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Experiments at the T-11M device in substantiation of the tokamak with Lithium loop cycle

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Introduction. The concept of permanent lithium circulation between the first wall and edge plasma [1] with its main cooling by noncoronal lithium radiation seems as reliable solution for steady state tokamak. This idea assumes the simultaneous solution of three main tasks: emission of lithium into the plasma, lithium collection before its absorption on a chamber wall, and its return into emission zone again. The lithium screening effect can serve as a physical basis of this concept. The tokamak local limiters could be used as an effective tool to control lithium behavior in the plasma periphery. It can be explained by a simple example of two lithium connected limiters [2, 3]. One hotter lithium limiter is positioned in a deep plasma SOL (scrape-of-layer) and works mainly as a lithium emitter. The second limiter is located in the shadow of the first one and works mainly as a collector of the lithium diffused out SOL to chamber wall ("emitter-collector" model [2, 3]). The Lithium collected by the second limiter can be return again onto the emitter limiter and to close the lithium loop in the plasma boundary region. The limiter with lithium capillary porous system (CPS [1]) was investigated as the lithium emitter early [3]. In this paper we present the first results of the lithium collection by the T-11M lithium limiter.

T-11M experiment. Three local rail limiters have been used in the T-11M device: lithium, molybdenum and graphite ones [2-4]. The Lithium migration and collection in a SOL region were studied by the postmortem analysis of the witness-samples located on a surface of limiters, and with the help of a mobile graphite probe (limiter), which could be considered as a recombination target with respect to the incident flux of Li ions. During the experiments on T-11M it was revealed, that the characteristic length of the energy deposition in a shadow of limiters is about of 1cm, while the characteristic length λ of lithium degradation in SOL was equal 2-3cm [4]. The special technique was used for the measurement of the lithium deposit on the lateral (normal to main magnetic field) surfaces of T-11M limiters.

The chemical finding of the absolute lithium amount in the sample deposit. It is known, that Lithium has a strong chemical activity to the basic components of air - nitrogen, oxygen and water vapor. During the extraction of samples from the tokamak chamber Lithium deposit has an inevitable contact with Nitrogen and the Oxygen of the air and forms mix **Li_3N:Li_2O=3:1** [5]. As result the finding of the absolute amount of the lithium deposed on a sample, represents a serious problem. It has been resolved in our experiments by the next way: the witness-samples subjected to exposure in plasma and then getting on air during opening the tokamak chamber, have been seated in the boiling water. Various chemical compounds of Lithium, which can form during the plasma exposure of witness-samples and their transportation through air, enter with boiling water following reactions: **$2Li + 2H_2O = 2LiOH + H_2$** , **$Li_3N + 3H_2O = 3LiOH + NH_3$** , **$Li_2O + 2H_2O = 2LiOH + H_2$** , **$Li_2C_2 + 2H_2O = 2LiOH + C_2H_2$.** Alkali **LiOH** appears always as their finished product**.** **LiOH** amount in the water solution and, accordingly, the initial lithium maintenance in a witness- samples were determined by a known method of chemical titrometric analysis. Absolute calibration of a method was carried out by the test lithium sample. The chemical reaction **LiOH** with the carbonic gas containing in the air could bring in measurements some error. The water is a poor solvent for **Li_2CO_3** compound. For the minimization of error the samples taken from the chamber were seated in the evacuated volumes with the minimal contents of the air and, accordingly, the carbonic gas.

Experimental results. This technique was used for measurements of the absolute amount of the lithium deposed on lateral surfaces of Li-limiter, shipped in SOL, by method of past mortem analysis of witness-samples. For this purpose two experiments have been lead. Firstly the witness-samples have been produced from a thin SS-wire grid (thick 0.03mm). Outside they have been covered by thin SS-mask (screen foil, 0.1mm) with number of holes (d=4mm), Fig.1**.**

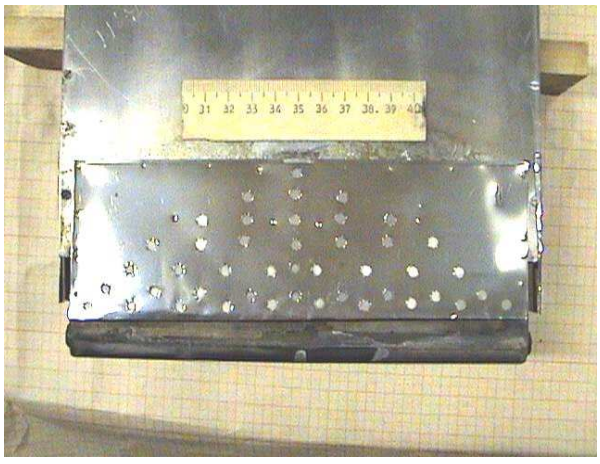

Fig.1.T-11M – witness-samples system.

The analysis of witness-samples after its exposition during approximately 200 T-11M shots has shown:

1. Li tends to remove from a "hot" zone of Li emission collect to the "cold" parts of limiter.
2. The lithium amount collected on the "ion side" of a limiter (that is, directed opposite toroidal ion drift direction) in 3-5 times above, than on "electron side".

