**Diffraction Of Electrons in a Polycrystalline lattice (Debye-Scherrer diffraction)**

**(Study of Electron Diffraction by Thomson and Reid Method)**

## Objectives:

1-To demonstrate wave property of electrons..
2-Determination of lattice planes spacing of graphite.

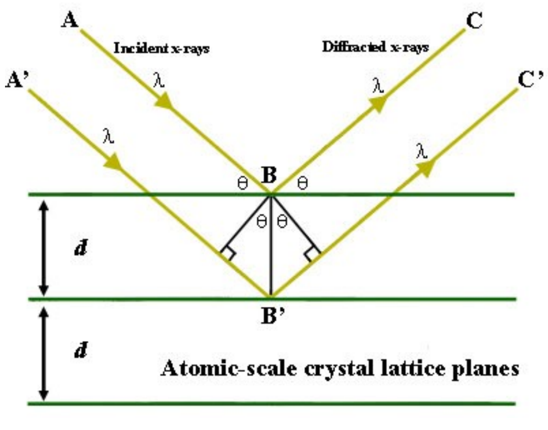
## Theory:

Electron diffraction, can be defined as the interference effects owing to the wavelike nature of a beam of electrons when passing near matter. According to the proposal (1924) of the French physicist Louis de Broglie, electrons and other particles have wavelengths that are inversely proportional to their momentum. Consequently, high-speed electrons have short wavelengths, a range of which are comparable to the spacing between atomic layers in crystals. A beam of such high-speed electrons should undergo diffraction, a characteristic wave effect, when directed through thin sheets of material or when reflected from the faces of crystals. Electron diffraction, in fact, was observed (1927) by C.J. Davisson and L.H. Germer in New York and by G.P. Thomson in Aberdeen, Scot. The wavelike nature of electron beams was thereby experimentally established, thus supporting an underlying principle of quantum mechanics.

Bragg's presented a simple explanation of the diffracted beams from a crystal. Suppose that the incident waves are reflected form parallel planes of atoms in the crystal. The diffracted beams are found when the reflections from parallel planes of atoms interfere constructively and that occur when

$$n\lambda = 2d\sin\theta \qquad \text{(eq. 1)}$$

such that,
$\lambda$ : wavelength of the electrons
$\theta$ : glancing angle of the diffraction ring.
$d$ : lattice plane spacing in graphite
( for further information see the proof of Bragg's law in page 6 )




(Fig.1 )Bragg's law

in this experiment the wave character of electrons is demonstrated by their diffraction at a polycrystalline graphite lattice .This setup uses a transmission diffraction type similar to the one used by G.P. Thomson in 1928.
the electrons are emitted by the hot cathode a small beam is singled out through a pin diagram. After passing through a focusing optical system the electrons are incident as sharply limited monochromatic beam on a polycrystalline graphite foil. this corresponds to a large number of small single crystallites which are irregularly arranged in space . As a result there are always some crystals where Bragg condition is satisfied. The atoms of the graphite can be regarded as a

space lattice which act as a diffraction grating for the electrons. On the fluorescent screen appears a diffraction pattern of two concentric rings which are concentric around the indiffracted beam see fig. 2

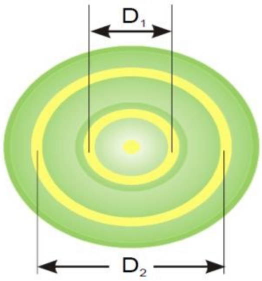



Fig.2 :the diffraction pattern of electrons on graphite. Two rings of diameters $D_1$ and $D_2$ are observed corresponding to lattice plane spacings $d_1$ and $d_2$.

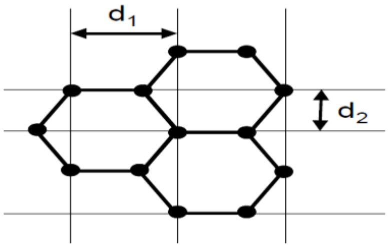



Fig.3 :lattice plane spacings in graphite: $d_1$=2.13 $^0$ A and $d_2$ =1.23 $^0$ A

From De Broglie hypothesis,

$$\lambda = \frac{h}{p} = \frac{h}{mv} \qquad \text{(eq.2)}$$

When electrons are accelerated through a potential difference V, they acquire Kinetic energy ,such that

$$\frac{1}{2}mv^2 = eV$$
$$v = \sqrt{\frac{2eV}{m}} \qquad \text{( eq.3 )}$$

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}} \qquad \text{(eq. 4)}$$

Since $h = 6.62*10^{-34} J.s$, $m = 9.11*10^{-31} kg$ and $e = 1.602*10^{-19} C$, equation (4) becomes:

$$\lambda = \sqrt{\frac{150}{V}}*10^{-10} m$$
$$= \sqrt{\frac{150}{V}} \overset{0}{A} \qquad \text{( eq.5)}$$

