Indian Institute of Information Technology, Allahabad
Department of Applied Sciences
(Material informatics C2 Exam)

Date: –/–/–   Total Marks: –

Duration: – hr

Subjective question:

Question 1: What is the purpose of the electron detector in an SEM?

Question 2: What is energy-dispersive X-ray spectroscopy (EDS) and how is it used in SEM**?**

Question 3: Why are X-rays used as the source beam?

Question 4: What are the relations between interplanar spacing and miller indices of the planes for Cubic lattice type?

Question 5: What is Bragg's law?

Question 6: In typical XPS spectra, both photoelectron peaks and Auger electron peaks are present. The questions are

(a) What instrumental parameter can be used to distinguish the two?

(b) What is the result?

Question 7: For a ground - state neutral atom with 13 protons, Describe

(a) Which element this is

(b) The quantum numbers, n , and l of the inner two core electrons

(c) The stationary state these inner two core electrons reside in using both spectroscopic and X - ray notation.

Question 8: After excitation from the x-rays, photoemission occurs, ejecting electrons from the sample with a variety of energies (forming an XPS spectrum). What energy of the electrons is being directly measured by the spectrometer?

Question 9: From Williamson-Hall Plot and size-strain plot, which method is more accurate to calculate the crystallite size and strain, and why?

Question 10: write down the equation for "Size strain plot" (SSP)?

Multiple choice questions:

Question 1: which one of the following statements is **NOT** true?

   (a) They have wavelength of about 1 Å.
   (b) These can be generated by bombarding a metal target by high energy electrons.
   (c) Due to their wavelengths being shorter, these can be used for radar systems.
   (d) These are also used for the treatment of certain forms of cancer.

Question 2: The longest wavelength that can be analyzed by a NaCl crystal of interplanar spacing 0.281 nm between its principal planes, in the first order, is;

(a) 0.654 nm   **(b)** 0.562 nm   **(c)** 0.969 nm   **(d)** 0.282 nm

Question 3: A beam of X-rays is constructively scattered in second order from the surface of the crystal at an angle of 30° and the spacing between layers of the atoms in NaCl crystal 4.5×10^{-10} m. The wavelength of X-rays is?

(a) 2.25×10^{-10} m   **(b)** 1.25×10^{-10} m   **(c)** 2.50×10^{-10} m   **(d)** 1.50×10^{-10} m

Question 4: The kinetic energy of the photoelectron energies is dependent on _____ of the atom, which makes XPS useful to identify the oxide state.

(a) Mass   **(b)** Charge   **(c)** Chemical environment   **(d)** Volume

Question 5: A scanning electron microscope uses _____ to produce an image.

(a) negatively charged particles   **(b)** positive charged particles

(c) neutral particles   **(d)** atoms

Solution:

Answer 1: The electron detector in an SEM collects secondary electrons or backscattered electrons emitted from the sample and converts them into an image of the sample.

Answer 2: Energy-dispersive X-ray spectroscopy (EDS) is a technique that uses X-rays generated by the interaction of the electron beam with the sample to determine the elemental composition of the sample. EDS can be used in conjunction with SEM to analyze the chemical composition of a sample, including the distribution of elements within the sample.

Answer 3: Since the interplanar distances in crystals are of the order of Angstroms, therefore X-rays are the suitable choice, as the wavelength of the wave should be of the order of the slit size for the phenomenon of diffraction to take place.

Answer 4: $\dfrac{1}{d^2} = \dfrac{h^2 + k^2 + l^2}{a^2}$

Answer 5: Bragg's law gives the condition for constructive interference to occur for X-rays scattered from different planes.
The condition is:

$2d \sin\theta = n\lambda$

Here, λ is the wavelength of the X-ray beam, d is the interplanar spacing and θ is the incident angle. Therefore the path difference between the X-rays scattered from two planes should be an integer multiple of the wavelength.

Answers 6:

(a) Use different X - ray source energies and compare the spectra.

(b) The Auger peaks move to different B.E . XPS values as the source energy is changed, whereas the photoelectron peaks remain at the same B.E . XPS.

Answer 7:

(a) Al

(b) n = 1, l = 0

(c) 1s, K

Answer 8: Kinetic energy
Explanation
The spectrometer directly measures the kinetic energy of the electrons that are ejected from the sample after being excited by x-rays. This is because the kinetic energy of the electrons is directly related to their velocity and can be measured by analyzing their motion in the spectrometer. Binding energy refers to the energy required to remove an electron from an atom, while thermal energy is the energy associated with the random motion of particles in a sample.

Answer 10:

$$\left(\frac{d\beta Cos\theta}{\lambda}\right)^2 = \frac{k\lambda}{D}\left(\frac{d^2\beta Cos\theta}{\lambda^2}\right) + \left(\frac{\epsilon}{2}\right)^2$$

Multiple choice questions:
Answer 1: (c) is correct.

Answer 2: (b) Given first order; n=1, d=0.281 nm
Now maximum wavelength will be
λ_{max} = 2d = 2×0.281= 0.562 nm

Answer 3: (a) d=4.5×10⁻¹⁰ m, θ=30°, n=2

We know that, nλ=2×4.5×10⁻¹⁰× sin 30°

λ= 2.25×10⁻¹⁰ m.

Answer 4: (c) The kinetic energy of the photoelectron energies is dependent on the chemical environment of the atom, which makes XPS useful to identify the oxide state. It also helps to identify the ligands of the atom.

Answer 5: (a) negatively charged particles