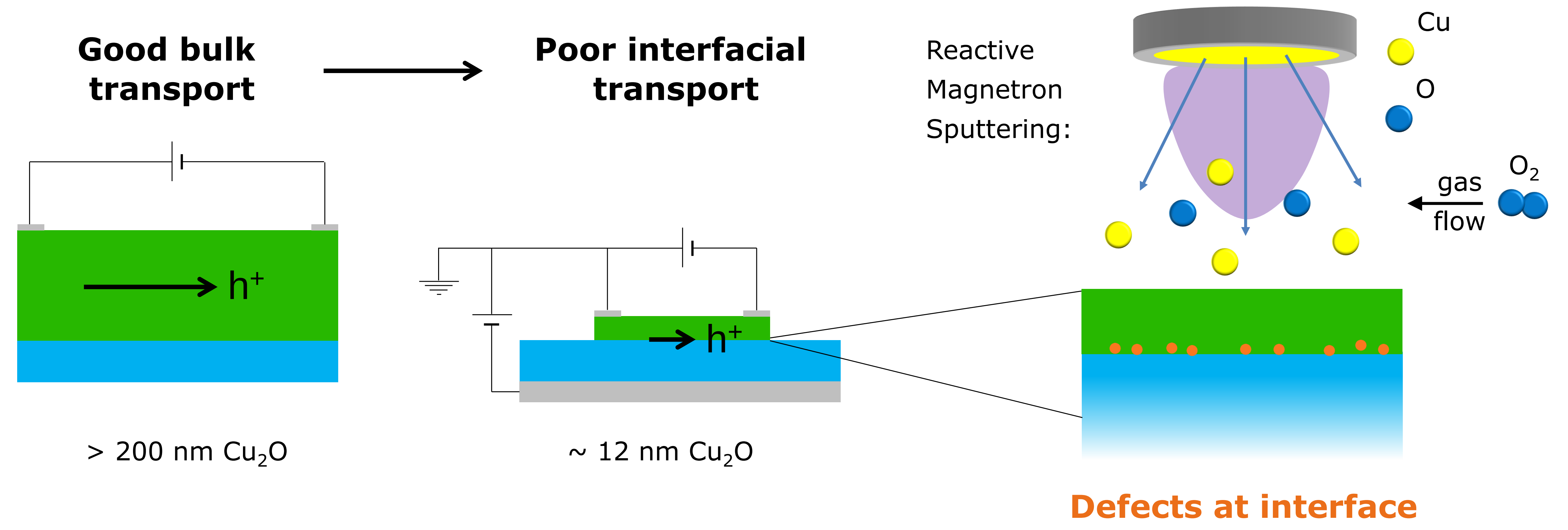
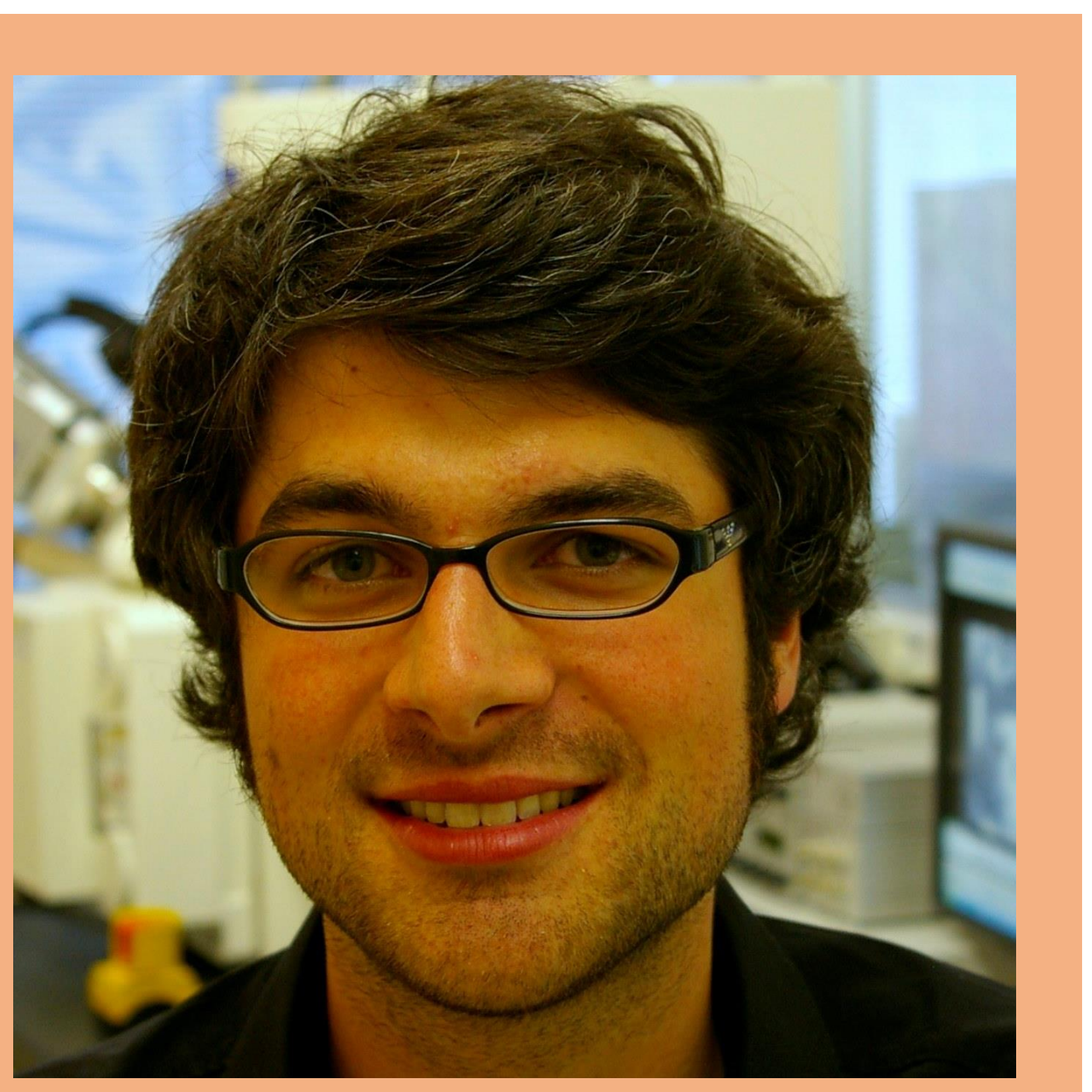
CENIMAT – Materials Research Centre, New University of Lisbon

