Karlsruhe Institute of Technology

KNMF Karlsruhe Nano Micro Facility

IAM Institute for Applied Materials

1 Institute for Applied Materials & Karlsruhe Nano Micro Facility (KNMF)
Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
2 Light Technology Institute, Engesserstrasse 13, 76131 Karlsruhe, Germany

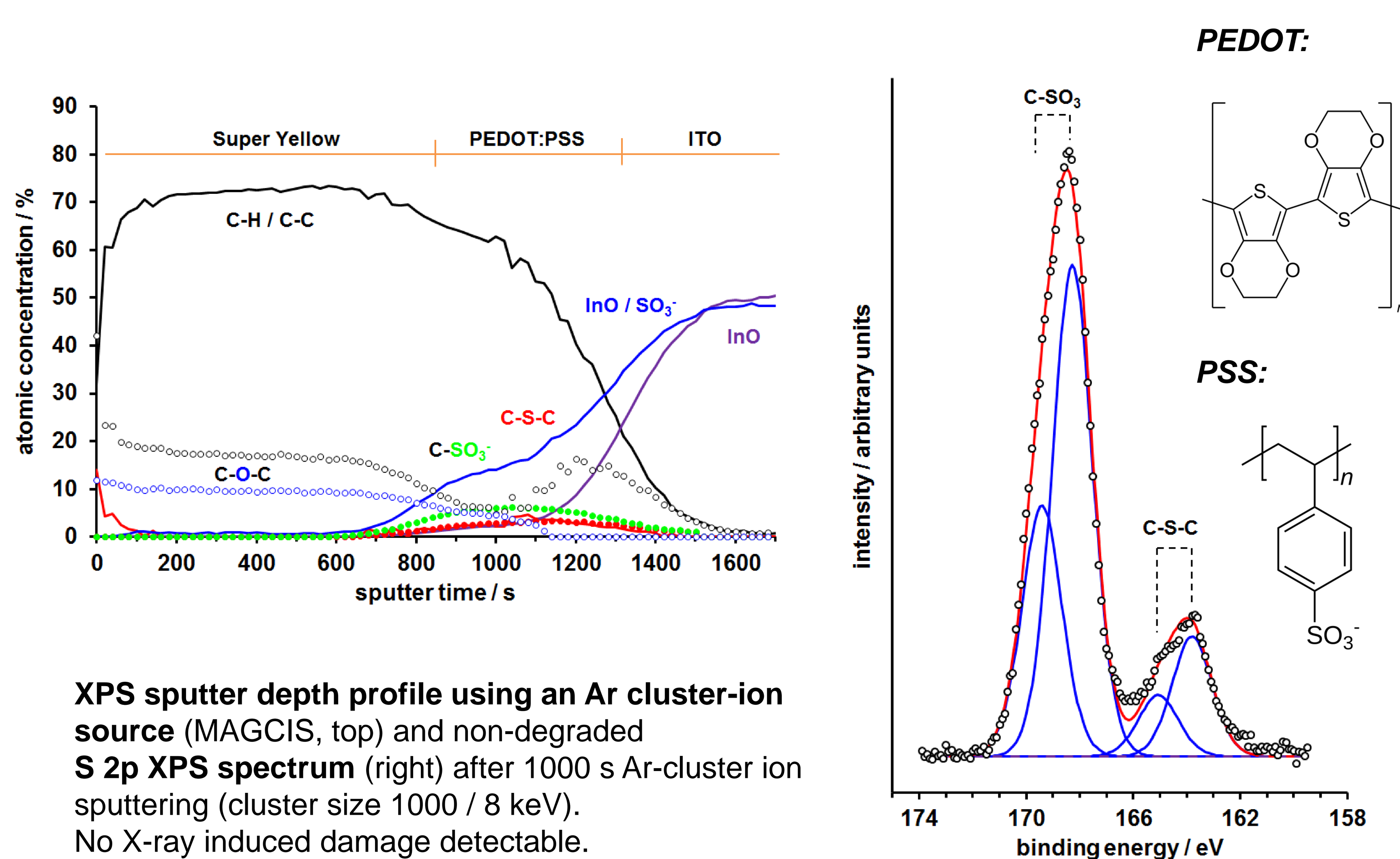
Corresponding author: michael.bruns@kit.edu

Combined XPS and ToF-SIMS Characterization of Solution Processed Organic Light Emitting Diodes (OLEDs)