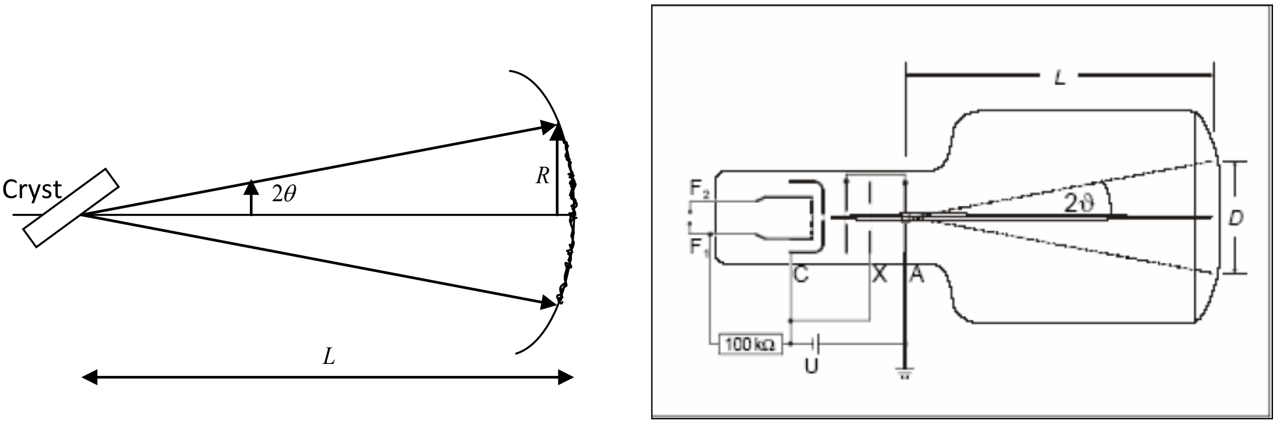



Fig.4 :Geometry of the experiment

from fig.4

$$\tan 2\theta = \frac{R}{L} \tag{7}$$

such that
$R$ : radius of the bright ring
$L$ : distance between the crystal and the screen
θ:is Bragg angle(angle between electron beam and lattice planes)

For small angles(cos θ≈1)

$$\begin{aligned} \tan 2\theta \approx \sin 2\theta &= 2\sin\theta\cos\theta \\ &= 2\sin\theta \end{aligned} \tag{8}$$

$$\therefore 2\sin\theta = \frac{R}{L} \tag{9}$$

Returning to the Bragg's law and substituting for $\lambda$ and $\sin\theta$, for n=1

$$\begin{aligned} R &= \frac{L}{d}\sqrt{\frac{150}{V}} * 10^{-10} \\ R &= \frac{L}{d}\sqrt{150} * 10^{-10}\,\frac{1}{\sqrt{V}} \end{aligned} \tag{10}$$

Knowing that $L = 13.5cm$,

$$R = \frac{1.653 * 10^{-10}}{d}\frac{1}{\sqrt{V}} \tag{11}$$

If $1/\sqrt{V}$ is plotted versus $R$ , we get

$$slope = \frac{1.653*10^{-10}}{d}$$

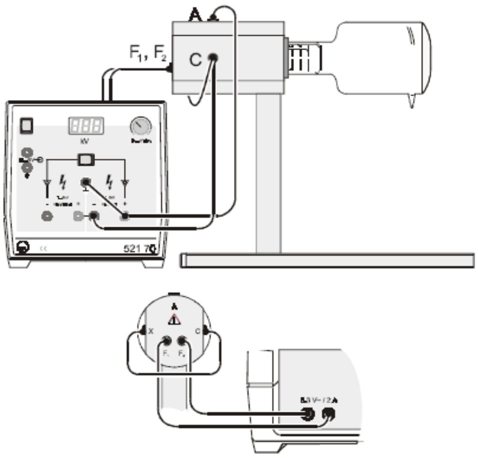
$$\therefore d = \frac{1.653*10^{-10}}{slope}$$

## Apparatus:

electron diffraction tube-tube stand-high voltage power supply-precision vernier callipers- connection wires

## Procedure:

1-connect the apparatus as shown in the wiring diagram(Fig. 3)



(Fig.5 )the wiring diagram

-Connect the cathode heating sockets F1 and F2 of the tube stand to the output on the back of the high voltage power supply 10 kV.
-Connect the sockets C (cathode cap)and X (focusing electrode)of the tube stand to the negative pole.
-connect the socket A(anode) to the positive pole of the 5kV/2mA output of the high-voltage power supply 10 kV.
-Ground the positive pole on the high voltage power supply 10kv.
2-Apply the accelerating voltage U<5kV and observe the diffraction pattern .
3-Vary the accelerating voltage U between 205 kV and 4. 5kV in step of 0.5 kV and measure the diameters D1 and D2 of the diffraction rings on the screen. to determine the diameters of the diffraction rings measure the inner and outer edge of the rings with the vernier calipers and take the average.

