Chalmers *Kursnr.: MMK073*
Industrial and Materials Science

Exam in Materialteknik-Z, Dec 20th, 2017

Examiner: Uta Klement (772 1264)
After the exam, the answers will be posted on the course webpage (Pingpong).
The results of the exam will be available electronically.

Checking (*granskning*) of the corrected exams: on Monday 22 and Wednesday 24st of January, between 12:00 and 13:00 at the IMS (Rännvägen 2A, second floor; contact Uta Klement). Written requests for revision of the correction must be handed in no later than February 12th, 2018.

Questions:
First, please read all questions! Don't write long answers but always motivate them.
Please, give back all the pages, even this front page!

1. Crystal structure and crystal geometry	5 P
2. Defects	7 P
3. Mechanical properties	5 P
4. Phase diagrams	4 P
5. Phase transformations	4 P
6. Joining and possible failures	5 P
7. Environment	5 P
8. Thermal properties	7 P
9. Electrical properties	4 P
10. Semiconductor devices	4 P
Σ :	**50 P**

Ranking:
3 ≥ 40 % (20 P)
4 ≥ 60 % (30 P)
5 ≥ 75 % (38 P)

Notice: During the exam a **calculator** (*typgodkänd räknare*) and an **English-Swedish dictionary (or the wordlist)** is allowed. The periodic system and 1 page with equations and formulas are included in the exam handout **- nothing else is needed!**

Gothenburg, December 13th, 2017

Good luck !! **Uta**

1. Crystal structure and crystal geometry (5 P)

a) Sketch the fcc and bcc unit cell and give the amount of atoms in each unit cell. Which of the structures has the higher density? (1 P)

b) Make a sketch of the hcp unit cell. (1 P)

c) Make a sketch of the cubic crystal plane with Miller indices ($\bar{6}\bar{2}6$). (1 P)

d) Draw the following direction vectors in a cubic unit cell: [$00\bar{1}$], [113], [$\bar{1}12$], [$\bar{5}2\bar{1}$]. (2 P)

2. Defects (7 P)

a) How can you distinguish between an edge and a screw dislocation? Describe briefly! (2 P)

b) The diffusion coefficients for self-diffusion and carbon diffusion in α-iron at 500ºC are $3.0\ 10^{-21}$ m^2/sec and $2.4\ 10^{-12}$ m^2/sec, respectively. Explain the huge difference! (1 P)

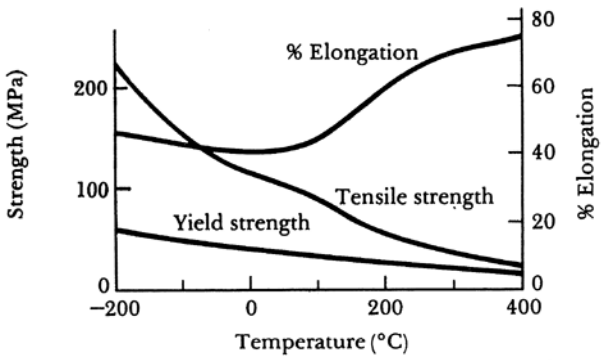
c) In order for two components to have complete solid solubility in each other, they usually have to follow certain conditions. Name them! (2 P)

d) Which hardening mechanisms (name all possible) can be achieved in an alloy with two elements that are totally soluble in each other? (2 P)

3. Mechanical properties (5 P)

a) You are supposed to deform both, copper (Cu) and Magnesium oxide (MgO). How are dislocations moving in these materials and what type of problem may you encounter (especially in MgO)? Describe in words or make a sketch for illustration. (2 P)

