First observations of particle tracks in condensed matter by an emission method

A. I. Bolozdynya, O. K. Egorov,[1] A. A. Korshunov,[1]
V. P. Miroshnichenko, B. U. Rodionov, L. I. Sokolov,[1] and
V. V. Sosnovtsev

Moscow Engineering-Physics Institute
(Submitted February 21, 1977)
Pis'ma Zh. Eksp. Teor. Fiz. **25**, No. 9, 401–404 (5 May 1977)

The operating conditions are described and photographs are presented of particle tracks obtained by an emission method in crystalline krypton.

PACS numbers: 29.40.Hy

The method used in the present study to register ionizing particles in condensed matter consists in the following: the particles traverse condensed matter that borders on a gas. The electrons drift from the particle tracks in a uniform electric field to the flat boundary of the condensed phase and emerge to the gas, where they continue their drift to the anode. Following the electron emission, a discharge-producing pulsed electric field is applied to the gas. Being localized near the electrons emitted from the condensed phase, this gas discharge makes visible the particle tracks in the condensed matter.

A review of the literature and a detailed analysis of the capabilities of a track detector or emission chamber based on the use of the above-described emission method of particle registration is contained in[1] (for a chamber filled with argon). In the present study we have realized a krypton variant of a two-electrode emission chamber. The chamber was a hermetically sealed parallel-plate capacitor cooled to the temperature of liquid nitrogen (≈ 78 K). The distance between the chamber electrodes was 1.6 cm, and diameter of the reticular part of the upper electrode, through which the photographs were taken, was 12 cm. The space over a 5-mm layer of crystalline krypton, deposited on the lower electrode, was filled with neon gas, so that the pressure in the chamber was close to normal (the partial pressure of the krypton vapor was approximately 2×10^{-3} atm).

The emission chamber was exposed to the beam of the ITEF (Institute of Theoretical and Experimental Physics) Proton synchroton. The energy of the protons and ions was approximately 3 GeV, and the average particle intensity in the chamber volume was approximately 10^{-3} sec^{-1}. Two scintillation counters mounted outside the chamber in the beam path (ahead of and past the chamber, respectively) recorded the single particles passing parallel to the chamber electrodes. The trajectory spreads were approximately 5 mm in height and 80 mm in width. By varying the heights of the counter locations it was possible to register particles passing through the condensed krypton or through the neon gas. To register the particle tracks in the condensed krypton (emission tracks), a homogeneous constant electric field of approximate intensity 2 kV/cm was produced between the chamber electrodes. The electrons drifted in this field from the particle tracks in the crystal through its surface and were

