Cu_2O nanowires produced by oxidation of Cu nanowires

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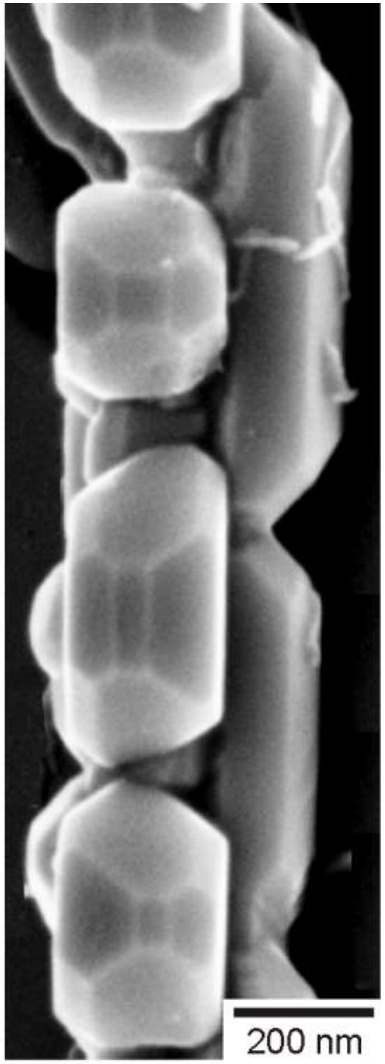
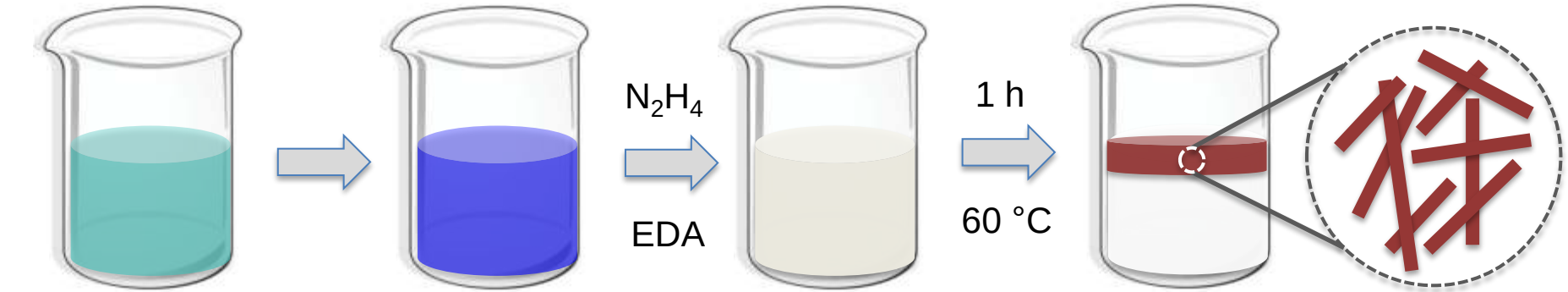
Outline

- Synthesis of Cu nanowires
- Oxidation
  - Furnace annealing
  - Microwave irradiation
- Structural characterization
- Possible applications



