Engineering Materials, Course No. 4202402, CCU ME

Mid-term Exam (I) **100.11.08.** **Lectured by:**敖仲寧

1. Total score: 120, **2.** Close-book, **3.** Using calculator is allowed, **4.** Keep question sheets and return answering sheets.

1. **(a)** List all primary and secondary interatomic bonds **(8%)**

(b) The net potential energy between two adjacent ions E_N may be expressed as $E_N = -\frac{A}{r} + \frac{B}{r^n}$, where r is the distance between two adjacent ions, and A, B are constants. Calculate the distance r_0, at which the potential energy E_N between two adjacent ions has a minimum value E_0 . (Hint: r_0 is expressed in terms of A, B and n.) **(10%)**

2. (a) List any 5 crystal systems and give for each crystal system the relationship between lattice constants (a, b, c) and the relationship between interaxial angles (α, β, γ). **(10%)**

(b) How many Bravais crystal systems are there? **(2%)**

3. (a) Determine the ***c/a*** ratio of an HCP unit cell. **(6 %)**

(b) Sketch the atomic arrangement of **(1 1 1)** plane in an FCC crystal system and give the **[1 $\underline{1}$ 0]** direction on the **(1 1 1)** plane **(5%)**

(c) The FCC and HCP structures have the same APF value of 0.74. Although both of them are close-packed structures, why are they still different? Where are the differences? **(6%)**

4. Consider a hypothetical metal that has a density of ρ=12.0 g/cm^3, an atomic weight of A= 131.1 g/mol, and an atomic radius of R=0.151 nm. Compute the atomic packing factor (APF) if the unit cell is a tetragonal system, with lattice constants a= 0.441 nm and c=0.373 nm. (Hint: In order to determine the APF, you have to first determine the number of atoms n in a unit cell. You will need the equation for theoretical density ρ=... to determine n. If you cannot solve n, then assume n=3, you'll be able to get max. score of **5%** in this case.) **(12%)**

5. (a) Determine the angle between plane (1 1 2) and direction [1 1 1]. **(5%)** (b) Find the Miller indices of the intersection **[u v w]** of the planes (1 1 2) and (1 1 1). **(5%)** (c) Find a third plane **(h k l)**, on which the intersection obtained in (b) also contains. **(5%)**

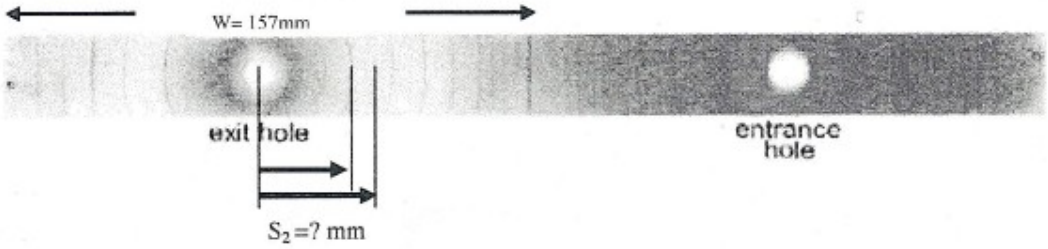
6. X-ray diffraction result on a pure metal powder specimen reveals diffraction patterns with first five peaks at $2\theta = 41.3°$, $58.2°$, $73.2°$, $87.0°$, and $106.6°$, the wave length of X-ray emitted from a Cu target is $\lambda = 0.1542$ nm.

