Modern Imaging Methods

TIF 030 and FIM 150

Saturday March 17th, 2007, 08.30- 12.30

V Building

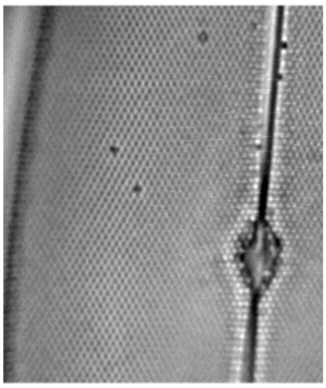
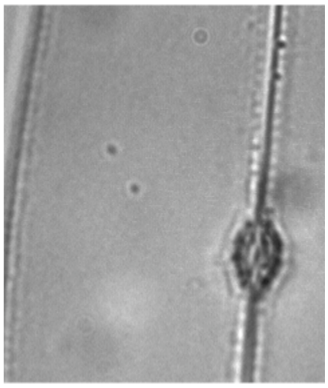
Aids: Formula sheets attached to the exam, "Physics Handbook", calculator, and writing tools.

Total marks available from exam: 30

Marks required to pass: 12

Question 1 (3p)

The images below show the same test diatom imaged through the same microscope but using different objectives. What is the difference between the objectives? Explain why this difference gives the change in appearance. (3p)

A  B 

Question 2 (3p)

Name three methods used for improving spatial resolution in fluorescence microscopy. Pick one and explain the basic principle, the basic set up, including schematic drawing (if possible), and explain when the method you have chosen is a better alternative than the other two. (3p)

Question 3 (3p)

Name two methods to study molecular diffusion in living cells. Describe their basic principles and what equipment you need. Make sure to include schematic drawings. (3p)

Question 4 (4p)

(a) Describe spherical and chromatic aberration in a lens. (1p)

(b) What is the most critical parameter that limits the spatial resolution for secondary electron imaging, backscatter electron imaging and EDS-analysis respectively of a bulk specimen in the SEM (1p)

(c) Assume that you are recording an image of a planar specimen in the SEM using the backscattered electrons. The specimen contains Si and Ge and you know from earlier X-ray diffraction experiments that two phases with different composition and lattice parameters are present in the specimen. You observe two intensity levels in the image, i.e. there are dark and bright domains in the image. What causes the difference in intensity levels? Assume that one of the intensity levels corresponds to pure Si. Is it the lower or the higher level? (2p)

Question 5 (2p)

(a) Draw a typical EDS spectrum including characteristic X-ray peaks and background for oxygen and iron in the interval 0-20 keV. (1p)

(b) You are to carry out EDS analyses of a bulk specimen and you need to optimise the spatial resolution. You need to consider the elements that you are to analyse and the spatial resolution. How do you choose the optimum acceleration voltage? Explain your answer. (1p)

Question 6 (3p)

(a) Draw a schematic ray diagram that shows how a diffraction pattern and an image are formed in the TEM. Include the specimen and the objective lens in the diagram. All other lenses can be omitted. (1p)

(b) Describe how Bright Field and Dark Field images can be obtained. Which aperture is used? (0.5p)

(c) How is an image showing phase contrast obtained in a TEM? (0.5)

(d) How is energy filtered imaging achieved in a TEM? Explain your answer using a schematic diagram of an EELS spectrum. (1p)

Question 7 (3p)

The diffraction patterns in Fig. 1 are obtained for a BCC crystal using a TEM operated at 200 kV.

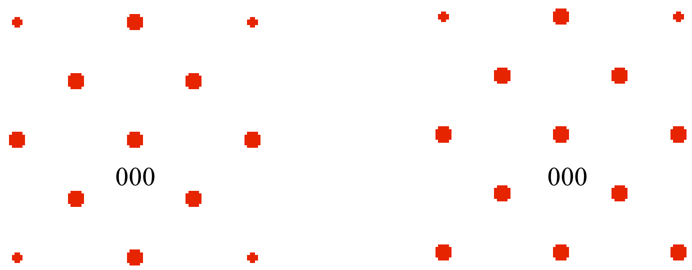
(a) Index the pattern. Explain how you check the validity of your indices. (1p)

(b) One of the patterns in Fig.1 is obtained with the electron beam incident along the zone axis. Which one? Explain your answer. (0.5p)

(c) Draw the Kikuchi lines corresponding to the 8 diffraction spots closest to 000 in the pattern that you choose in Question 6a). (0.5p)

(d) The other pattern in Fig. 1 is obtained after rotation around one axis. Which one? Explain your answer. (0.5p)

(e) What is the effect on the Kikuchipattern? Explain your answer. (0.5p)



a) b)

Fig. 1. Diffraction patterns from a BCC crystal.

