§ 40. Modeling of Erosion and Redeposition of Divertor Tiles

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The erosion and redeposition patterns on a divertor plate after plasma exposure provide us important information regarding the local and global transport of impurities in the plasma edge. The EDDY code [1] is applied in order to simulate the erosion and redeposition patterns on a graphite plate which was used in the third experimental campaign of LHD.

For one of the LHD divertor plates, the values of T_e and n_e at a strike point are typically 24 eV and 1×10^{12} cm^{-3} and the decay length in the poloidal direction is 0.55 cm for both; T_e=T_i is assumed. In the third campaign, the divertor plate was exposed to He plasmas (~2×10^{21} cm^{-2}) and H plasmas (~1.2×10^{21} cm^{-2}). The plasma contains impurities of carbon, oxygen, and metals, whose concentrations are estimated to be 2%, 1%, and 0.1% (Fe), respectively [2], and we assume their charge states to be +4. An areas of 4 cm×4 cm on the plate is divided into 20×20 segments. In each segment, the following dynamic erosion and deposition processes are simulated: sputter erosion, impurity deposition and collisional mixing. Sputtered and reflected impurities undergo successive ionizations by plasma electrons and gyrate in an oblique magnetic field of 1 T. Some ionized impurities redeposit promptly on the same segment as well as different segments after migration in the divertor plasma.

Figure 1 shows the typical erosion and redeposition patterns. Owing to deposition of sputtered Fe from the stainless steel wall under glow discharge cleaning, original plate surface is assumed to be covered by a Fe layer at a thickness of 0.03μm. The He plasma causes net erosion, but the H plasma causes net deposition. The total net erosion depth, therefore, is about 6μm, which is close to the measured depth [3]. The erosion and deposition are influenced by the concentrations of impurities (Fig. 2) and the temperature of the plasma exposed to the surface. As demonstrated in [4], for the H plasma, C deposition around the strike point reduces Fe atom density at the top layer of the surface, and Fe atoms are distributed inside the bulk. On the other hand, for the He plasma, Fe atoms are strongly sputtered around the strike point; at the early stage of exposure (~10^{20} cm^{-2}), the Fe density decreases to ~30% of the initial value. Furthermore, prompt redeposition of sputtered Fe with $v\times B$ can explain the observed asymmetry in Fe distributions on the divertor plate [3]. This indicates that the distribution is dominated by the He discharge.

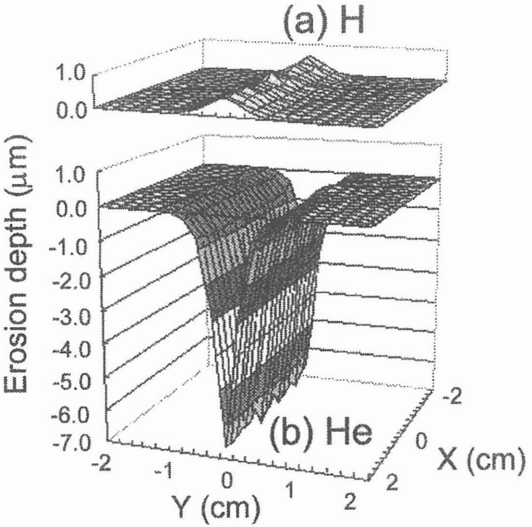

Fig. 1. Erosion and redeposition patterns after exposures of (a) H and (b) He plasmas containing impurities of C (2%), O (1%), and Fe (0.1%).

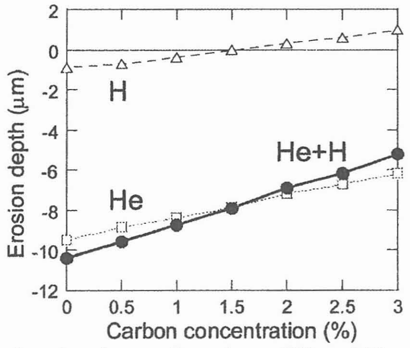

Fig. 2. Erosion depth as a function of H and He plasmas.

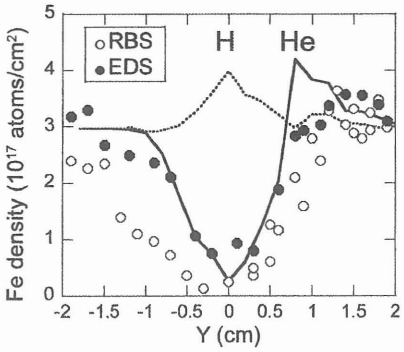

Fig. 3. Calculated and observed Fe distributions on the divertor plate.

References

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