Electron localization over a liquid hydrogen surface

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Electron localization on stationary levels in a two-dimensional potential well over a liquid hydrogen surface has been detected. The lifetime of the electron layer is on the order of 1 minute. Tests with liquid neon showed the absence of long-lived electron states.

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Stationary "dielectric levels" of electrons which occur in potential wells near cosmic dust particles consisting primarily of hydrogen are considered in[1]. These dielectric levels, whose eigenfrequencies are in the $10^{11} - 10^{15}$ Hz range, may play an essential part in the formation of cosmic radiation in the submillimeter band.[2]

Stationary electron levels in a two-dimensional potential well above a liquid He^4 surface have been well studied.[4,5] Electron levels over a He^3 surface have been investigated.[4] In principle, such levels exist at the surfaces of a number of other dielectrics,[6] however, they have not yet been observed.

The foregoing explains the interest in studying the electron levels above a hydrogen surface. Electrons in the lower level should form a two-dimensional layer at a spacing of 20 Å from the liquid hydrogen surface; the depth of the lower level is 11.5 MeV or 3×10^{12} Hz. Such levels were detected in this work, and tests were performed to observe electron levels above a liquid neon surface.

The following "diode method" was used in this work to detect a two-dimensional

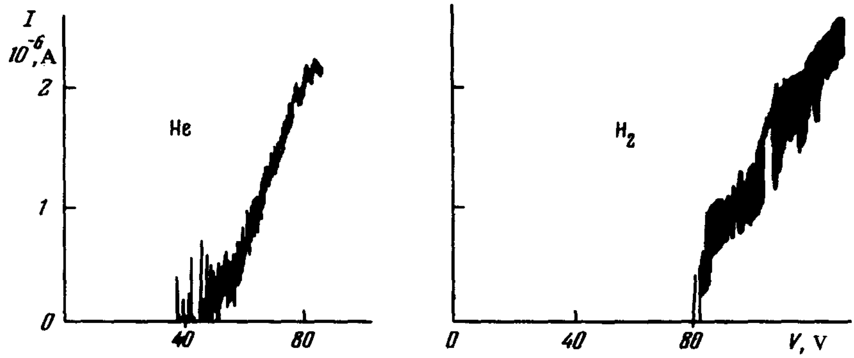

FIG. 1. Current-voltage characteristic of a diode (V is the voltage on the diode) containing: a-He, 75 mm Hg pressure and 2.48 K temperature; b-H_2, 170 mm Hg pressure and 16.1 K temperature.

electron layer over a liquid (He, H_2, Ne) surface. The method consists of measuring the current-voltage characteristic of the diode formed by two plane-parallel horizontal electrodes (ϕ 15 mm) in the gap between which (4.2 mm) the surface of the fluid being investigated is positioned. Electrons enter the gap from a glow discharge at the point of a discharger which is above the upper electrode, a grid-fabricated cathode (the cell is 30 μm). The diode is placed in a sealed glass Dewar with the cold duct soldered underneath.

The temperature in the Dewar is regulated by its displacement along the vertical in the cryostat relative to the liquid He^4 bath, and is measured by means of the vapor pressure of the gas being investigated in the Dewar. The quantity of condensed fluid and the state of its surface are checked visually.

The current-voltage characteristic of the diode, obtained in a controlled test with He^4, is shown in Fig. 1a. There is no current through the diode when an electron layer exists above the liquid surface for a field $E < E_{cr}$ in the gap, where E_{cr} is the critical field at which instability of the charged liquid surface sets in.[7,8] (Let us note that E_{cr} is considerably less than the field of electrical breakdown of the liquid layer in the gap.) For $E = E_{cr}$ current appears and grows rapidly with the increase in the field E, becoming equal in order of magnitude to the current flowing through the diode filled with gas (when the liquid surface drops below the lower electrode, the anode). For $E < E_{cr}$ the liquid surface is at rest and slightly depressed by the effect of the field E on the electron layer; for $E > E_{cr}$ and current through the diode, the liquid surface fluctuates. This picture and the measured values of E_{cr} agree with the results of Ref. 8.

