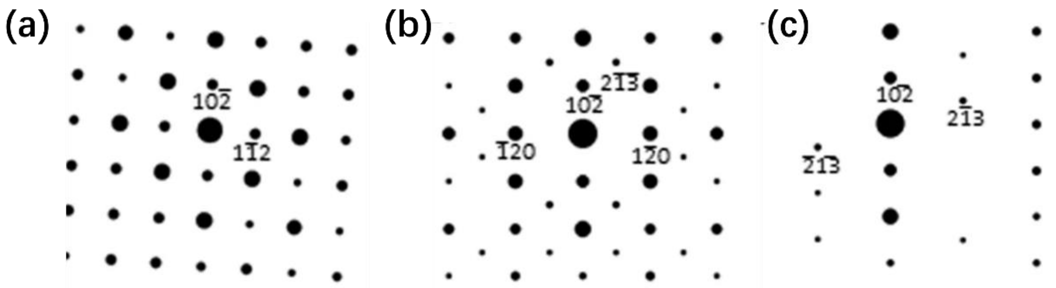
MAEG5140 Materials Characterizations Techniques Final Exam Answers

1. **How does the aberration of the magnetic lens occur, and how do we eliminate and reduce the aberration? (2 points). What is the working mechanism of the spherical aberration corrector? (2 points) .**

(1) **Spherical aberration** is caused by the different **refractive abilities** of electrons in the center area and edge area of the magnetic lens. Increasing the excitation current of the lens can reduce spherical aberration.
(2) **Astigmatism** is caused by the **asymmetric rotation of the axial magnetic field** of the electromagnetic lens. Compensation can be achieved by introducing a corrective magnetic field whose intensity and orientation can be adjusted.
(3) **Chromatic aberration** is caused by a certain change in the **wavelength or energy** of electronic waves. Stabilizing the accelerating voltage and lens current can reduce chromatic aberration.

The corrector **diverges the electron beam** at different angles to form a point.

2. **We have known the diffraction patterns of highly strained $BiFeO_3$ as follows. Please calculate the crystal band axis. (3 points).**



We can use Zone law to calculate the crystal band axis index [***uvw***]

$$u = k_1l_2 - k_2l_1 = 0,\ v = l_1h_2 - l_2h_1 = 0,\ w = h_1k_2 - h_2k_1 = 1$$

For figure (**a**), ***u*** = 2, ***v*** = 4, ***w*** = 1 [241]
For figure (**b**), ***u*** = 2, ***v*** = 1, ***w*** = 1 [211]
For figure (**c**), ***u*** = 2, ***v*** = 7, ***w*** = 1 [271]

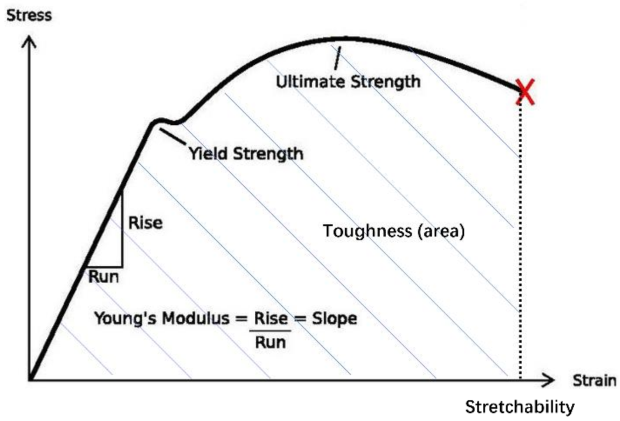
3. **What signals are produced when an electron beam hits a solid sample? (3 points). What factors affect the resolution of a scanning electron microscope? (2 points). Which kind of signal is used for SEM to have better resolution? (1 point).**

Six signals: X-ray, backscattered electron, secondary electron, Auger electron, transmitted electron and absorbed electron.

The **beam spot size** of the electron beam, the **type of detection signal**, and the **atomic number of the detection site** are three major factors that affect the resolution of the scanning electron microscope.

Therefore, the resolution of the scanning electron microscope is expressed by the **secondary electron** image resolution.

4. **Please mark the (1) yield strength, (2) strength, (3) elastic modulus, (4) stretchability, and (5) toughness in the stress-strain curve of the metal. (5 points).**



5. **What is the similarity and difference between Raman and Infrared Spectroscopy? (3 points).**

Similarity: both of them represent the energy of the first vibrational level and carry structural information that reflects the molecule.

Difference: The **wavelength** of the incident light in the infrared spectrum is continuous, while the incident light in the Raman spectrum is monochromatic; the infrared spectrum detects the **absorption** of light, while the Raman spectrum detects the **scattering** of light. The generation mechanisms of the two are different. The infrared spectrum mainly reflects the **functional groups of the molecule**, while the Raman spectrum mainly reflects the **skeleton of the molecule**; for molecules with a symmetry center, the two have a **mutually exclusive rule**: vibrations that are symmetrical to the symmetry center are invisible in the infrared, and visible in Raman; vibrations that have no symmetrical relationship with the symmetry center are visible in infrared and invisible in Raman.

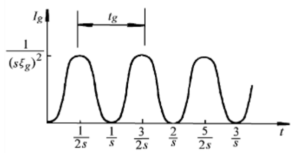
6. **What is the main difference between diffraction kinematics and diffraction dynamics? (1 point). In which scenarios the kinematics are applicable? (2 points). What is equal-thickness fringe, and how is it generated? (2 points).**

Main difference: dynamics theory considers the **interaction** between the **transmission** and **diffracted** beams.

Kinematic theory applies to **extremely thin samples** and is suitable for **large deviation parameters**.

Equal-thickness fringes: **light** and **dark strips** contrast at the edge of holes or inclined grain boundaries.

$$I_g = \Phi_g \cdot \Phi_g^* = \left(\frac{\pi}{\xi_g}\right)^2 \frac{\sin^2(\pi t s)}{(\pi s)^2} \longrightarrow I_g = \frac{1}{(s\xi_g)^2}\sin^2(\pi s t)$$



The thickness ***t*** of the wedge edge changes continuously, causing the diffraction intensity I_g to change periodically, which corresponds to alternating dark and black strips.

7. **What are the main apertures in a transmission electron microscope, and what are they used for? (2 points). What are the main parameters of an electron microscope to control resolution and magnification? (2 points).**

Three types of apertures: **condenser aperture**, **objective aperture**, and **selection aperture**.
Condenser aperture is used to limit and change the half angle of the illumination aperture and intensity.
Objective aperture is used to reduce the spherical aberration and improve the image contrast.
Selection aperture is used to limit and select the sample analysis area.

The resolution of a transmission electron microscope depends on the **manufacturing level** of the electromagnetic lens, the **spherical aberration coefficient**, and the **accelerating voltage** of the transmission electron microscope. The magnification of a transmission electron microscope changes with the **height of the sample plane**, **accelerating voltage**, and **lens current**.