PHYSICS OF CRYSTALS

Chapter 2

Doç. Dr. Ş. Barış EMRE

PRODUCTION OF X-RAYS

Natural X-rays

artificial X-rays

Natural X-Rays: From K energy shell by atomic nucleus electron capture occurs through alpha decay, internal conversion and beta decay.
High energy electrons coming or being sent to an atom o electrons detach from the first rings of the atom. Instead of this electron detached from the atom, electrons from higher levels (upper rings) jump and fill the gap in the place of the ejected electron. Meanwhile, the resulting excess energy is released in the form of X-rays. One of the protons in the nucleus captures the electron in the first rings of the atom during its motion and becomes neutral. An X-ray can occur when an electron leaps from another ring to the discharged place in the ring of this captured electron.

Artificial X-Rays: Matter; electron, proton, particles or

It consists of interacting with accelerated particles such as ions or with photons emanating from the X-ray tube or other suitable radioactive source.

Characteristic (line) X-rays are obtained from the interaction of matter with photons. Both characteristic and continuous X-rays are obtained from its interaction with charged particles.

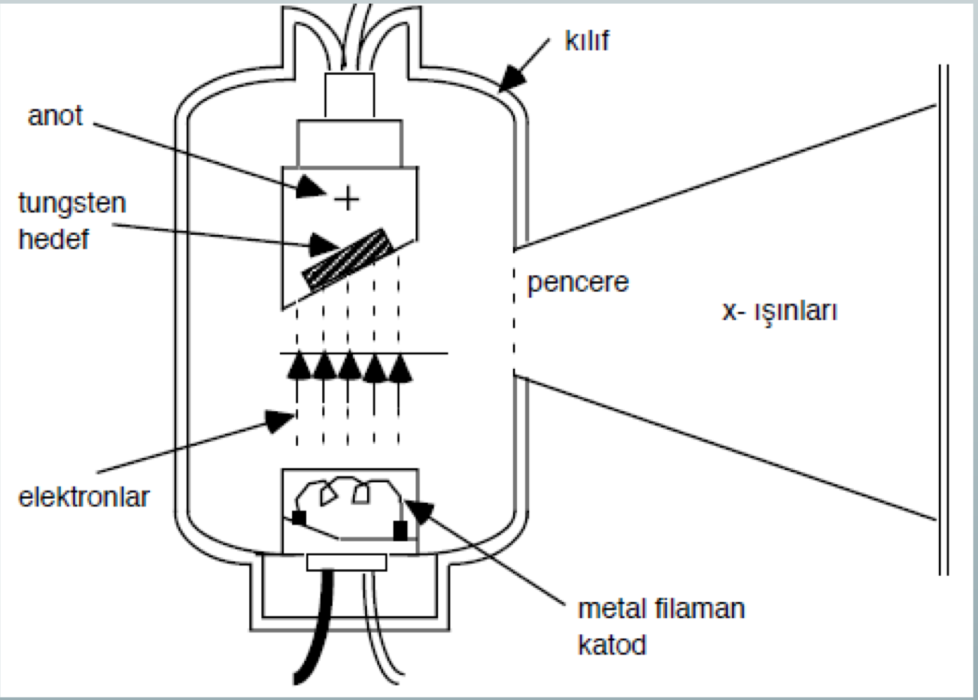
$$c = \nu\lambda \qquad (\mathrm{ms^{-1}})$$

$$E = h\nu = \frac{hc}{\lambda} \qquad (\mathrm{J})$$

$$E\,(\mathrm{keV}) = \frac{1.240}{\lambda\,(\mathrm{nm})}$$

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

X-Ray Tube: X-ray tube is a high voltage cathode ray tube. The tube consists of a high vacuum evacuated glass cover. It has an anode (positive electrode) on one end and a cathode (negative electrode) on the other, both of which are tightly sealed with solder. The cathode is a streamer made of tungsten material that releases electrons when heated. The anode consists of a thick rod and a metal target at the end of this rod. When high voltage is applied between the anode and cathode, electrons are emitted in the cathode filament. These electrons are accelerated towards the anode under high voltage and reach high speeds before hitting the target. When high-speed electrons hit the metal target, a photon is emitted, transferring their energy. The resulting X-ray beam passes through the thin glass window inside the glass envelope. Some tubes use a filter to obtain a single wavelength X-ray.