The current-voltage characteristic of the diode obtained in the test with H_2 is shown in Fig. 1 on the right: it evidently agrees qualitatively with the characteristic of a diode containing He^4. Under the effect of the field $E = 1$ kV/cm $< E_{cr}$, the charged surface is lowered ~0.2 mm relative to the uncharged surface (outside the diode). The measured values of E_{cr} for H_2 correspond to the results of a computation according to Ref. 7, with the field inhomogeneity in the capacitor taken into account:

E_{cr}, kV/cm	1.30	1.45	1.47	1.48	1.68
h, mm	0.96	1.21	1.35	1.49	1.79

(where h is the thickness of the liquid layer).

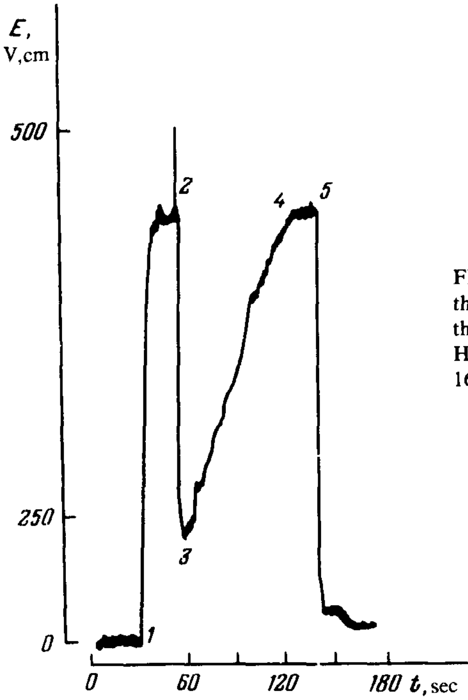

FIG. 2. Record of the change in the electrical field under the diodes upper electrode (cathode) in a test to measure the electron lifetime in a two-dimensional layer above a H_2 surface. Pressure is 190 mm Hg and temperature is 16.3 K.

An instrument described in Ref. 8 was used to measure the lifetime of the electron layer above the liquid H_2. A capacitor with a capacitive sensor of the displacement of the upper plate suspended elastically and drawn into the electrical field E above the fluid was placed at the site of the diode. The course of the test is demonstrated in Fig. 2. At time *1* a voltage was applied to the capacitor which caused a change in the sensor signal proportional to E^2. At time *2* the electron emitter (the excursion on the record) was switched on for a short time, after which the field above the liquid turned out to be almost completely shielded *3* by the electron layer above the H_2 surface. The number of electrons diminished with time and they vanished completely *4* after ~ 80 sec. Disconnecting the field at time *5* resulted in a return of the sensor signal to the initial value.

The electron drift from the H_2 surface is apparently explained by its boiling: microscopic gas bubbles approaching the surface capture the electrons and then move to the anode under the effect of the electrical field [just as bubbles do in superfluid He^4 (Ref. 8)] on which they are discharged. The electron drift from the surface is also observed for He^4 above the λ-point and for He^3.[3,4]

The diode current-voltage characteristic in the test with Ne was almost linear, without exhibiting the existence of a noticeable E_{cr}, although the value of E_{cr} computed by means of Ref. 7 for Ne is of the same order of magnitude as for He and H_2. At the same time, the current through the diode in the presence of a liquid Ne surface in the gap turned out to be 2 orders of magnitude less than the current through diodes with gaseous Ne. Therefore, if electron levels exist above a Ne surface, then their lifetime is estimated to be of the magnitude ~ 1–10 msec. The reason for the absence of a stable electron layer above a liquid neon surface is still not clear and needs clarification.

Thus, stationary electron levels in a two-dimensional potential well were detected above a liquid hydrogen surface in the experiments described; the stability characteristics of the two-dimensional electron layer are almost those expected. The lifetime of the electron layer turned out to be on the order of 1 minute under the conditions of the experiment.

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