Electrostatic emission of free electrons from solid xenon

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Results are presented of experiments on the investigation of the electrostatic emission of free electrons from crystalline xenon into the gas phase. It is shown that at an approximate electric field intensity 5 kV/cm the emission probability reaches unity, so that the observed effect can be employed in particle detectors.

We present here the results of experiments on the electrostatic emission of free electrons from crystalline xenon. The construction of the two-electrode chamber for the measurements is shown in Fig. 1. The lower electrode was cooled with liquid nitrogen, and the xenon was first liquified on this electrode and then crystallized from the liquid phase. The crystal thickness in our experiments was 1—3 mm (approximate diameter 6 cm), and the interelectrode gap exceeded the crystal thickness by one order of magnitude (1—3 cm). To ionize the crystal, an α-particle source and a window covered with thin foil were placed on the lower electrode; the xenon could be bombarded with x rays through the window. The upper electrode was made of thin parallel wires and the internal volume of the chamber could be viewed through it. The emission of the electrons from the condensed phase to the gas was registered by the electroluminescence of the neon[1] with which the chamber was filled to a pressure of approximately 6 atm. The xenon and neon were purified beforehand by circulating through chipped calcium heated to 700 °C.

The light was registered through a glass window with a photomultiplier.

Figure 2 (a, b, and c) shows typical oscillograms of the signals from the photomultipliers obtained by bombarding the xenon with single α particles (the signal amplitude is proportional to the emission intensity). In the absence of an electric field, the oscillogram of Fig. 2a shows only the scintillation flash. On the other hand, if the electron with crystal are at negative potential relative to the upper grounded electrode, the free elec-

trons drift through the crystal towards its interface with the gas, and the scintillation flash is followed by electroluminescence of the neon, the intensity of which increases and the duration of which decreases with increasing field intensity (Figs. 2b and c). The duration of the electroluminescence is determined by the time of electron drift through the layer of neon gas. Since the range of the α particle in the xenon crystal is approximately 40 μ, i.e., much less than the crystal
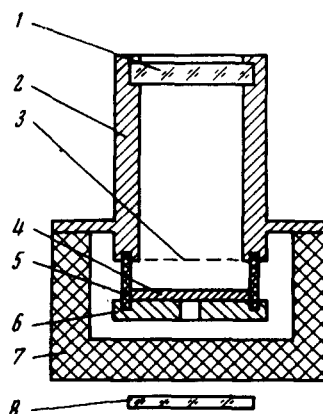

FIG. 1. Diagram of chamber: 1—glass window with thin layer of optical converter (quaterphenyl); 2—brass housing; 3—wire electrode; 4—xenon crystal; 5—teflon tube of 10 cm diameter; 6—brass electrode with α-particle source on the inner surface and with a window for the entry of the x rays; 7—foamed-plastic vessel for the liquid nitrogen; 8—auxiliary scintillation counter (the photomultipliers are not shown).
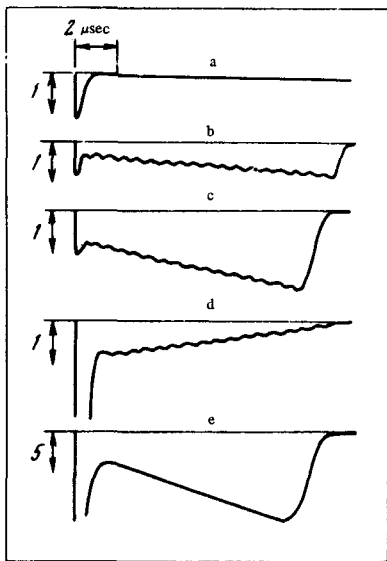
FIG. 2. Signal oscillograms: a—scintillation flash from α particle in solid xenon ($T \approx 100\,°K$); b, c—scintillations in xenon and electroluminescence of neon gas, initiated by the emission electrons from the α-particle tracks in fields 3.3 and 4.7 kV/cm; d, e—scintillations in xenon and electroluminescence of neon in an approximate electric field 3 kV/cm, initiated by cosmic particles; d—electrons drifting downward; e—electrons drifting upward (from the crystal into the gas).

FIG. 3. Probability of electron emission from solid xenon at various electric field intensities E. Measurement results are given for two crystals 1 mm thick, that differ in quality because of the difference in their crystallization regimes.

thickness, the electroluminescence of the gas (which is absent if the field polarity is reversed) offers unequivocal proof that free electrons have been emitted from the solid xenon.

To determine the emission efficiency, we performed experiments with relativistic particles. The passage of such a particle through the chamber was revealed by coincidence of the xenon scintillation flash with a signal from an auxiliary scintillation counter (Fig. 1). The oscillograms pertaining to this case (Figs. 2d and 2e) were obtained with an applied field of opposite polarity. If the electric field causes downward motion of the electrons (Fig. 2d), then relatively weak electroluminescence of neon, which attenuates in time because of the electrons produced by the particle in the gas go off into the crystal, is produced in addition to the scintillation flash (no electroluminescence of the crystal is produced at our field values). On the other hand, if the field is so directed that the free electrons produced by the particle in the crystal escape into the gas, then intensive electroluminescence of the neon is produced by the large number of the electrons leaving the
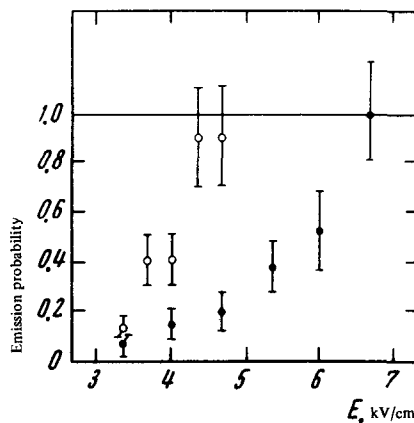
crystal (Fig. 2e). Since the electron recombination on the tracks of relativistic particles in a strong electric field is negligible, [2] and the intensity of the electroluminescence is proportional to the number of drifting electrons, [1] it is easy to determine the probability of electron emission from the crystal by performing two experiments in fields of opposite polarity. Figure 3 shows that in fields of several kV/cm the emission probability is close to unity.

The oscillograms obtained by bombarding xenon with a pulsed x-ray beam are analogous to those shown in Fig. 2.

The results show that the method of detecting tracks of ionizing particles in condensed matter, based on the emission of free electrons into the gas phase and described by us for the case of liquid argon in[2] can be extended to include also two-phase solid-gas systems. Just as in the case of liquid argon, it is possible to determine uniquely the particle coordinates and their ionizing ability.

[1]Yu. A. Butikov, B. A. Dolgoshein, V. N. Lebedenko, A. M. Pogozhin, and B. U. Rodionov, Zh. Eksp. Teor. Fiz. 57, 42 (1969) [Sov. Phys.-JETP 30, 24 (1970)].
[2]B. A. Dolgoshein, V. N. Lebedenko, and B. U. Rodionov, ZhETF Pis. Red. 11, 513 (1970) [JETP Lett. 11, 351 (1970)]; B. A. Dolgoshein, A. A. Kruglov, V. N. Lebedenko, V. P. Miroshnichenko, and B. U. Rodionov, JINR Preprint R1-6145, Dubna, 1972; Fiz. El. Chast. At. Yad. 4, 167 (1973) [Sov. J. Part. Nuc. 4, 70 (1973)].