Analyses of the plasma generated by laser irradiation on sputtered target for determination of the target thickness used for plasma generation†

M. Kumaki,[*1,*2] Y. Fuwa,[*1,*3] S. Ikeda,[*1,*4] M. Sekine,[*1,*4] N.Munemoto,[*1,*4]
D. Cinquegrani,[*5] T. Kanesue,[*6] M. Okamura,[*1,*6] and M. Washio[*2]

A Laser Ion Source (LIS) has been developed at Brookhaven National Laboratory (BNL) [1]. A focused high-power laser is used to generate plasmas containing highly charged ions from solid targets. For every laser shot, we provide a new surface because the irradiation creates a crater, and the second irradiation on the same spot causes beam instability. However, the depth of the target required to generate the plasma is not yet clear. We assumed that only the surface layers of the material were converted to the plasma, and knowledge of the surface layers to be converted to the plasma is necessary to understand the initial processes of laser-ablation plasma creation. We prepared a carbon-coated aluminum plate as a target. By analyzing the contents of the ablation plasma, the effective depth required to generate the laser plasma was investigated.

The target surface was divided into four segments, and each segment has different carbon coating thickness; the thicknesses were about 25 nm, 125 nm, 250 nm, and 500 nm. To generate ablation plasma, the segmented target with multi thickness coating was irradiated by a Nd:YAG 1064 nm focused laser (Brilliant Quantel, Energy: 728 ± 5 mJ (rms); Pulse Width: 6 ns). We analyzed the generated plasma using an electrostatic ion analyzer (EIA) and a secondary electron multiplier (SEM) to measure the current distribution of ions of each charge state [2].

Figures 1 and 2 show the charge-state distribution of measured ions of the un-coated aluminum target and 500 nm carbon-sputtered target, respectively. These current distributions were reconstructed from the signals obtained using the SEM with the scanning EIA voltage. The C^{6+} could be clearly separated, but C^{5+} and C^{4+} were contained by the Al^{11+} and Al^{9+} signals.

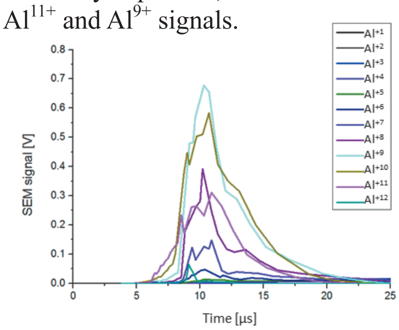

Fig. 1. Current distribution of each charge state (pure Al)

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*1 RIKEN Nishina Center
*2 Cooperative Major in Nuclear Energy, Waseda University
*3 Department of Physics and Astronomy, Kyoto University
*4 Department of Energy Sciences, Tokyo Institute of Technology
*5 American Nuclear Society, University of Michigan
*6 Brookhaven National Laboratory

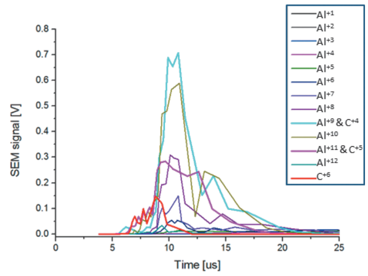

Fig. 2. Current distribution of each charge state (500nm)

Figure 2 indicates that the plasma was generated from the layers deeper than 500 nm because the Al ions still occupy the biggest fraction of the plasma contents. It is also noted that the C^{6+} ions appeared in the earliest part of the observed plasma, and the combination of Al^{+9} and C^{4+} produced the highest yield of ions at the peak position.

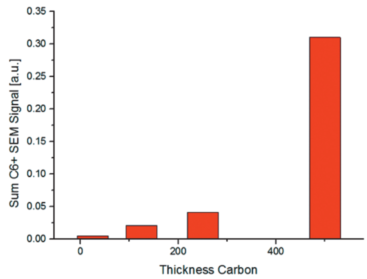

Fig. 3. Total C^{6+} particle number

Figure 3 shows the total yield of C^{6+} ions for each carbon-thickness case. The amount of C^{6+} ions was not linearly increased by the sputtered carbon thickness. The result implies that the surface layer has less contribution to form the ablation plasma. The layers from 250 nm to 500 nm were used more efficiently than the surface layer up to 250 nm depth to generate the plasma.

Using the carbon-coated aluminum target, the charge-state distribution was measured. We confirmed that the required thickness of the target for the plasma generation is more than 500 nm. We also found that the surface layer up to a few hundred nanometers in depth has less contribution than the deeper carbon layers. To investigate further, we need to prepare thicker carbon-sputtered targets thicker than 500 nm.

References

1) M. Okamura, et al., High current carbon beam production with DPIS, Rev. Sci. Inst. 77, 03B303, 2006.
2) S. Kondrashev, T. Kaneue, M. Okamura, K. Sakakibara Journal of applied physics 100,1 (2006)