Transparent p-type transistors based on Cu_2O – Understanding material properties to enhance device performance





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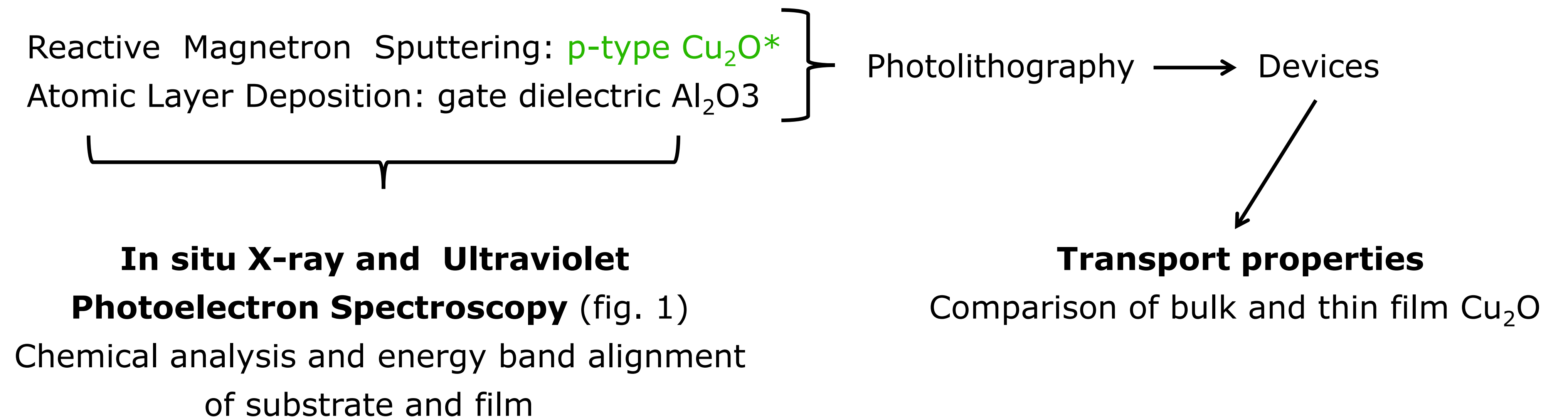
Objectives

What is responsible for limited device performance of p-type oxide TFTs?	Electronic defects? Diffusion? Where in the device?
How can we measure this?	Electrical characterization? Photoelectron Spectroscopy on interface?
Can we overcome the limitations?	Mechanisms intrinsic to the material? Complications induced by fabrication?
What can we do to improve devices?	Alternative combination of materials? New device structures? … ?

