Electron diffraction

OBSERVE THE DIFFRACTION OF ELECTRONS ON POLYCRYSTALLINE GRAPHITE AND CONFIRM THE WAVE NATURE OF ELECTRONS.

- Measuring the diameters of the two diffraction rings for different accelerator voltages.
- Determining the wavelength of the electrons for different accelerator voltages by applying the Bragg condition.
- Confirming the de Broglie equation for the wavelength.

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BASIC PRINCIPLES

In 1924 *Louis de Broglie* put forward the hypothesis that particles can in principle also possess wave properties, and that the wavelength depends on the momentum. His theories were later confirmed by *C. Davisson* and *L. Germer* by observing the diffraction of electrons by crystalline nickel.

According to *de Broglie*, the relation between the wavelength λ of a particle and its momentum p is given by:

$$\lambda = \frac{h}{p} \tag{1}$$

h: Planck's constant.

For electrons that have been accelerated by a voltage U_A, this leads to the equation

$$\lambda = \frac{h}{\sqrt{2 \cdot m \cdot e \cdot U_A}} \tag{2}$$

m: mass of the electron, e: elementary electric charge.

For example, if the accelerator voltage is 4 kV, one can assign to the electrons a wavelength of about 20 pm.

In the experiment, the wave nature of electrons in an evacuated glass tube is demonstrated by observing their diffraction by polycrystalline graphite. On the fluorescent screen of the tube one observes diffraction rings around a central spot on the axis of the beam. The diameter of the rings D depends on the accelerator voltage (see Fig. 1). They are caused by diffraction of electrons at those lattice planes of the microcrystals that satisfy the Bragg condition (see Fig. 2):

$$2 \cdot d \cdot \sin \vartheta = n \cdot \lambda \tag{3}$$

ϑ: B the Bragg angle, n: diffraction order,
d: distance between the lattice planes

The diameter of the diffraction ring corresponding to the Bragg angle ϑ is given by:

$$D = 2 \cdot L \cdot \tan 2\vartheta \tag{4}$$

L: distance between the graphite foil and the fluorescent screen.

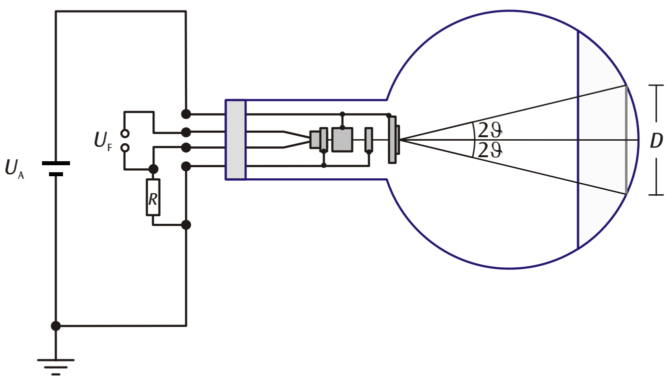

Fig. 1: Schematic diagram of the electron diffraction tube

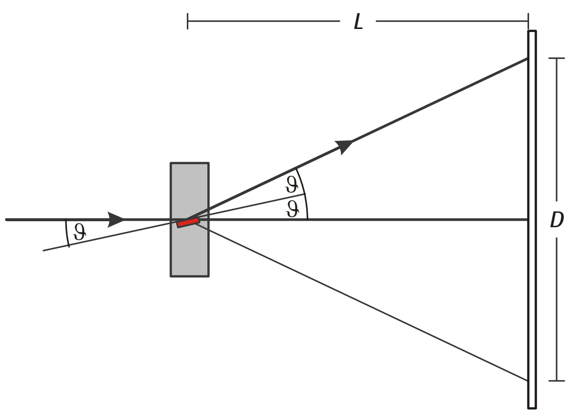

Fig. 2: Bragg reflection at a "favourable" group of lattice planes in a typical crystallite of the graphite foil

As graphite has a crystal structure with two different lattice plane distances, d_1 = 123 pm and d_2 = 213 pm (see Fig. 3), the first-order diffraction pattern (n = 1) consists of two diffraction rings with diameters D_1 und D_2.

From the diameters of the two diffraction rings and the distances between the lattice planes, we can determine the wavelength λ by applying the Bragg condition.

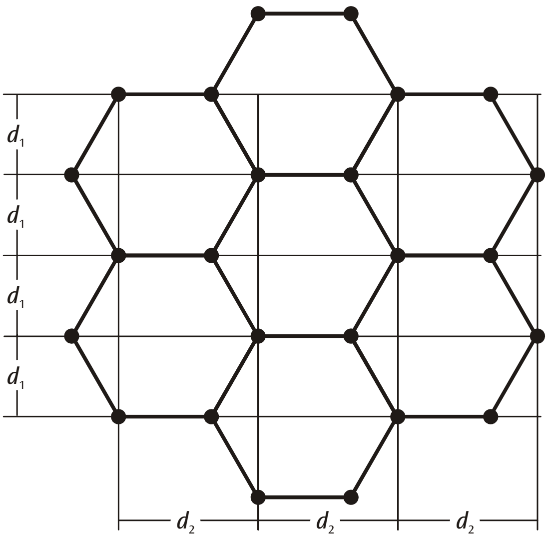

Fig. 3: Crystal structure of graphite with the two lattice constants d_1 = 123 pm und d_2 = 213 pm.