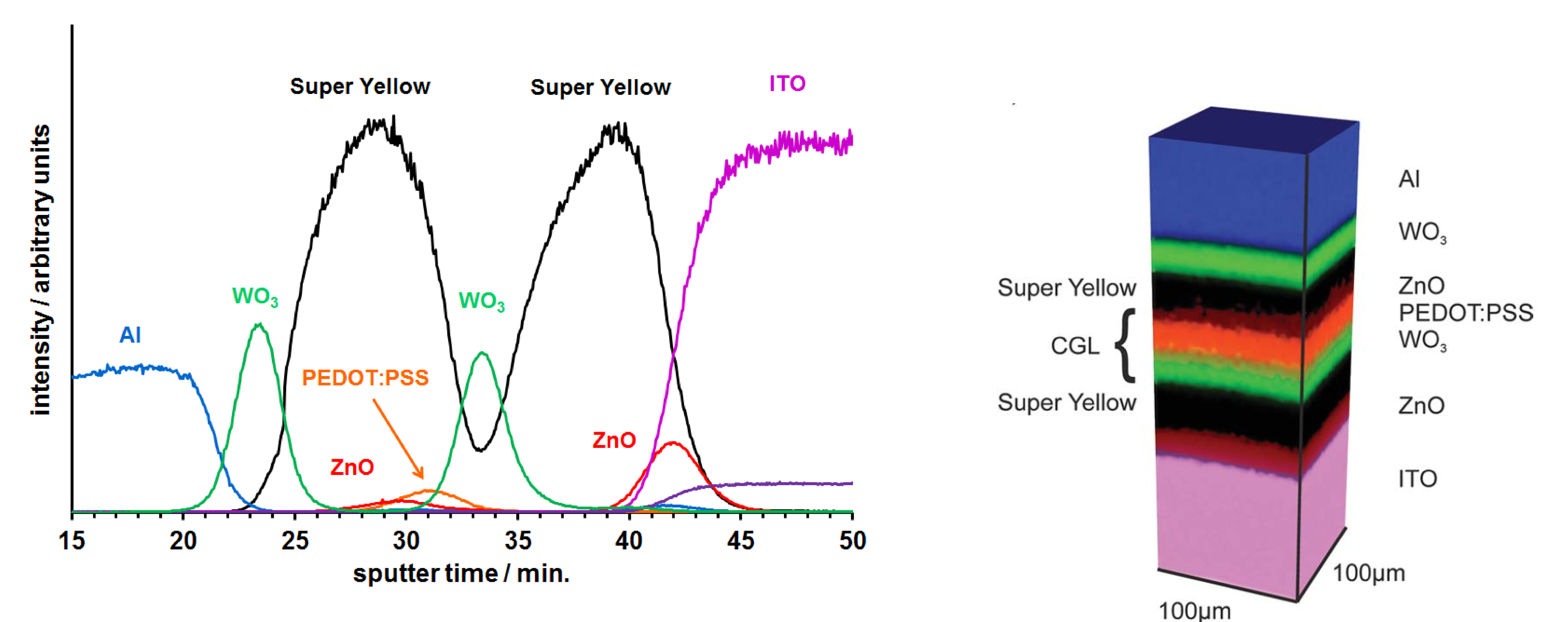
M. Bruns[1], S. Hoefle[2], A. Colsmann[2]

Solution processing of organic semi-conductor devices is one of the keys towards low-cost optoelectronic devices. State-of-the-art organic light emitting diodes (OLED) are mostly fabricated by thermal evaporation in vacuum because these processes allow stacking of an arbitrary number of functional layers on top of each other. In contrast, solution deposition (printing and coating) is ruled by solvent limitations. Therefore, an important issue is to prove the achievement of well-defined multi-layer systems of high purity with sharp interfaces and stoichiometries similar to evaporated layers. The present study focuses on the surface analytical characterization of OLED multilayer stacks using X-ray photoelectron spectroscopy (XPS) and time-of-flight secondary ion mass spectrometry (ToF-SIMS).

