§3. Hydrogen Depth Profiles Using Laser-induced Breakdown Spectroscopy (LIBS) on Graphite Target of Divertor in LHD

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Laser-induced breakdown spectroscopy (LIBS) is one of useful analytical methods for hydrogen isotopes with depth profiles on materials [1]. Advantages of LIBS as ex-situ measurements are (1) short time analysis, (2) elements can be detected including hydrogen isotopes, and (3) intensities mappings at 2-D positions are possible.

Nd:YAG laser that a wavelength of 1064 nm is injected to a target material under low pressure in a vacuum chamber. A laser energy per pulse is 100 mJ and a pulse length is 5 ns. A spectrometer has seven silicon CCD array detectors. A gas extraction system was installed to create a controlled Ar atmosphere

An isotropic graphite (IG-430U, Toyo Tanso Co.) exposed to hydrogen divertor plasmas using the material probe system at the 4.5 lower port in LHD. A size of IG-430 target sample is 10 mm x 50 mm x 1 mm and three targets set on a sample holder made by molybdenum as shown in Fig.1 (a). A target “C” was selected to LIBS measurement. Figure 1 (b) shows a picture of target "C" after LIBS analysis. A spot size of analyzed position is about 1 mm and each interval is about 1 mm. Analyzed points are written in Fig.1 (b). Positions 4 or 5 (P4 or P5) are located at the divertor footprint of LHD and smaller numbers are located at private regions of divertor configuration.

Figure 2 shows depth profiles of H, Mo, C and O elements at position 11 of target sample “C”. A sputtering rate by a laser pulse is not calibrated yet, but it is estimated about 100 nm / laser pulse. Higher hydrogen intensities are detected about 500 nm from the top surface. In this analytical setup, a counting of 150 (a.u) is background signal level and sufficient counts were detected near top surface regions. High molybdenum intensity at the first laser pulse are shown, due to deposited one by sputtered molybdenum holder. Carbon and oxygen intensities are uniform on this depth profile.

At present, quantitative values cannot be analyzed using LIBS, but this results using the graphite target show one of an advantage of LIBS, such as a lower detection limit of analyzers.

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[1] C.Li, et al.,J. Nucl. Mater. (2015) in press.

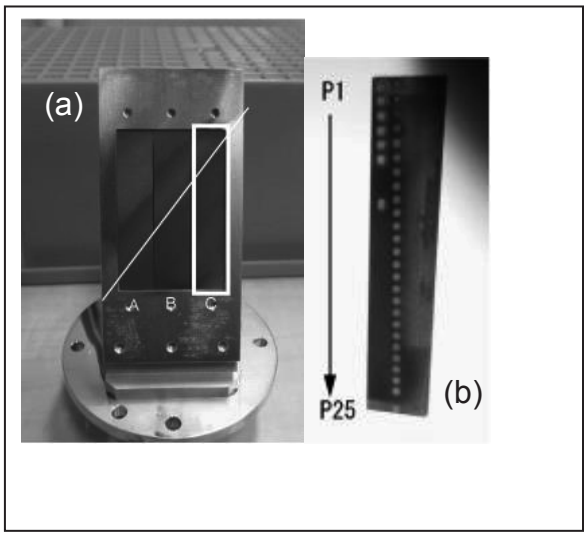

Figure 1 (a) A picture of a sample holder with IG-430U targets after plasma exposure. A line indicated the divertor footprint. (b) A picture of target “C” after LIBS analyses. Holes at 25 positions from P1 to P25 are analyzed traces by erosions of Nd:YAG laser.

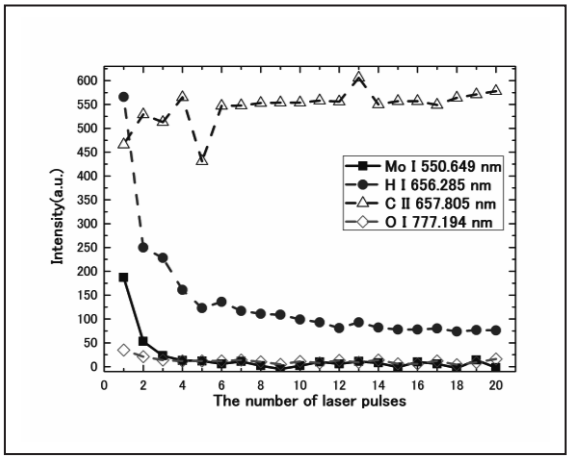

Figure 2 Depth profiles of H, Mo, C, and O elements at position 11 of target sample “C” in Fig.1.