Solution based methods



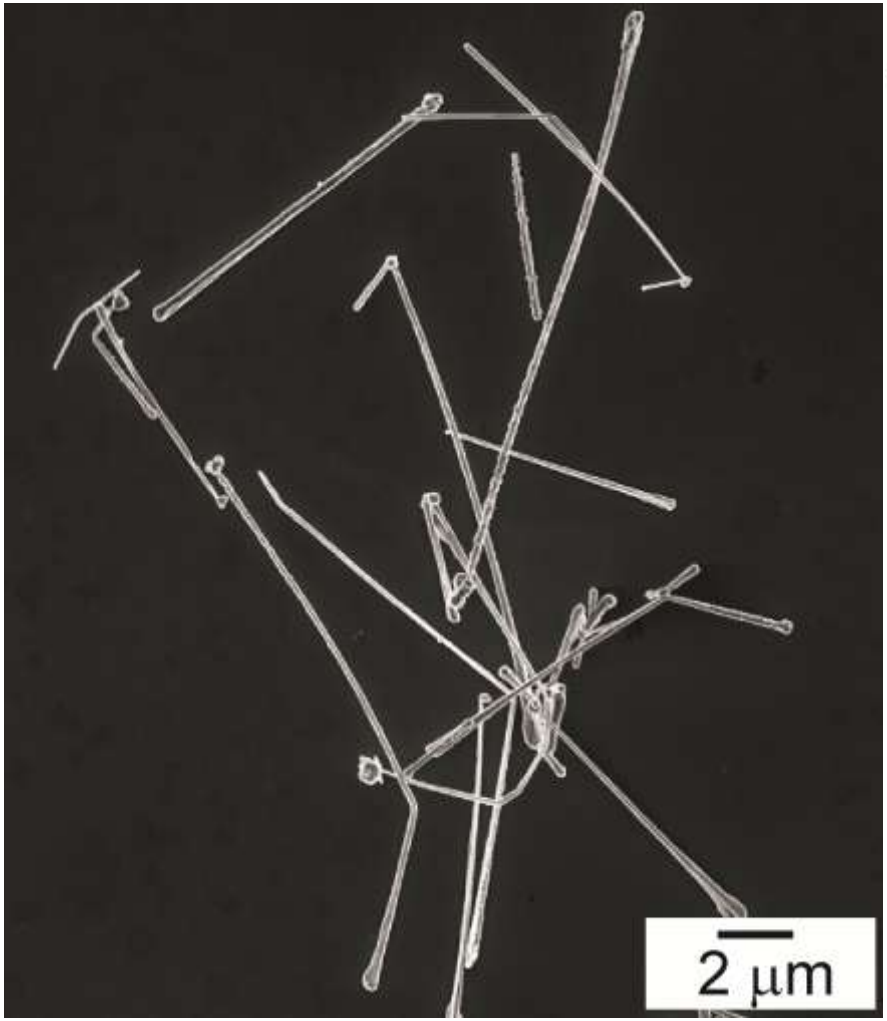
- 24g of NaOH in 40 mL H_2O
- 0.5 g of Cu precursor in 20 mL of H_2O
- 0.050 mL Ethylenediamine (EDA)
- 0.010 mL Hidrazyne – N_2H_4