Methods and techniques



Reactive Magnetron Sputtering: p-type Cu_2O*
Atomic Layer Deposition: gate dielectric Al_2O3

Photolithography → Devices

In situ X-ray and Ultraviolet Photoelectron Spectroscopy (fig. 1)
Chemical analysis and energy band alignment of substrate and film

Transport properties
Comparison of bulk and thin film Cu_2O

*General characterization of material:
X-ray diffraction, Scanning Electron Microscopy, Hall-Effect, UV-Vis-NIR Spectroscopy, ...

Results

Non-stoichiometric $Cu_{2-y}O$:
- More oxidized state (y>0) → more intrinsic acceptors V_{Cu} → higher hole concentration [1]
  → Keep Cu_2O stoichiometric, even down to the interface level

Top-gate geometry: Clear chemical damage to Cu_2O channel by Al_2O_3 deposition [2] (fig. 2)
- Al_2O_3 by Atomic Layer Deposition → reduction to Cu(0), Schottky-barrier formation
- Al_2O_3 by reactive Magnetron Sputtering → oxidation to Cu(II), lower Fermi energy
  → No working transistor devices

Bottom-gate geometry: Evidence for defective growth of Cu_2O on dielectric
- High Hall mobility (32 cm^2/Vs) but low field-effect mobilty and on-off ratio in TFT (fig. 3)
- In situ XPS: Cu(II) in Cu_2O changes with increasing film thickness (fig. 4)
- In progress: Temperature- and time-dependent electrical measurements of bulk Cu_2O and TFTs to tackle questions on defect mechanisms

