EXPERIMENTAL INVESTIGATION OF RADIAL DISTRIBUTIONS OF Li^+, H^+, D^+ IN THE SOL OF T-11M TOKAMAK WITH LITHIUM LIMITER

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Introduction. Liquid Lithium (LL) is a unique material that can be used as a protective self-recovering PFC of steady state (SS) tokamak [1,2]. The migration of lithium in tokamak from a hot area of the limiter onto its cold one and the vacuum vessel wall is not known well enough but this problem is very important for the future SS tokamak-reactor design. The results of the experimental investigation of the radial lithium distribution in the SOL in T-11M tokamak were presented before [3]. The plasma parameters in the SOL (Scrape Of Layer) depend on many tokamak parameters and have great influence on the behaviour of impurities, erosion and migration in the Hydrogen/Deuterium plasma. The erosion and migration of the materials in the tokamak vessel may be the key problem in the creation of steady state tokamak-reactor. The problem of erosion will possibly be solved by the use of liquid metal (Lithium) placed into capillary porous structure [2]. In this case the most important problem is the problem of migration. The migration of impurity from "hot" areas of LL limiter or divertor to its "cold" areas and the wall of tokamak vessel in the process of tokamak discharge greatly depends on abnormal transversal diffusion of impurity ions as well as Hydrogen ions in the turbulent plasma of the SOL. Lithium is one of the main impurities for tokamak with LL limiter. The migration of Lithium in the vessel is a very important and not so well studied question. That is why the experimental investigation of radial distributions of Lithium in the SOL started on tokamak T-11M [3]. In this paper we present some new results concerning the distribution not only of Li^+, but also H^+, D^+ in the SOL of T-11M tokamak with LL limiter.

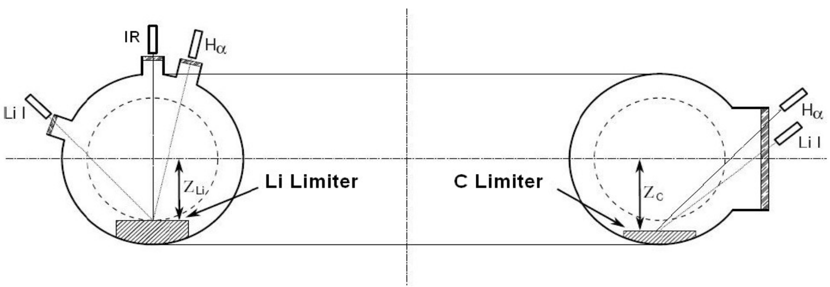

Fig.1. The experiment arrangement of the Li and Carbon limiters on T-11M tokamak and optical diagnostics.

Experiments on the tokamak. The experiments were performed in an ohmic mode (Ip=70kA, Bt=1.2T) in T-11M. The isotopic composition of gas in the tokamak vessel was checked with a mass spectrometer during the process of pumping of the vessel. Besides, during the discharges the ratio of fluxes of Hydrogen and Deuterium charge exchange neutrals from plasma was measured with mass spectrometer “Lakmus”. Both methods showed the ratio of Hydrogen and Deuterium approximately about 80 and 20% respectively when they were used in the experiment. The experiment arrangement of the Li and Carbon limiters on T-11M tokamak and optical diagnostics are shown in Fig.1. Two limiters were used: a lithium one, which was used as the main limiter, located at the fixed radial position 17.5cm, which was the source of Lithium and an auxiliary graphite limiter on radial position from 18 to 26cm on the opposite position (180°) of the tokamak tore, which was the movable probe. The recycling light intensity of neutral lithium spectral line (Li I λ=670,8nm) and H-alpha line (λ=656,3nm) was measured from the vicinity near the graphite probe limiter surface with two photodiode receivers with narrow-band interference filters. Since the intensity of the neutral atom spectral line is proportional to the flux of neutrals into the plasma and the flux of neutrals is proportional to the flux of Li^+ ions to the surface, it is obvious that the intensity of the line (Li I/H-alpha) is proportional to the flux of $Li^+/H^+/D^+$ ions. So the distribution of lithium and hydrogen/deuterium fluxes in a SOL can be obtained by measuring the Li I and H-alpha spectral line intensity on the C-limiter surface as a function of its position. The response signal from C- limiter and the input signal from Li-limiter (the source) are shown in Fig.2.