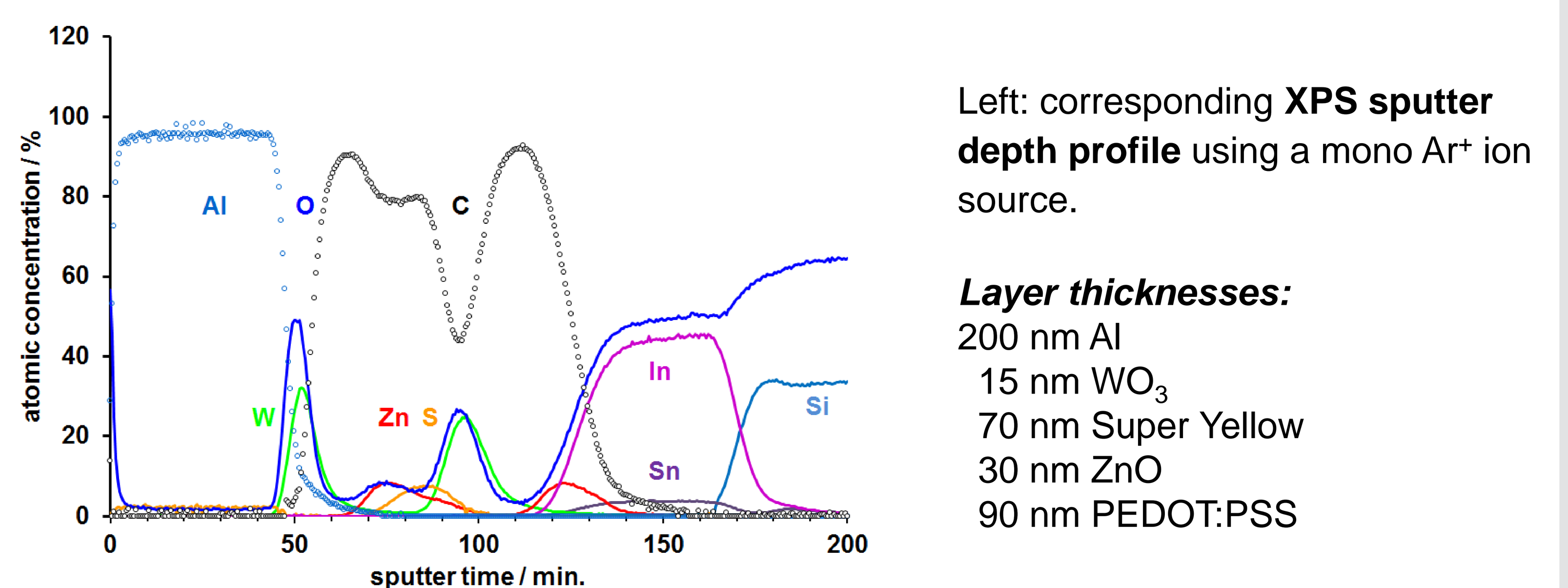
Solution processed, white emitting tandem organic light-emitting diodes with inverted device architecture



XPS sputter depth profile using an Ar cluster-ion source (MAGCIS, top) and non-degraded **S 2p XPS spectrum** (right) after 1000 s Ar-cluster ion sputtering (cluster size 1000 / 8 keV). No X-ray induced damage detectable.