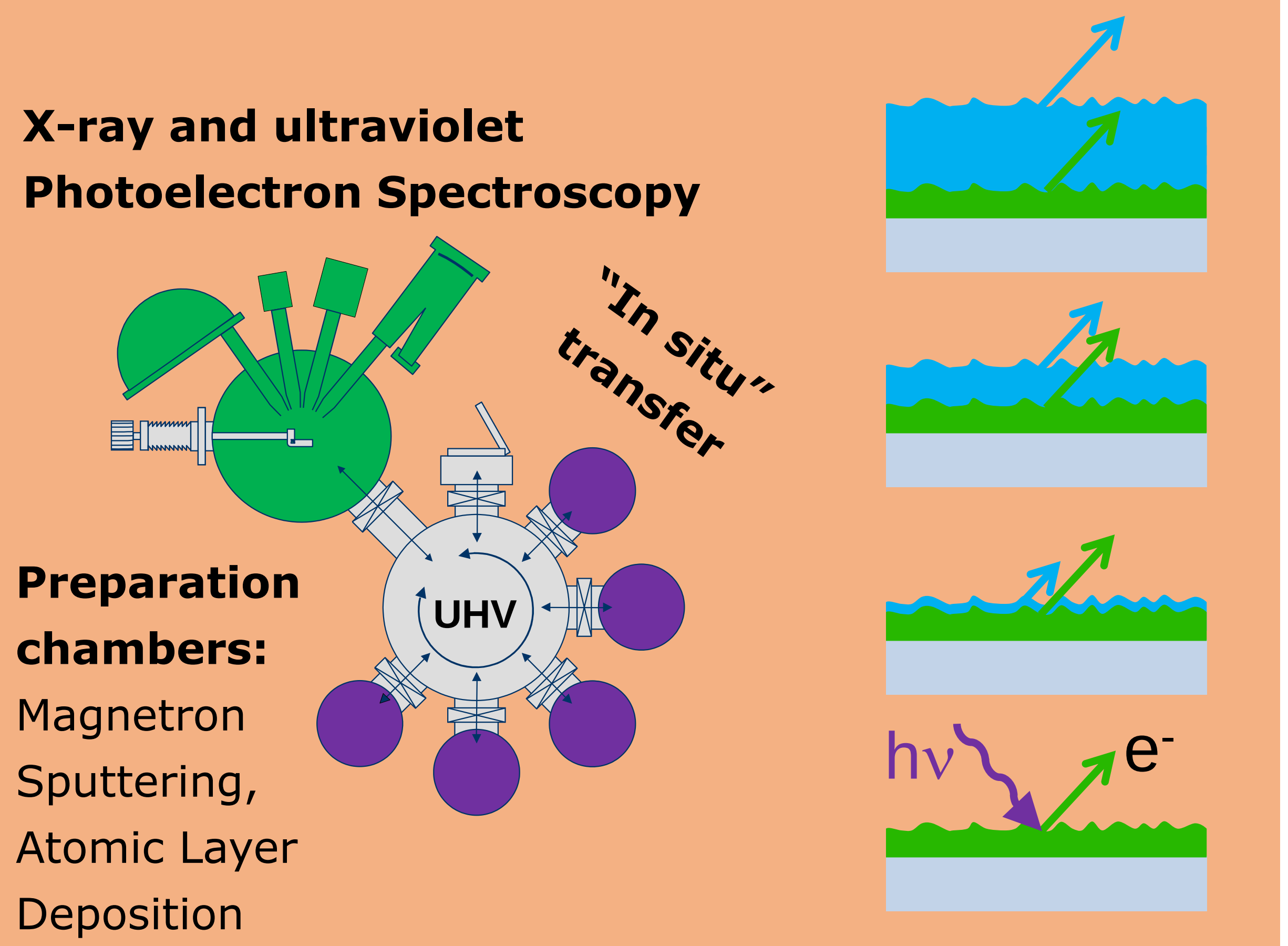