(a) Index the Miller indices of the planes (h k l) of these five peaks in a correct sequence. **(10%)**

(b) For the first peak, determine the interplanar spacing d_{hkl} ,the lattice constant a and atomic radius R of this metal powder. **(12%)**

(d) Check the table below to find the unknown metal powder. **(4%)**

(e) If the experiment was conducted using a powder-film X-ray diffraction, the diffraction patterns on the film are shown below. The half length of the film w is 157mm, determine the position of the second pattern S_2. **(5%)**



Characteristics of Selected Elements

Element	Symbol	Atomic Number	Atomic Weight (amu)	Density of Solid, 20°C (g/cm³)	Crystal Structure, 20°C	Atomic Radius (nm)	Ionic Radius (nm)	Most Common Valence	Melting Point (°C)
Aluminum	Al	13	26.98	2.71	FCC	0.143	0.053	3+	660.4
Argon	Ar	18	39.95	—	—	—	—	Inert	−189.2
Barium	Ba	56	137.33	3.5	BCC	0.217	0.136	2+	725
Beryllium	Be	4	9.012	1.85	HCP	0.114	0.035	2+	1278
Boron	B	5	10.81	2.34	Rhomb.	—	0.023	3+	2300
Bromine	Br	35	79.90	—	—	—	0.196	1−	−7.2
Cadmium	Cd	48	112.41	8.65	HCP	0.149	0.095	2+	321
Calcium	Ca	20	40.08	1.55	FCC	0.197	0.100	2+	839
Carbon	C	6	12.011	2.25	Hex.	0.071	~0.016	4+	(sublimes at 3367)
Cesium	Cs	55	132.91	1.87	BCC	0.265	0.170	1+	28.4
Chlorine	Cl	17	35.45	—	—	—	0.181	1−	−101
Chromium	Cr	24	52.00	7.19	BCC	0.125	0.063	3+	1875
Cobalt	Co	27	58.93	8.9	HCP	0.125	0.072	2+	1495
Copper	Cu	29	63.55	8.94	FCC	0.128	0.096	1+	1085
Fluorine	F	9	19.00	—	—	—	0.133	1−	−220
Gallium	Ga	31	69.72	5.90	Ortho.	0.122	0.062	3+	29.8
Germanium	Ge	32	72.59	5.32	Dia. cubic	0.122	0.053	4+	937
Gold	Au	79	196.97	19.32	FCC	0.144	0.137	1+	1064
Helium	He	2	4.003	—	—	—	—	Inert	−272 (at 26 atm)
Hydrogen	H	1	1.008	—	—	—	0.154	1+	−259
Iodine	I	53	126.91	4.93	Ortho.	0.136	0.220	1−	114
Iron	Fe	26	55.85	7.87	BCC	0.124	0.077	2+	1538
Lead	Pb	82	207.2	11.35	FCC	0.175	0.120	2+	327
Lithium	Li	3	6.94	0.534	BCC	0.152	0.068	1+	181
Magnesium	Mg	12	24.31	1.74	HCP	0.160	0.072	2+	649
Manganese	Mn	25	54.94	7.44	Cubic	0.112	0.067	2+	1244
Mercury	Hg	80	200.59	—	—	—	0.110	2+	−38.8
Molybdenum	Mo	42	95.94	10.22	BCC	0.136	0.070	4+	2617
Neon	Ne	10	20.18	—	—	—	—	Inert	−248.7
Nickel	Ni	28	58.69	8.90	FCC	0.125	0.069	2+	1455
Niobium	Nb	41	92.91	8.57	BCC	0.143	0.069	5+	2468
Nitrogen	N	7	14.007	—	—	—	0.01–0.02	5+	−209.9
Oxygen	O	8	16.00	—	—	—	0.140	2−	−218.4
Phosphorus	P	15	30.97	1.82	Ortho.	0.109	0.035	5+	44.1
Platinum	Pt	78	195.08	21.45	FCC	0.139	0.080	2+	1772
Potassium	K	19	39.10	0.862	BCC	0.231	0.138	1+	63
Silicon	Si	14	28.09	2.33	Dia. cubic	0.118	0.040	4+	1410
Silver	Ag	47	107.87	10.49	FCC	0.144	0.126	1+	962
Sodium	Na	11	22.99	0.971	BCC	0.186	0.102	1+	98
Sulfur	S	16	32.06	2.07	Ortho.	0.106	0.184	2−	113
Tin	Sn	50	118.69	7.17	Tetra.	0.151	0.071	4+	232
Titanium	Ti	22	47.88	4.51	HCP	0.145	0.068	4+	1668
Tungsten	W	74	183.85	19.3	BCC	0.137	0.070	4+	3410
Vanadium	V	23	50.94	6.1	BCC	0.132	0.059	5+	1890
Zinc	Zn	30	65.39	7.13	HCP	0.133	0.074	2+	420
Zirconium	Zr	40	91.22	6.51	HCP	0.159	0.079	4+	1852

