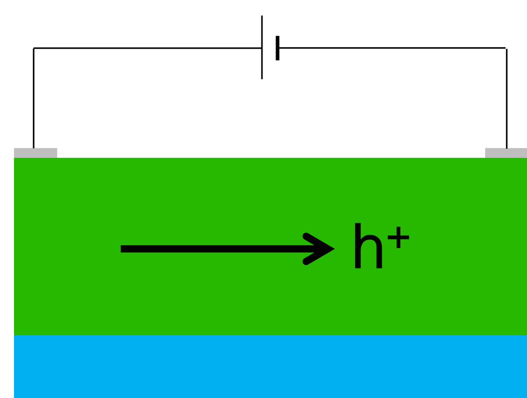
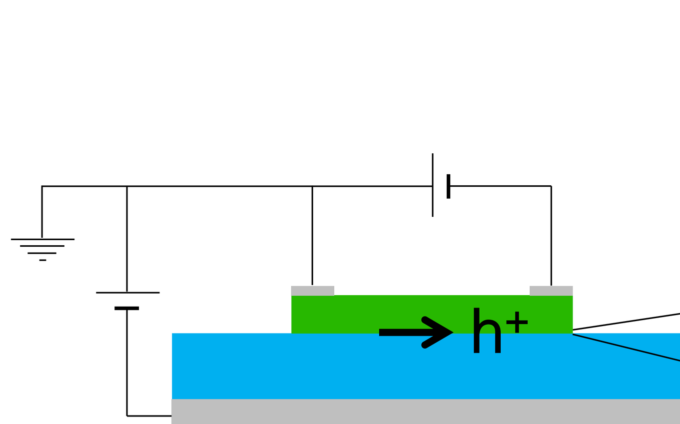
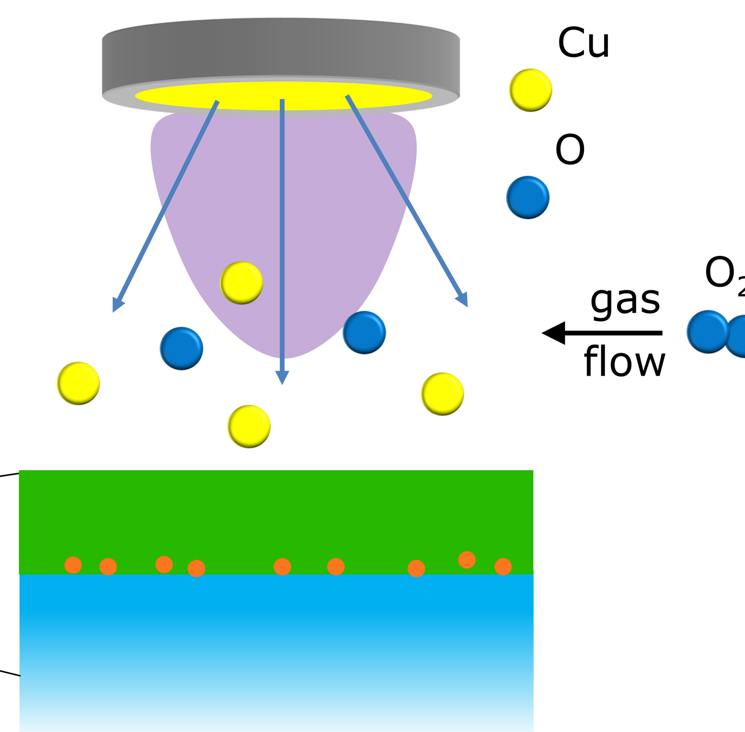
CENIMAT/i3N, FCT-UNL
Surface Science, TU Darmstadt

Origins of limited electrical performance of polycrystalline Cu_2O thin-film transistors







