§2. Wall Plasma Interaction Using Ablated Plasma Plumes Induced with Laser and Ion Beams

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Our collaborative research has welcomed the final year as LHD project research fund that has connected Osaka University, NIFS, Univ. Hyogo, U. of Electro Communications. Throughout the course, we were successful to produce unique research results related to the reactor damage studies relevant to MFE and IFE. Reactor components such as divertor plate are subject to extreme environments where plasma, liquid, gas, and solid phases exist at the same time. It is thus of critical importance to study these extreme states in order to have a good understanding and design criteria for future reactors with a systematic manner. The systematic means here that we should be able to cover various materials with a broad range of incoming thermal flux assisted with a full scale computer simulation. Our main machines were laser and plasma systems rather different from the previous studies of this kind.[1]

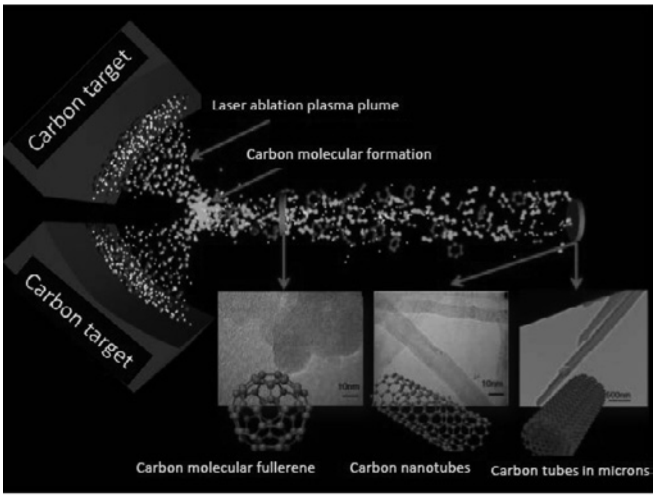

Figure 1 Carbon nano tube formation in laser ablated colliding plasma plumes.

We have performed several experiments using both laser and plasma devices. In our double laser beam configuration where two laser beams irradiate orthogonally two solid targets that have a 1.25 cm radius concave curvature. Once the ablated plasma is created on each target, two plasma plumes cross each other. We define one of the plasma plume as an incoming plasma and the other as a shielding plasma plumes. The laser specifications are 1J, 351 nm, 6 nanoseconds as the laser energy, laser wavelength, laser pulse width. The plasma parameters at the plasma cross point are 10^{12}-10^{15} /c.c. and 1-2 eV as electron plasma density and temperature for most of the target materials. The energy of incoming plume flux is absorbed with the shielding plume through the collisions. As a result of the collisions [2] in the case of Carbon-Carbon plasma plumes, carbon molecular formation has been observed such as carbon nano tubes, onion fullerene etc. and has been patented [1].

In Fig. 1, we show such experimental configuration. Ablated plasma plumes collide at 1.3 cm away from the target surface. In our separate time and space resolved measurements, the molecular formation has took several micro seconds while the laser pulse width is only 6 nanoseconds and plume expanding speed is of the order of 20 km/sec.

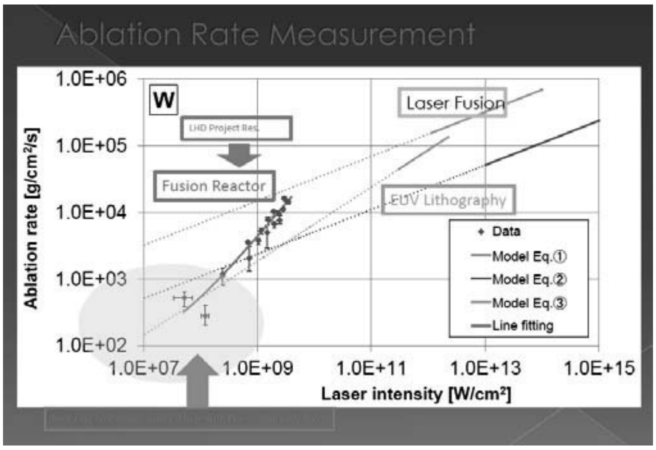

Figure 2 Ablated mass measured with both laser and plasma gun.

Another unique feature in this final report is that we have measured the mass ablation rate of various materials in the intensity region of ablation threshold. This ablation rate has not been measured so far since the laser fusion and EUV lithography studies has focused incoming flux intensity much higher than the ablation threshold such as at above 10^{14} W/cm^2. Our ablation study data has been shown in Fig. 2 with the previous laser fusion and EUV data too. Notable difference of the data dependence on the laser intensity is clear; the laser intensity is rather linear compared to the ones for laser fusion and EUV lithography show the two-third power dependence. This reason is explained by the laser absorption mechanisms are different at these two regions: one at above 10^{11} W/cm^2 and another at 10^7 W/cm^2. One more point should be noted in this figure. The ablation rate data taken at the plasma machine at U. Hyogo are shown at the lowest data points of a few times 10^7 W/cm2. These data taken at both laser and plasma ablation are shown first time to be consistent each other.

[1] Y. Hirooka, K.A. Tanaka, et al., J. Phys. Conf. Ser. 244, 032033 (2010); Y. Hirooka,et al., Fusion Sci. Technol. 60, 804 (2011); K.A. Tanaka, et al., Fusion Sci. Technol. 60, 329 (2011).

[2] S. Misaki, A. Sunahara, T. Kono, T. Yabuuchi and K.A. Tanana., APS-DPP, 53rd Ann. Meet., UP9.00090 (2011); A. Sunahara, K.A. Tanaka, Fusion Engineering and Design 85 (2010) 935–939