem? how the thickness the of stagnant layer can be controlled without changing geometry? **[3]**
10. In an Impedance spectroscopy measurement, draw Nyquist plots for (i) metal (ii) ionic conductor with blocking (iii) ionic conductor with non-blocking (iv)) capacitor and (v) supercapacitor . **[5]**

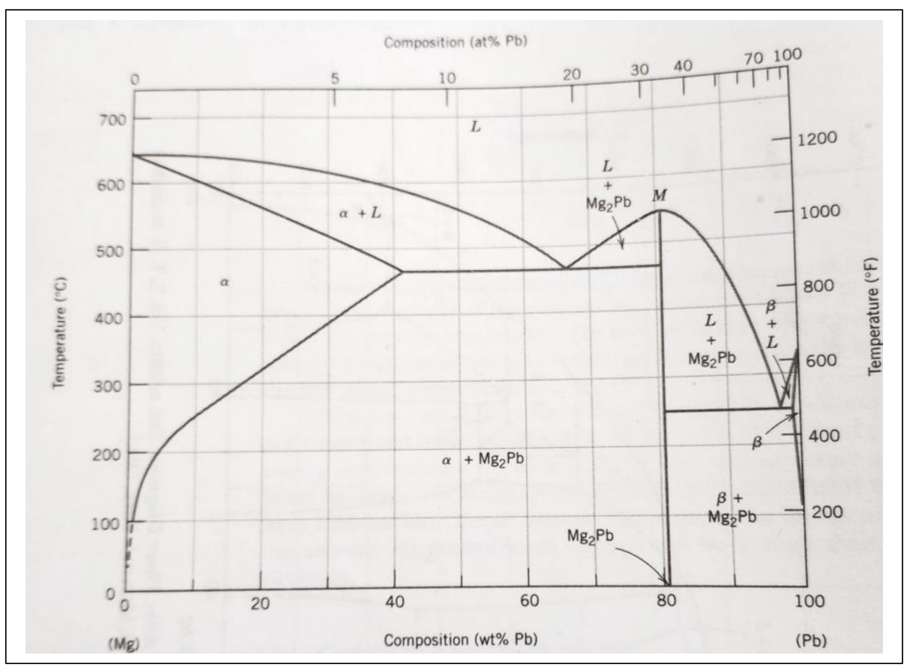
Table 5.1 Tabulation of Error Function Values

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

Part B (closed book) 40 marks

1. Explain the working principle of a Li^+ ion battery elaborating importance of electrodes, electrolytes and giving qualitative chemical reactions. How it is different from a Lithium battery? **[6]**
2. Explain the working principle of a supercapacitor. How it is different from a battery? Explain the difference between an ordinary and a conventional supercapacitor. **[6]**
3. Consider a phase diagram of Pb-Mg.
   - **(i)** A 60wt%Pb-40wt%Mg alloy is rapidly quenched to room temperature from an elevated temperature in such a way that high-temperature microstructure is preserved. This microstructure is found to be consisting of α-phase and Mg2Pb, having respective mass fractions of 0.42 and 0.58. Find the approximate temperature from which the alloy was quenched. **[4]**
   - **(ii)** A 1 kg Mg_2Pb alloy with a composition of 90%Pb-10%Mg is cooled just below the eutectic isotherm (~ 250 °C).The eutectic point is at a composition 96 wt% of Pb, intermetallic congruent transformation is seen at 81 wt% of Pb, and the solubility limit of the β-phase is roughly 98 wt% of Pb. Find in 1 kg (a) amount of Mg2Pb and the β-phase. (b) eutectic phase and Mg_2Pb and (iii) the amount of Mg2Pb in the eutectic phase. **[8]**





4. Explain scanning tunneling microscopy technique, its advantages and limitations **[8]**
5. Explain using the structure factor concept why the peaks with odd miller indices are missing in KCl, whereas they are present in the diffraction pattern of KBr. **[8]**

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DATE: 23.12.2022 **Part C (Closed book) 40 marks**

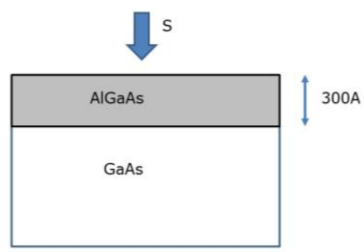
1. In an experiment of doping a semiconductor by the process of diffusion

(a) a pre-deposition process is carried out for 30 mins on an n-type Si wafer with a phosphorous dopant concentration of 10^{18} atoms/cm^3 at 1000 °C using diborane gas. Find the junction depth. Given that at 1000 °C the boron saturation concentration is 3.8 x 10^{21} atoms/cm^3 and the boron diffusion constant is 5 x 10^{-15} cm^2/s. **[8]**

(b) After the initial pre-deposition process as described in (a), sample undergoes a drive-in process for 1 hr at 1300 °C. What is the final junction depth at this temperature when the Boron diffusion constant is 5 x 10^{-12} cm^2/s. **[7]**

2. A GaAs wafer is implanted with sulfur (S) at an energy of 100 keV and dose of 10^{13}/cm^2. The wafer has a 300 A thick layer of AlGaAs on the top. Assume that the cover layer behaves just like GaAs. Take R_p = 750A, ΔR_p = 400A (i) At what depth the concentration be highest? What is the concentration at this point? (ii) What fraction of S atoms remain in AlGaAs layer? Use the graph provided. [**7+8]**

You may need: $\int_0^x e^{-u^2} du = \frac{\sqrt{\pi}}{2} erf(x)$



3. Schematically sketch a hypothetical Molecular beam epitaxy setup which must have the relevant in situ measurement facilities, along with basic requirements, for the following characterization (i) mass to charge ratio (ii) particle size calculation and inner crystal structure determination (iii) exclusive surface structure determination (iv) suitable vacuum system and gauges (v) Phosphorous doping facility. No explanation is requied. **[10]**