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# Investigation of the pulse plasma stream influence on the lithium Capillary Porous System

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**Abstract** In this report we present a first series of tests of the lithium Capillary Porous System (CPS). We suppose that such a system can be used as a first wall in a thermonuclear reactor. The main goal of the presented work was to study the behavior of the lithium CPS in the condition simulating the influence of plasma in various operating regimes of the thermonuclear reactor. The tests were conducted in a Plasma Focus (PF) installation. The preliminary analysis of the received results confirms the high resistance of the lithium CPS to the pulse influence of plasma flows.

**Key words** interaction of plasma with matter • lithium capillary porous system • plasma dynamics • plasma focus • thermonuclear reactor

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## Introduction

The behavior of plasma-facing materials (the first wall, diverters and others) is very important for successful and reliable operation of future thermonuclear reactors based on plasma installations. Such a process as the erosion of plasma-facing components, due to thermal energy strike of plasma flows, can severely limit the lifetime of materials and thus diminish the economic feasibility of these reactors.

Now, the concept of a lithium thermonuclear reactor [3] is developing. An important aspect of this development is the substantiation of the stability of the lithium CPS to the influence of plasma flows. It is supposed that the lifetime of CPS is significantly longer than that of pure condensed materials (like carbon or beryllium), because of replenishment of CPS by liquid lithium, due to the capillary forces between plasma pulses.

An investigation done on the TRINITI plasma quasi-stationary accelerator QSPA (plasma temperature $T < 1$ keV, energy flow density $\sim 3 \times 10^6$ J/cm$^2$, pulse duration less than 1 ms) demonstrated a great stability of the CPS to the pulse influence of hydrogen plasma. On the contrary, the condensed material is intensively destroyed in similar conditions.

In this work we study the pulse plasma stream influence on the lithium capillary porous system in another energetic and temporal range. For such investigation we used a Plasma Focus installation with the following parameters of plasma flows: energy density flux of plasma flow – $10^8$–$10^9$ W/cm$^2$, pulse duration – 100 ns; fluence of fast $D_2$ ions (10–40 keV) – $10^{14}$–$10^{15}$ [4], pulse duration – less than 100 ns.

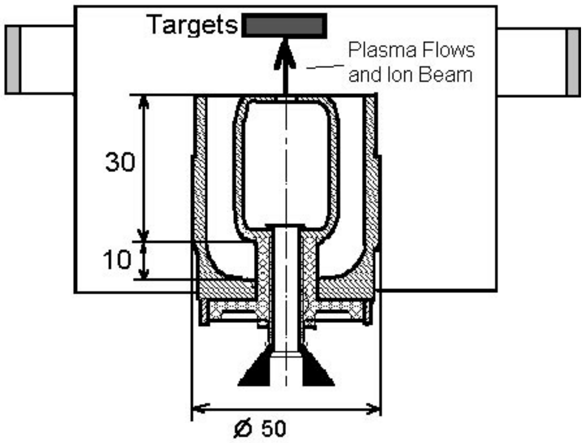


Fig. 1. Scheme of the experiment.

Fig. 2. A revolver arrangement with the samples of CPS.

## Experimental set-up

Experiments were done with the 4 kJ Plasma Focus device with special electrodes [1] (Fig. 1). Parameters of PF were as follows: energy in capacitors 2–4 kJ, maximum current 400 kA, $T_{1/4}$ = 1.5 μs. The samples of CPS were placed in the revolver arrangement (Fig. 2) at a distance of 4–5 cm from the PF anode end. The sample of CPS was a stainless wire mesh filled with liquid lithium (Fig. 3). In the experiment two types of CPS were used (Fig. 4). Diagnostics included the investigation of plasma dynamics by means of a MCP converter with the 3 ns time-resolution (in the optical range); laser interferometry; absolute neutron yield measurements; weighing before and after irradiation of the samples; microscopic investigation of the CPS surface.

## Experimental results and discussions

The weighing of the studied samples (before and after irradiation) showed that the mean loss of the CPS mass per one shot does not depend on the CPS type, and is equal to $10^{-4}$ g per pulse. Microscopic study of the sample surface after the tests showed that the space redistribution of lithium along the CPS surface took place; the melting of lithium occurred at a depth smaller than the thickness of the mesh wire; and no traces of plasma effects on the wire base of the CPS were found.

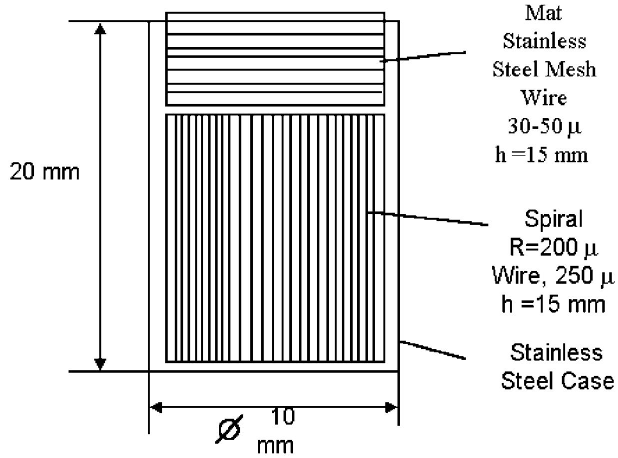


Fig. 3. Scheme of CPS sample.

Supposing that the mass loss of CPS is due only to the evaporation, we can estimate the energy flux $Q_1 = q\ \Delta m/N$ = 1.96 J ($q = 19.6\times10^3$ J/g – specific heat of evaporation, g – loss of mass, N – number of shots).

