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Investigation of hydrogen isotopes interaction with lithium CPS under reactor irradiation

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HIGHLIGHTS

- The results of a study of tritium generation and release from the lithium CPS under neutron irradiation are described.
- The distribution of free tritium atoms concentration in lithium CPS depending on temperature is presented.
- The diffusion coefficients of free tritium atoms in lithium under neutron irradiation were obtained. The Arrhenius dependence for diffusion coefficients is described by $D = 0.17 \cdot exp\left(-145/RT\right)$.

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ABSTRACT

This work describes the experimental results of a study of tritium generation and release from the lithium capillary porous system (CPS) under neutron irradiation. The experiments were performed at the IVG1.M research reactor (Kurchatov, Kazakhstan) at a power level of 6 MW and temperatures from 325 to 840 °C. The studies were performed using two modes: with constant pumping out of the experimental ampoule device (differential mode) and with tritium accumulation in ampoule device (AD) with absence of the pumping out (integrated mode). The diffusion coefficients of free tritium atoms in liquid lithium under neutron irradiation were obtained. The Arrhenius dependence of free tritium atoms diffusion coefficient in lithium was derived as $D = 0.17 \cdot exp\left(-145/RT\right)$.

1. Introduction

Lithium CPS is a new composite material based on capillary-porous system made from different metals and alloys filled with liquid lithium, which was proposed in Russia [1]. This material has a self-retainable surface with self-regulating lithium consumption.

The experiments carried out in operating tokamaks and stellarator (NSTX [2], FTU [3], T11-M [4], EAST [5], TJ-II [6]) using liquid lithium and lithium CPS proved the advisability of lithium application and its attractiveness compared to traditional materials [7].

Activities in this area are also carried on at the KTM (Kazakhstan Tokamak for Materials testing) – the only tokamak in the world designed to solve the problems of materials science [8]. Now Kazakhstan scientists in collaboration with the leading international scientific organizations are implementing a major project to build and test the mock-up of lithium diverter (MLD) [9]. MLD is one of the removable segments of the diverter receiving device in KTM. The receiving plate of MLD diverter element is covered by lithium CPS based on stainless steel mesh and tungsten felt. One of the problems connected with application of such liquid lithium systems in fusion reactors is determination of interaction parameters of plasma facing surfaces with working gases under conditions of fusion devices in real operation, e.g. under neutron and gamma radiation.

In fusion devices under neutron irradiation tritium will be generated in lithium CPS according to ^{6}Li(n,α)T reaction. The information about tritium generation and release parameters in lithium CPS is very important to assess these processes influence on fusion device's operation.

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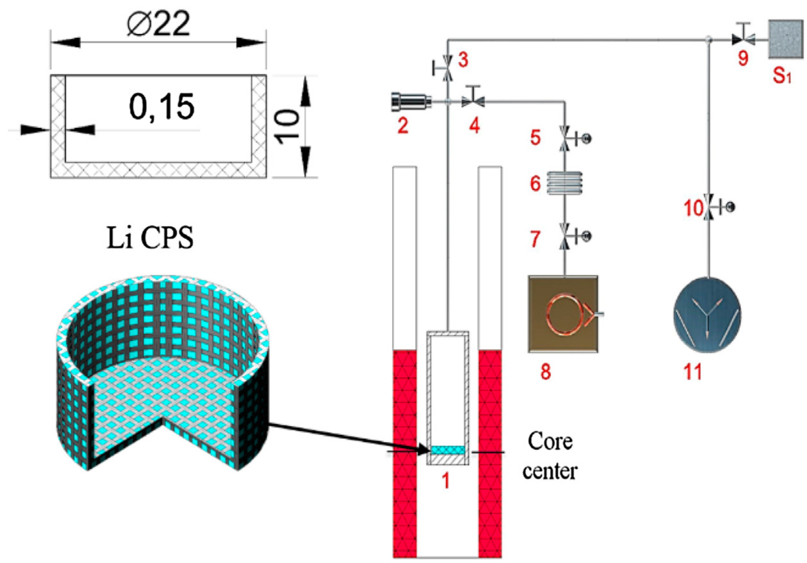

Fig. 1. Investigated sample and scheme of the experiments: 1–AD with sample; 2–pressure sensor; 3, 4, 9–manual valve; 5, 7, 10–controlled valve; 6–nitrogen trap; 8–fore-vacuum pump; 11–high-vacuum pump; S_1–mass-spectrometer.

