§12. Analysis of a Graphite Plate Interacting with a High-density Hydrogen Plasma

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We are investigating the interaction between high-density hydrogen plasma and a graphite plate by using a compact divertor simulator excited by helicon-wave discharge.[1,2] In this year, we carried out the analysis of the graphite plate using a scanning electron microscope (SEM) and a laser-desorption time-of-flight mass spectrometer.

A graphite plate was installed on the end plate that terminated the high-density plasma column with a diameter of 16 mm. The temperature of the graphite plate was controlled at 400 °C using a heater. The rf power and the H_2 gas pressure were 2.5 kW and 40 mTorr, respectively. The plasma density in this discharge condition was roughly 8×10^{12} cm^{-3}. To avoid over heating of the plasma source, the plasma was produced in a pulsed mode with a duration of 4 ms and a repetition rate of 10 Hz.

A remarkable change was seen with the naked eyes on the graphite plate after the irradiation of the high-density hydrogen plasma. The changed region corresponded to the diameter of the plasma column. The change at the center was most significant. Figure 1 shows a SEM image at the center of the graphite plate after the irradiation of 8 hours (the net irradiation duration was 19.2 min). It was observed that many particulates with a diameter of several micrometers were produced on the graphite plate. The production efficiency of particulates was significantly dependent on the radial position.

The laser-desorption time-of-flight mass spectrometer employed the forth harmonics (266 nm) of a Nd:YAG laser. The fluence, the duration, and the repetition frequency of the YAG laser pulse were 50 mJ/cm^2, 10 ns, and 10 Hz, respectively. Positive ions were produced by the irradiation of the laser pulse, and the ions were accelerated by electric field. After flying a free space, the ions were detected using a microchannel plate. To enhance the mass resolution, the trajectories of the ions were turned using a reflectron. The masses of the ions were determined from their flight times. Figure 2(a) shows the mass spectrum obtained from the graphite plate that was irradiated by the hydrogen plasma for 8 hours. For the sake of comparison, Fig. 2(b) shows the mass spectrum obtained from an original graphite plate. It was found that bigger-size cluster ions were produced from the graphite plate with the irradiation of the hydrogen plasma. In addition, it in not seen from the figure clearly, mass peaks corresponding to CH^+, $C_2H_3^+$, and $C_2H_4^+$ are included in the spectrum shown in Fig. 2(a). This result confirms the existence of hydrogen in the particulates and/or the bulk graphite plate after the irradiation of the hydrogen plasma, and suggests a critical problem from the view point of safety hazards such as tritium inventory in D-T nuclear fusion reactors.

1) M. Aramaki, K. Kato, M. Goto, S. Muto, S. Morita, and K. Sasaki: Jpn. J. Appl. Phys. 43 (2004) 1164.
2) K. Sasaki, T. Maeda, N. Takada, M. Aramaki, M. Goto, S. Muto, and S. Morita: submitted to Jpn. J. Appl. Phys.

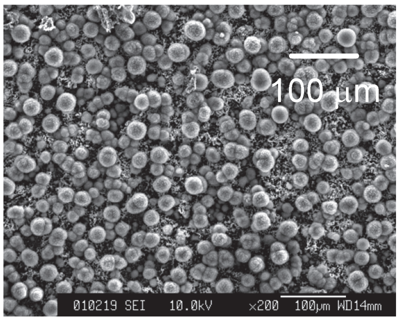

Fig. 1 SEM image of a graphite plate irradiated by the high-density hydrogen plasma for 8 hours.

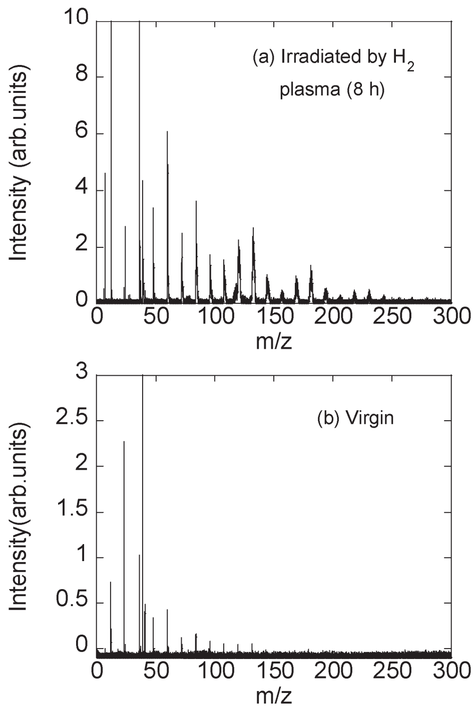

Fig. 2 Mass spectra obtained using a laser-desorption time-of-flight mass spectrometer (a) from a graphite plate with the irradiation of the hydrogen plasma for 8 hours and (b) from a virgin graphite plate