§14. Preliminary Experiment on Erosion Properties of Tungsten at Elevated Temperatures

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Tungsten (W) is one of the most promising candidates for plasma-facing materials (PFMs) in future fusion reactors because of the low hydrogen isotope retention, the low sputtering yield, the high melting temperature, and the high thermal conductivity. The lifetime of W PFM depends largely on the erosion yield. Further, the influence of W impurities on core plasma performance is significant because of the strong radiative loss. Thus, better understanding of W erosion properties is required for the steady-state operation of fusion reactors. While the physical sputtering yield of W is well documented[1)], the erosion properties at elevated temperatures are not well understood. For low-Z metals such as beryllium and lithium, enhanced erosion due to the formation of loosely bound surface adatoms has been observed at elevated temperatures under plasma bombardment in the linear divertor plasma simulator PISCES-B[2)]. For W, the existence of enhanced erosion at elevated temperatures is not confirmed yet; two contradictory experimental results have been reported for W[3), 4)]. In this campaign, a preliminary experiment on this issue was carried out.

A castellated W target with a thickness of 1.5 mm was inserted into the scrape-off layer region of the Large helical device (LHD) using the material probe system located at 4.5L. A line-of-sight looking at the W surface from the top of the device (4.5U) was used to observe black-body radiation (for surface temperature measurements) and W I lines (for erosion yield measurements) as well as background plasma emission.

Fig. 1 shows observed spectra with and without plasma from shot 115870. First of all, no W I lines were observed, meaning that the effect of physical sputtering is negligibly small. Black-body radiation was clearly seen even in this visible range, indicating that the surface temperature is definitely higher than room temperature. In Fig. 2, black-body radiation spectra are plotted at various temperatures, which are calculated with Planck's law,

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{\exp\left(\frac{hc}{\lambda kT}\right)-1}. \qquad (1)$$

Here, the symbols are used in the standard meanings. From comparison of the observed and calculated spectra, the surface temperature during plasma exposure (5400-5489 ms) in Fig. 1 is roughly estimated to be around 1100 K, while it is around 1000 K just after plasma exposure (5600-5689 ms). However, the intensity calibration data used for the optical system is thought to be not very accurate, because the Hα emission intensity is weaker than Hβ and Hγ. Thus, the temperatures estimated above may be somewhat underestimated.

Since enhanced erosion, if any, is expected to occur from > 2000 K, a further temperature increase is necessary, which can be achieved by exposing a W target to divertor plasmas in the next campaign.

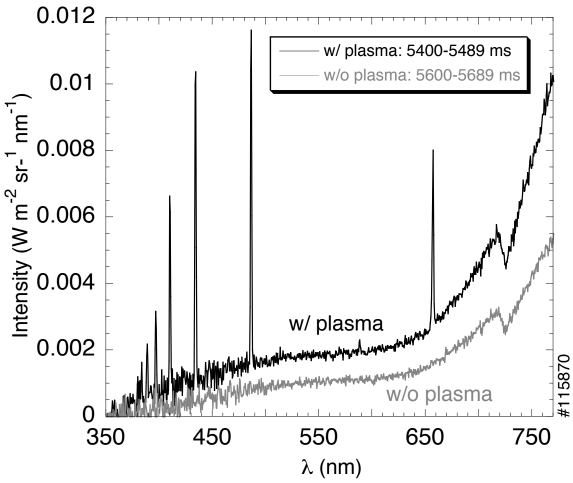

Fig. 1. Observed spectra with (5400-5489 ms) and without plasma (5600-5689 ms) in shot 115870.

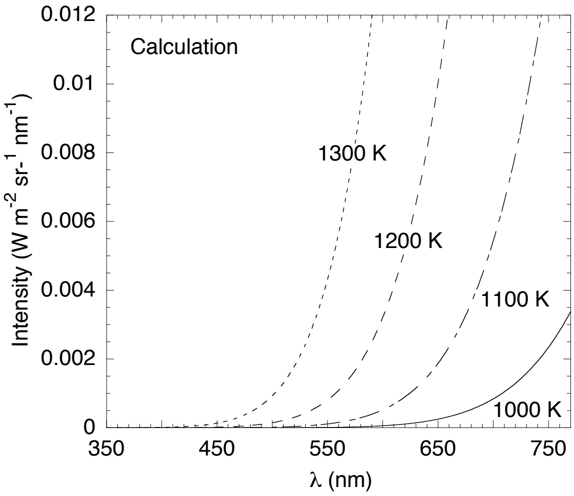

Fig. 2. Calculated black-body radiation spectra.

1) Eckstein W.: IPP-Report 9/132 (2002).
2) Doerner, R.P. et al.: J. Appl. Phys. **95** (2004) 4471.
3) Sergienko, G. et al.: presented at EPS 2005.
4) De Temmerman G. et al.: presented at PSI 2012.