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Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

Abstract

Full Text

Physics

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Relaxation Oscillations in Dielectrics

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In work (^1) a phenomenon discovered for the first time was described—the occurrence in silicon of current oscillations when a П-pulse of sufficient voltage is applied. After the publication of article (^1), a number of works appeared, for example ([2-5]), devoted to the study of this phenomenon.

The phenomenon is explained as follows. Charges from impurity levels of the semiconductor are captured by surface traps, forming, in the near-surface layer of the semiconductor, a region of space charge with high resistance. When an external potential difference is applied, the main voltage drop occurs across this layer. When a sufficiently strong field is reached, multiplication of current carriers and neutralization of the space charge begin. This leads to a uniform distribution of the potential in the specimen and to a decrease of the field in the near-surface layer, and consequently to the restoration of the space charge. As a result, electrical oscillations arise in the circuit, which can continue indefinitely if the semiconductor does not heat up. Such oscillations were first obtained with pulsed voltage, then with direct voltage under cooling by liquid air, and, finally, it proved possible to obtain specimens generating under direct voltage without artificial cooling.

A very similar phenomenon has been observed in dielectrics. The present work describes results obtained with a specimen of polycrystalline barium titanate. An analogous picture has already been observed for a number of other substances, and there is reason to suppose that it may be observed for all dielectrics.

Fig. 1

Fig. 2

Figures 1, 2, and 3 show oscillograms that characterize rather well the main

Fig. 3

Figure 3: Fig. 3

features of the observed phenomenon. The oscillograms show the time dependence of the current through a barium titanate specimen 1 mm thick, with one flat and the other point electrode. The oscillograms were obtained at a direct voltage equal to 700 V. The time

the sweep for the oscillograms (Figs. 1 and 2) is equal to 0.1 sec, and for Fig. 3 to 10^{-3}. The input resistance of the oscilloscope is 10^6 Ω.

The current pulses, although not strictly periodic, are nevertheless not entirely irregular. It was often possible to observe clearly expressed groups of pulses with strictly defined amplitudes and repetition frequencies. Small amplitudes correspond to a high repetition frequency and, conversely, large amplitudes to a lower frequency.

The circuit resistance consists only of the resistance of the specimen and the input resistance of the oscilloscope. A change in the load resistance has a quite unusual effect on the picture observed on the oscilloscope screen. Changing the input resistance from 10^6 to 10^4 Ω almost does not change the amplitudes of the current pulses (with the sensitivity of the oscilloscope amplifier unchanged), but sharply reduces the duration of the pulses. For a circuit resistance equal to 10^4 Ω, the current rise time is no more than 10^{-6} sec, and the current decay time is of the order of $5 \cdot 10^{-6}$ sec.

Fig. 3

The results obtained can be explained either by the fact that the current pulses are purely capacitive, or by the fact that during the pulses the resistance of the specimen falls by 7-8 orders of magnitude.

At first, after obtaining these results, attempts were made to explain the observed phenomena not by a change in the resistance of the specimen, but by a change in its dielectric permittivity, which would be in agreement with the work of (6). However, upon careful consideration these attempts proved untenable. In particular, this process cannot be purely capacitive, since the amount of electricity flowing through the specimen during the rise of the current (discharge of the capacitor) is considerably smaller than during the decay of the current (charging of the capacitor). It follows from this that a substantial part of the current is not capacitive, but passes through the specimen. The specimen is not destroyed by the large current because the trapping of charges by surface traps and the restoration of the large resistance occur in such a short time that the current does not even have time to rise to the value determined by the minimum resistance of the specimen and the voltage of the circuit.

The final picture, although close to the occurrence of oscillations in silicon and germanium, proves to be considerably more complex, with the essential difference that in dielectrics, at the moments of the current pulses, the resistance falls not only in the near-electrode region but also in the main bulk of the specimen.

For a complete explanation of the observed processes, it is apparently necessary to take into account the formation of space charges and, consequently, of layers of increased resistance at both electrodes. The onset of the process is caused by autoelectronic emission at one of the electrodes, which produces an increase of the field in the bulk of the dielectric and an increase of the potential jump at the other electrode, leading to injection of current carriers into the main bulk of the dielectric.

All these processes lead to an increase of the current through the dielectric. Then the trapping of charges by surface traps at that one of the electrodes whose field has decreased again leads to an increase in the resistance of this layer, a decrease of the field both in the bulk of the dielectric and at the second electrode, and, consequently, to a decay of the current through the specimen.

It should be noted that the power consumed by the "generator" is so small that it can operate for tens of minutes from a capacitor of several microfarads charged to 700 V.

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Note: Figure translations are in progress. See original paper for figures.