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# SPECTROSCOPIC CHARACTERIZATION OF LASER-INDUCED PLASMA ON DOPED TUNGSTEN

BILJANA STANKOV[1], MARIJANA R. GAVRILOVIĆ BOŽOVIĆ[2],
JELENA SAVOVIĆ[3] and MILIVOJE IVKOVIĆ[1]

[1]*Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia*

[2]*Faculty of Engineering Sciences, University of Kragujevac, Sestre Janjić 6, 34000 Kragujevac, Serbia*

[3]*Vinca Institute of Nuclear Sciences, University of Belgrade, Mike Petrovića Alasa 12-16, 11000 Belgrade, Serbia.*

*E-mail ivke@ipb.ac.rs*

**Abstract.** In this paper, the dependence of plasma characteristics, excitation temperature, and electron number density on the presence of fusion relevant doping elements (La and Th) in tungsten is evaluated and compared with a pure tungsten sample. It was found that different doping elements have little to no influence on plasma temperature, while electron number density seems to be more sensitive to the doping element type.

## 1. INTRODUCTION

The properties of tungsten, i.e., high melting point, high thermal conductivity, and low tritium retention, make it a promising material for fusion-related applications. On the other hand, its high Z number limits allowed concentration in plasma, which, with poor machinability, explosion dust potential, and irradiation-induced transmutations, pose a significant challenge for stable and safe operation. Although a large variety of tungsten grades and alloys already exist, numerous attempts to further optimize these materials are ongoing, Waseem et al., 2016. Investigations are needed to address many different issues related to the plasma-facing material (PFM) performance when exposed to thermal loads, neutron irradiation, and the plasma, Pintsuk et al. 2019. Erosion of tungsten under high localized thermal loads occurring during plasma disruption, vertical displacement events (VDEs), and the edge-localized mode (ELM) have an analogy with W erosion during laser ablation, Oderji et al. 2016. Following this analogy, the present research was undertaken to study plasma properties produced by laser ablation of pure and doped tungsten (with La and Th) using optical emission spectroscopy methods. Both doping elements are relevant for fusion technology, Gietl et al., 2022, and Raj et al., 2022. The idea is to get insight into the dependence of plasma characteristics on different doping elements present in tungsten targets, which is essential for clarifying the impact of these elements in fusion-related applications.

## 2. EXPERIMENTAL SETUP

Different tungsten targets (pure W; 98,5%W+1.5%$La_2O_3$, 98%W+2%$ThO_2$) were placed on the PC controllable x-y table. A Q-switched Nd:YAG pulsed laser (Quantel, $\lambda$ = 532 nm, energy 40 mJ, pulse duration 0.6 ns) was used to induce plasma on the target. The laser beam was focused on a target using a lens of 10 cm focal length. Light emitted from a plasma was collected with a fiber optic cable (Ø = 400 μm) and detected using an imaging spectrometer Shamrock 303 Andor equipped with the Andor iStar DH734 camera. The iCCD camera was operated in the full-vertical binning mode and controlled using a pulse generator (DDG 535, Stanford Research Systems). Delay was set to 0.5 μs, and the gate used was 2.5 μs. All measurements were performed in an argon atmosphere at 10 mbar pressure.

## 3. RESULTS

Typical spectra obtained with the employed setup are shown in Fig 1.

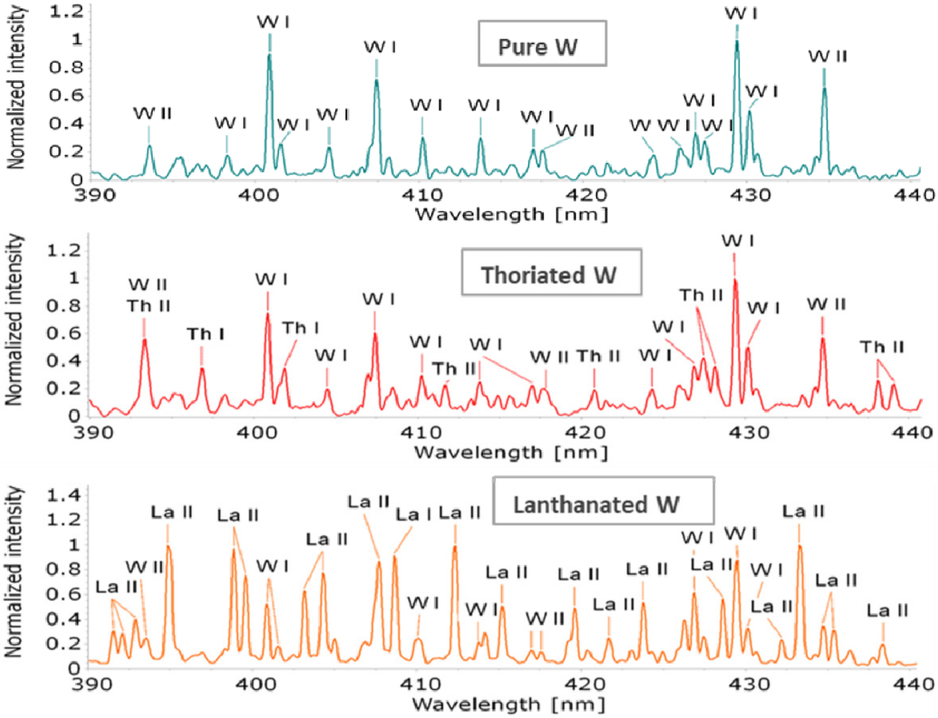

Figure 1: Characteristic LIBS spectra of pure and doped tungsten samples.