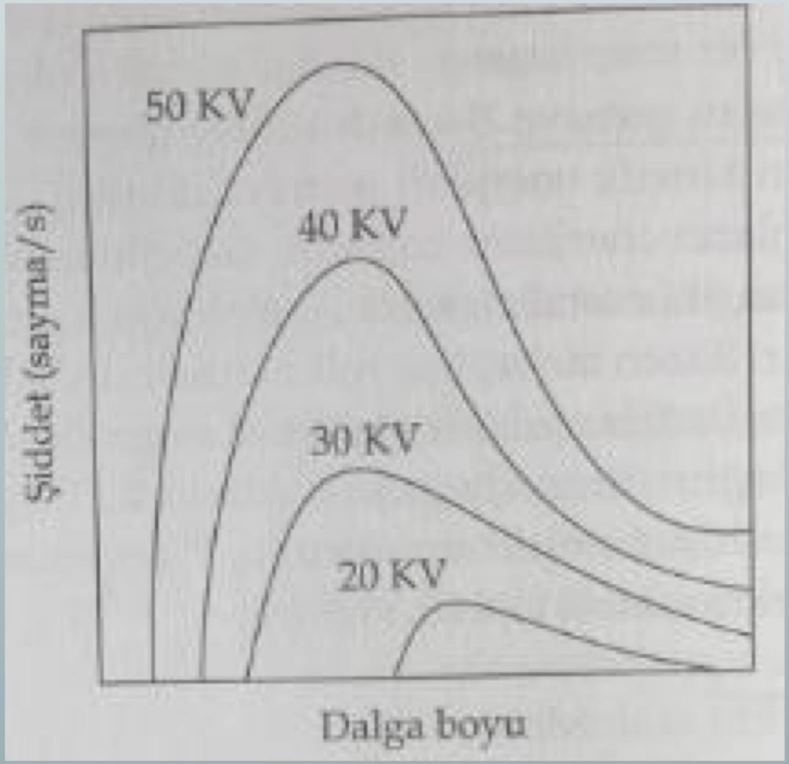
A moving electron has kinetic energy. When a high-speed electron hits tungsten, it collides with a tungsten atom. The electron may have to collide with many atoms until it is stopped. One percent or less of the kinetic energy lost during the stopping of the electron is converted into X-ray radiation and the remaining part into heat energy.
The power of X-rays to penetrate the material, which is obtained by bombarding the target in the vacuum lamp (in the X-ray tube) with electrons, is called "hardness." The hardness of these rays depends mainly on two things. The lower the number of gas molecules, the less the number of electrons that deviate from the target by colliding with these molecules.The second factor is the intensity of the voltage applied to the tube, ie the electrical pressure.

- Most X-ray lamps in use today are Coolidge lamps. This type of lamp was developed by the American scientist William David Coolidge (1873-1975).

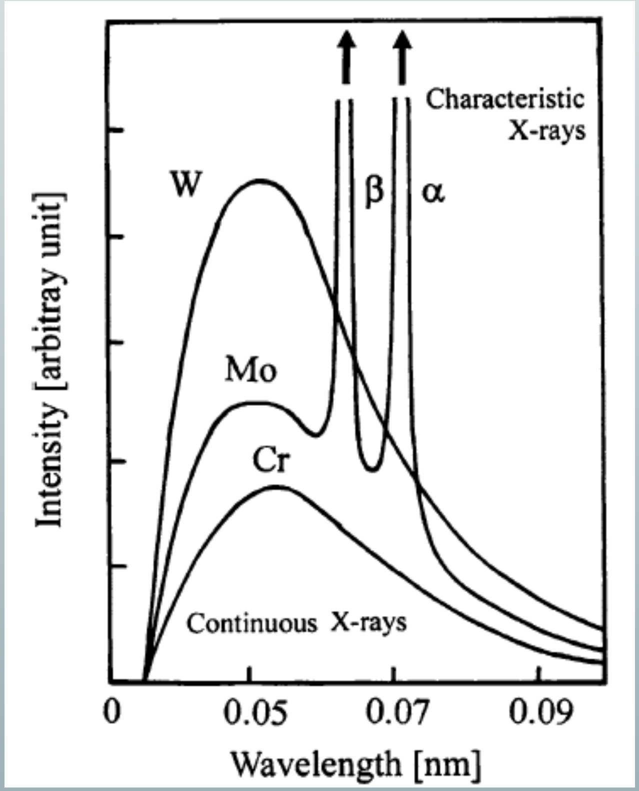
- In these lamps, which have an extremely high vacuum level, electrons emanate from a hot filament (a thin wire) as in radio lamps. Electrons emanating from the cathode and accelerated by a high voltage of up to 1 million volts are struck by a heavy tungsten rod. Tungsten can withstand the high temperatures caused by electron bombardment without melting.

- The end of the tungsten rod close to the filament is cut with a certain bevel; this end is called the target. X-rays are emitted from the target, but since the lamp is covered with a thick layer of lead outside of a certain opening, the X-rays only come out of that opening, so they travel in a beam.

2 types of X-rays are obtained according to the way they interact.
a) Continuous (White) X-Rays: Electron beam, target. of the atom When it approaches the nucleus, it is affected by the electric field caused by the positive charge of the nucleus and emits photons by being forced to make an accelerated motion. These photons with a continuous energy spectrum are called continuous x-rays, this event is called bremsstrahlung or braking radiation.



b) Characteristic X-Rays: After the interaction of the electrons sent on the target atom with the electrons in the plane of the target atom, they reach the upper energy levels with the energy they receive. When these unstable energy levels decay back, photons are emitted to the outside. These photons, whose energies are equal to the difference in levels, are called characteristic x-rays.