For explanation of these features of lithium deposit we could assume:

1. Either the secondary erosion of the Lithium deposited on the "electron side" is essentially above its “ion side” erosion as a result of its higher heating, for example, or lithium ions should participate in the movement along torus with speed equal their thermal speed.
2. The reason of the liquid lithium run to colder areas can be the decrease of lithium surface tension with growth of its temperature. In that case the liquid lithium droplets are forced against a gradient of temperature of a substrate (SS-foil) in a "cold" area (Marangoni -effect). Fig.2 shows droplets of lithium (0.1-1mm) on a screen foil after plasma exposition. Maximal droplets collected in the area of the foil-limiter good thermal contact (down).

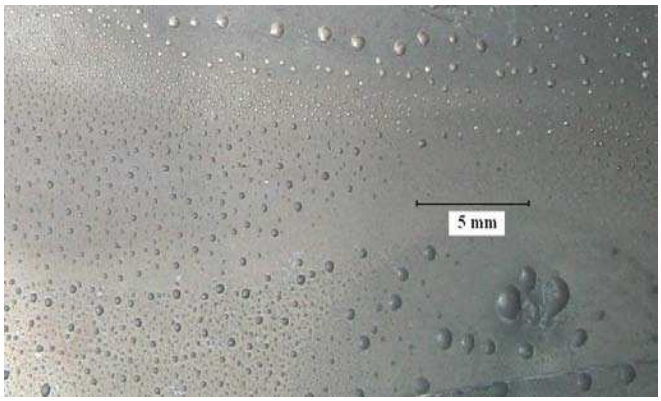

Fig. 2. Capillary forces (Marangoni) effect.

In the following experiment (1000 shots of T-11M) thin witness-samples have been replaced by rather massive (thick 1mm) tungsten "wings" (width 5mm Fig.3) to eliminate effects connected with heating of samples. Distribution of the lithium deposed on wings (Fig.4) shows:

1. As well as in the first experiment the significant asymmetry of the electron and ion sides is observed testifying in favor of the assumption of existence in SOL the lithium ions movement along torus with

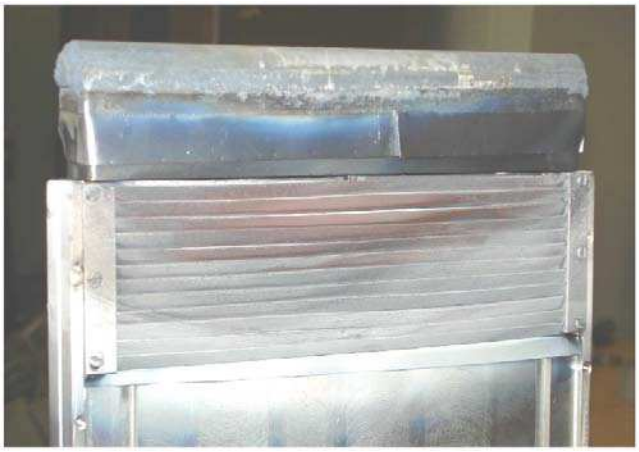

Fig. 3. Lithium limiter with W-wings.

speeds of scale its thermal speed in a direction of ion drift (that is, in a direction of main current J_p). This phenomenon should be taken to account in design of a future lithium collectors.

2. From the hot emitter towards the chamber wall the density of lithium deposit on wings falls down, and then increases again. Finally distinction of the ion and electron sides of a limiter practically disappears. It is obvious, that this phenomenon specifies different character of lithium behavior near the limiter edge and near the chamber wall (δ=5cm). It is possible to assume, that the first fall is evidence of lithium diffusion in SOL. The experiments performed earlier with Li emission probe [4] specify this assumption. Secondary rise is connected, possibly, with the lithium flux from the chamber wall. This question demands the further researches.

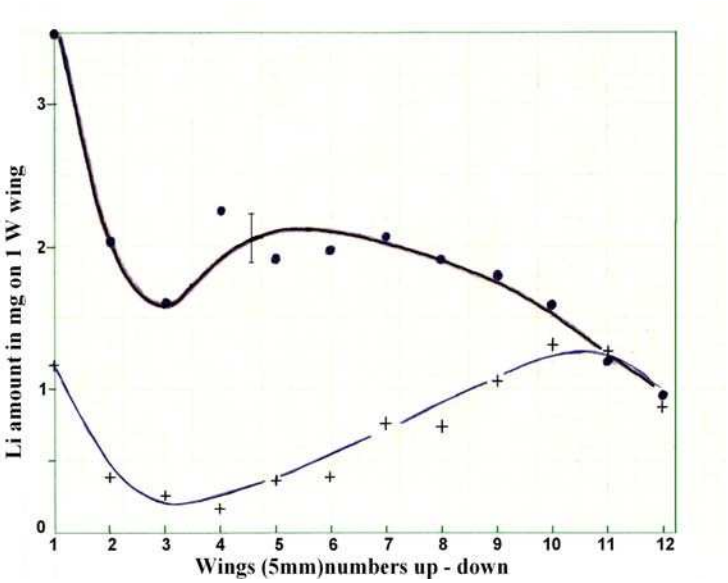

Fig 4. Distribution of Li-deposit on wings.

3. The full amount of lithium (nearby 70mg), collected by all limiters of T-11M (lithium-65 %, graphite - 20 %) and the ICRH antenna (15 %) corresponds within 30 % to the estimated lithium charge of the lithium limiter, which it lost during of all plasma shots.

However it is necessary to point, that about 5g of lithium has been put on the tokamak wall during the wall conditioning and the glow discharge cleaning of the lithium limiter. Its role in lithium circulation between wall and limiters demands the further researches.

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