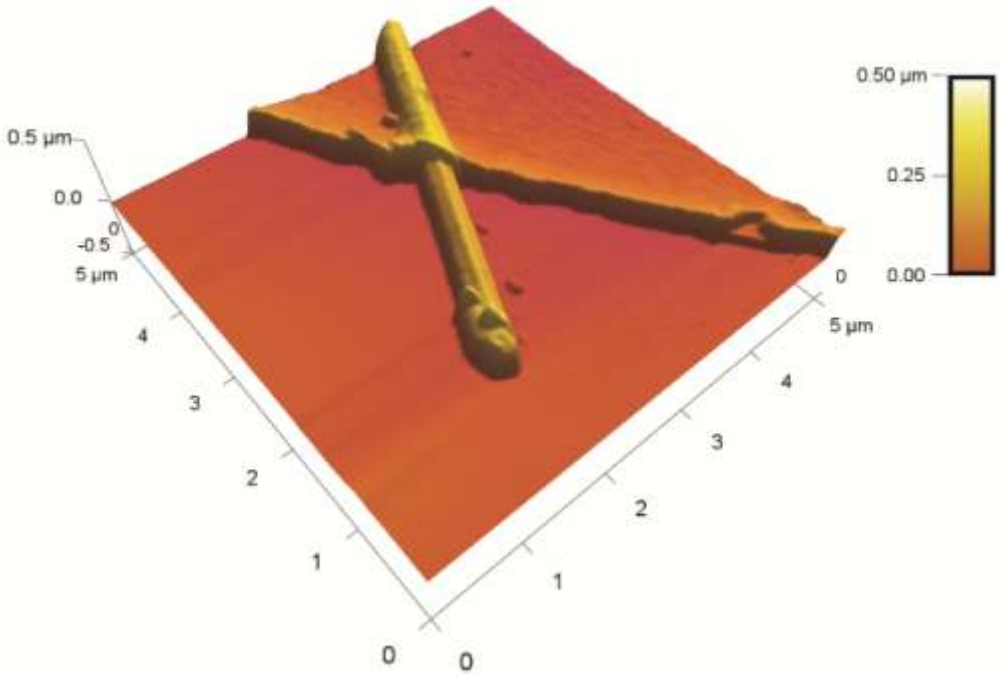
Reactions

$$Cu(CO_2CH_3)_2 + 2NaOH \rightarrow Cu(OH)_2 + 2NaCO_2CH_3$$

$$Cu(OH)_2 + N_2H_4 \rightarrow Cu + N_2 + H_2 + 2H_2O$$

Cu nanowires





Oxidation reactions

- Cu possesses high oxygen affinity to oxygen

- Both Cu_2O and CuO can be produced from oxidation of metallic copper

- The most common oxidation states of Cu are:
  - +1 - Cu_2O (cuprous oxide)
  - +2 - CuO (cupric oxide)

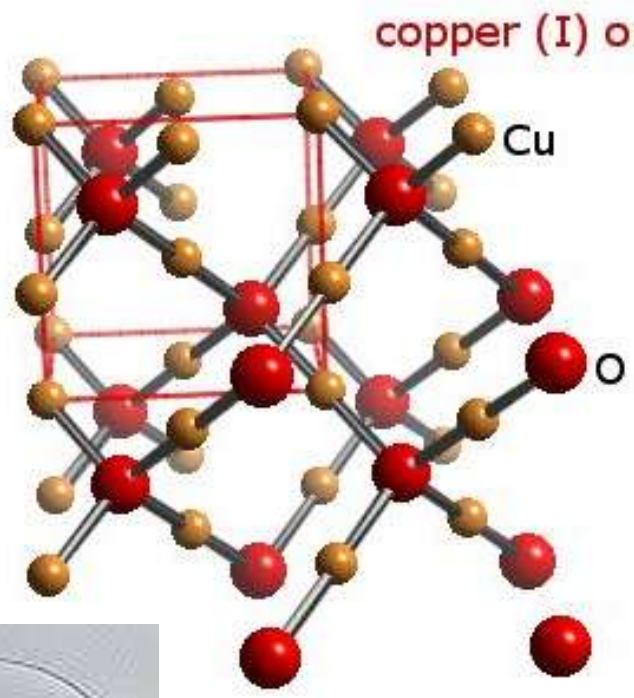
- Cu_2O phase serves as a precursor to CuO, and the latter forms above a certain critical thickness of the Cu_2O layer.

$$4Cu + O_2 \rightarrow 2Cu_2O$$
$$2Cu_2O + O_2 \rightarrow 4CuO$$

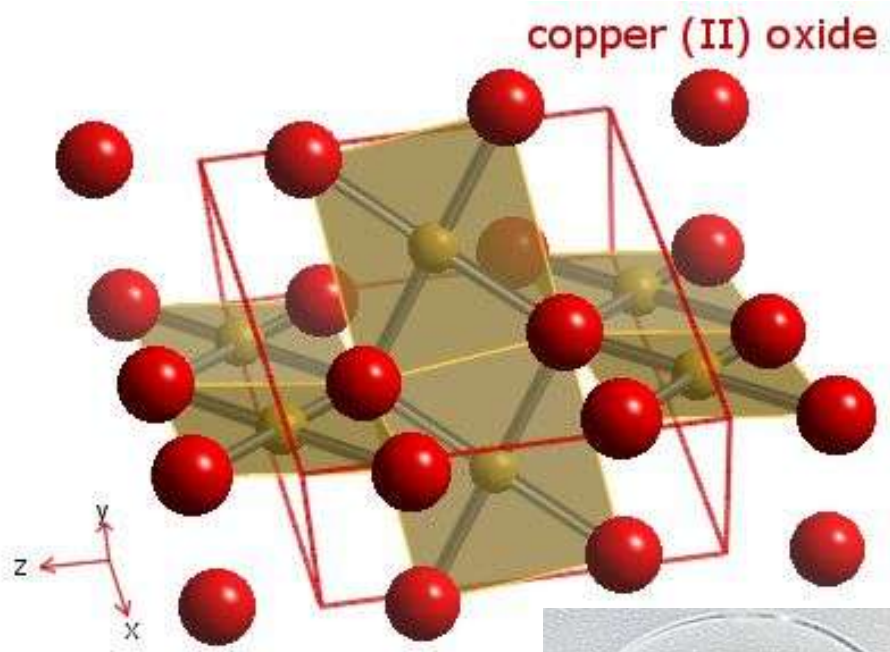
Korshunov, A. V.; Il'in, A. P. Oxidation of copper nanopowders on heating in air. *Russ J Appl Chem* **2009**, *82*, 1164-1171