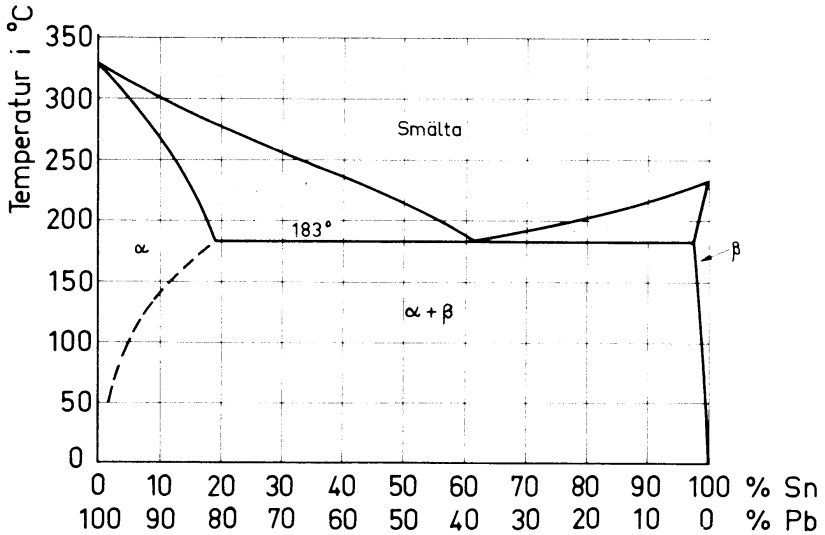
b) Below, you find a figure where strength and elongation of an Al alloy (melting temp. about 500ºC) is shown over temperature. What it meant with yield strength and tensile strength and describe what is happening in the material! (3 P)



4. Phase diagram (4 P)

a) Draw cooling curves of a single component and a binary system! (2 P)

b) A Sn-Pb alloy of composition 30 wt.% Sn – 70 wt.% Pb is slowly heated from a temperature of 150ºC.



(i) How does the microstructure of that alloy look like? Make a sketch! (1 P)

(ii) At what temperature does the first liquid form? (0.25 P)

(iii) What is the composition of this liquid phase? (0.25 P)

(iv) At what temperature does complete melting of the alloy occur? (0.25 P)

(v) What is the composition of the last solid remaining prior to complete melting? (0.25 P)

5. Phase transformations (4 P)

a) What is a martensitic transformation? Explain! Where to find martensite in the Fe-C phase diagram? (1 P)

b) Explain the difference between homogeneous and heterogeneous nucleation and state which one is more advantageous and why! (2 P)

c) You have a lamellar structure, for example pearlite. How can the width of the lamellae tell you if the microstructure was achieved at higher or lower temperature? (1 P)

6. Joining and possible failures (5 P)

a) Explain what is meant with electromigration! (2 P)

b) Explain ball bonding and name the wire which has to be used! (2 P)

c) What are a direct and an expanded contact? Explain advantages! (1 P)

7. Environment (5 P)

a) Give estimates of the *used energy over life time* of a civil airplane and a vacuum cleaner. Motivate your answer! (2 P)

b) With respect to recyclability compare metals and polymers. Recyclability of which of the materials is more economic and why? For comparison, how would you rank fiber-reinforced polymers? Motivate! (3 P)

8. Thermal properties (7 P)

a) How is heat transported? Explain! (2 P)

b) What is thermal expansion and how is it related to bonding? Explain! (2 P)

c) Why don't you burn yourself at your steel sink when you are doing the dishes? Explain briefly! (2 P)

d) Knowing the electron energy band structure, why can you predict if a material is a good or bad thermal conductor? (1 P)

9. Electrical properties (4 P)

a) Explain - in words and with a sketch - the difference in electrical conductivity (or electron concentration) upon temperature of an intrinsic semiconductor and an extrinsic semiconductor. (2 P)

b) Sketch the electron energy band structure of a p-type semiconductor and explain in works with its help how conductivity can be achieved. (1 P)

c) What are the major charge carriers in (i) an intrinsic semiconductor, (ii) an n-type semiconductor, (iii) a p-type semiconductor, and a (iv) metal? (1 P)

10. Semiconductor devices (4 P)

a) What is epitaxy? Explain briefly! (2 P)

b) What is happening when you join a p-type and an n-type semiconductor? Explain! (2 P)