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SPECTRAL LINE CHARACTERISTICS IN THE Sn IV SPECTRUM

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Abstract. The prominent Sn IV spectral lines and their characteristics (line width and shift) have been investigated in the pulsed helium discharge. The Stark broadening mechanism was found to be dominant at the electron density of about $10^{22}\mathrm{m}^{-3}$, and electron temperature around 20 000 K.

1. INTRODUCTION

The importance of elements in astrophysics beyond the iron group (Z>26) lies in their role in the process of nucleosynthesis. Their production is maintained by neutron capture and β- decay. Tin (Sn) is one of the elements (Z=50) from this group. Nucleosynthesis of tin mainly involves slow neutron capture, which is believed to take place in helium-burning shells of asymptotic giant branch stars (Schectman et al. 2000; Cameron 1982; Käppeler et al. 1989; Chayer et al. 2005; O'Toole, 2004; Proffitt et al. 2001; O'Toole and Heber, 2006). Interstellar tin was detected by Hobbs 1993. Later on, Cardelli and Federman in 1997. made compilation between interstellar tin abundance, with the ones obtained in the Solar System. The authors remark that the interstellar tin abundance appears to be greater than the values found in meteorites. Similar conclusions are also found by other authors (Sofia et al. 1999). It is evident that the interest in astrophysics to the Sn spectral lines show growing tendency. In our work we wish to present behavior of several Sn IV (triply ionized) spectral line shapes in a pulsed helium laboratory plasma at about 20 000 K of electron temperature and $10^{22}\mathrm{m}^{-3}$ electron density.

2. EXPERIMENT

A linear low-pressure pulsed arc (Djenize, 2007) was used as an optically thin plasma source. A pulsed discharge was produced in a Pyrex glass discharge tube. The tube had a 5 mm inner diameter, and the plasma length was 14 cm. Tin atoms were sputtered from the tin cylindrical electrodes placed on the ends of the axial part of the discharge tube. Helium was used as a working gas at a perssure of 665 Pa in flowing regime. The discharge was created using a capacitor of 14 μF charged to 45 J of stored energy. The spectroscopic observations were made end-on along the axis of the discharge tube. The spectral line profiles were recorded using the

McPherson spectrograph and the Andor iStar intensified CCD camera as a highly-sensitive detection system. McPherson model 209 spectrograph (with a 1.33 m focal length) is equipped with a holographic grating containing 2400 grooves/mm, and it was used over wavelengths ranging from 200 to 640 nm. This spectrograph had a reciprocal linear dispersion of 0.28 nm/mm in the first order. The camera was triggered at a specified moment and with an exposure time (0.1 μs - 1.0 μs) adapted to the line intensity. To reduce thermal noise, the ICCD camera was kept at a temperature of -25°C. The system was calibrated by using a set of pen-light sources (Ne, Ar and Hg) produced by the LOT-Oriel. A relative radiometric calibration is done by using a deuterium light source (StellarNet SL3-CAL) for UV region from 200 to 400 nm. Measured line intensities are corrected to the sensitivity of the electro-optical detection system and normalized to the 0.5 s exposure time.

Instrumental broadening (spectrograph + ICCD camera) is of a Voigt type with the FWHM (full-width at half of the maximum line intensity) of 8.7 pm at 265 nm. Some recorded Sn IV line profiles are presented in Fig. 1. We have checked plasma reproducibility by monitoring intensity of prominent He I and Hg II lines, and the discharge current by a Rogowski coil signal (Rogowski and Steinhaus 1912). It is found that scatter of current peak value, from shot to shot, is within ±5%.

The plasma parameters were determined by using standard diagnostical methods. Thus, the electron density (N) decay was determined using known Stark FWHM of the 468.6 nm He II spectral line (Griem, 1974) within ±11% accuracy. The electron temperature was obtained using the relative intensity ratio method (Saha equation in Griem, 1964) between O II (395.436 nm and 397.326 nm) and O III (396.157 nm) spectral lines with an estimated error of ±13% assuming the existence of the Local Thermodynamical Equilibrium (LTE). The necessary atomic data were taken from the latest NIST database (2011). We have obtained values for T = (20 000 ± 2200) K and N = (0.63 - 0.89) x $10^{22}\mathrm{m}^{-3}$ at the moment when the line profiles were recorded.