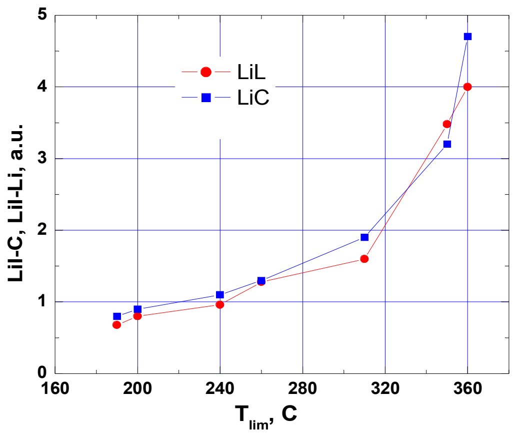

Fig.2. Response and input signals: intensities of the LiI line near the Li-limiter surface (LiL-red points) and graphite limiter (LiC-blue points) depending on initial temperature of the Li-limiter. The graphite limiter was in the “shade” of the Li-limiter on the radius about 20 cm.

Results of the experiments. The results of radial distributions of recycling light intensity or Li^+ and H^+/D^+ ions measurement in Hydrogen discharge are presented in fig.3 in logarithmic scale. The data were received with average electronic density $\mathbf{n_e}\approx 2*10^{13}cm^{-3}$. The initial temperature of the Lithium limiter was about 220 °C. Both curves have characteristic breaks on the radius about 21cm. It is the radius on which the edge of HF antenna is. This edge also serves as an additional limiter [3]. The characteristic length of decrease λ (coefficient in exponential function in Fig.3) characterizes the radial decrease of Lithium and Hydrogen ions flux.

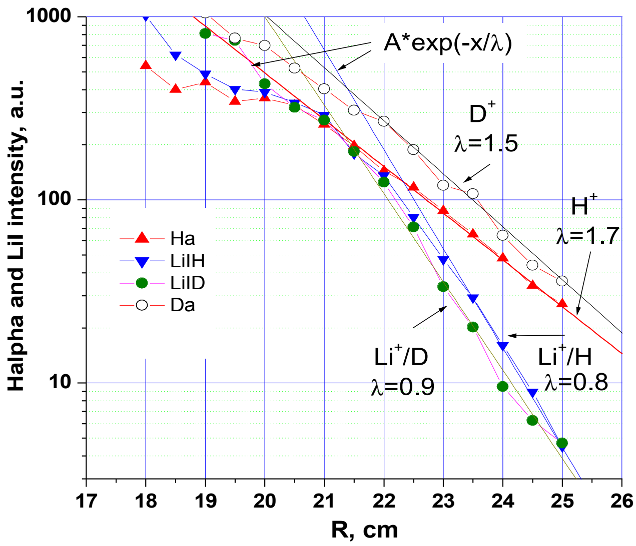

Fig.3. Radial distributions of recycling light intensity of Li^+ and H^+/D^+ ions in the SOL of lithium limiter of T-11M.

From Fig.3 one can see that the radial flux distributions (and density) of Lithium and Hydrogen ions in the "shade" of the limiter considerably (about 2 times for λ) differ. I.e. Hydrogen ions penetrate into the SOL area considerably deeper than Lithium ions. SOL plasma parameters on different radiuses in this set of experiments were measured by mobile Langmuir probe. These results are shown in fig.4. The characteristic length of decrease λ was also determined according to this data and for electron density λ_N coincided with λ for Hydrogen ions. So the independent method of measurements has confirmed the correctness of the method of optical measurements of characteristic decrease length λ. Besides the correspondence between λ_N for electron density and λ for Hydrogen flux shows that absolute value of Lithium ions density is considerably less than Hydrogen ions density in the SOL area.