The most dominant lines belong to neutral and singly ionized tungsten for all target materials. These rich spectra of tungsten were suitable for excitation temperature determination by a Boltzmann plot method. An example of a Boltzmann plot for a pure tungsten target is given in Fig 2. The excitation temperature, $T_{\mathrm{exc}}$ calculated from the lines of singly ionized W was 13500K±1000K, slightly higher than the calculated temperature using neutral W lines (12300K±900K). The observed difference in temperature values obtained from a neutral atom and ion emissions is expected for spatially integrated measurements. As explained by J.A. Aguilera et al., 2004, in that case, the Boltzmann plots of neutral atoms and ions provide two different apparent excitation temperatures that correspond to the respective population averages of the local electronic temperature in the plasma. For all target materials, the obtained temperature values were similar (within the measurement uncertainty), implying an insignificant influence of doping elements on the plasma temperature.

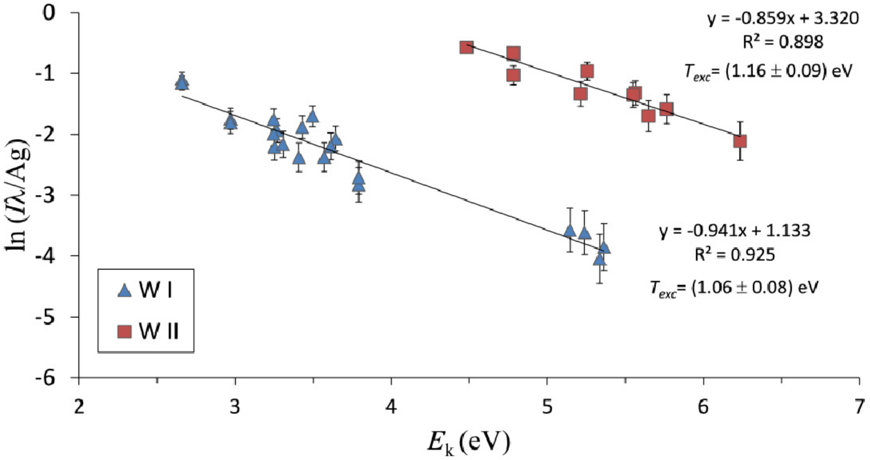

Figure 2: Boltzmann plot used to determine excitation temperature in LIBS plasma induced on a pure tungsten target.

For electron number density, $N_e$, estimation, a Stark broadening of the $H_\alpha$ line was used, Fig. 3. Based on the FWHM of the $H_\alpha$ spectral line and using the approximative formula (1), $N_e$ was calculated. The results are shown in Table 1.

$$N_e[m^{-3}] = 10^{23} * (w_{SA}[nm]/1.098)^{1.47135} \tag{1}$$

Table 1: Electron number density determined using Stark broadening of $H_\alpha$ line.

| Target | $H_\alpha$ | $N_e$ ($10^{22}$ $m^{-3}$) |
|---|---|---|
| Pure W | 0.503 | 2.84 |
| Thoriated W | 0.557 | 3.37 |
| Lanthanated W | 0.510 | 2.91 |

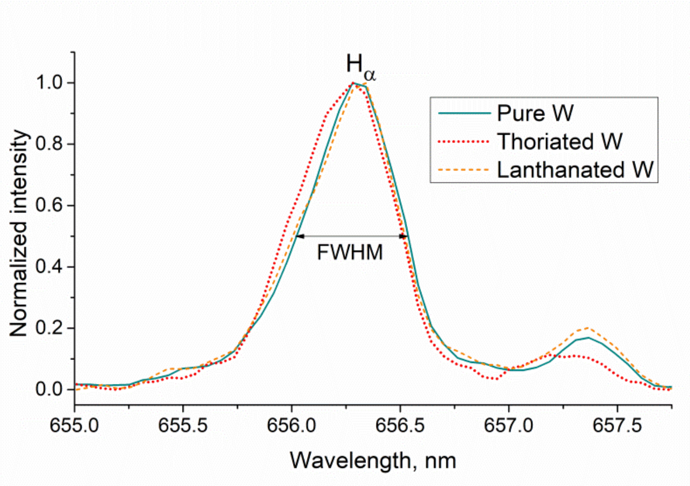

Figure 3: Stark broadened $H_\alpha$ line profiles used to evaluate $N_e$.

## 4. CONCLUSION

Different doping elements seem to have a negligible impact on laser-induced plasma excitation temperature. Electron number density shows slightly higher values in the case of thoriated W compared both to pure and lanthanated tungsten. A possible reason for this is the lower energy needed for significant erosion of thorium doped tungsten, already observed in experiments with tungsten-based cathodes, Casado et al., 2002. For a deeper understanding of the influence of doping elements on plasma properties, temporally and spatially resolved measurements are needed and are currently underway.

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