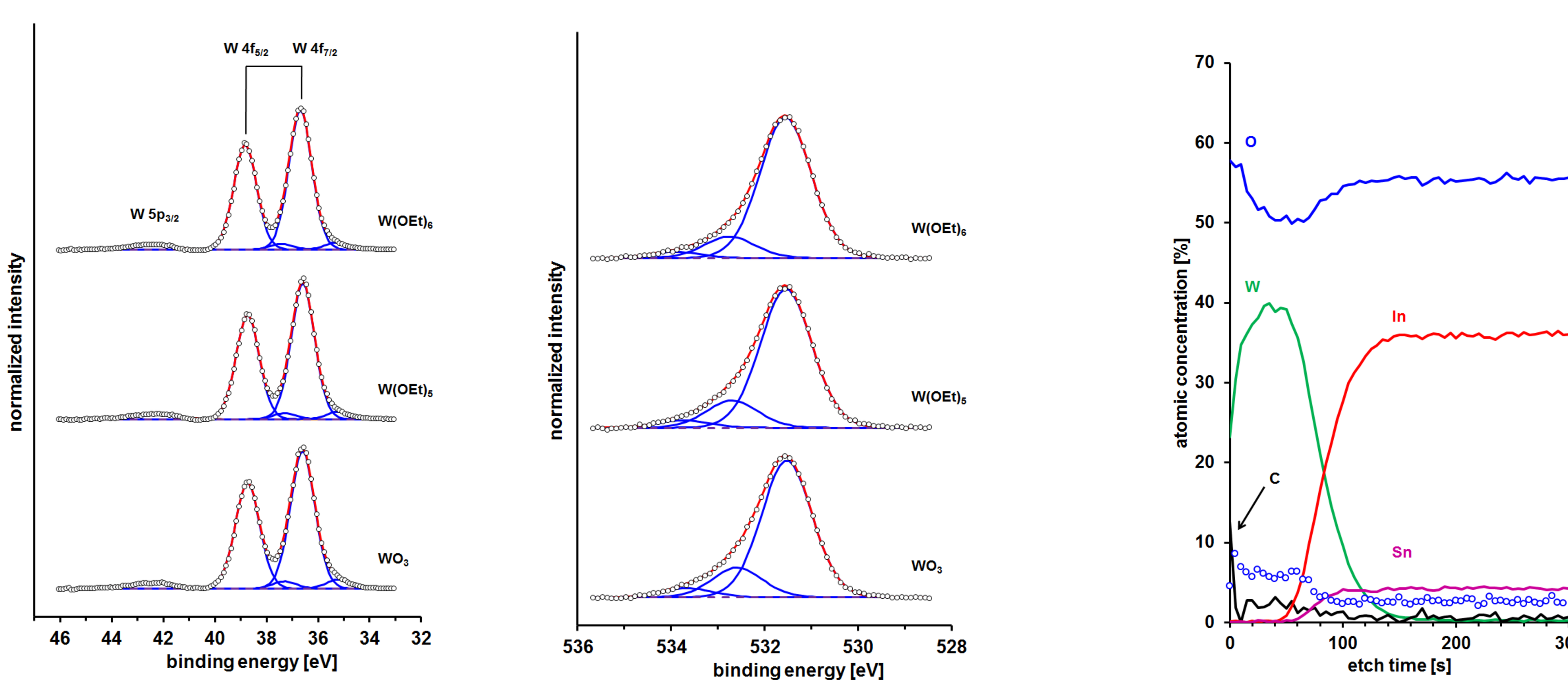
ToF-SIMS sputter depth profile and 3D visualisation of a tandem OLED using the relevant fragments C_4^- (Super Yellow, Poly(para-phenylenevinylene), S_2^- (PEDOT:PSS), ZnO^- (ZnO), Al_3^- (Al), InO_2^- (ITO), and WO_2^- (WO_3).[1]



Left: corresponding **XPS sputter depth profile** using a mono Ar^+ ion source.

Layer thicknesses:
200 nm Al
15 nm WO_3
70 nm Super Yellow
30 nm ZnO
90 nm PEDOT:PSS

Tungsten oxide buffer layers fabricated in an inert sol-gel process at room-temperature



XPS evidences: sol-gel processed WO_3 layers (top, middle) using different precursors have the same stoichiometry as CVD deposited WO_3 layers (bottom). [2]

XPS sputter depth profile to prove the full conversion of the precursor due to the absence of organic compounds throughout the WO_3.[2]

Conclusions

- Both mono Ar^+ (XPS) and Cs^+ (ToF-SIMS) ion beam sputter depth profiles of solution-processed typical monochromatic tandem OLEDs prove well-defined multilayer systems without intermixing.
- XPS justifies the same WO_3 stoichiometry for solution processed and common evaporated layers.
- High mass Ar cluster ion sources for XPS enable sputter depth profiling of organic materials while preserving the chemical information.
- No X-ray induced degradation for PEDOT, PSS and Super Yellow layers detectable for the overall necessary X-ray acquisition time during Ar-cluster ion sputter depth profiling.
- However, high energy mono ion etching leads to sputter-induced reduction of the WO_3 and ITO layers with coincidental oxygen depletion.

Experimental

Thermo Fisher Scientific K-Alpha and K-Alpha+ XPS-Instruments

- Micro-focused monochromatic AlKα X-ray source, 400 µm spot size
- Monoatomic and gas cluster ion source (MAGCIS), 8 keV, cluster size: 1000 atoms, crater size 2x4 mm²
- Ar^+-ion source, 1 keV, crater size 2x4 mm²

ION-TOF GmbH ToF.SIMS⁵ Spectrometer

- 25 keV Bi^+ primary ions, FoV = 100x100 µm²
- Negative analyzer polarity
- Cs^+-ion source, 1 keV, crater size = 500x500 µm

References

[1] S. Höfle, A. Schienle, C. Bernhard, M. Bruns, U. Lemmer, and A. Colsmann, Adv. Mater. 2014, 26, 5155.
[2] S. Höfle, M. Bruns, S. Strässle, C. Feldmann, U. Lemmer, and A. Colsmann, Adv. Mater. 2013, 25, 4113.

Acknowledgement

This work was supported by the Federal Ministry of Economics and Technology on the basis of a decision by the German Bundestag.

Federal Ministry of Economics and Technology