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In-depth Surface Studies on Mg Photocathodes for higher Quantum Efficiency

Introduction

- Metal cathodes are commonly used in RF Guns because they work robust and tolerate poor vacuum
- The main prerequisite for a high QE is the surface cleanness (atomically clean surface)
- At ELBE, a successfully established process to clean Mg surfaces is laser cleaning [1]
- Although this laser cleaning improves the QE, it causes a non-uniform surface and a potential surface damage
- Generally, an alternative process producing an atomically clean, smooth, and damage-free surface is desired

HZDR System & Material

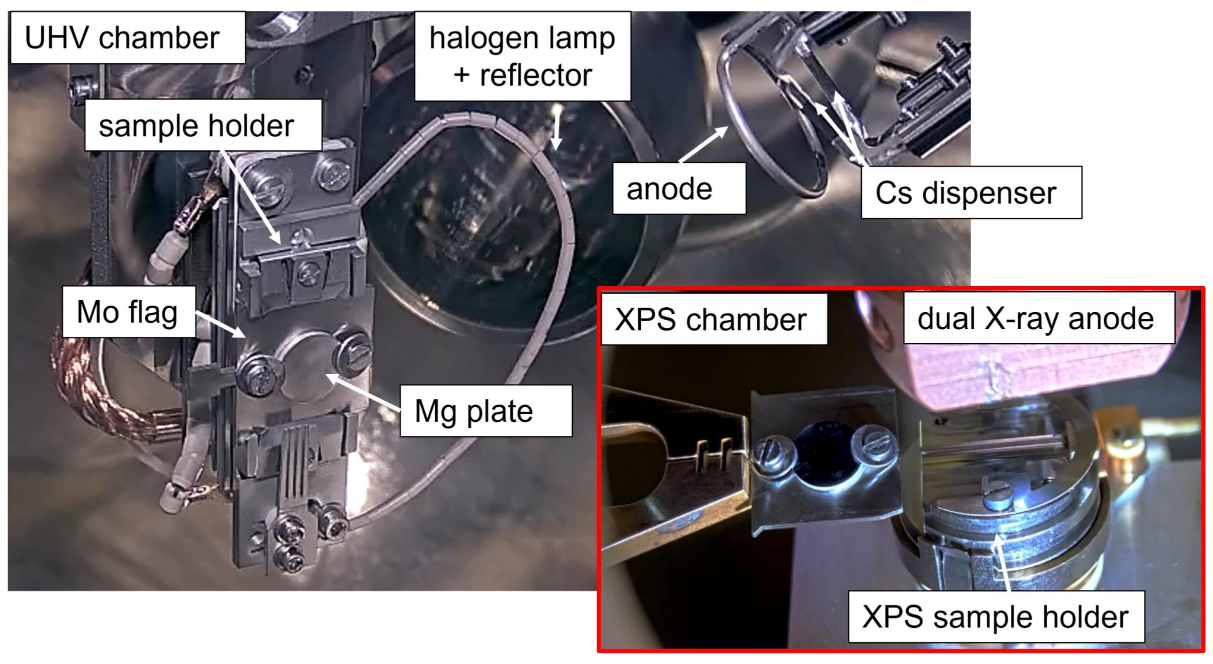

Fig. 1: The interior of the UHV chamber and the adapted XPS analysis chamber.

- 99.98 % pure Mg rod (Goodfellow, polycrystalline)
- Cut in 9 x 9 mm Mg plates
- The Mg plates were mirror-like polished by mechanical polishing
- Cleaned in iso-propanol in ultrasonic bath
- Transported under N_2 atm. into vacuum chamber

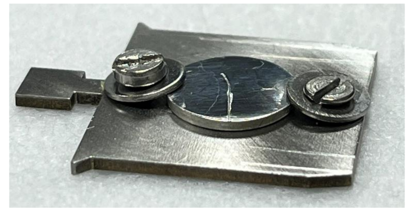

Fig. 2: fixed Mg plate on Mo flag.

