Radiation damage in materials (SH2605) – VT 2016
Written Exam

14.00 – 19.00, March 21, 2016, FB51, AlbaNova, KTH, Stockholm

Allowed aids: pocket calculator, BETA (maths handbook) or similar, ruler, pencil/pen, eraser, snacks

To pass the exam you need at least **6 points out of 16.**

Grading is determined by the total number of points:
F: 0–5.0; Fx: 5.5; E: 6–8; D: 8.5–10.5; C: 11–12.5; B: 13–14; A: 14.5+

Half-points can be rewarded for partially correct answers.

Write clearly. Motivate your answers by calculations, text and figures if pertinent.

Make your own, reasonable assumptions, when necessary. Make sure to explicitly state what assumptions you make in the text.

Good luck and have fun!

Problem 1 [2p]

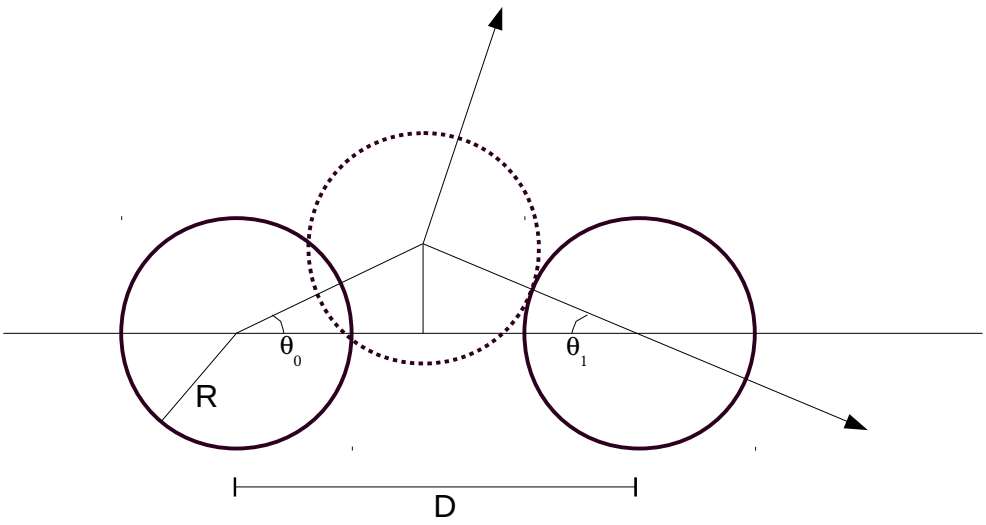
a) Determine the *atomic* diffusion coefficients D_a^v (for the vacancy mechanism) and D_a^i (for the self-interstitial mechanism) for bcc Fe at 100°C. [1p]
b) Determine the *defect* diffusion coefficients D^v and D^i for the same conditions and discuss eventual differences with respect to the atomic diffusion coefficients. [1p]

Problem 2 [3p]

a) Derive an expression for the maximal energy transfer from a relativistic *electron* interacting with an ion in a lattice, assuming the ion recoil is non-relativistic. [2p]
b) How high does the voltage have to be in a transmission electron microscope to induce damage as well as to resolve images of a thin gold sample? [1p]

Problem 3 [3p]

Focusing means that a chain of successive collisions in a crystalline solid converges the collision angles to zero. It can occur when a PKA has a velocity vector close to a high-symmetry direction. Assume that the atoms scatter elastically as hard-spheres.
a) Using the nomenclature of the figure below, derive the criterion for focusing to occur. [2p]
b) In which direction is focusing most likely to occur, in e.g. a fcc lattice? [1p]



Problem 4 [2p]

Consider a closed pressure vessel of height H, radius R and wall thickness d. Along which direction will the vessel crack if it is over-pressurized? Assume that $d << R$ and make your argument based on comparing the stresses in the different directions. [2p]

Problem 5 [3p]

The critical size of a void nucleus is determined by the change in Gibbs free energy due to a void of n vacancies, $\Delta G_n = -n k_B T \ln S_v + \left(36\pi\Omega^2\right)^{1/3} \gamma n^{2/3}$

a) Determine an expression for the critical void embryo radius. [2p]

b) What is the critical void embryo radius in fcc gold where the irradiation at 300°C is such that the vacancy number concentration is 10^{-8} per atom ? [1p]

Problem 6 [3p]

a) Order the {100},{110}, {111} planes in a bcc crystal according to their planar density. [1p]

b) Which and how many are the slip systems in a bcc crystal? [1p]

c) Which slip system will activate first during plastic deformation of the crystal in the direction n_T = [1, 2, 3] ? [1p]

Data sheet:

Various properties of selected metals:

	a_0	A	Z	E_d	H_f^v	S_f^v	H_m^v	E_f^i	S_f^i	H_m^i	γ	ν
bcc Fe	2.86 Å	56	26	40 eV	2.1 eV	2.4 k_B	0.7 eV	4.0 eV	0.7 k_B	0.3 eV	1.8 J/m²	15 THz
fcc Au	4.08 Å	197	79	40 eV	1.3 eV	1.9 k_B	0.8 eV	2.6 eV	0.6 k_B	0.2 eV	1.0 J/m²	49 THz

(The migration entropies of both vacancies and SIAs are very close to zero)

Stress

$$\sigma = F/A$$

Constants:

Boltzmann's constant	$k_B = 1.38\cdot10^{-23}\,J/K$
Elementary charge	$e = 1.602\cdot10^{-19}\,C$
Electron rest mass	$m_e = 9.11\cdot10^{-31}\,kg$
Speed of light	$c = 3\cdot10^{8}\,m/s$
Relativistic energy	$E^2 = (pc)^2 + (m_0c^2)^2$