Table 1
Conditions of reactor experiments.

Parameter	Value
Residual gas pressure in measuring channel, Pa	10^{-5}
Sample's temperature range, °C	325–840
Reactor power, MW	6

The purpose of this work is to determine tritium generation and release parameters from lithium CPS under conditions of neutron irradiation.

2. Experimental part

The cylindrical CPS matrix sample was made of metal mesh (stainless steel 12Ch18N10T) with thickness of 0.1 mm and cell size 100 μm. The free surface area of CPS was ≈9 cm^2. After the matrix preparation procedures (washing, drying, annealing) it was filled with pure lithium. The investigated sample of lithium CPS and the scheme of the experiments is presented in Fig. 1.

The mass of lithium in the sample was ≈0.42 g.

Then, the irradiation experiment of lithium CPS was carried out with mass-spectrometer registration of releasing gases. The sample in a special designed ampoule device (AD) [10] was loaded in central experimental channel of the IVG1.M [11] research reactor on the level of core center. The irradiation at 1 and 2 MW was performed with constant pumping out of the experimental AD with sample at given temperatures (differential mode). When power level was 6 MW the pumping out of the AD was alternately stopped and tritium released from the sample was accumulated in the AD (integrated mode). In the integrated mode experiments the sensitivity of the measuring system increases up to 15 times. The experimental conditions are presented in Table 1. The neutron flux in the core center of the IVG.1 M reactor is presented in Table 2.

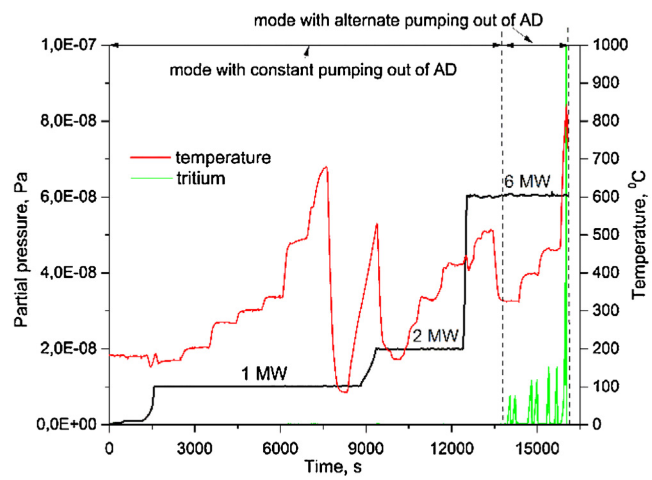

Fig. 2. Diagram of reactor experiment with lithium CPS at power levels 1, 2 and 6 MW.

3. Results of experiments

As can be seen from the experiments diagram (Fig. 2) during irradiation at 1 and 2 MW with a constant pumping out of experimental AD the tritium was not released from lithium CPS. When the pumping out was stopped at 6 MW of power level tritium started to be released from the sample, and at temperatures exceeding 750 °C a sharp peak of tritium yield was observed.

The enlarged region of experimental diagram corresponding to the integral mode of tritium release from lithium CPS at 6 MW is shown in Fig. 3. One can see from the graph that:

- When the sample's temperature was constant tritium was released linearly. Thereby linear growth occurred in less than 10 s after pump disconnection;.

Table 2
Neutron flux in the IVG.1 M core center at the power level 6 MW.

Energetic group	0–0.67 eV	0.67 eV–0.10 MeV	0.10–10.00 MeV	Integral flux
Neutron flux, 1/(cm^2 s)	$0.87 \cdot 10^{14}$	$0.42 \cdot 10^{14}$	$0.22 \cdot 10^{14}$	$1.50 \cdot 10^{14}$

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