試卷碼	CCUME 100A - 4202402 - M001					任課老師	教仲章
學年	100	學期	A	日期	2011/11/08	試別	□平時考 ■期中考 □學期考
科目	工程材料(一)					評分	
姓名	許維驛	班別	機二A			學號	4994200[illegible]

#1. (b) $\frac{d}{dr} E_N = \frac{d}{dr}(-Ar^{-1} + Br^{-n}) = \frac{A}{r^2} - \frac{nB}{r^{n+1}}$

when $r = r_0$ $\frac{d}{dr} E_N = 0$.

$\frac{A}{r_0^2} = \frac{nB}{r_0^{n+1}}$ $(r_0)^{1-n} = \frac{A}{nB}$ $r_0 = \left(\frac{A}{nB}\right)^{\frac{1}{1-n}}$.

+10.

$E_0 = \frac{-A}{\left(\frac{A}{nB}\right)^{\frac{1}{1-n}}} + \frac{B}{\left(\frac{A}{nB}\right)^{\frac{n}{1-n}}}$.

(a)

primary：金屬鍵. 共價鍵. 離子鍵. +4

secondary：氫鍵. 凡得瓦力 ~~庫倫作用力~~. +2

偶極鍵

#2. (a)

cubic. $a=b=c$. $\alpha=\beta=\gamma=90°$.

Monoclinic $a=b\neq c$ ~~$\alpha=\beta=90°\neq\gamma$~~ $\alpha=\gamma=90°$ $\beta\neq 90°$.

Triclinic $a\neq b\neq c$ $\alpha\neq\beta\neq\gamma\neq 90°$.

Orcharhombic $a\neq b\neq c$ $\alpha=\beta=\gamma=90°$.

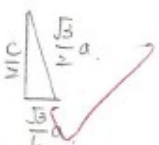
Tetragonal. $a=b\neq c$ $\alpha=\beta=\gamma=90°$.

+9

(b)

~~7. 種.~~ 14. 種.

#3. (a). 正四面體邊長為 a，高度 c/2.

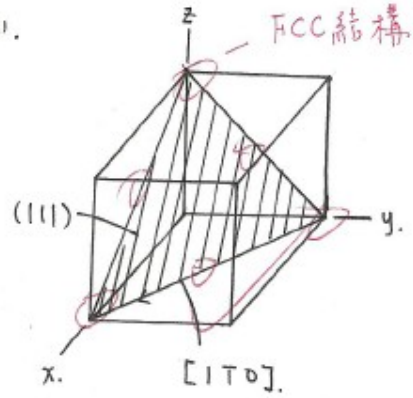


+6

$\frac{c}{2} = \sqrt{\frac{3}{4}a^2 - \frac{3}{36}a^2} = \sqrt{\frac{2}{3}}a$.

$\frac{c}{a} = 2\cdot\sqrt{\frac{2}{3}} \doteq 1.633$

(b). FCC結構原子排列需標出.



+2

(c) 原子排列順序不一樣.

HCP A B. ABABi

在 (0001) ABAB 排列.

Fcc. A B C ABCABCi

在 (111) ABCABC 排列.

