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LOW-PRESSURE STREAMER CHAMBER IN A MAGNETIC FIELD

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Operation of a streamer chamber is studied at low pressure (P = 1.3–15 Torr) in a magnetic field H = 0–9 kG. It is shown that localization of tracks at these pressures in the plane perpendicular to the electric field is no worse than in operation at normal pressure. The dependence of the streamer diameter and the electron diffusion coefficient in the track on the magnetic field strength is obtained.

1. INTRODUCTION

THE reduction of electron diffusion in a gas in a magnetic field can be utilized to improve the localization of particle tracks in streamer chambers.[1] This effect is stronger if the gas pressure is lower. On the other hand, reduction of the gas pressure in the chamber is interesting from the point of view of reducing the amount of material in the particle path or in extending the possibility of ionization measurements. The latter fact is especially important, since it is known that under certain conditions precision measurements of the specific ionization of relativistic particles are possible in a streamer chamber.[2] These conditions can be reduced to choice of the optimal gas pressure, which is determined by electron diffusion and by the specific number of ionizing collisions in the particle track.

Reduction of the electron diffusion by placing the chamber in a magnetic field permits a substantial reduction of the working gas pressure, which on the one hand makes possible measurement of the ionization of slow particles (here the ionization can be hundreds of times greater than for relativistic particles), and on the other hand provides new possibilities of use of the streamer chamber as a spectrometer for high energy particles, since with reduction of the gas pressure the density effect in the ionization loss is shifted to higher energies.

In the present work we have investigated the properties of a streamer chamber in a magnetic field with gas pressures of 1–30 Torr.

2. EXPERIMENTAL APPARATUS

We used a streamer chamber of dimensions 30 × 15 × 5 cm in which was placed a Po^{210} α source (α-particle energy 5.3 MeV) and a semiconductor detector (DKP sd-125). The chamber was placed in a magnet with a maximum field H = 9.1 kG. The high-voltage pulse, which was produced by a three-electrode spark gap in a short circuited cable, had a rectangular shape with a rise time $\tau_r \sim 6$ nsec and a height and length which could be varied depending on the experimental conditions. The minimal delay of the pulse with respect to the particle passage was ~0.6 μsec. Photography of the tracks was accomplished through an opening in the magnet yoke by means of a three-stage electron-optical image converter. The chamber was filled with He and Ne to a pressure of 1 to 30 Torr.

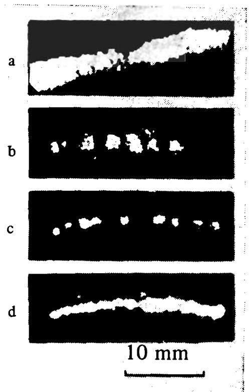

FIG. 1. Nature of particle tracks in the chamber (enlarged 1.5 times). a—chamber filled with helium, P = 15 Torr, no magnetic field; b—chamber pressure P = 1.3 Torr, H = 7.3 kG; c—chamber pressure P = 2.52 Torr, H = 7.3 kG; d—chamber pressure P = 12.6 Torr, H = 7.3 kG.

3. EXPERIMENTAL RESULTS

The nature of the tracks in the chamber is illustrated in Fig. 1. In the absence of a magnetic field, uniform luminescence of a wide region along the particle track in the chamber is observed (Fig. 1a). Turning on the magnetic field leads to appearance of a streamer track (Fig. 1b). For a pressure $P \approx 12.6$ Torr the ionization produced by an α particle in He is large and the recorded track (Fig. 1d) is a continuous band whose width in projection perpendicular to the electric field depends on the magnetic field strength. Figures 1b and c show tracks for chamber pressures of 1.3 and 2.5 Torr, respectively. At these pressures the streamers in the track have practically no overlap. Figure 2 shows the half-width of the track in He for a pressure P = 15 Torr as a function of magnetic field strength. The solid curve in this figure shows the theoretical dependence of the track half-width σ on magnetic field.

We also made a study of the change in streamer diameter with magnetic field strength and chamber pressure. The results of these measurements are shown in Fig. 3. It can be seen from curve 1 in this figure that the streamer diameter decreases with magnetic field strength much more slowly than does σ.

4. DISCUSSION OF RESULTS

The equation for the electron diffusion coefficient in a magnetic field[3] is well known:

$$D_H = \frac{D_0}{1+(\omega/\nu)^2}, \tag{1}$$

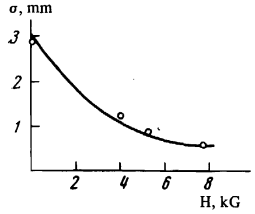

FIG. 2

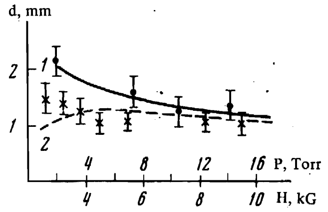

FIG. 3

FIG. 2. Half-width of track as a function of magnetic field strength. P = 15 Torr.

FIG. 3. Streamer diameter as a function of magnetic field strength (curve 1, P = 3.8 Torr) and pressure (curve 2, H = 7.8 kG).

where D_0 is the electron diffusion coefficient in the absence of a magnetic field, $\omega = eH/mc$ is the Larmor frequency, and $\nu = v/\lambda$ is the frequency of collisions of electrons with gas atoms.

For sufficiently low pressures or high magnetic fields ($\omega \gg \nu$) $D_H \sim 1/H^2$. In this case the mean square deviation of the electrons (streamers) in a track, which is determined by the well known relation $\sigma = (2D_H t)^{1/2}$ where t is the delay time in application of the high-voltage pulse, decreases in proportion to the increase of magnetic field, $\sigma \sim 1/H$. The experimental points in Fig. 2 are in good agreement with this dependence.

The slower decrease in streamer diameter with increasing magnetic field (curve 1 in Fig. 3) indicates that at such low pressures the streamer size is not determined by free diffusion of the electrons. The process determining the streamer size in this case can be electrostatic repulsion of the electrons in the streamer. Lozanskiĭ and Firsov[4] discuss a qualitative streamer theory which takes into account the role of electrostatic repulsion. According to this model the streamer diameter is $d \approx 0.8\sqrt{lR/2}$, where l is the streamer length determined experimentally; R is the radius of the avalanche at the moment of its transition to a streamer, $R \approx \sqrt{4D_0 t}$; D_0 is the electron diffusion coefficient; and t is the time of avalanche development before the transition to a streamer. In a magnetic field the streamer diameter is

$$d \approx 0{,}8 l^{1/2} t^{1/4} D_H{}^{1/4}. \tag{2}$$

Equation (2) was used to calculate the streamer diameter as a function of magnetic field strength and gas pressure in the chamber for an average electron energy ~3–4 eV.[5] The results of this calculation are shown in Fig. 3 (curves 1 and 2).

The experiment which has been performed confirms the possibility of using a streamer chamber at pressures a hundred times less than atmospheric. Here the localization of the tracks in a plane perpendicular to the electric field depends on the magnetic field strength and is essentially no poorer than for operation of the chamber at a normal pressure.

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