SET-UP

Fig. 4: Experiment set up

- Push the electron diffraction tube into the tube holder, ensuring that the contact pins of the tube engage with the correct holes of the holder. The middle pin of the tube should project slightly at the back of the holder.
- Connect sockets F3 and F4 of the tube holder to the heater voltage output terminals of the 5 kV high-voltage power supply.
- Connect the negative output terminal of the 5 kV high-voltage power supply to socket C5 of the tube holder and the positive output terminal to socket G7, and connect the safety earth terminals.

LIST OF APPARATUS

1	Electron Diffraction Tube S	U18571
1	Tube Holder S	U185001
1	High Voltage Power Supply 5 kV	U33010
1	Set of 15 Safety Experiment Leads, 75 cm	U138021

SAFETY INSTRUCTIONS

Hot cathode tubes are thin-walled, highly evacuated glass tubes. Treat them carefully as there is a risk of implosion!

- Do not subject the tube to mechanical stresses.

When the tube is in operation, the stock of the tube may get hot.

- If necessary, allow the tube to cool before dismantling.

EXPERIMENT PROCEDURE

- Apply the high voltage at 5000 V and measure the diameters of the two diffraction rings on the curved fluorescent screen.
- Reduce the voltage in steps of 500 V and measure the diffraction rings in each case.

SAMPLE MEASUREMENTS

Distance to the fluorescent screen: L = 130 mm,
Diameter of the glass sphere of the electron diffraction tube: D = 100 mm,
Lattice constants: d_1 = 123 pm, d_2 = 213 pm

Table 1: Diameters of the diffraction rings and calculated electron wavelengths at different accelerator voltages

U / V	$\lambda(U)$/ pm	D_1 / mm	sin ϑ_1	λ_1 / pm	D_2 / mm	sin ϑ_2	λ_2 / pm
2500	24.6	58	0.105	25.9	32	0.060	25.8
3000	22.4	50	0.092	22.7	29	0.055	23.4
3500	20.8	47	0.087	21.4	26	0.049	21.1
4000	19.4	43	0.080	19.7	25	0.048	20.3
4500	18.3	41	0.077	18.9	23	0.044	18.7
5000	17.4	39	0.073	18.0	22	0.042	17.9

EVALUATION

The theoretical de Broglie wavelengths $\lambda(U)$ are calculated from the values of the voltage U in Table 1 by applying Equation 2.

As the diameters D_1 and D_2 of the diffraction rings are measured on the curved surface of the fluorescent screen, the curvature, defined by the diameter D of the glass sphere, must be taken into account for determining the Bragg angle ϑ_1 or ϑ_2. Applying Equation 3 we obtain:

$$\lambda = 2 \cdot d_{1/2} \cdot \sin\vartheta_{1/2} \quad \text{where} \quad \sin\vartheta_{1/2} = \frac{D \cdot \sin\left(\frac{D_{1/2}}{2 \cdot D}\right)}{4 \cdot L}$$

Table 1 lists the theoretical de Broglie wavelengths $\lambda(U)$ and the electron wavelengths λ_1 and λ_2 calculated from the experimental data by applying the Bragg condition. The comparison is shown graphically in Figure 5. The straight line in the figure is calculated on the assumption that the two wavelengths (experimental and theoretical) are identical.

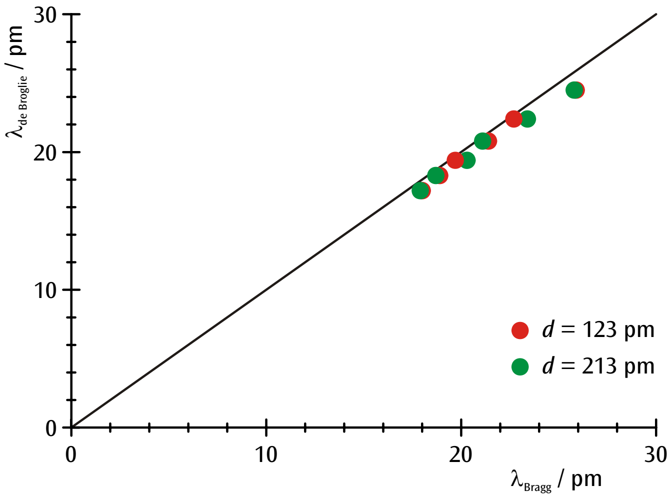

Fig. 5: The relation between wavelengths determined experimentally using the Bragg condition and the theoretical de Broglie wavelengths