EVALUATING THE MASS CONTENT AND THE ENERGY SPECTRUM OF A PLASMA JET IN A CONICAL PULSE ACCELERATOR

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Results are shown of an experimental study concerning the mass content and the energy spectrum of a plasma jet generated in a conical erosive accelerator. The effect of the discharge-circuit parameters on the ion component and on the electron temperature in the plasma has been established.

Important characteristics of a plasma jet generated in a pulse accelerator are its mass content and its energy spectrum [1]. These characteristics were studied in [2, 3] in plasma systems with an injection of gas into the discharge chamber. It would be of interest to know these characteristics also in the case of an erosive plasma accelerator.

Here are given results obtained by a mass-spectroscopic analysis of plasma clusters generated in a conical erosive accelerator.

The test apparatus (Fig. 1) consisted of a conical plasma accelerator 1, an energy storing element 2, a high-voltage discharger 3, and a vacuum system 4. The plasma accelerator included a conical Teflon-3 $[C_2F_2Cl]_n$ insulator and copper electrodes located one at the apex and one at the base of the discharge chamber. The generatrix of this cone was 100 mm long and its angle was 20°. The electrode at the base was hollow with an inside diameter 44 mm. The electrode at the apex was cylindrical with a diameter 9 mm. Inside this electrode was installed a spark source for initiating the fundamental electric discharge [4]. The energy storing element was a 200 μF bank of KIM-8 capacitors which could be charged up to 5 kV from a high-voltage rectified supply. The plasma generated by such a powerful discharge of the capacitor bank did, by erosion of the structural components in the accelerator, propagate along the vacuum chamber (Fig. 1). For the extraction of ions from the plasma, the latter was first collimated by means of diaphragms, whereupon its sample for analysis was driven into the accelerating gap and there the ion component was separated. After that, the ion flux was transmitted through a system of ion optics, where the ions were segregated according to their charge density. The ions were recorded on nuclear grade MK photographic film plates. Legible traces on these plates were produced as a result of 25 identical discharges each. The films were then developed under stringently maintained conditions. In this way, the number of ions of a given category could be determined from the degree of their interaction with the film emulsion [6].

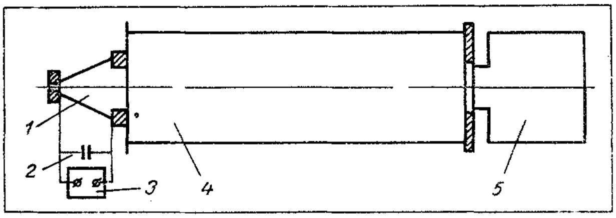

Fig. 1. Basic schematic diagram of the test apparatus.

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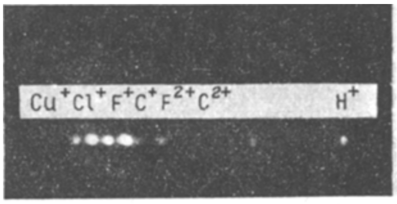

Fig. 2

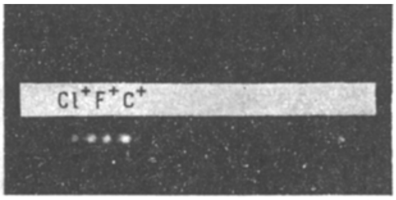

Fig. 3

Fig. 2. Mass-spectrogram of a plasma jet, obtained at voltage U_0 = 2 kV and circuit inductance $L_0 \sim 0.2\ \mu H$.

Fig. 3. Mass-spectrogram of a plasma jet, obtained at U_0 = 2 kV and $L_0 \sim 1\ \mu H$.

The mean electron temperature in the plasma was estimated with the aid of an electrostatic probe [7] placed along the axis of the plasma accelerator. The probe design and the measuring circuit were the same as in [8].

The photographic films, after appropriate processing, have revealed that the main plasma ingredients are ions of the insulator decomposition products Cl^+ chlorine, F^+ fluorine, and C^+ carbon, as well as ions of the electrode material, copper (Fig. 2). At a constant capacitor bank energy Q_0, an increase of the circuit inductance L_0 results in a lower blackening intensity of traces on the photographic film, which indicates a smaller number of impinging ions (Fig. 3). Photometric measurements of the films with inductance L_0 varying from 0.1 to 8 μH have shown that the blackening intensity p varies according to

$$p \sim \frac{1}{L_0},$$

and that this relation seems to be valid for all ions generated from the products of erosion of the accelerator materials. At a constant value of L_0, an increase of the capacitor bank energy Q_0 results in more ions in every category. We note that these relations correspond, in a qualitative sense, to those based on total-mass measurements in erosive systems [9, 10].

Our experimental studies have shown that the plasma contains not only single-charge Cl^+, F^+, and C^+ ions but also multicharge C^{++} and F^{++} ions, though only an insignificant amount of the latter ones. This is confirmed by the fact that already at $L_0 \geq 0.5\ \mu H$ and Q_0 = 500 J no F^{++} or C^{++} ions have been recorded even after 200 discharge pulses.

In addition to determining the mass content of a plasma, this method yields also the energy spectrum of ions when the velocities of the latter are spread over a wide range [5]. Actual measurements have shown that the plasma of a conical erosive accelerator does not contain enough ions with an anomalously high energy (of the order of 1 kV). The energy spectrum of the ions was not examined in detail, however, because of the inadequate resolving power of the given analyzer.

The temperature of the electron component T_e was measured with an electric probe and, according to the data, this temperature is only a weak function of the electric circuit parameters, namely of the inductance L_0 and the energy Q_0. While these quantities were varied over a wide range of values, temperature T_e changed only from 2 to 3.5 eV. Typically, the electron temperature decreased noticeably along the jet (down to 1.5 eV under the given test conditions). Estimates of the maximum ion density, based on the probe volt–ampere characteristic for a single isolated probe indicate that it does not exceed 10^{15} cm^{-3} under the given test condition and varies as a function of Q_0 and L_0. According to [11], in a conical accelerator with reverse current feed the main mass of the active medium is accelerated gasodynamically, while in cylindrical erosive discharge systems, according to [12], thermodynamic equilibrium prevails in the plasma already within the interelectrode region as a consequence of the high plasma density (up to 10^{15} cm^{-3}). On this basis and also on the basis of our results, then, it is possible to explain the predominance of single-charge ions in the plasma jet under these particular conditions.

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