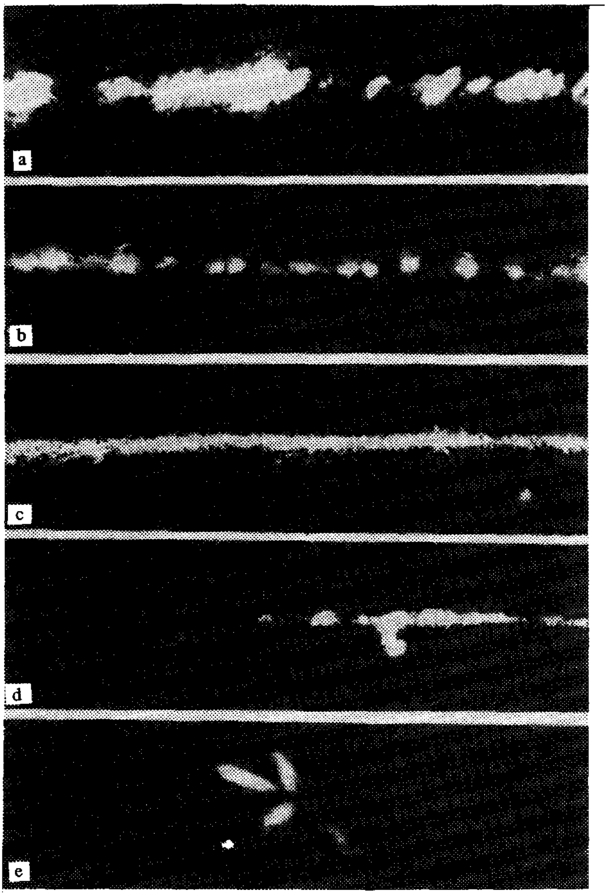

FIG. 1. Photographs of particle tracks in emission chamber (horizontal dimension of photograph 10 cm). a) Particle track in neon gas at room temperature and 1.8 atm pressure. There is no drift field and the amplitude of the high-voltage pulse is approximately 10 kV/cm. b) Track of particle passing through the gas over crystalline krypton (see below concerning the photography conditions). c) Typical emission track. Multiple scattering of the particle in the crystalline krypton is noted. d) Emission track with δ electron. Despite the intense development of the discharge along the δ-electron track, the trace of the relativistic particle generated by it is clearly seen. e) "Star"—several simultaneously produced tracks of strongly ionizing particles in the krypton crystal. In cases b, c, d, and e the krypton layer was 5 mm thick, the temperature 78 K, the neon pressure normal, and the constant field approximately 1.5 kV/cm. The duration of the high-voltage pulse was approximately 60 nsec in all cases. The track quality depends little on the pulse-field intensity in a wide range (2—5 kV/cm). Photography with "zenith" camera with "Yupiter-9" lens and "Type 29" aerial film.

emitted into the neon gas.[2] The tracks were made visible by the method customarily used in streamer chambers, by applying a high-voltage pulse to the chamber electrodes at 0.5 μsec after the passage of the ionizing particle through the counters. The pulse waveform was bell-shaped, the duration at the base was 60 nsec, and the amplitude was varied. The optimal delay of the high-frequency pulse relative to the instant of the passage of the ionizing particle, as well as the chamber memory time (1.6 ± 0.2 μsec), were determined experimentally, from the efficiency of track registration at different delays. The photography conditions are described in the track-photograph caption.

A typical emission track is shown in photograph (c). For comparison, photographs (a) and (b) show tracks of particles passing through the gas: in case (a) the chamber was filled with neon exclusively and operated at room temperature, while in case (b) the chamber operated in the emission regime (at the boiling temperature of liquid nitrogen, with a layer of condensed krypton at the bottom), but the counters discriminated particles passing through the gaseous neon. The photographs were taken at an approximate angle of 20° to the streamer motion direction [see photograph (a)]. The emission track appears to be almost continuous (c). The continuity of the emission tracks is due to the high density of the electrons on the tracks of the relativistic particles in krypton (approximately 2×10^5 electrons per centimeter of the path of a particle with minimum ionizing ability). Photographs (d) and (e) show that the emission chamber also registers successfully tracks of strongly ionizing particles: photograph (d) shows a relatively short track of a relativistic proton that crosses the krypton layer at a small angle and produces in it a δ electron. Photograph (e) shows the tracks of the secondary strongly ionizing particles produced simultaneously as a result of nuclear interaction (apparently at the bottom of the chamber). No local breakdowns took place when short-range strongly ionizing particles were registered.

Photographs (c) and (d) show that the emission chamber is a particle detector of remarkable sensitivity. In fact, we see on these photographs distinct tracks of particles in which the number of electrons initiating the discharge differ by an approximate factor of one thousand (the photographs were obtained under identical visualization conditions). Since, in principle, it is possible to make single electrons visible on a track, the emission chamber is capable of registering a particle with negligible ionizing ability, thus outproducing in this sense any existing detector by not less than a hundred times. The emission chamber can be used to search for particles with much less than the elementary electric charge, or for particles having no electric charge at all but having a magnetic charge (magnetic monopole), or else a magnetic or electric dipole moment.

Thus, particle tracks in condensed matter were obtained for the first time by a controllable purely electronic method.

The high electron density makes it possible to determine accurately the track axis. Single tracks are registered for the most part even in a relatively intense beam (10^6 particles/sec). This is due to the short memory time and to the high operating speed of the emission chamber.

[1]Institute of Theoretical and Experimental Physics (ITÉF).

[2]The electron drift velocity in crystalline krypton and in neon gas, as well as the electron emission from the krypton, were monitored by an electroluminescence procedure.[1] The drift velocities in the crystal and in the gas were both close to 10^6 cm/sec.

---

[1]B. U. Rodionov, "Emission-Chamber Project," in: Eksperimental'nye metody yadernoi fiziki (Experimental Methods of Nuclear Physics), No. 1, p. 36, Atomizdat 1975.