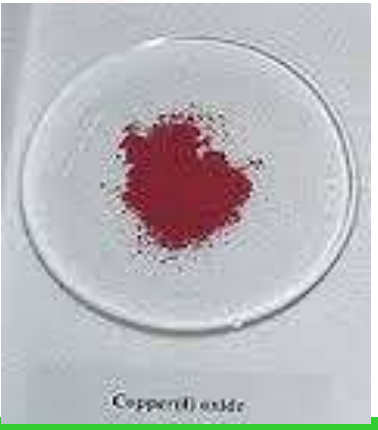
Oxide structures: Cu_2O e CuO

Face-centered cubic unit cell



Monoclinic unit cell



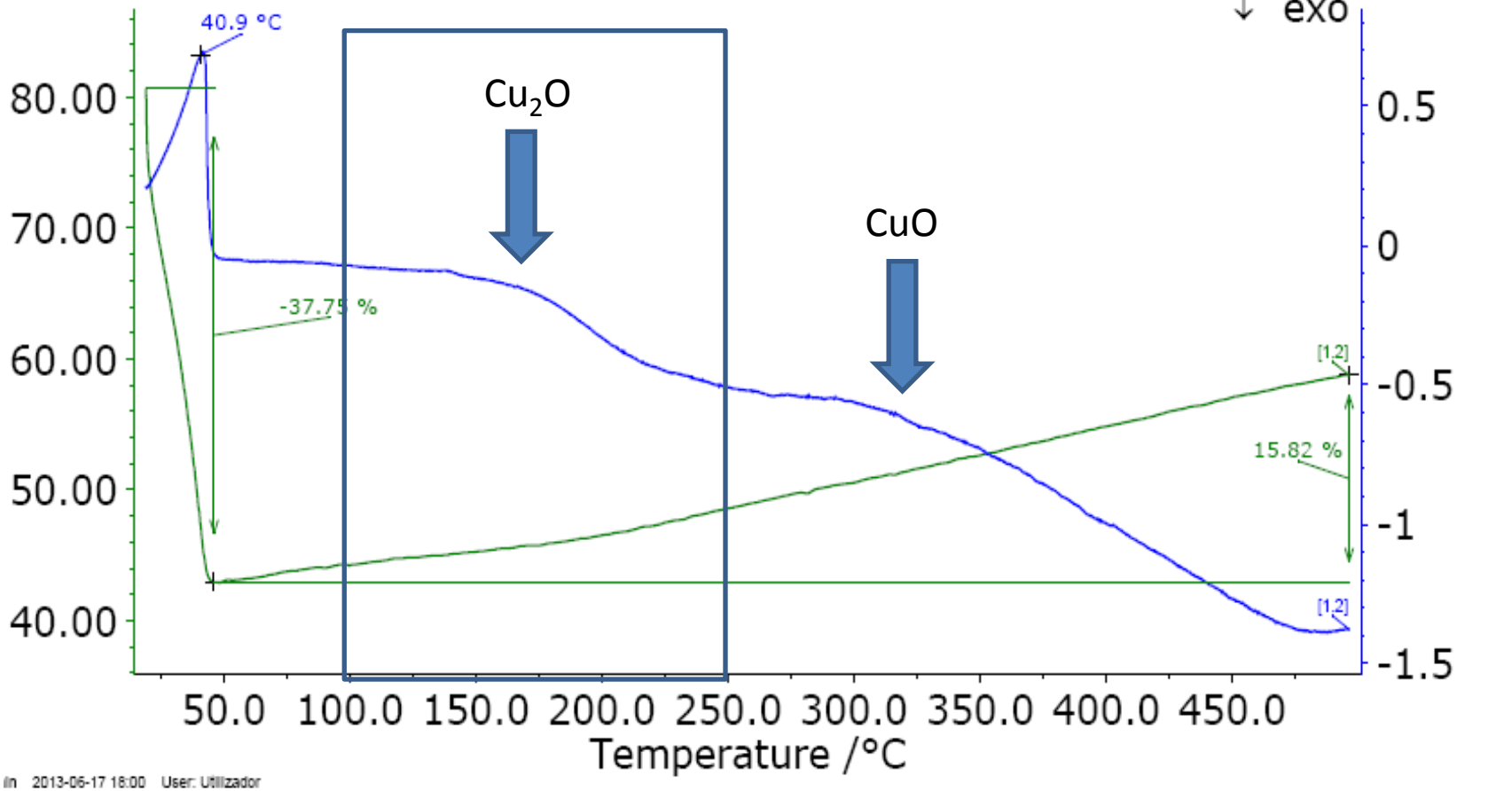