+3

#4. ρ = 12.0 g/cm³ , A = 131.1 g/mol. , atomic R = 0.151 nm

tetragonal ⇒ a = 0.441 nm. , c = 0.373 nm.

$$APF = \frac{n \cdot \frac{4}{3}\pi \cdot (0.151)^3}{0.441 \cdot 0.373 \cdot 0.441} = 0.1988n$$

+3

$$\rho = \frac{n \cdot A}{V_c \cdot N_A} \quad +4$$

$$12 = \frac{n \cdot (131.1)}{\frac{4}{3}\pi (0.151 \cdot 10^{-7})^3 \cdot (6.02 \cdot 10^{23})}$$

$$12 = 15.1n, \quad n = 0.795$$

⇒ APF = 0.1988 · 0.795 ≒ 0.158.

$$APF = \frac{4 \cdot \frac{4}{3}\pi \cdot (0.151)^3}{(0.441)^2 \cdot (0.373)} = 0.79523$$

$$12 = \frac{n \times (131.1)}{(0.441 \cdot 10^{-7})^2 \cdot (0.373 \cdot 10^{-7}) \cdot (6.02 \cdot 10^{23})}$$

⇒ n = 3.99 ≒ 4.

#5.

(a) $\vec{n}_a = (1,1,2)$.

$\vec{n}_b = (1,1,1)$

$\vec{n}_a \cdot \vec{n}_b = |\vec{n}_a| \cdot |\vec{n}_b| \cdot \cos\theta \cdot 2$.

$4 = 2\sqrt{6} \cdot \sqrt{3} \cdot \cos\theta$

$\theta = \cos^{-1}\left(\frac{4}{3\sqrt{2}}\right) = 19.47°$.

+8 +3

(b)

$\vec{n}_a = (1,1,2)$

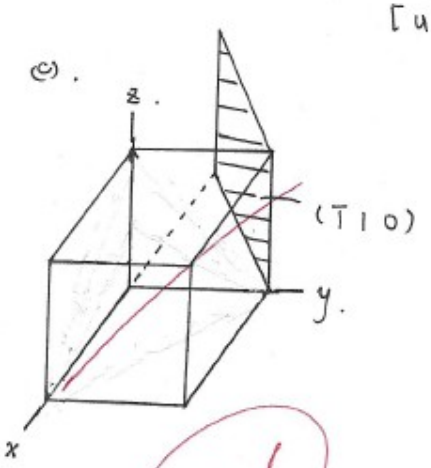
$\vec{n}_b = (1,1,1)$

$\vec{n}_a \times \vec{n}_b = \begin{vmatrix} i & j & k \\ 1 & 1 & 2 \\ 1 & 1 & 1 \end{vmatrix} = i + 2j + k - k - 2i - j = -i + j$

+5

$[u\ v\ w] = [\bar{1}\ 1\ 0]$.

(c).



+26

#6.

	θ.	sinθ	$\sin^2\theta$	(h k l)	N.
1.	20.65°	0.3527	0.1244.	(1 1 0)	2
2.	29.1°	0.4863	0.2365	(2 0 0)	4
3.	36.6°	0.5962	0.3555	(2 1 1)	6
4.	43.5°	0.6884	0.4738	(2 2 0)	8
5.	53.3°	0.8018	0.6428.	(3 1 0)	10.

+10

+12

(a) 1st (1 1 0), 2nd (2 0 0), 3rd (2 1 1), 4th (2 2 0), 5th (3 1 0)

(b) BCC, $a = \frac{4}{\sqrt{3}}R$. $n\lambda = 2 \cdot d_{hkl} \cdot \sin\theta$. $d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$ $a = \frac{4}{\sqrt{3}}R$.

$1 \cdot 0.1542 = 2 \cdot d_{hkl} \cdot 0.3527$. $a = \sqrt{2} \cdot 0.2186$ $R = \frac{\sqrt{3}}{4} \cdot (0.3091)$

$d_{hkl} = 0.2186$ nm. $a = 0.3091$ nm. $R = 0.1338$ nm.