3. RESULTS

The recorded line profiles were of a Voigt type due to convolution of the Lorentz and Gauss profiles resulted by Stark, Doppler and instrumental broadenings. A standard deconvolution procedure was applied (Davies and Vaughan, 1963; Bukvić et al. 2005, 2008). For the mentioned plasma parameters we found symmetrical profiles with domination of the Lorentz fraction caused by Stark broadening. On the other hand, the components of the ten natural tin isotopes do not influence the symmetry of the Sn IV line shapes at the mentioned plasma conditions. The obtained Stark FWHM (W) are presented in Table 1. The line shift are found to be about 0 pm with 5% accuracy. Finally, we would like to emphasize that, unfortunately, no theoretical Sn IV W values exist (NIST, 2011), making the comparison with our W values practically impossible.

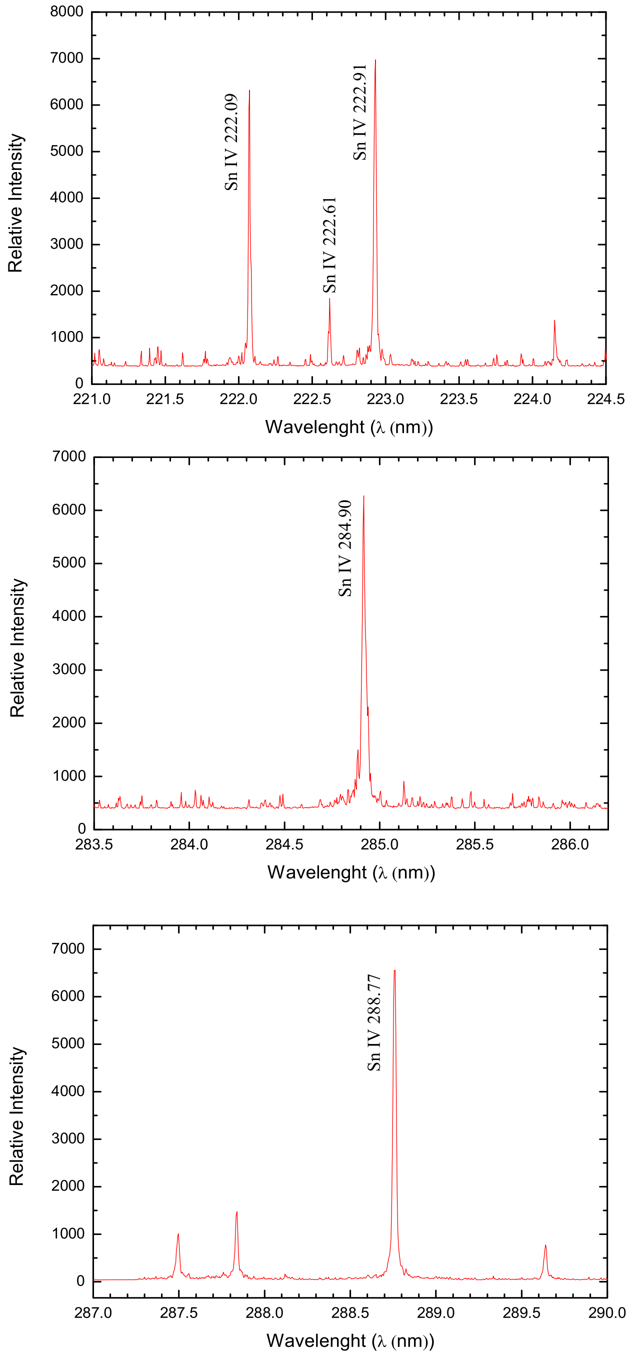

Figure 1: The recorded Sn IV line profiles.

Table 1: The measured Sn IV Stark FWHM (Wm) at T = (20 000 ± 2200) K and N = (0.63 - 0.89) x 10^{22}m^{-3}. Wavelengths and transitions are taken from (Pinnington et al. 1987.)

Transition	$\lambda(nm)$	$Wm(pm)$
$4f^2$ F^0 - $5g^2$ G	208.30	24.8±6.2
$5d^2$ $D_{3/2}$ - $4f$ ^{2} $F^0{}_{5/2}$	222.09	14.6±2.9
$5d^2$ $D_{5/2}$ - $4f^2$ $F^0{}_{5/2}$	222.91	12.4±2.5
$6p^2$ P^0 - $6d^2$ D	284.90	20.2±5.0
$5d^3$ $D_{3/2}$ - $6p^2$ $P^0{}_{3/2}$	288.77	22.7±5.7

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