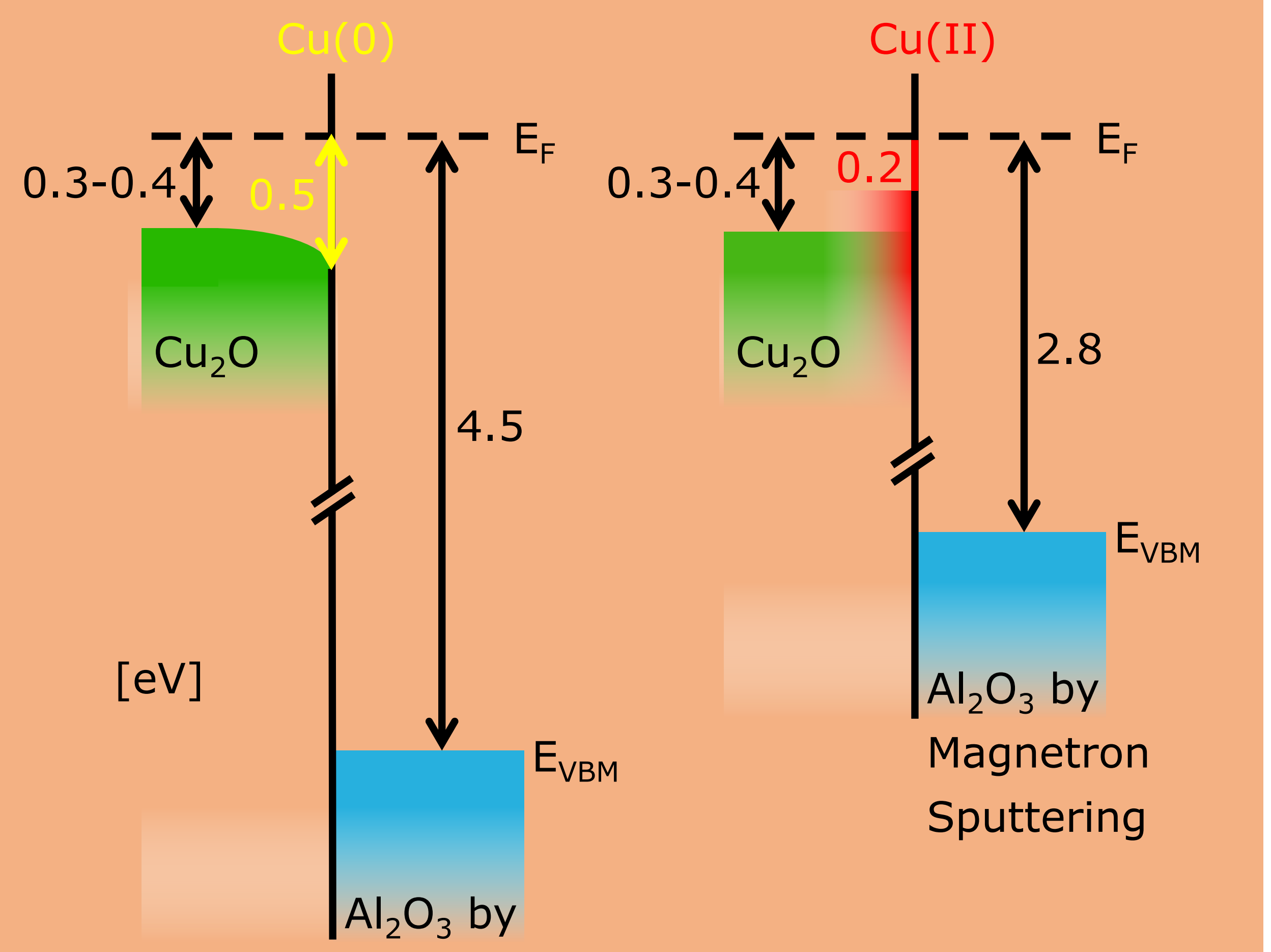


