DISCHARGE OVER THE SURFACE OF CARBON-GRAPHITE MATERIALS

E. A. Zobov, V. G. Sokolov,
A. N. Sidorov, T. I. Smirnova,
and Yu. V. Tomashevich

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High-current discharges in gases have recently attracted interest as possible sources of light for the optical pumping of lasers.

The discharge is usually excited using the electrical explosion of wires (EEW) [1] or of a system of wires [2]. In [3], along with the electrical explosion of a wire, the problem of the initiation of a high-current discharge using sliding sparks was discussed in detail.

Along with these methods for initiation, a discharge over a semiconducting surface can also be used [4]. A discharge at a carbon-graphite surface is of great interest; however, the wide use of this type of discharge has been hindered by difficulties in the fabrication of devices with a large long discharge gap (more than 20 cm). Recent advances in technology [5] have made it possible to overcome these difficulties. At the present time, the industry is producing an assortment of carbon-graphite materials which can be used for the initiation of a breakdown in discharge gaps of practically any given length. Under these conditions, it appeared of interest to investigate a breakdown at the surface of carbon filaments (CF) with a length of the discharge gap greater than 0.2 m in different gases, as well as the dynamics of its development and the dependence of the breakdown on the parameters of the parameters of the voltage source.

1. The electrical scheme of the experimental unit was an LCR discharge circuit. The capacitance C had a value of 16, 27, 2400 μF. The maximal discharge voltages were, respectively, 20, 40, and 5 kV. The inductance of the circuit in all cases was of the order of 1-1.5 μH. The role of the resistance R was played by a carbon-graphite filament, the discharge at whose surface was the subject of the investigation. The filament was put into a vacuum chamber made of Plexiglas. The discharge circuit was closed by a control commutator. The current in the circuit was recorded by a Rogowski loop.

The media currounding the carbon filament were air, carbon dioxide, helium, neon, and sulfur hexafluoride with pressures from 35 to 760 mm Hg.

The dynamics of the development of the breakdown at the surface of the filament were recorded in a shadow unit under continuous scanning conditions.

2. The voltage of the sparkover E_S of the surface of the carbon filament for all the media was found to lie in the range from 10 to 30 V/cm, and did not depend on the kind of surrounding medium (air, CO_2, He, SF_6, Ne) or on its pressure. The lower limit of E_S corresponds to small lengths of the filaments ($l \leq 0.5$ m). With an increase in the length of the gap, E_S rises and, with $l = 4$ m, is equal to 25-30 V/cm. Evaluations of the temperature of the filaments at which sparkover of the surface takes place showed that, for all the brands of carbon filaments used in the work (VMN-2, VMN-4, UT-2, TGI-2 m, UTÉP-2, TKK-2), it lies within the limits from 800 to 2400°K. The energy W', evolved in the filament at the moment of sparkover, is 6-30 kJ/g. It must be noted that, in this case, the filament is conserved and, in some cases, can be used again (at least up to a discharge energy of 50-100 kG).

The sparkover of a carbon filament takes place in the following manner: With the imposition of a voltage a current passes through the filament; the filament is heated. Under these circumstances, there is intense resorption of gases. According to the data of [5], carbon graphite can resorb up to 0.4 cm^3/cm^3 of gas with heating up to 2000°C. These gases form a hot surface layer, separating the filament from the surrounding medium. When a sufficient conductivity (thermoemission from the filament) has been attained in the layer, part of the discharge current goes over from the filament into this layer. Redistribution of the current leads to overheating and breakdown. The whole process of sparkover of the surface of the filament takes place in the

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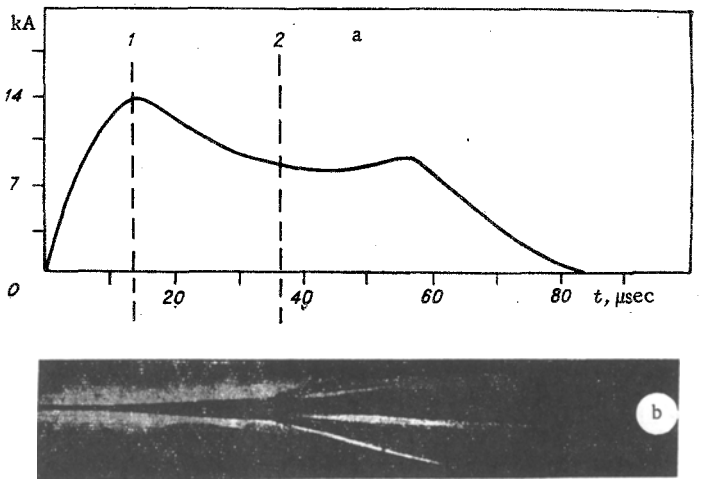

Fig. 1

a layer, consisting mainly of resorbed gases. Thus, the effect of the kind of surrounding medium and its pressure on the value of E_S is excluded.