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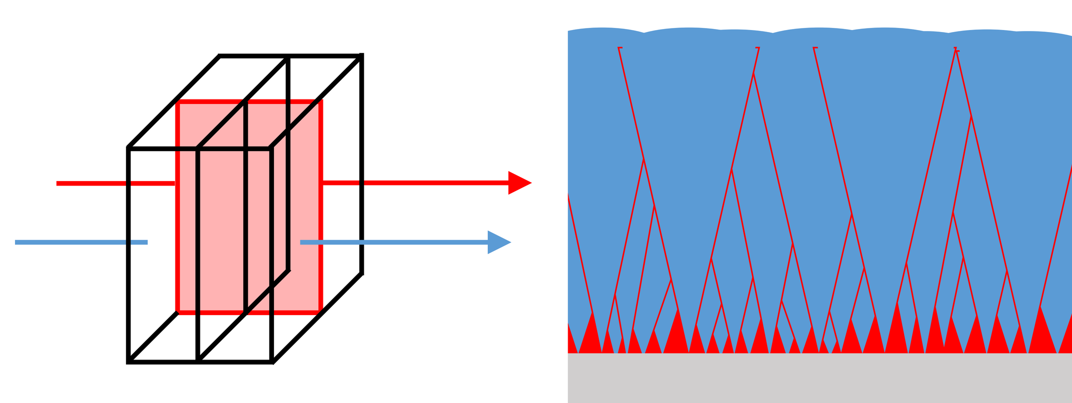
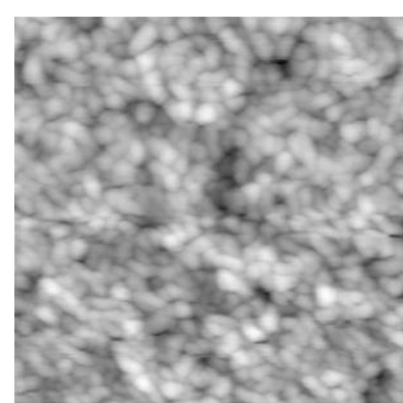
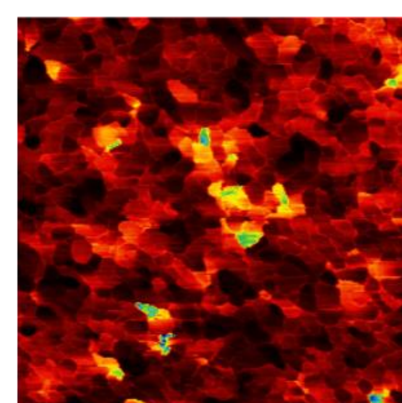
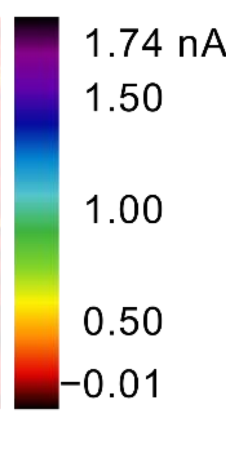
Resume

Increased conductivity of grain boundary and interface region in Cu_2O due to localized oxidation to Cu(II)