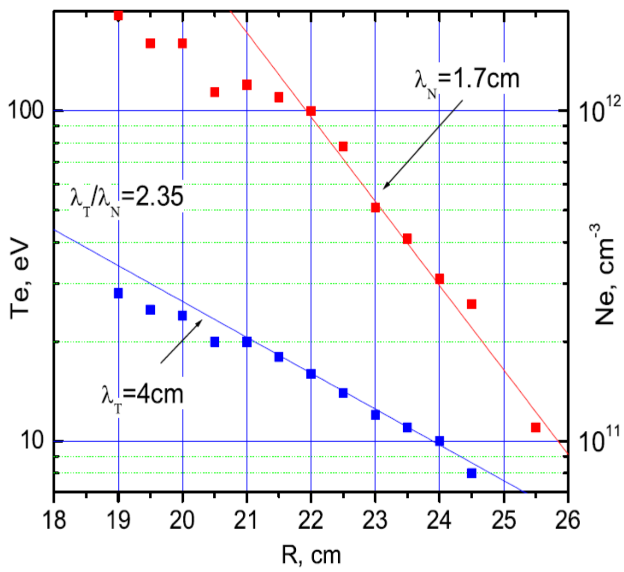

Fig.4. Radial distributions of electron density and temperature in the SOL of lithium limiter for T-11M.

Radial distributions for Li^+ and D^+ obtained in the experiments are shown on fig.3. Transversal diffusion coefficients for Li^+, H^+ and D^+ were calculated from the experimental curves (Fig.3) and turned out to be close to Bohm diffusion coefficient $D_B = kT_e/16eB \approx D_\perp \approx 1 m^2/s$ for Li^+ and substantially greater for D^+ and H^+ ions $D_\perp \approx 5 m^2/s$. We believe this difference is due to the higher mobility of D^+ ions and it needs to be taken into account to explain the migration of Li.

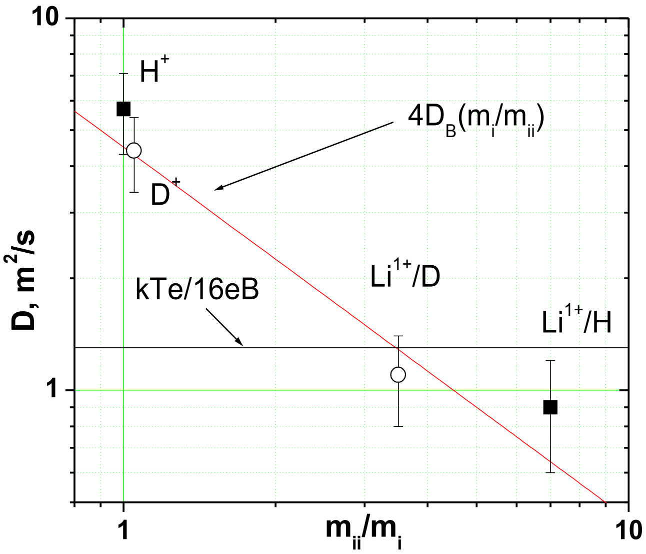

Fig.5. Dependence of transversal diffusion coefficients of Li^+, H^+, D^+ ions in the SOL of T-11M. Here: $\mathbf{m_{ii}}$ is mass of impurity ions and $\mathbf{m_i}$ is mass of main plasma ions (here it is $\mathbf{m_H}$ or $\mathbf{m_D}$).

Conclutions. The study of radial distributions for Li^+, H^+ and D^+ ions in the "shade" of the Lithium limiter was carried out in T-11M tokamak. It was experimentally shown that radial distributions for Li^+, H^+ and D^+ ions considerably differ. The characteristic length of decrease λ of Hydrogen ions flux density is about 2 times more than the correspondent length for Lithium ions in T-11M conditions. The same behaviour of distributions was found for D^+ and Lithium ions in the deuterium discharge. The analyses of flux characteristic length of decrease λ in the "shade" of the limiter allowed determining transversal diffusion coefficients for Li^+, H^+ and D^+ ions. Transversal diffusion coefficients of Li^+, H^+ and D^+ were calculated from the determined experimental λ (Fig.5) with using the value of magnetic line length [3]. It was shown that transversal diffusion coefficients for H^+ and D^+ ions in the range of experimental accuracy are almost the same while transversal diffusion coefficients of Li^+ in deuterium and hydrogen plasma differ approximately by factor $m_{H,D}/m_{Li}$ from transversal diffusion coefficients for H^+ and D^+ ions (Fig.5) and determine radial distributions of Li^+ ion density in the SOL area of the tokamak. The results on diffusion coefficients of Lithium ions in deuterium and hydrogen plasma allow calculating and simulating the behaviour of plasma in the SOL area for a tokamak with lithium limiter or divertor.

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