Aalto University
School of Engineering

COE-C2004 - Materials Science and Engineering
2021-2022 Autumn II

Assignment 4, 22.11.2021

General rules:

1. Learning Group work is encouraged for this course. You could form a group with max one additional peer to review the lecture/exercise content and discuss the tasks in the assignment. After discussion, please finish your assignment independently and submit your individual report. Please note the duplicate report is not accepted!
2. If you have a learning group, please indicate who your group member is in the submitted report. In addition, clearly state the individual contributions of each group member.
3. When required, always show the step-by-step derivation or calculation processes, without which hinting the number does not qualify for grades.
4. When required, always give a brief and concise explanation or description, without which hinting the right choice or answer does not qualify for grades.
5. Citation is necessary if you are using any figures/data that are not generated by yourself.
6. Handwriting/plotting is acceptable, just make sure that your handwriting/final photo in the system is clear enough, otherwise it may affect the grading for details/calculation process.
7. Only PDF type file is accepted for submission, please summarize all your answers/solutions in one PDF file for every assignment. It is appreciated to sort the PDF pages in the TaskNr order, which is helpful to speed up the evaluation process. Please name your assignment files with the assignment number and your first name and surname, and link them with short underlines: 'ANr_Firstname_Surname.pdf', e.g. for the first Assignment 'A1_Wenqi_Liu.pdf'.
8. Assignment 4 will take 5 points in the final grade system.

Due date: 18:00, 28.11.2021.
Contact: MyCourses 'General discussion' channel

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Task 1. Diffusion (10 points, Lecture7)

1.1 For a steel alloy it has been determined that a carburizing heat treatment of 17 h duration at 763 °C will raise the carbon concentration to 0.56 wt% at a point 2.2 mm from the surface. Estimate the time necessary to achieve the same concentration at a 5.3 mm position for an identical steel and at a carburizing temperature of 1000 °C. Assume that D_0 is 1.5×10^{-5} m^2/s and Q_d is 104 kJ/mol. Gas constant is 8.31 J/mol·K and Planck's constant is 6.63×10^{-34} J · s. (Please give the detailed calculation process.)

1.2 (a) If [m] atoms of helium pass through a [a] square meter plate area every [t] hours, and if this flux is constant with time, compute the flux of helium in units of atoms per square meter per second.

(b) If water molecules pass through a membrane with a steady-state flux of [j] mole/(m^2 day), how long will it take, in hours, for [m] kg of water to pass through a [a] square centimeter of the membrane? (Please give the detailed calculation process.)

Task 2. Phase diagram (45 points, Lecture7)

2.1 Give the schematic sketch of binary phase diagrams of (a) eutectic system, (b) eutectoid system, and (c) peritectic system. On your schematic drawings, label the various phase regions, liquidus, solidus, and solvus lines, and give the reaction equations for these three systems. (Please create it on your own, copy/paste from textbook/slides is not accepted!)

2.2 Draw the Fe–Fe_3C phase diagram with the carbon content in the range of 0-6.7 wt%, indicate the phases, mark three important temperatures and five carbon contents. (Please create it on your own, copy/paste from textbook/slides is not accepted!)

2.3 For a 99.6 wt% Fe-0.40 wt% C steel at a temperature just below the eutectoid, determine the following:

(a) The compositions of Fe_3C and ferrite (α).

(b) The amount of cementite (in grams) that forms in 100 g of steel.

(c) The amounts of pearlite and proeutectoid ferrite (α) in the 100 g.

Task 3. Phase transformation (45 points, Lecture8)

3.1 (a) List at least six important phases that are found in steel alloys. (b) Give the crystal structure and describe the microstructure for each. (c) Discuss and compare their mechanical properties.

3.2 Give the definition of martensite phase transformation. Explain the reasons for the high strength of martensite.

3.3 Calculate the average phase transformation rate based on the following JMAK function:

$$y = 1 - \exp(-kt^n)$$

where y is the fraction of the transformed phase, t is the time in second, and the parameters k=0.02 s^{-n}, n=2.

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