Investigations of the dynamics of the development of the breakdown by a shadow method with synchronous recording of the discharge current confirmed the above picture of the development of the breakdown over the surface of a brand UT-2 filament (Fig. 1, length of gap l = 27 cm). On the shadow scan (Fig. 1b), the number 1 shows the moment of departure of the resorption products from the surface of the layer and vaporization of the material. The vaporization takes place at a very high rate. The diameter of the filament increases by 3-5 times due to swelling of the fibers. The number 2 denotes the moment of sparkover of the filament, the development of a plasma at its surface, and the appearance of a shock wave. On the oscillogram of the current (Fig. 1a), there is a point of inflection and a second maximum of the current, brought about by a sharp drop in the resistance of the discharge circuit. At this moment, it is determined by the resistance of the plasma of the surface discharge, which is much less than the resistance of the filament.

Figure 2 shows the dependences of the resistance of the discharge circuit of the gap on the time with different values of the initial voltages in the condenser battery (15 kV (1), 17 kV (2), 20 kV (3), 26 kV (4)). Curve 1 corresponds to the time course of the change in the resistance of the filament with pulsed heating without a surface breakdown. In this case, the resistance of the filament R_1 in 15-20 μsec decreases by 6 times and is stabilized at this value; it characterizes the dynamic resistance of the filament in the discharge circuit and determines the heating temperature and the rate of the resorption process and the process of the vaporization of the material of the filament. Curve 2 corresponds to the dependence R(t) with E = E_S = 15 V/cm; for curves 3 and 4, E = 22-25 and 35 V/cm. The moment of sparkover is determined by the point of inflection on the curve of R(t). With this resistance, in 10-15 μsec the gap decreases from R_1 to R_2 (the drop is approximately 10 times). With an increase in the voltage above E_S, the character of the dependence R(t) does not change. The duration of the state corresponding to R_1 decreases. With a value of E_S = 35-40 V/cm, on the curve of R(t) the section corresponding to R_1 disappears, and the resistance of the gap drops from R_0 to R_2 in a time of 15-20 μsec. In

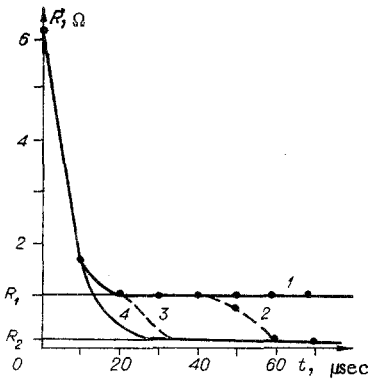

Fig. 2

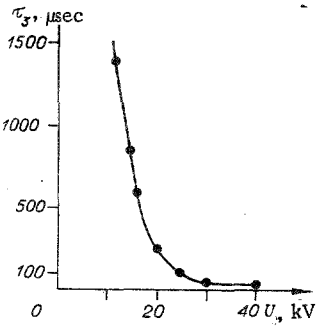

Fig. 3

this case, the sparkover, along with the thermoemission, is affected by autoemission from a multitude of micropoints, covering the carbon-graphite filament.

Between the moment of the application of the voltage to the gap and the sparkover of the surface of the gap, there is a time pause τ. With initial small resistances ($R_0 \sim 10$-50 Ω/m) and masses of the filaments of 1-2 g/m, τ does not exceed 30-50 μsec. With $R_0 > 1$ kΩ/m and 0.1-0.8 g/m, τ = 1-5 μsec, τ determined the duration of the heating of the material of the filament up to the temperatures of intense gas evolution and thermoemission. With a rise in the voltage E above E_s, τ decreases rapidly. Figure 3 shows an example of the dependence of τ on the voltage for a filament of brand TKK (length of gap l = 50 cm, medium air, C = 27 μF). With a value of the voltage $E = 2E_s$, the duration τ decreases by more than two orders of magnitude.

If we compare a discharge at the surface of carbon-graphite filaments with other methods of initiating extended discharges, a number of its advantages must be noted.

1. The low value of the sparkover voltage. Breakdown of a gap with a length of 3-4 m can be effected with a voltage of 20-25 kV in the condenser battery. For the electrical explosion of wires of this length 40-50 kV is required.

2. The possibility of selecting the resistance of the discharge gap over a wide range (R_0 from 1 Ω/m or more). This makes it possible to achieve compatibility between the load and a source of energy in the form of an inductive energy accumulator or a magnetocumulative generator. With the use of these energy sources, the "interception" of the accumulated energy of the load depends on its initial resistance [6, 7]. With a resistance of the load much less than the resistance of the breaker, the losses in the breaker can be considerably reduced and expenditures of energy for preliminary heating of the gas-discharge load up to the required value of the resistance can be eliminated.

3. With a discharge at the surface of carbon filaments, there is no pause of the current, which, in the case of the electrical explosion of wires, is frequently the reason for the development of considerable overvoltages in the circuit.

With open discharges, a filament can be used for the initiation of 3-4 successive discharges.

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