Observation of indirect ionization of W$^{7+}$ in EBIT plasma

Q Lu$^{1,2}$, J He$^{1,2}$, H Tian$^{1,2}$, M Li$^{1,2}$, Y Yang$^{1,2}$, K Yao$^{1,2}$, C Chen$^{1,2}$, J Xiao$^{1,2}$, J G Li$^{1,3}$, B Tu$^4$ and Y Zou$^{1,2}$

$^1$Institute of Modern Physics, Department of Nuclear Science and Technology, Fudan University, Shanghai 200433, China
$^2$Key Laboratory of Nuclear Physics and Ion-beam Application (MOE), Fudan University, Shanghai 200433, China
$^3$Institute of Applied Physics and Computational Mathematics, Beijing 100088, China
$^4$Max-Planck-Institute für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Synopsis

In this work, visible and EUV spectra of W$^{7+}$ have been measured using the high-temperature superconducting electron-beam ion trap at the Shanghai EBIT laboratory under extremely low-energy conditions. The relevant atomic structure has been calculated by using the flexible atomic code package and the GRASP2K code. A hypothesis for the charge-state evolution of W$^{7+}$ is proposed based on our results. The occurrence of W$^{7+}$ ions results from indirect ionization caused by stepwise excitation between some metastable states of lower-charge-state W ions, at the nominal electron beam energy of 59 eV.

Based on the previous study by Mita et al.[1], the spectra of W$^{7+}$ are measured in the visible and EUV range at SH-HtscEBIT[2] under extremely low electron beam energy conditions. The 574.49(3) nm M1 line of W$^{7+}$ is observed at the nominal electron beam energy of 59 eV which is below the ionization energy of W$^{5+}$. The multi-configuration Dirac-Hartree-Fock calculation further confirms the identification of this line. A hypothesis of charge-state evolution from W$^{5+}$ to W$^{7+}$ is proposed, based on our theoretical studies on the energy levels of these charge states, in order to explain the appearance of W$^{7+}$ spectra. Indirect ionization via cascade excitations from the long-lived metastable states of lower charge W ions play a key role in occurrence of W$^{7+}$. In addition, the EUV spectra at 75 eV as well as the FAC calculations also prove that W$^{7+}$ can be and is created via indirect ionization out of W$^{5+}$.

Figure 1. Spectra of tungsten obtained by SH-HtscEBIT at the nominal electron beam energy of 55, 58, 59, 70, 90 and 130 eV in the range of 559-623 nm. The line at 574.49(3) nm is the M1 transition between the fine structure splitting in the $^2F$ ground term of W$^{7+}$.

References

[1] Mita M et al 2017 Atoms 5 13
[2] Xiao J et al 2013 Proceedings of IPAC2013 MOPFI066