

X-ray absorption spectrum of strontium vapor in *K*-edge region

R. Hauko¹, A. Kodre^{2,3}, J. Padežnik Gomilšek¹, and I. Arčon^{4,3,5}

¹Faculty of Mechanical Engineering, University of Maribor, Smetanova 17, SI-2000 Maribor, Slovenia

²Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia

³J. Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia

⁴University of Nova Gorica, Vipavska 13, SI-5000 Nova Gorica, Slovenia

⁵Centre of Excellence Low-Carbon Technologies (CO NOT), Hajdrihova 19, SI-1000 Ljubljana, Slovenia

Atomic absorption spectrum of an element is a fundamental property, revealing the details of its inner dynamics. It is a perfect check of atomic models, unobscured by the effects of chemical or solid-state binding of the atom. The state of free atoms can be readily studied in noble gases and in vapors of many metals. Of these, the more volatile metals have already been examined, and with the increase of vaporization temperature the experiment is becoming ever more demanding. A container for the vapor of the surface density in the range of 1 mg/cm^2 at the temperature over $1000 \text{ }^\circ\text{C}$ remaining stable for the duration of ~ 1 hour is required, equipped with windows sufficiently well transparent for the x-ray beam. The basic solution is a cylindrical absorption cell in a tunnel oven [1]. For higher temperatures, quite sophisticated systems have been developed [2].

As an improvement over the sealed cells with welded windows we have constructed a multiple-use cell with a vacuum »keyhole« (Fig. 1a). The 22-cm long cell with an inner diameter of 8 mm was filled with a 5-mg batch of strontium metal and evacuated in a helium bag, and then transferred into the He atmosphere of the oven tunnel and subsequently aligned onto the x-ray beam. The absorption experiment has been performed at the C beamline of the DORIS ring, equipped with a two-crystal Si 111 monochromator with resolution of $\sim 1 \text{ eV}$ at the photon energy of Sr *K* edge (16105 eV). The beam harmonics were suppressed by setting the monochromator feedback control at 50% of the rocking curve. The intensity of the beam was measured with three ionization detectors (600 mbar Ar, 300 mbar Kr and 500 mbar Kr), with the oven placed between the first pair and with a Sr metal foil for the energy calibration between the posterior pair of the detectors. The foil was prepared by pressing a speck of the metal in a drop of paraffin oil between two kapton foils in a hydraulic press.

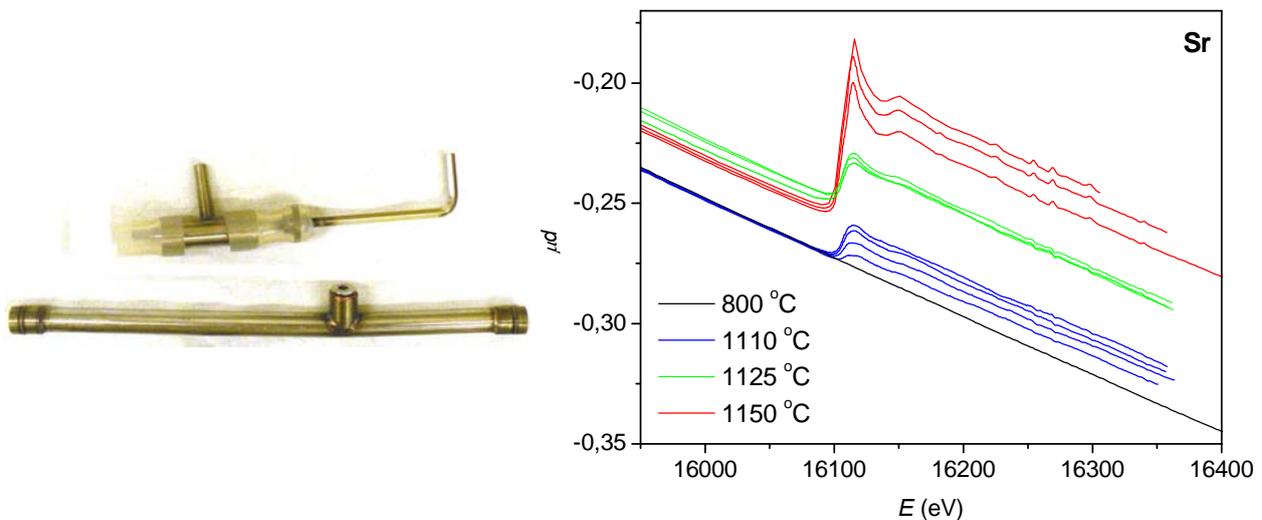


Figure 1: Left: Sr vapor absorption cell with the vacuum keyhole. Right: Sr *K*-edge absorption spectra measured at indicated temperatures in the absorption cell.

