M-X-ray emission in interaction of slow highly charged Xe^{q+} ions (q=26-40) with metallic foils

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Synopsis Emission of M-X-rays in interaction of slow highly charged Xe^{q+} ions, delivered by electron beam ion source (EBIS), with metallic surfaces was studied. Measured M-X-ray spectra for different charge states give access to interpret both the dynamics of neutralization of highly charged ions at surfaces and relaxation processes of hollow atoms formed in this process. The measured spectra are interpreted in terms of the performed atomic structure calculations using the GRASP code.

In interaction of slow highly charged ions (HCI) with matter the so-called "hollow atoms" are formed in the process of fast neutralization of HCI at the surface [1,2]. In these exotic atomic states a large part of the electrons are in high Rydberg levels while the inner shells remain empty. The X-rays and Auger electrons emitted in deexcitation of hollow atoms carry information about formation and the structure of hollow atoms as well as their relaxation processes. In particular, the observed X-rays from hollow atoms give access to identify the mutivacancy configurations corresponding to a moment of X-ray emission.

In this work we report on the measurements of X-rays emitted in interaction of ~3 keV×q Xe^{q+} ions (q=26-40) with metallic foils of Be, Au, Ti and Ta. The ion beams were produced in the EBIS-A facility [3,4] consisting of the electron beam ion trap (EBIT), ion extraction and beam transport system, analyzing dipole magnet and UHV experimental chamber equipped with a 5-axis sample manipulator. The X-rays were measured with the XFlash silicon drift detector (SDD) having a resolution of about 80 eV in 1-2 keV photon energy range studied.

The X-rays measured for different charge states of Xe^{q+} ions were interpreted as the M-x-ray nl-3l transitions (where $n \geq 4$) corresponding to different multivacancy configurations, including thus both x-ray satellites and hypersatellites. The energies of these transitions were calculated using the multiconfiguration Dirac-Fock (MCDF) method using the GRASP code [5].

In order to interpret the measured spectra, the experimental broadening of spectral lines have been taken into account. The observed intensities of nl-3l transitions, including their satellite structures, yielded information about population of electrons in high n-states. In this way an initial population of electrons as appears in ion neutralization process, followed by the Auger and radiative deexcitation cascade was probed experimentally. Consequently, the predictions of the classical over-the-barrier model (OBM) describing the neutralization of HCI at surfaces were tested experimentally. For Xe^{26+} ions with no M-shell vacancies expected the observed M X-rays may indicate more complex electronic structure of these ions or the internal dielectronic excitation process [6].

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References

[1] H. Winter and F. Aumayr 1999 *J. Phys. B* **58** R39
[2] J.-P. Briand *et al.* 1990 *Phys. Rev. Lett.* **65** 159
[3] G. Zschornack *et al.* 2008 *Rev. Sci. Instrum.* **79** 02A703
[4] D. Banaś *et al.* 2010 *J. Instrum.* **5** C09005
[5] P. Jönsson *et al.* 2013 *Comp. Phys. Comm.* **184** 21972203
[6] R. Schuch *et al.* 1993 *Phys. Rev. Lett.* **70** 1073

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