Laser induced breakdown spectroscopy as diagnostics for fuel retention and removal and wall composition in fusion reactors with mixed-material components

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Laser Induced Breakdown Spectroscopy (LIBS) is one of the candidate methods for diagnostics of fuel retention and removal and wall composition in ITER. However, it is still questioned if its reliability and accuracy can meet the high requirements for diagnostics for the next-step fusion reactors. The main concerns lie in:

- the repeatability and quality of the spectroscopic signal in stable and well-defined conditions (i.e. power density of delivered laser beam, plasma parameters),
- behavior of the method for mixed material components, especially metals due to high number of spectroscopic lines of them,
- sensitivity of the method for thin layers which contain small amounts of fuel species.

All these issues, despite many experiments in different laboratories, have not yet been thoroughly investigated. At the IPPLM, after obtaining repeatable and relatively high quality signals (with S/N ratio better than 10) an effort was made to address the two other problems.

The experiments, which are in the scope of this paper were carried out to assess the method for the laser treatment of ASDEX Upgrade (AUG) strike-point tiles and calibrated C:W:Al samples prepared by the Institute of Electronic Materials Technology (IEMT).

Two types of AUG samples were investigated – with 4 and with 200 μm tungsten coatings produced by PVD and VPS respectively on a graphite substrate. Most of the surface of the PVD samples was in deposition zone where co-deposition/implantation of fuel ions is expected during AUG operation. The samples from IEMT were covered with ~3 μm layers with various calibrated mixes of C, W and Al (used as the Be analogue) by the means of sputter deposition.

To irradiate the samples Nd:YAG laser system was applied. The laser delivered series of 3 ns, 0.6 J laser pulses at 1.06 μm with repetition rate up to 10 Hz. A Mechelle 5000 spectrometer with ICCD was used to collect spectra of light emitted from plasma in the vicinity of the laser-treated sample located in a vacuum chamber at $\sim 5 \cdot 10^{-5}$ mbar. For the AUG samples the presence of a deuterium line (Dα at 656.47 nm) was recorded only for the first two laser shots in. The subsequent shots allowed for observation of the tungsten layer removal which, in spectra, was manifested by the decrease in tungsten lines and growth of carbon ones – in PVD samples the change took place between 15th and 25th pulse. The quantified differences in this processes were observed in experiments with calibrated samples which make it possible to preliminarily estimate calibration curves for their components.

The spectroscopic results were entirely confirmed by ion time of flight diagnostics performed under the same conditions with the use of an Electrostatic Ion Energy Analyser which recorded the same composition evolution during subsequent laser shots. Craters induced by different number of laser shots were investigated by means of optical microscopy.

Overall, the results proved that optical spectroscopy, although not straightforward in use, can give reliable results even for small amounts of fuel species present in the mixed–material layer, although more effort is needed to investigate more calibrated samples, to optimize the method itself and to yield a quantitative measure of fuel retention.