Reddish, but depends on the particle size

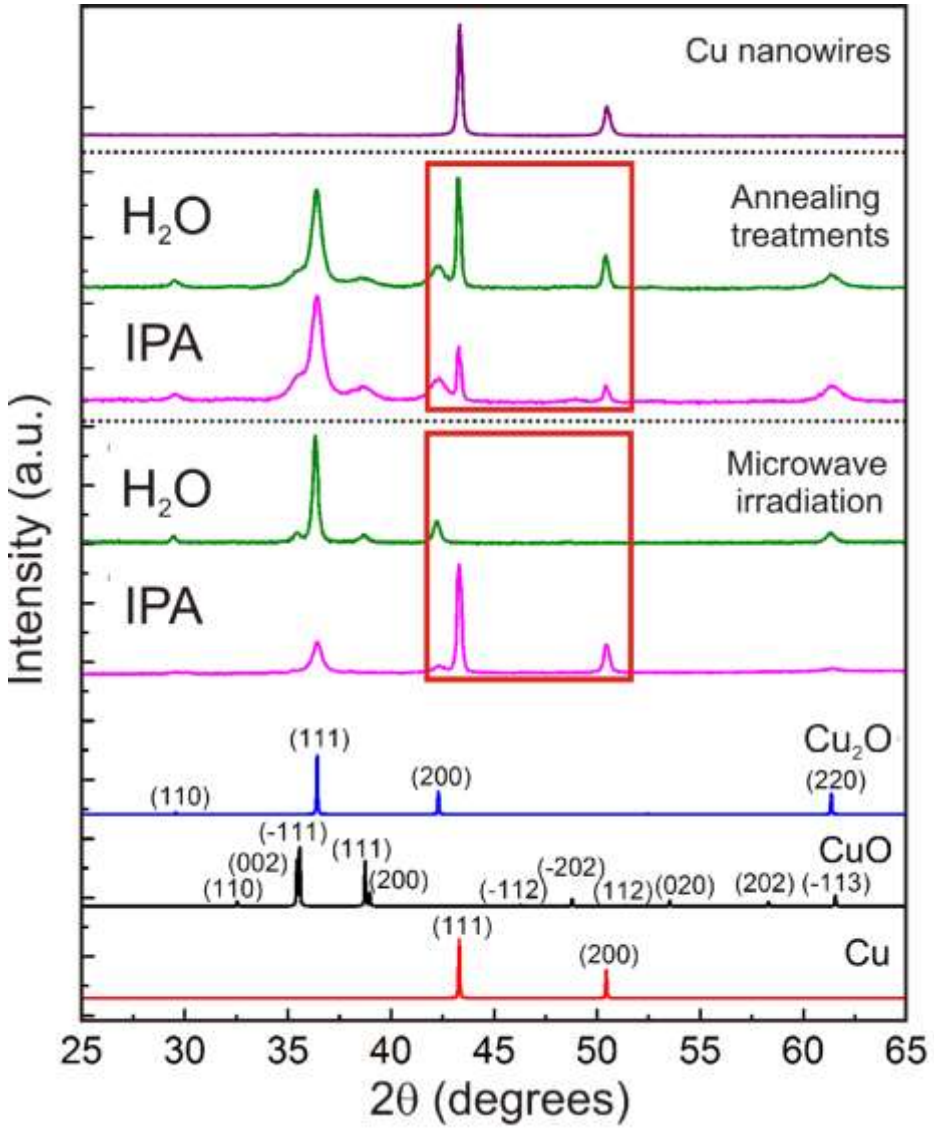
Black color

Cu nanowires

$$Cu \rightarrow Cu_2O \rightarrow \cancel{CuO}$$

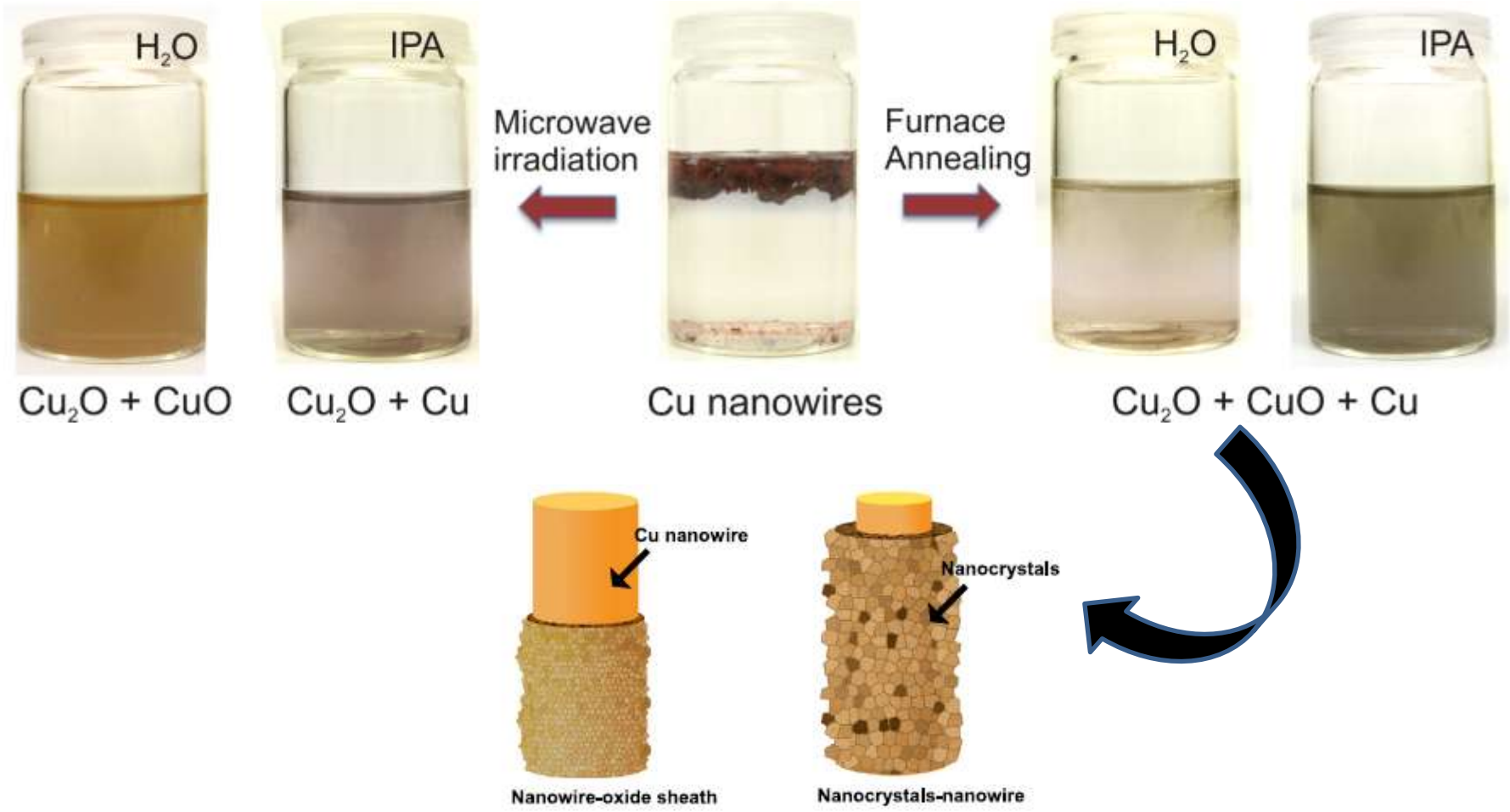