(d) Molybdenum. +4

(e) $S_2 = 0.1542 + 0.2186 = 0.3728\ nm = 3.728 \cdot 10^{-8}\ mm.$

$\frac{W}{S} = \frac{\pi}{2\theta}.$

$2\theta_2 = 58.2^\circ \quad \therefore S_2 = \frac{2W \cdot \theta_2}{\pi} = \frac{58.2 \cdot 157}{180} = 50.76\ nm.$

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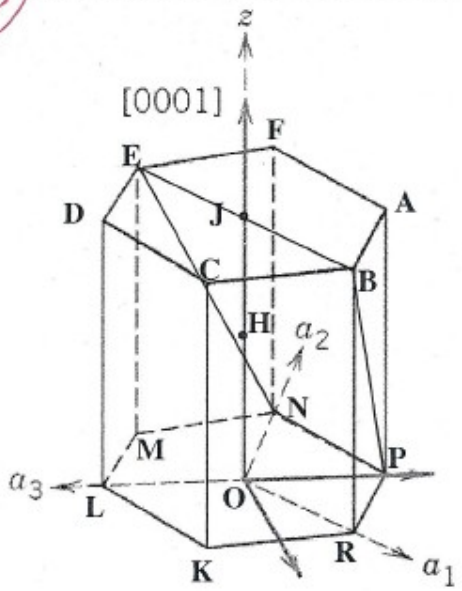
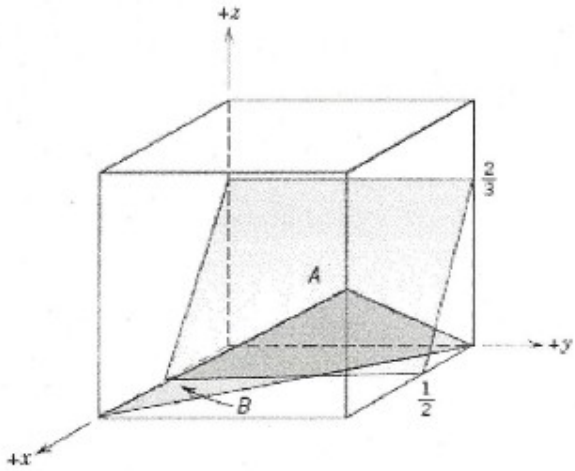
系班級 機二A. 學號 49942oo13 姓名 許維驛.

7. Determine the Miller or Miller-Bravais indices ***step by step!***
(a) Plane ***EBPN*** (this plane also passes through point ***J*** in HCP **(5%)**
(b) Plane ***A*** in cubic unit cell **(5%)**

+15





(a)

a_1	a_2	a_3	c.
∞	1	−1	1
0	1	−1	1.
0	1	$\bar{1}$	1

$(0\ 1\ \bar{1}\ 1)$

(b)

a	a	a.
$\frac{1}{2}$a	∞ a	$\frac{2}{3}$a.
$\frac{1}{2}$	∞	$\frac{2}{3}$.
2	0	$\frac{3}{2}$
4	0	3

(4 0 3)

+5 +5

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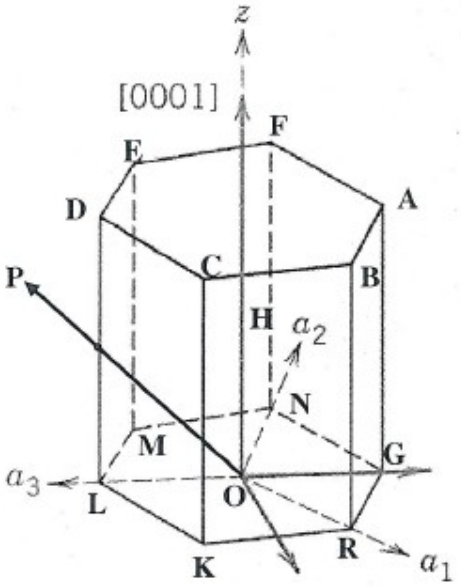
7. (c) Direction ***OP*** within an HCP unit cell. **(5%)**



$\frac{1}{2}a_1$ $\frac{1}{2}a_2$ $1a_3$ $\frac{1}{2}c$.

$\frac{1}{2}$ $\frac{1}{2}$ 1 $\frac{1}{2}$

1 1 2 1.

$\bar{1}$ $\bar{1}$ 2 1

[$\bar{1}$ $\bar{1}$ 2 1]

15