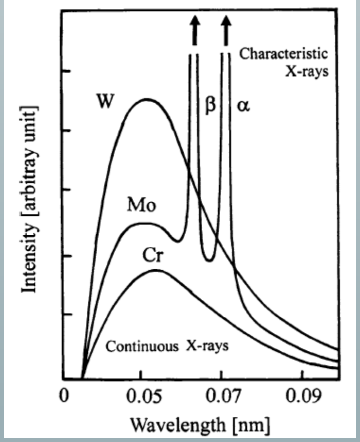
When an electron loses all its energy in a single collision, the generated X-ray has the maximum energy.
The shortest wavelength (λ_{SWL}) limit value can be estimated from the acceleration voltage V between the electrodes.

$$eV = h\nu_{max}$$

$$\lambda_{SWL} = \frac{c}{\nu_{max}} = \frac{hc}{eV}$$

The total X-ray intensity oscillating in a fixed time interval is equivalent to the area under the curve in Figure. It is related to the atomic number of the anode target Z and the tube current i.

$$I_{cont} = AiZV^2$$



According to the equation, it would be desirable to use a larger Z atom such as gold or tungsten to have more white radiation, high V and large current.

ABSORPTION OF X-RAYS

X-rays which enter a sample are scattered by electrons around the nucleus of atoms in the sample. The scattering usually occurs in various different directions other than the direction of the incident X-rays, even if photoelectric absorption does not occur.

As a result, the reduction in intensity of X-rays which penetrate the substance is necessarily detected.When X-rays with intensity I_0 penetrate a uniform substance, the intensity I after transmission through distance x is given by.

$$I = I_0 e^{-\mu x}$$

Here, the proportional factor is called linear absorption coefficient, which is dependent on the wavelength of X-rays, the physical state (gas, liquid, and solid) or density of the substance, and its unit is usually inverse of distance

Linear absorption coefficient is very important in crystal structure analysis. The value of this coefficient tells whether to make an absorption correction to the x-ray diffraction intensity data. LAC is calculated from the density of the crystal, the x-ray wavelength, and the mass absorption coefficients defined for the x-ray used of the atoms that make up the crystal.

$$I = I_0 e^{-\left(\frac{\mu}{\rho}\right)\rho x}$$

$$\left(\frac{\mu}{\rho}\right) = w_1 \left(\frac{\mu}{\rho}\right)_1 + w_2 \left(\frac{\mu}{\rho}\right)_2 + \cdots = \sum_{j=1} w_j \left(\frac{\mu}{\rho}\right)_j$$

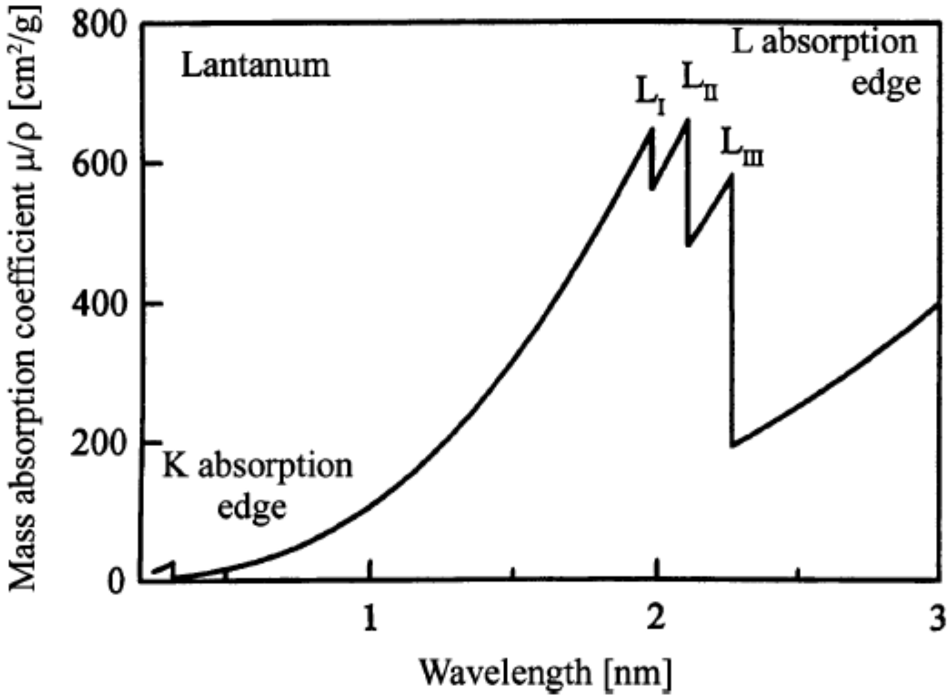


Fig. 1.2 Wavelength dependences of mass absorption coefficient of X-ray using the La as an example

INTRODUCTION

- Crystal: Atoms, molecules or groups of atoms and molecules that are arranged periodically in three dimensions are called crystals.
- Amorphous: If there is no periodic arrangement in a solid substance, it is called amorphous.

Kristal

- Tek kristal (0.1-0.3 mm)
- Poli-kristal (Tek kristallerin düzensiz yığılımı)
- Toz kristal (10^{-3} mm)