- The UHV chamber is equipped with heating options, and a steel anode and an external UV-LED
- The UHV chamber (p = 2 x 10^{-10} mbar) is connected to a PHI 5600 spectrometer (p = 5.3 × 10^{-9} mbar) using an Al K_α line (hv = 1486.6 eV)
- *in-situ* XPS guarantees in-depth surface studies of Mg surfaces under vacuum
- The Mg was illuminated with an UV-LED (275 nm and 102 µW) +
- 500 V was applied to the steel anode to track the Mg photocurrent

Results – thermal cleaning

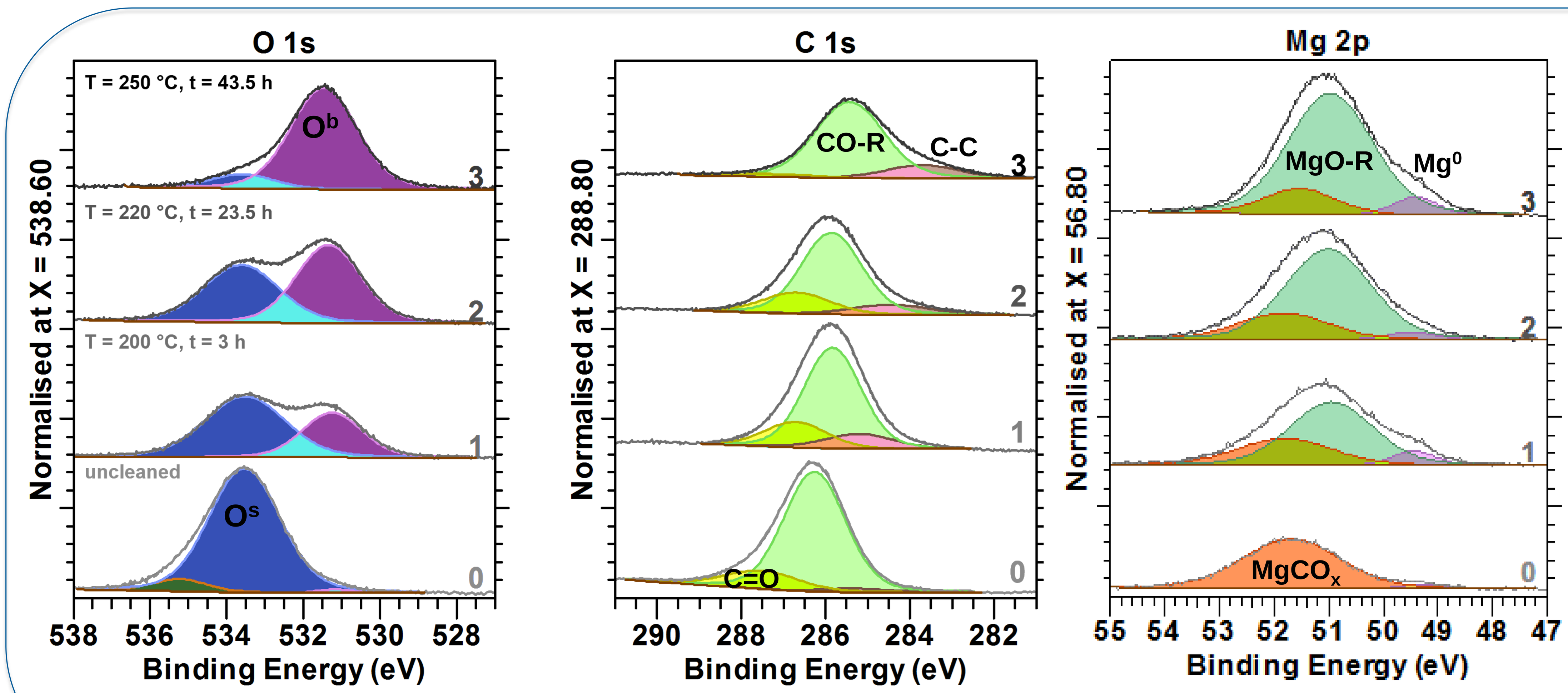

Fig. 3: O 1s, C 1s and Mg 2p photoelectron spectra for a Mg surface, cleaned with iso-propanol (line 0), thermally cleaned at 200 °C (line 1), 220 °C (line 2) and 250 °C (line 3).

- Thermal cleaning was applied through the backside of Mg
- The surface showed surface O (O^s) that changed its peak intensity during the thermal cleaning
- The O^s peak intensity decreased while the peak intensity of O (O^b) in the bulk increased
- C was **not** completely removed !
- MgCOx was reduced but not entirely removed (MgO-R remains on surface)
- Thermal cleaning takes a long time (over 40 h @ 200 – 250 °C)

Max. achieved QE: 0.1 % @ 275 nm

Results – Ar^+ bombardment

- Ar^+ ions (N = 5, 1.5 keV) were used to bombard the Mg surface
- Original surface O (O^s) began to change under the bombardment and
- The O^s intensity decreased rapidly
- C was removed completely!
- After 300s of Ar^+ bombardment: Mixed phase of O^s/O^b and MgO-R/Mg^0
- After 480s: O^b peak disappeared
- Intensive Mg^0 peak appeared in spectra (+ plasmon peaks)

