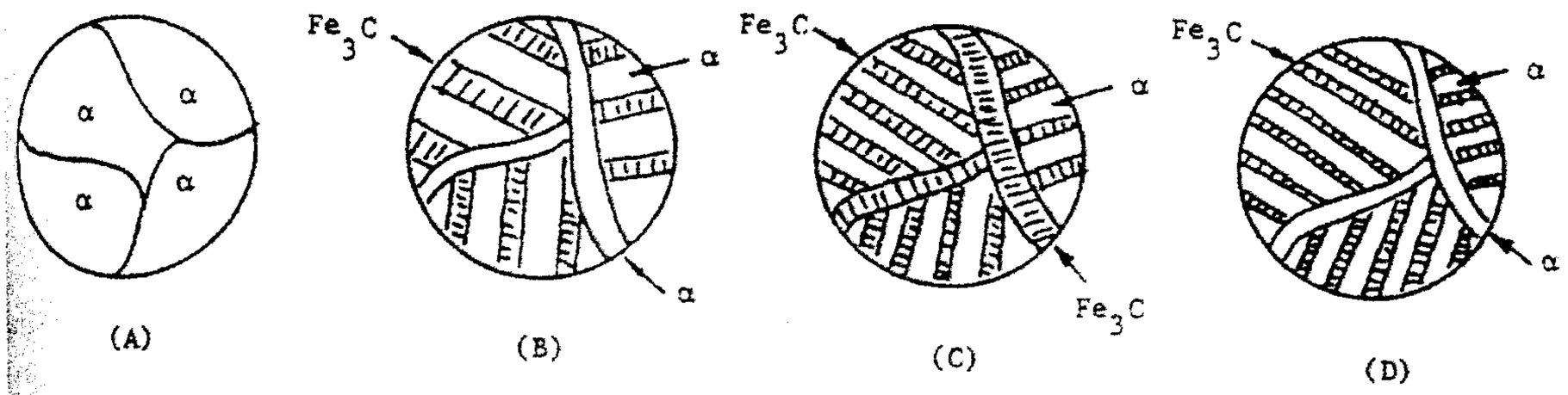
國立清華大學 103 學年度碩士班考試入學試題

系所班組別：核子工程與科學系研究所 甲 組（工程組）

考試科目（代碼）：物理冶金 （2805）

1. Below are shown schematic room temperature microstructures for four iron-carbon alloys.



(a) Rank them from the hardest to the softest, and justify this ranking.

(b) Identify the above materials with the strengthening mechanisms and discuss their major mechanisms. (20%)

2. The wear resistance of an alloy steel shaft is to be improved by hardening its surface. It is accomplished by increasing the nitrogen content within an outer surface layer as a result of nitrogen diffusion into the alloy steel. The nitrogen is supplied from an external nitrogen gas at an elevated and constant temperature. The initial nitrogen content of the alloy steel is 0.002 wt%, whereas the surface concentration is to be maintained at 0.50 wt%. For this treatment to obtain the required hardness, a nitrogen content of 0.10 wt% must be established at a position 0.45 mm below the surface. The preexponential and activation energy for the diffusion of nitrogen in iron are 3×10^{-7} m^2/s and 76,150 J/mol, respective , over the temperature of heat treatment. Specify appropriate heat treatments in terms of temperature and time for temperatures of 500, 550, and 600 ℃

The semi-infinite solution of Fick's second law is $\frac{Cx - C_0}{Cs - C_0} = 1 - erf(\frac{x}{2\sqrt{Dt}})$

R = 8.31 J/mol· K (20%)

Table 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

3. Explain yield-point phenomenon for (a) iron single crystals containing small solute additions of interstitial carbon and nitrogen, and (b) single crystals of silicon, germanium, and lithium fluoride. (20%)

4. (a) Give a list of the different types of fracture that occur in single crystals, and discuss their failure mechanisms.
   (b) Now consider a polycrystalline metal. Indicate how grain boundaries add to the fracture possibilities; also discuss their related failure mechanisms. (20%)

5. An Al-5%Cu ingot unidirectionally solidified under the conditions of no diffusion in the solid, complete diffusion in the liquid and local equilibrium at the interface, so that the Sheil equation applies.
   (a) Calculate the composition of the liquid when the ingot is 5% solid. What is the average composition of the solid?
   (b) What is the interface temperature at this point?

(c) How much eutectic and second phase θ will have formed when the ingot is completely solidified?

(d) Plot the composition profile in the solidified ingot. (20%)

$$C_l = C_o(1-f_s)^{(k-1)}$$
$$C_s = kC_o(1-f_s)^{(k-1)}$$

The Al-Cu phase diagram is shown in the attached figure.