Experiment 13

DETERMINATION OF THE CHARACTERISTIC CURVES OF THE DIODE VALVE

In this experiment on the diode valve the anode current is measured as a function of the potential difference between cathode and anode. The three-halves-power law for the diode is also verified.

INTRODUCTION

The emission of electrons from a wire heated to a high temperature is called thermionic emission or the thermionic effect. There is a minimum amount of energy required for the electron to overcome the attractive forces of the positive ions which form the lattice of the metal and free it from of the surface of the metal. This energy is called the work function of the metal and it is different for different metals with their values lying in the range 2 - 5 eV. At room temperatures very few electrons have this amount of energy. However an increase in the temperature of the metal increases the energy of the electrons and at sufficiently high temperatures a significant emission of electrons will occur. Indeed the saturation current which is equal to the current emitted from the surface depends strongly on the temperature. The density J_S of that current is given by

$$J_S = A\,T^2\,e^{-\frac{\Phi}{kT}} \qquad (13.1)$$

where T is the temperature of the surface, Φ is the work function, k is the Boltzmann's constant and A is the Richardson's constant. As can be seen from (13.1) the temperature at which significant thermionic emission is attained depends on the value of the work function and it is in the range from 800 K to 2300 K.

The diode valve consist of two electrodes, the cathode which is an emitter of electrons and the anode which is held at higher voltage with respect to the cathode. The anode attracts the electrons producing an electron current in the valve. The current reaching the anode depends on the potential difference between the cathode and anode and its dependence is shown in figure 13.1. At V_{ac} equal zero the current i_a at the anode is not zero because electrons leaving the cathode surface have an initial velocity with which they can reach the anode.

To prevent

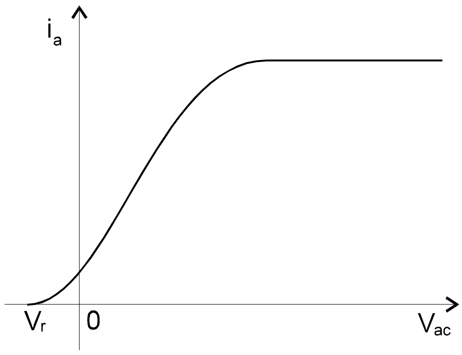

Fig. 13.1. A graph showing anode current i_a in a diode valve as a function of the potential difference V_{ac} between the anode and cathode

their reaching the anode a retarding field is necessary which is produced by a voltage of V_r. As the anode voltage is increased the current in the diode increases and at a certain value of the voltage becomes saturated. If the potential difference between anode and cathode is not very high the anode current is limited by the space charge created in the vicinity of the cathode. For this region of V_{ac} the three-halves-power law for the diode applies

$$i_a = C\, V_{ac}^{\frac{3}{2}} \tag{13.2}$$

where C is a constant depending on the geometry of the electrodes.

Figure 13.1 and also equation (13.2) show that the diode valve does not obey Ohm's law. It indicates that the anode resistance R_a of the valve which is defined as

$$R_a = \frac{V_{ac}}{i_a} \tag{13.3}$$

is not constant and its value varies with the current i_a.

APPARATUS AND METHOD

The diode and its power supply circuit are shown schematically in figure 13.2. The potential difference between anode and cathode is controlled by an adjustable power supply and is read on a voltmeter. The current in the diode is

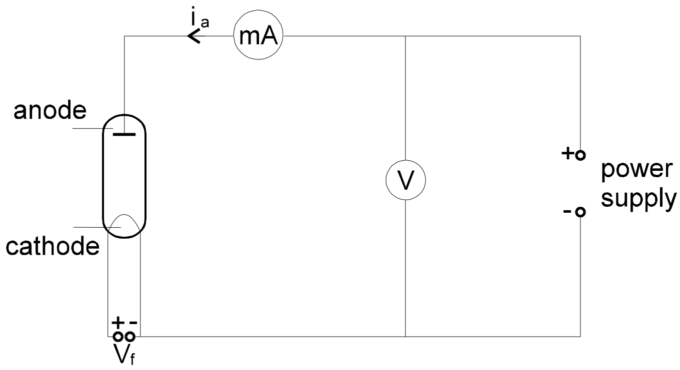

Fig. 13.2. Diagram of an electrical circuit used to measure the characteristic curves of the diode valve

recorded by a milliammeter. The cathode filament current and thus the temperature of the cathode is regulated by adjusting the filament voltage V_f.

In the present experiment the three-halves-power law can be verified by producing a logarithmic plot of the anode current as a function of the anode voltage. From equation (13.2) the following relationship can be obtained,

$$\log i_a = \frac{3}{2} \log V_{ac} + \log C \tag{13.4}$$

and thus a straight line can be drawn for a plot of log i_a against log V_{ac}. The slope of this line is equal to $\frac{3}{2}$, the exponent of V_{ac} in equation (13.2). The region of V_{ac} in which the experimental points fit well the linear dependence indicates the voltage region for which the three-halves-power law holds.

MEASUREMENTS

1. Measure the anode current of the diode valve as a function of the anode voltage in the range from zero to a value which gives saturation of the current. Repeat these measurements for two different values of filament voltage V_f.
2. Draw plots of the anode current against the anode voltage on linear and logarithmic scales and find the voltage region for which the three-halves-power law holds.
3. Draw plots of the anode resistance against the anode current.

ANALYSIS OF ERRORS

The uncertainties in the measurements of current and voltage are to be determined during the experiment and should be included in the figures as error bars.

QUESTIONS

1. Give Ohm's law and indicate the difference in the characteristic curves of a diode and a resistor obeying Ohm's law.
2. Explain how you would measure the charge and mass of an electron.
3. Explain whether it is possible to obtain straight line motion of a charged particle in the presence of electric and magnetic fields which are perpendicular to the particle's velocity and to each other.
4. Describe another physical processes (apart from the thermionic emission) where the work function plays a critical role.