Max. achieved QE: 0.35 % @ 275 nm

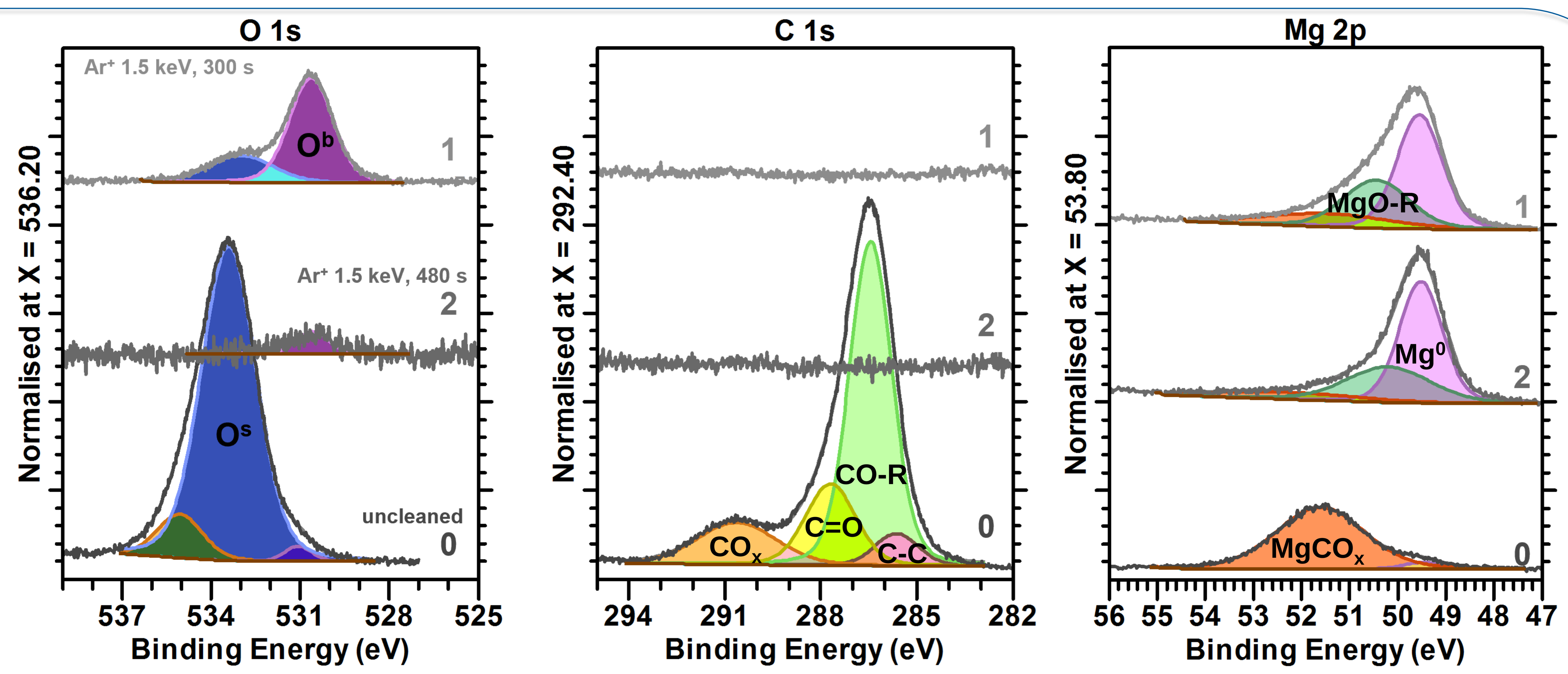

Fig. 4: O 1s, C 1s and Mg 2p photoelectron spectra for a Mg surface, cleaned with iso-propanol (line 0), irradiated 300s with 1.5 keV Ar^+ (line 1), and 480s with 1.5 keV Ar^+ (line 2).

Conclusion

- Two different cleaning methods were tried to study the behaviour of the Mg surfaces
- The Mg photocathode quality is defined by the surface conditions e.g. contaminations and its morphology (surface roughness)
- Thermal cleaning needs a long time and is a potential risk for Mg evaporation
- Ar^+ sputtering leads in highest QE so far, but has the disadvantage of surface roughening

Outlook

- Ar^+ ion bombardment under a different angle ?
- Use of other low energy ions for bombardment (He^+, H^+, H_{atom}) ?
- Using monocrystalline Mg ?
- Mg nanostructures as new Mg idea?

References:
[1] J. Teichert *et al.* "Successful user operation of a superconducting radio-frequency photoelectron gun with Mg cathodes". Phys. Rev. Accel. Beams **24**, 033401

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See you @ EWPAA 2024 in Dresden

Bundesministerium für Bildung und Forschung
DRESDEN concept