Cu nanowire oxidation



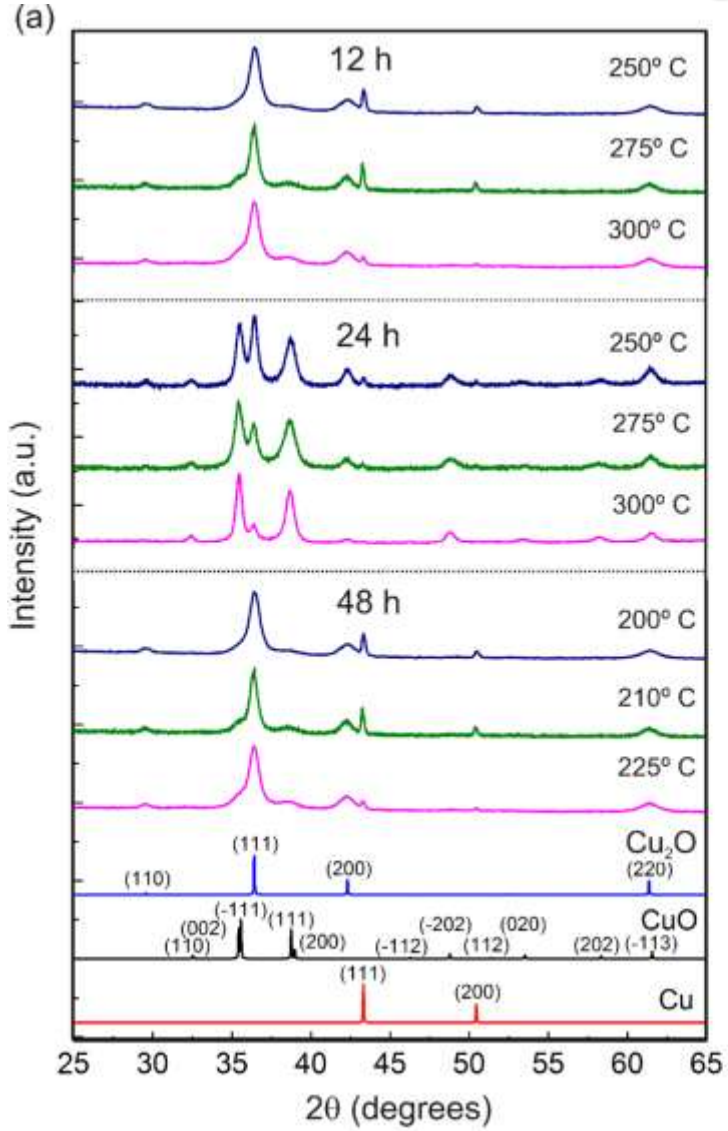
Solvent selection

Oxidized material dispersions



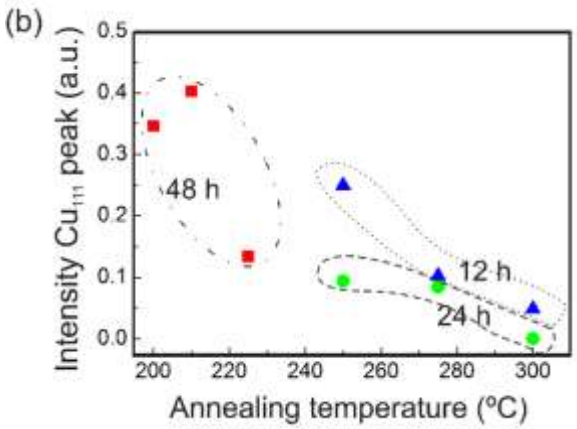
Kevin, M.;Ong, W. L.;Lee, G. H.; Ho, G. W. Nanotechnology 