Neutron measurements: For the all series of the tests the mean value of the absolute neutron yield was about $10^7$ per pulse.

The study of plasma dynamics in visible light (by means of the MCP converter) showed that in all shots (with or without neutron emission) at a final stage of PF the axial moving appears from the anode to the cathode and the plasma flows with the velocity $V_z \sim 1.5\times10^7$ cm/s are produced (Fig. 5). From Fig. 6 one can clear see the formation of a plasma layer near the surface of the tested sample. The measurement of the electron density in the flows, as performed by

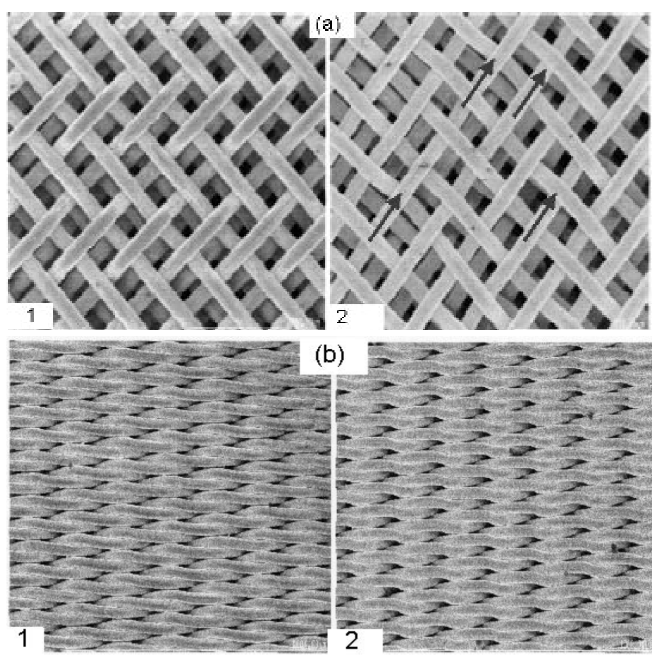


Fig. 4. Two types of the CPS samples (a and b): 1 – before the test, 2 – after the test. Arrows show some disturbances which arose during the tests.

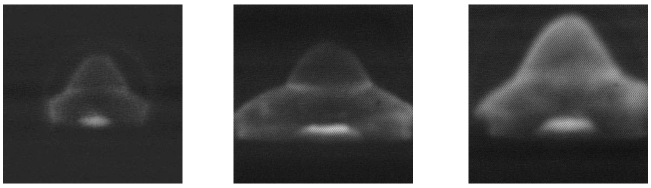


Fig. 5. Pinhole images of PF in visible light, as registered with the 3 ns exposition. “Zero” time instant corresponds to the maximum of the pinch compression (the first compression).

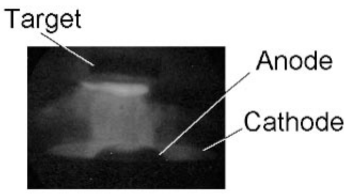


Fig. 6. The formation of a plasma layer near the sample surface.

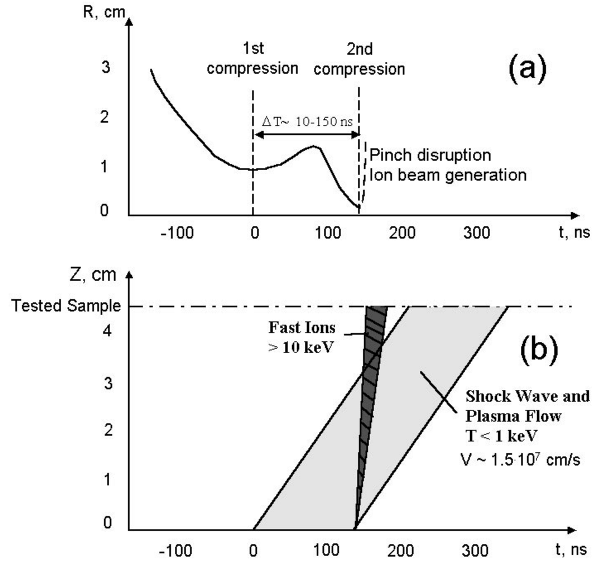


Fig. 7. The sequence of the processes in PF: (a) – R-t diagram of the pinch dynamics, R – radius of pinch, (b) – dynamics of the ion beam and the axial plasma flows.

means of the laser interferometer, gave the value $N \sim 10^{18}$ $cm^{-3}$. Hence, we can estimate the energy flux density on the target. This value is significantly higher than that estimated from the weighing.

Thus, we can give the following sequence during the processes of interaction of the plasma flows in PF with the target: using the results of research [2] on plasma dynamics of PF, the MHD calculation [5], and the results of plasma dynamics study done in this work, we can build R-t diagrams of the pinch compression and plasma flows motion (Fig. 7). It is clear seen from these R-t diagrams that fast ions should come to the target earlier than the plasma flows. These ions create a dense plasma layer near the target surface, which can diminish the plasma flow influence on the target. In accordance with the experiment done by Feugeas [4], the fluence of such ions with the energy higher than 10 keV is about $10^{14}$–$10^{15}$. Hence, the total energy of the ion beam is near 1 J. This value is in accordance with the results obtained with weighing of samples.

## Conclusion

The Plasma Focus device can be used for testing materials irradiated with plasma flows and ion beams within a wide energy range of $10^7$–$10^{10}$ W/cm$^2$. It is also worth pointing that (using special initial conditions) it is possible to suppress the generation of the fast ions in PF discharges. The preliminary analysis of the received results confirms the high resistance of the lithium CPS to the pulse influence of plasma flows and ion beams.

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