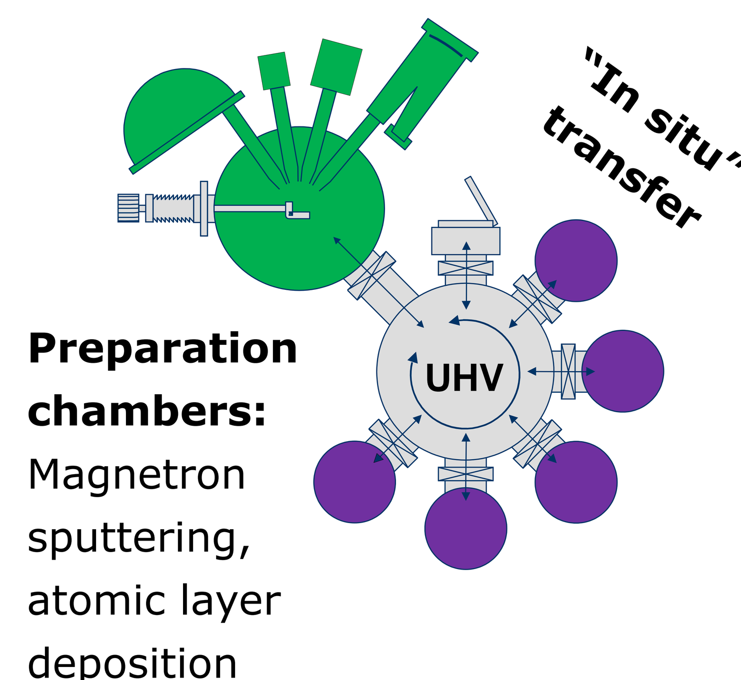








X-ray and ultraviolet photoelectron spectroscopy



Preparation chambers: Magnetron sputtering, atomic layer deposition

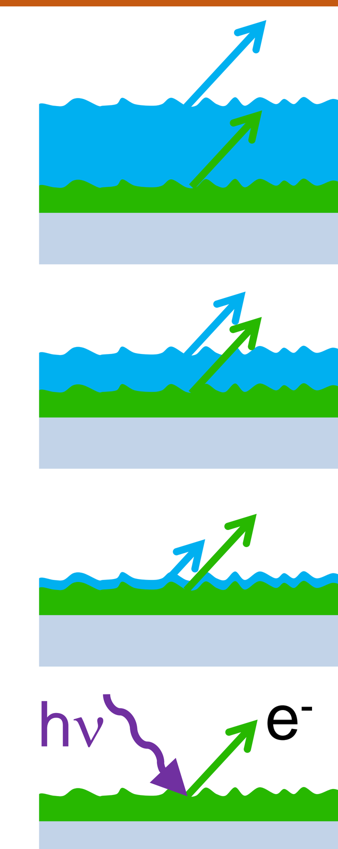


Figure 1

Methods and techniques

Reactive magnetron sputtering: p-type Cu_2O
Atomic layer deposition: gate dielectric Al_2O3

Photolithography → Devices

In situ electrical resistance + X-ray photoelectron spectroscopy (Fig. 1)
Chemical analysis and energy band alignment of substrate and film

