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INVESTIGATION OF ELECTRICAL EXPLOSION OF CYLINDRICAL FOILS IN AIR. COAXIAL HIGH-CURRENT DISCHARGES

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Recently great interest has been revealed in electrical explosion of foils due to wide possibilities of its practical application. These possibilities range from foil current breakers, in which precautions are taken to suppress shunting discharge [1-3], to electric discharge light sources [4-7], in which exploding foils initiate and form high-current discharge.

The present report gives the investigation results of electrical explosion of cylindrical foils in air and explosion-initiated high-current discharge. The experiments were carried out in two regimes:

a) the exploded foil cylinder was an internal current-carrying conductor of the coaxial system (geometry of self-pressed discharge);

b) the cylinder was an external current-carrying conductor of the coaxial system (geometry of expanding discharge). In the experiments the aluminium foil cylinders, mounted on an insulating rod, were exploded. The cylinder length and perimeter (l = 550 mm, b =150 mm) remained constant, only the foil thickness varied (h = 6,10,20, 50 μm). The experiments were carried out at a capacitor bank charge voltage U_0 = 35 kV which corresponded to a stored energy W_0 = 180 kJ.

In our experiments besides of the Rogovsky loop for measuring discharge current and the voltage divider on discharge gap for recording its ohmic component, number of diagnostics for studying the high-current discharge properties have been applied. They included high-speed photography of discharge, recording of plasma omission spectrum, measurements of its brightness temperature T at various wave lengths, probe measurements of plasma magnetic fields and calorimetric measurements of radiation energy.

The experimental set-up and diagnostic methods are described in detail elsewhere [3,4].

As earlier study on electrical explosion of foils in self-pressed discharge geometry showed [3-5], electric-discharge plasma radiation in the region of wave lengths λ = 270÷500 nm approaches black body radiation. Maximum brightness temperature of plasma and rate of its radial expanding do not depend on the mass of exploding foils ($T \simeq 2.5$ eV, υ = 1.5 ÷ 3 km/s).

At the same time the change in foil thickness in this range leads to the significant change in T(t) dependence. With the "thin" foils which serve only to initiate the discharge, plasma achieves T_{max} in a time equal roughly a quarter of the discharge circuit natural period. With the "thick foils" which serve also as commutators to switch the current into gas discharge, effect of "sharpening" of plasma radiation pulse is observed.

In fig.1a,b the results of measurements at the investigation of exploding foils in the expanding discharge geometry are given. The upper parts of fig.1 show initial curves-discharge current I(t) and voltage at a discharge gap U(t). Absolute and relative resistance curves R(t), R/R_o, where R_o is the initial resistance of the foil cylinder; curves of total electric power $P = U \cdot I$ and power $p = P/m_o$ per unit of the foil mass;

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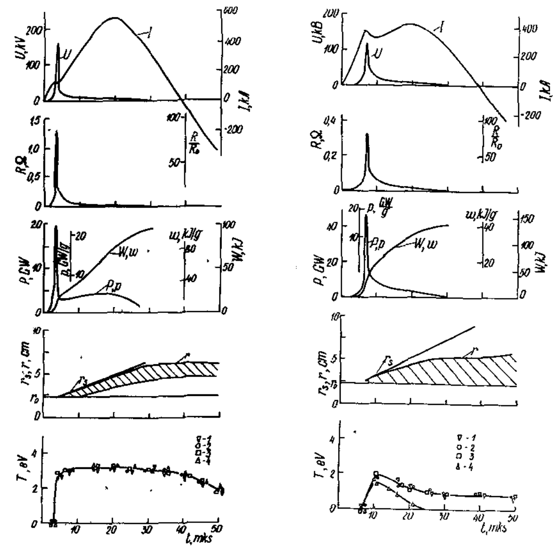
curves of energy $W(t) = \int_0^t P \cdot dt$ deposited to the instant t and energy per unit of the foil mass $w = W/m_0$, these curves are calculated.

The bottom parts of fig.1 shows temporal dependences of radii r and r_s for the plasma luminous column and secondary shock wave, and of brightness temperature T measured at various wave lengths.



a b

Fig.1.

h (μm) : a - 6, b - 20

λ (nm) : 1 - 490, 2 - 365, 3 - 280, 4 - 265

All regularities earlier observed in the investigations of electrical properties of exploding foils in self-pressed discharge geometry [3,4], are also valid with exploding foils in expanding discharge geometry. The largest changes were observed in the character of plasma column expanding and in the temporal behaviour of its brightness temperature.

At the explosion of thicker foils (Fig.1b) the intensively radiating plasma remains in the dielectric rod region as with self-pressed discharge. In contrast, with the thinner exploding foils (Fig.1a) electric-discharge plasma, affected by the magnetic field pressure, departs from the rod and shock front (v_s = 2 km/c) does not practically break away from the plasma contact surface. Earlier probe measurements showed that at the plasma front an additional current layer is formed, in which the current is pumped from the main layer [6].

As for the behaviour of T , in the thin foil regime quasistationary phase with roughly constant temperature during $\sim$40 μs at rise-time of $\sim$ 2 μs occurs. Such a phase does not exist at the explosion of thicker foils, and in this case equilibrium radiation in the short-wave region is violated.

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