Modern Imaging Methods

TIF 030 and FIM 150
Monday March 6th, 2006, 14-18
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)
Make schematic drawings of the illumination and imaging paths according to the Köhler design and mark the different conjugate planes and parts of the optical microscope.

Question 2 (3p)
What is meant by the Rayleigh criterion for resolving two pointlike objects separated by a distance d and what is the criterion?
What is the criterion for resolving a grating with grating constant d, and why is this the case?

Question 3 (3p)
In a few sentences and/or drawings, describe the basic principles and use of:
a) FRAP
b) FRET
c) NSOM

Question 4
(a) Which are the three most critical lens aberrations in electron microscopy? (1p)
(b) Which electron source gives the best spatial resolution? Explain your answer. (0.5p)
(c) Calculate the depth of field for an SEM image with the spatial resolution of 2 nm and recorded at 10 kV, with 4 mm working distance, 30 μm aperture and 100 000 times magnification. (1.5p)

Question 5
(a) Describe the information that is obtained in an EBSD pattern. (0.5p)
(b) What spatial resolution can be achieved with EBSD? (0.5p)
(c) Draw a typical EDS spectrum including characteristic X-ray peaks and background for oxygen and iron in the interval 0-20 keV. (1p)
(d) What factors determine the spatial resolution in EDS analysis in the SEM? (1p)

Question 6

The diffraction pattern in Fig. 1 is obtained for a gold crystal with the electron beam incident along the [110] direction in a TEM operated at 200 kV.

(a) Draw the Kikuchi lines corresponding to the 6 diffraction spots closest to 000 in Fig 1. (1p)

(b) Draw the Kikuchi lines for spot A when the crystal is tilted so that the Bragg condition for spot A is fulfilled. (1p)

(c) What happens to the pattern in Fig 1 if the acceleration voltage is reduced to 100 kV? (1p)

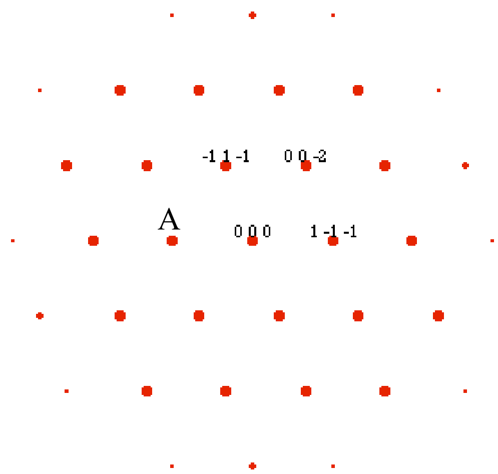


Fig. 1. Diffraction pattern from a gold crystal with the electron beam incident along the [110] direction.

Question 7

(a) Draw a TEM. The following parts must be included: electron gun, condenser lens system, objective lens, magnifying lenses, fluorescent screen, selected area aperture, objective aperture, condenser aperture and specimen holder. (0.5p)

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

(c) Describe how Bright Field and Dark Field images can be obtained. (0.5p)

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

(e) What are the roles of the condenser lenses in the TEM? (0.5p)

Question 8

An EDX-analysis is carried out in a TEM at 100 kV. The spectrum shows K-lines from Si and Ge. The number of counts summed over the energy ranges corresponding to the Si and Ge lines are 5 453 and 4 639 respectively. The background intensities are 296 and 532 counts.

The specimen thickness is 50 nm and the probe diameter 1 nm. The specimen is an epitaxial multilayer film with layer thicknesses of 2 nm.

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

(b) What qualitative effect would absorption have on the calculated composition? Why? (0.5p)

(c) Describe the effect of beam broadening. (0.5p)

Question 9 (4p)

(a) Describe the principle and operation of a scanning tunneling microscope (STM). (1p)

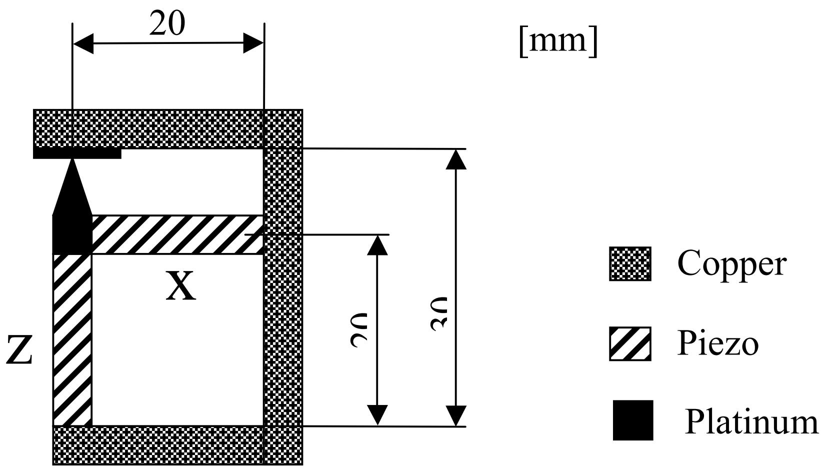
(b) What is imaged and how does this depend on the sample bias? (1p)

(d) How can one get chemical information and e.g. identify the compositions of molecules using an STM? (1p)

(e) How will a molecule adsorbed on a surface be imaged in the STM? (1p)

Question 10 (2p)

A student using an STM has been a bit careless and left the door open to his STM lab while he was doing measurements. The temperature in the room, and of the STM, then increased by 1°C during one hour. How would this affect his measurements if it takes about 1 minute to take an image? Estimate the effects using the schematic figure of the STM below.



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	

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

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

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

$n > (5/C)^2$

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

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

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

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