Transport properties
Comparison of bulk and thin film Cu_2O

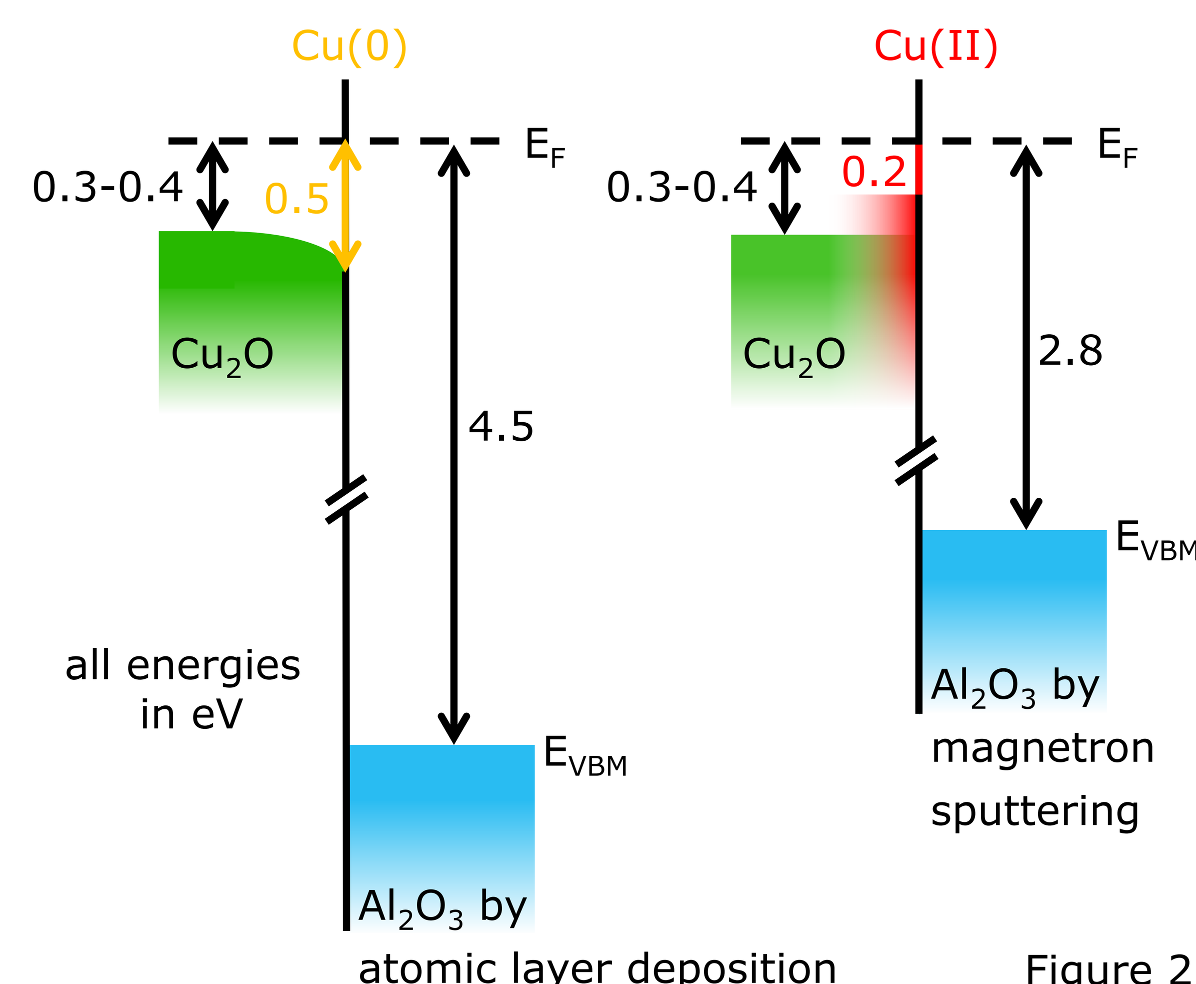


Figure 2

Results

Non-stoichiometric $Cu_{2-y}O$:

- More oxidized state (y>0) → 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 (Fig. 2) [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 [3]

- High Hall mobility (32 cm^2/Vs) but low field-effect mobility and on-off ratio in TFT
- In situ XPS: Cu(II) in Cu_2O changes with increasing film thickness d (Fig. 3) with a parallel increased conductance at low film thickness (Fig. 4)
  → Increased conductivity through grain boundaries

