§64. Damage Study of Laser Fusion Reactor Wall Using Laser-accelerated Ions

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In laser fusion reactors, the fuel pellet is compressed to high density to initiate ignition by the irradiation of high power, nano-second laser pulses. In the implosion process, the laser-irradiated surface of fuel shell expands rapidly so that the remaining part moves to the center of the shell, which is so called "rocked effect". The imploded fuel plasma will cause fusion process for their stagnation period. The burning time will be ~100's ps. The ablated matter can reach the reactor wall and may cause damage in the wall. The ablated matter is originally in the state of plasma and could be partially ionized or neutral atoms when they arrive the wall. The fusion processes will also produce energetic particles. The particles arriving the reactor wall can be very intense due to short pulse duration as seen in Ref 1., which is unique to the laser fusion reactors. It is important that the wall of laser fusion reactors are designed to sustain its soundness under the heavy loads due to the irradiation of such high energy flux particles (HEFP).

The HEFP irradiation may cause the ablation or the melt of the wall surfaces if the particle flux is too high. One approach to this issue is to use a liquid metal as a reactor wall since the flowing liquid can quickly recover the ablated area. Another possible approach is to keep the fusion power low so that the particle flux can be kept lower than the ablation or melting threshold as proposed by Goto et al. [2]. The later approach can be good to avoid reactor wall damage due to the thermal effects, such as ablation or melting, in the short operation period. However, in the reactor design, it is also important to consider the damage of the wall in long-term operation. For example, the energetic particles can cause lattice defects in solid matter. Such atomic processes, namely radiation damage, could not be negligible in the fusion reactors. The damage production in thermal or atomic processes by the irradiation of HEFP has not been studied well. We have proposed to study the damage production processes by the usage of energetic, intense ion beams produced via ultra-intense laser-matter interactions.

In FY14, we have performed the first experiment using LFEX laser at the Institute of Laser Engineering, Osaka University. The laser energies were up to ~600 J in ~1 ps pulse duration. The laser pulse was focused on the wedge glass target and produced energetic electrons. The energetic electrons excites the sheath field around the target, which accelerates ions, mainly protons, towards the surface direction of the target. The process is well known as the target normal sheath acceleration (TNSA). Since a wedged target was used in the shots, the sheath accelerated ions are emitted to a different direction from the laser axis or the normal direction of the target surface irradiated with the laser pulse as shown in Fig. 1. The samples to irradiate the accelerated ions are placed in the direction of the target rear normal direction to maximize the ion flux and to reduce the irradiation of the fast electrons and target debris mainly emitted to the laser axis or the target front normal direction. In the experiment, iron and nickel chips (5x5x1 mm) were placed at ~3 cm from the wedge target as samples after they were annealed and polished to enable various observation means using optical microscopes and electron microscopes, for example.

Figure 2 shows the surface of ion samples before and after the shots (625 J/1.5 ps). The pictures were taken with an optical microscope. It is seen that the samples after the laser shot is clearly damaged. The inside of the samples are under investigation using electron and x-ray beams to study if there is atomic damage.

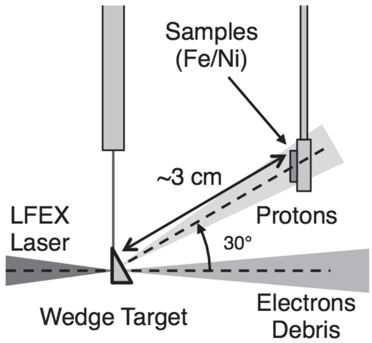

Fig. 1. Schematic of the experimental setup (side view).

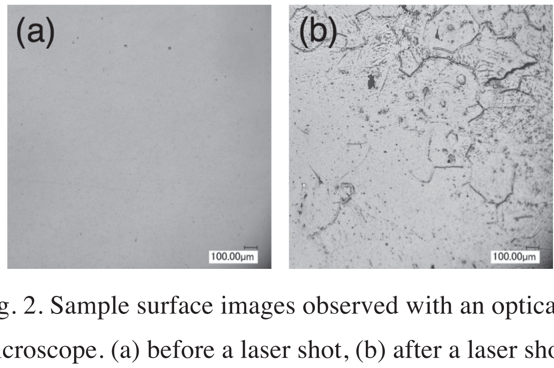

Fig. 2. Sample surface images observed with an optical microscope. (a) before a laser shot, (b) after a laser shot.

1) Yamamoto, K. et al.: J. Plasma Fusion Res., **83** (2007) 19.
2) Goto, T, et al.: Nucl. Fusion, **49** (2009) 075006.