## safety notes:

**1-When the electron diffraction tube is operated at high voltages over 5 KeV ,**

**X-rays are generated. Do not exceed 4.5 KeV.**

**2-the diffraction tube is made of thin-walled glass so treat it with care .**

## Measurements:

### Table:

| V(kV) | V(v) | D1(cm) | R1(m) | D2(cm) | R2(cm) | $V^{-1/2}$ ($v^{-1/2}$) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
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| | | | | | | |
| | | | | | | |

## Results:

### a-Graph

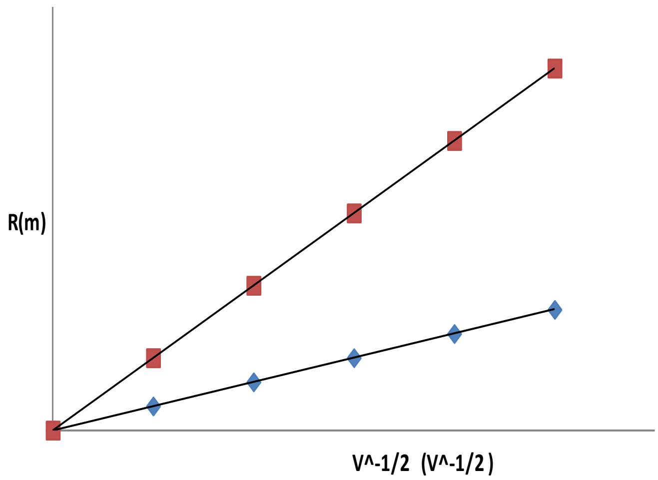
- plot $1/\sqrt{V}$ versus $R$ as shown in fig.6

### b-Calculations

-Find the slopes of both lines .

-find $d_1$ and $d_2$

-find the percentage error in $d_1$ and $d_2$ .

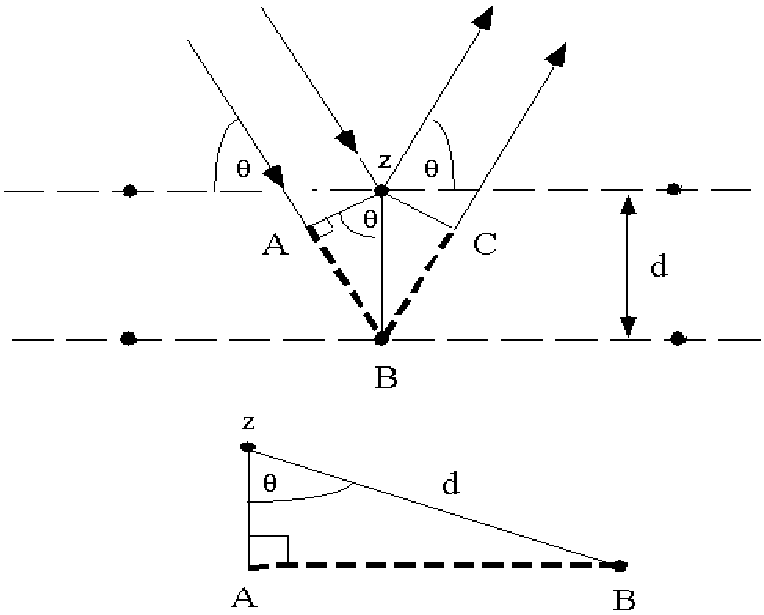



(Fig.6 ) :Ring diameters D1 and D2 as a function of vc $^{-1/2}$

## Deriving Bragg's Law

Bragg's Law can easily be derived by considering the conditions necessary to make the phases of the beams coincide when the incident angle equals and reflecting angle. The rays of the incident beam are always in phase and parallel up to the point at which the top beam strikes the top layer at atom z (Fig. 7). The second beam continues to the next layer where it is scattered by atom B. The second beam must travel the extra distance AB + BC if the two beams are to continue traveling adjacent and parallel. This extra distance must be an integral (n) multiple of the wavelength ($\lambda$) for the phases of the two beams to be the same:

(eq 12) $n\lambda = AB + BC$ .




Proof of Bragg,s law

Recognizing d as the hypotenuse of the right triangle Abz, we can use trigonometry to relate d and $\theta$ to the distance (AB + BC). The distance AB is opposite $\theta$ so,

(eq 13) $AB = d \sin\theta$ .

Because AB = BC eq. (2) becomes,

(eq 14) $n\lambda = 2AB$

Substituting eq. (3) in eq. (4) we have,

(eq 15) $n\lambda = 2\, d \sin\theta$

and Bragg's Law has been derived. The location of the surface does not change the derivation of Bragg's Law.