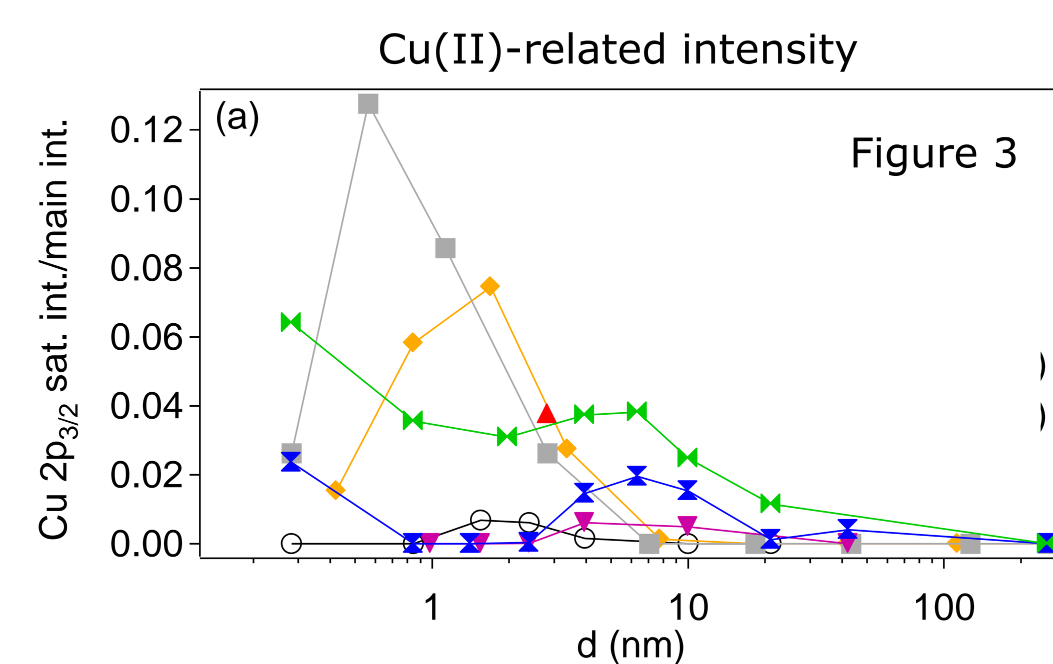


Figure 3

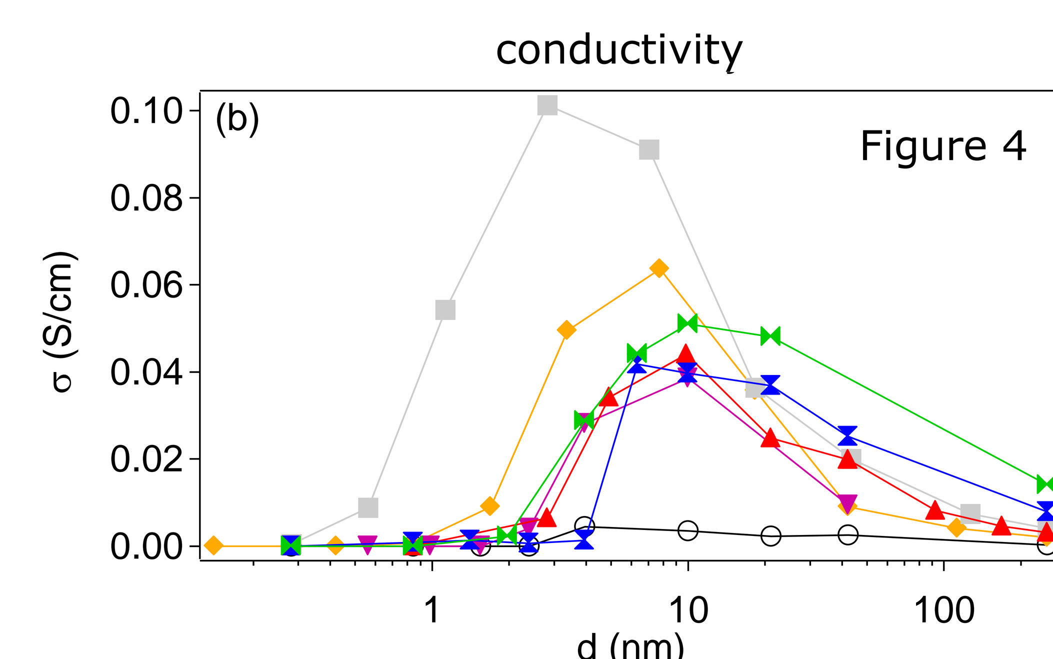


Figure 4

Publications

[1] Deuermeier, J. et al., Reactive magnetron sputtering of Cu_2O: Dependence on oxygen pressure and interface formation with indium tin oxide. *J. Appl. Phys.* 109, 113704 (2011).

[2] Deuermeier, J. et al., Substrate reactivity as the origin of Fermi level pinning at the Cu_2O/ALD-Al_2O_3 interface. *Mater. Res. Express* 3, 046404 (2016).

[3] Deuermeier, J. et al., Highly conductive grain boundaries in copper oxide thin films. *J. Appl. Phys.* 119, 235303 (2016).

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