§32. Induced W-rod Melting Experiment in the LHD Divertor

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Tungsten (W) is a candidate of plasma facing material (PFM) in the next generation fusion devices such as DEMO from the viewpoints of tritium retention and dust generation in vacuum vessel. One of the problems of W as PFM is surface modification by melting [1]. Melting also causes impurity injection to core plasma with splash or spray phenomena [2]. So it is necessary to predict the motion of the melt layer, and to investigate the transport of droplets of W in the next generation fusion devices for safety and steady operation. In LHD, small W-rods were exposed to divertor plasma by using movable material probe system to investigate melting layer behavior and droplets transport.

Figure 1(a) shows the material probe setup. Three W-rods with different lengths (5×5.6×1mm, 5×20.2×1mm, 5×15.1×1mm) were on the graphite stage. The graphite stage was for collecting W ejected from the rods. Incident angle of magnetic field lines was ~70 degree to the rods surfaces, and parallel to the graphite stage surface. This material probe was installed from a bottom port (4.5L port) in LHD. The rods were exposed to NBI heated hydrogen discharges, and total exposure time was ~ 4 s. We could not observe spray, splash and droplet motion during experiment. The surface analyses of the rods and the graphite stage were conducted after the exposure.

Figure 1(b) shows the rods after the exposure. Two rods' edges melted, but the shortest rod did not melt. That means the high heat flux area was narrow as shown in Fig. 1(b) like a sheet-plasma. It was consistent with the previous observation of the divertor plasma profile with Langmuir probes [3]. Forces to melt layer are gravity, Lorentz-force (***J***×***B***) and plasma pressure. J is current between plasma and rods caused by electron thermal emission. The melt layers did not move in the gravity direction, but they seemed to move plasma flow direction. In this experiment, Lorentz-force was considered to be small because the angle between J and B was small.

Figure 2(a) shows the surface of the graphite stage after the exposure. Droplets were not observed on the stage. Around the melted rods, the surface color was changed by deposits. EDX (Energy Dispersive X-ray analysis) was conducted, and the dominant deposit was confirmed to be W. Figure 2(b) shows the two dimensional distribution of the W composition ratio around the top rod. The extension of the distribution at the plasma upstream side (front) was smaller than that at the plasma downstream side (back). Figure 2(c) shows the comparison between measured W composition ratios profiles at the front and back sides and simple cosine distribution. At the back side, they were similar though the composition ratio profile was much narrower than cosine distribution in the front side. From these results, it is considered that W sputtered or evaporated from the rods deposit on the graphite stage, and W atoms were ionized in the divertor plasma in the front side. The mean-free-path of sputtered W for ionization is around 10mm.

1) Roth, J. et al.: Journal of Nuclear Materials **390-391** (2009) 1.
2) Coenen, J.W. et al.: Journal of Nuclear Materials, in press.
3) Ezumi, N. et al.: Journal of Nuclear Materials **313-316** (2003) 696.

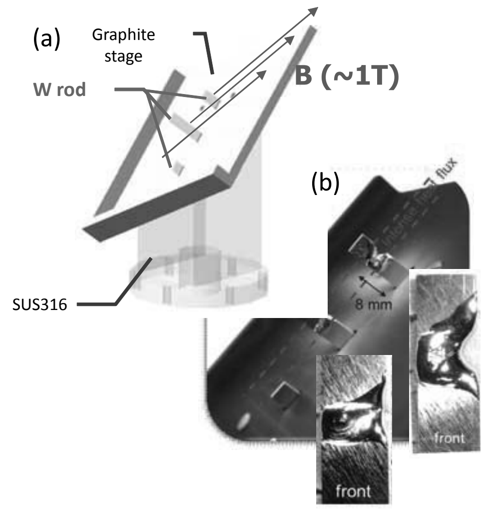

Fig. 1. (a) Experimental setup. (b) W-rods after plasma irradiation.

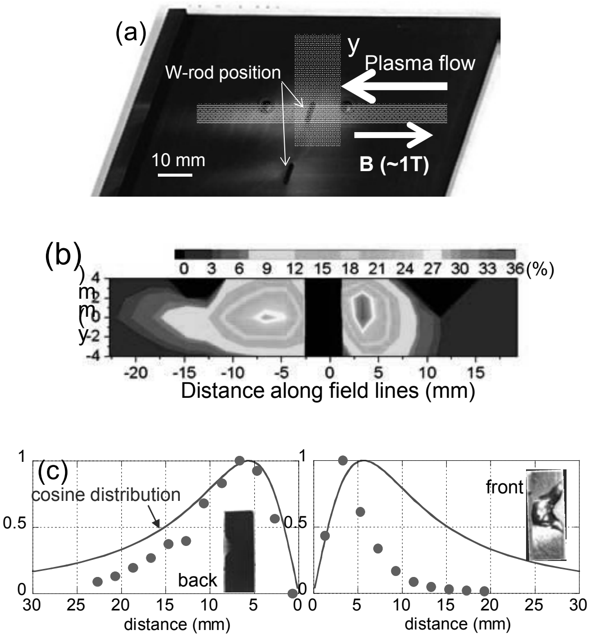

Fig. 2. (a) W deposited graphite stage. (b) 2D distribution of W composition ratio on the stage. (c) W composition ratio profiles normalized by the max value along y=0 line at front and back sides, respectively. The composition ratio was measured by EDX (Energy Dispersive X-ray analysis).