Figure 1



Atomic Layer Deposition

Figure 2

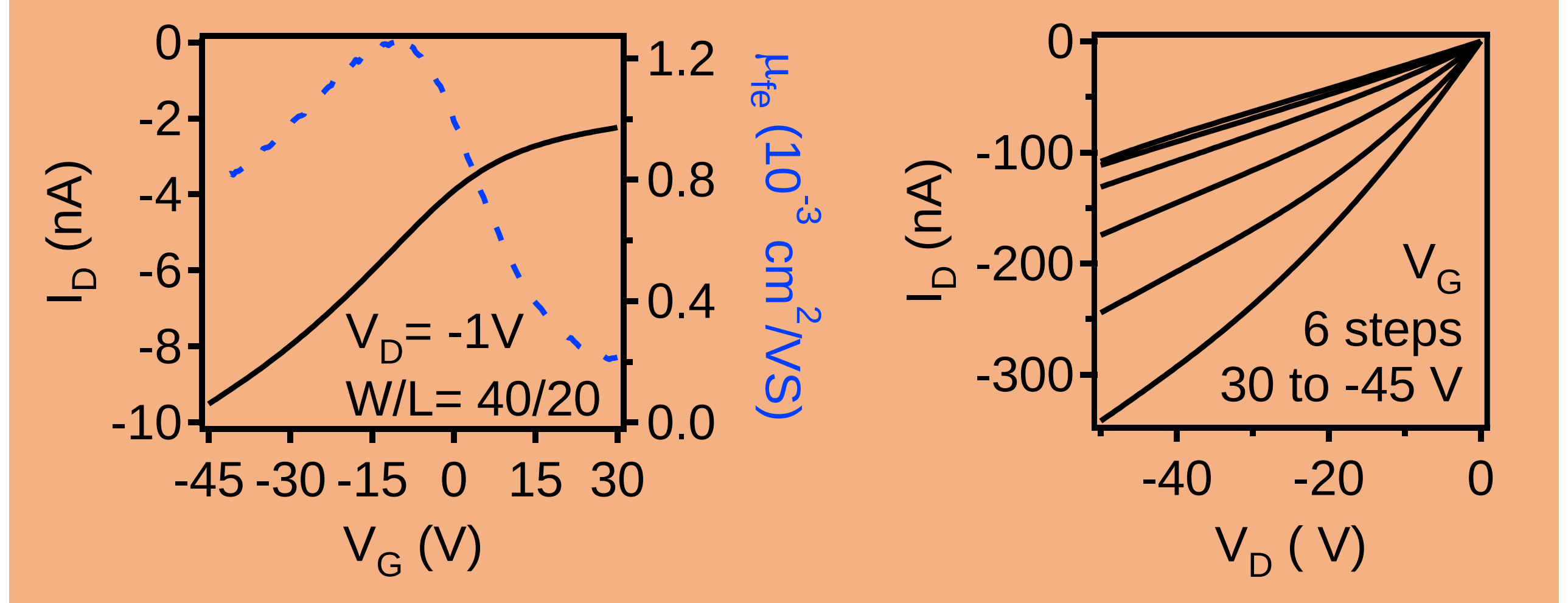


Figure 3

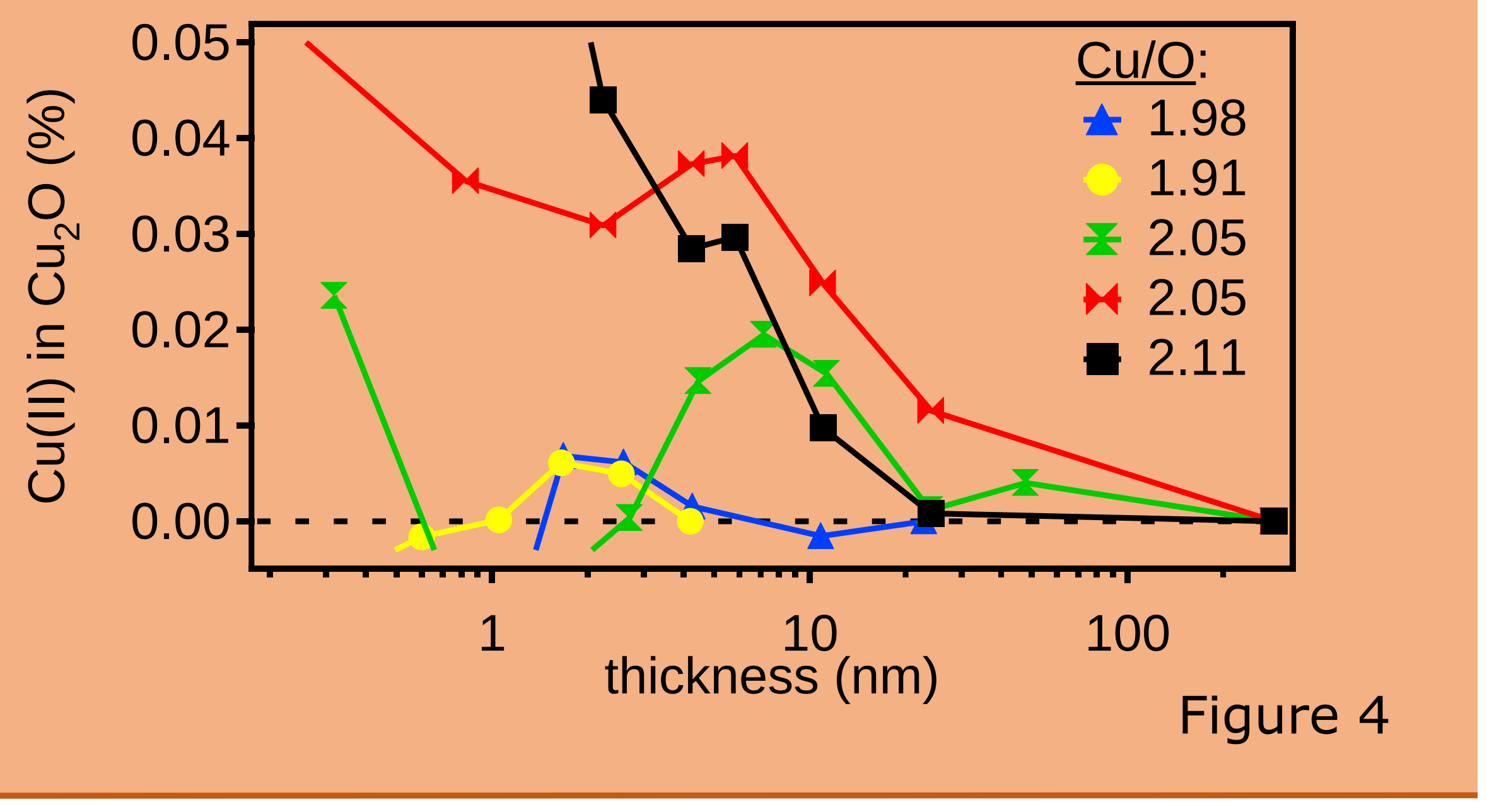


Figure 4

Publications

[2] **Deuermeier, J.**, Yanagi, H., Bayer, T. J. M., Martins, R., Klein, A., and Fortunato, E., *Advanced Materials Interfaces* (submitted)

Figueiredo, V. , Pinto, J. V., **Deuermeier, J.**, Barros, R., Alves, E., Martins, R., and Fortunato, E., *J. Disp. Technol.* 9, 735–740 (2013).

Bayer, T. J. M., Wachau, A., Fuchs, A., **Deuermeier, J.**, and Klein, A., *Chem. Mater.* 24, 4503–4510 (2012).

[1] **Deuermeier, J.**, Gassmann, J., Brötz, J., and Klein, A., *J. Appl. Phys.* 109, 113704 (2011).

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