The heating of the oven was adjusted to 6 °C per minute and the absorption in the cell was repeatedly scanned over the range (-200, 300 eV) relative to the *K* edge, to monitor the *1s* edge profile and the strongest multielectron excitation groups *1s3d* and *1s4p*. The first appearance of a small *K* edge was observed at ~ 1100 °C, following by a steady increase up to edge jump of 0.02 while the temperature within the cell saturated. With increasing heating to thermostat settings of 1125 and 1150 °C, the jump value of 0.2 was ultimately reached but with an increasing EXAFS component indicating absorption in a solid or molecular state.

The analysis shows not just the increase of the edge amplitude, but also a marked change of the edge profile, indicating a change in the chemical state of the element during the experiment. It is conceivable that some metal is resublimated onto the windows during the heating or even sprayed in a fast Leidenfrost evaporation. It is also conceivable that some oxide – or even nitride – was formed if some air remained trapped in the cell or was introduced by a leak in the He system. To demonstrate the effect, the measured spectra from different phases of the experiment are compared to the spectrum of Sr metal and of SrO, measured later for the purpose (Fig. 2). It is rather obvious that some admixture of either is present in the series. On the other hand, there is also a good evidence of some edge profile features not contained in the admixture spectra, representing most likely the vapor contribution. Currently, a code is in preparation to separate the components of the spectra by a variational procedure akin to factor analysis.

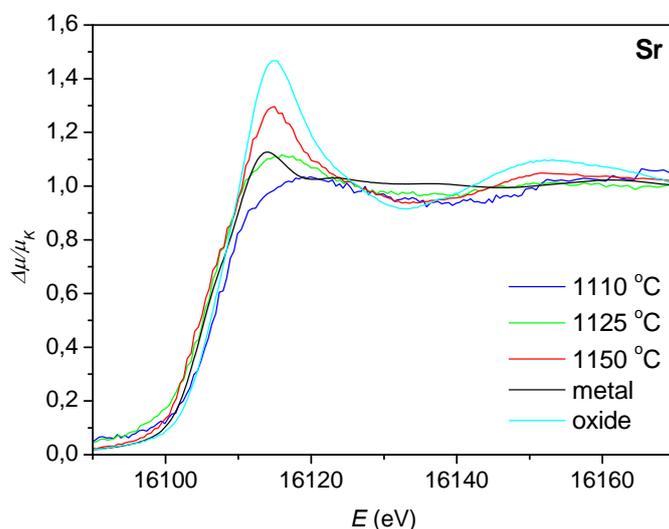


Figure 2: Normalized *K*-edge profiles of Sr metal, SrO and some Sr *K*-edge absorption spectra measured at indicated temperatures in the absorption cell.

Acknowledgements:

This work has been supported by the Slovenian Research Agency Research Programme P1-0112, by Centre of Excellence Low-Carbon Technologies (CO NOT) Slovenia, and by DESY and the European Community's Seventh Framework Programme (FP7/2007–2013) under grant agreement CALIPSO n° 312284 (EU Support of Access to Synchrotrons/FELs in Europe). Access to synchrotron radiation facilities of HASYLAB (project I-20110082 EC) is acknowledged. We would like to thank Roman Chernikov and Edmund Welter of HASYLAB for expert advice on beamline operation.

References

- [1] R. Prešeren, I. Arčon, M. Mozetič, A. Kodre, and A. Pregelj, Nucl. Instrum. and Methods in Phys. Research B **111**, 161 (1996).
- [2] O. Keski-Rahkonen, G. Materlik, B. Sonntag and J. Tulkki, J. Phys. B: At. Mol. Phys. **17**, L121 (1984).