Question 8 (3p)

An EDS-analysis is carried out in a TEM at 100 kV. The spectrum shows K-lines from Al, Ti and Mo. The number of counts summed over the energy ranges corresponding to the Al, Ti and Mo lines are 21 300, 16 700 and 12 000 respectively. The background intensities are 100, 210 and 300 counts. The specimen thickness is 50 nm and the probe diameter is 0.5 nm.

(a) Which background intensity belongs to Al, Ti and Mo? Explain your answer. (0.5p)

(b) Calculate the composition in weight per cent. Neglect the absorption. (2p)

(c) Assume that you would like to investigate if there is segregation of an element to a grain boundary. Explain the effect of specimen thickness and acceleration voltage on the quality of the analysis. (0.5p)

Question 9 (4p)

a. Describe the principle and operation of a scanning tunneling microscope (STM). (1p)
b. What is actually imaged and how does this depend on the sign and magnitude of the sample bias? (1p)
c. What kind of information can one get from recording the current as a function of bias, i.e. current versus bias curves? (1p)
d. What kind of mechanisms (give two examples) can give undesirable damages to a surface during imaging and how can these effects be minimized? (1p)

Question 10 (2p)

A platinum tip is used to image a gold surface using a total tunnelling current of 1 nA and a sample bias of 0.01 V (see fig. 1). How would the step on the surface be imaged in a) constant current mode and b) constant height mode? (2p)
(Calculate both the z-position and the current, after passing the step in the two cases)

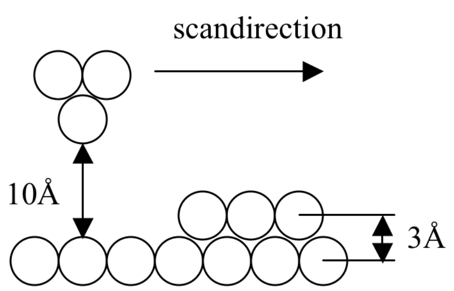


Fig. 1: A platinum tip is scanned to the right in the figure across an atomic step on the surface.

Formula sheet

Element (A)	k_{ASi} (1) 100 kV
Na	5.77
Mg	2.07 ± 0.1
Al	1.42 ± 0.1
Si	1.0
P	
S	
Cl	
K	
Ca	1.0 ± 0.07
Ti	1.08 ± 0.07
V	1.13 ± 0.07
Cr	1.17 ± 0.07
Mn	1.22 ± 0.07
Fe	1.27 ± 0.07
Co	
Ni	1.47 ± 0.07
Cu	1.58 ± 0.07
Zn	1.68 ± 0.07
Ge	1.92
Zr	
Nb	
Mo	4.3
Ag	8.49
Cd	10.6
In	
Sn	10.6
Ba	

$\lambda = h / [2m_0eV(1 + eV/2m_0c^2)]^{1/2}$

$d_p = (d_g^2 + d_s^2 + d_d^2 + d_c^2)^{1/2}$

$r_{Sch} = 0.66\ C_s^{1/4}\ \lambda^{3/4}$

$n > (5/C)^2$

$2\ d_{hkl} \sin\Theta = n\lambda$

$b = 7.21 \times 10^5\ (\rho/A)^{1/2} t^{3/2}\ (Z/E_0)$

$$I \propto U\rho_S(E,r)e^{-2\frac{\sqrt{2m_e(\phi - E_F)}}{\hbar}d}$$

Thermal expansion coefficient of piezo materials: $4.7 \cdot 10^{-6}\ K^{-1}$