2011, 22, 235701.

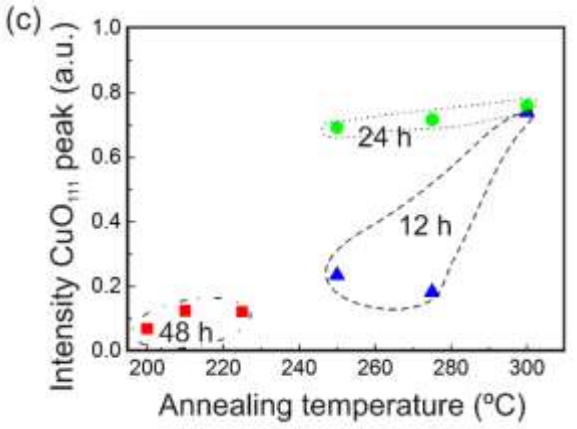
Furnace annealing



Function of time and temperature

- Higher annealing temperatures (≥ 250º C) / shorter annealing times (12 h) → $CuO + Cu_2O + Cu_{(residual)}$
- Lower annealing temperatures (≤225º C) / longer annealing times (48 h) → $Cu_2O + Cu$

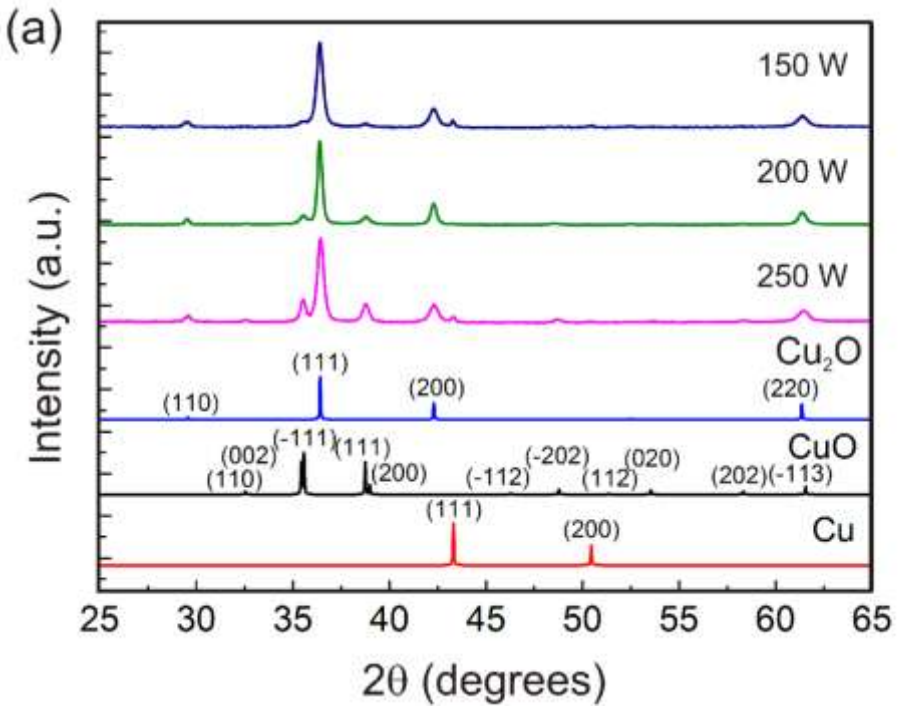


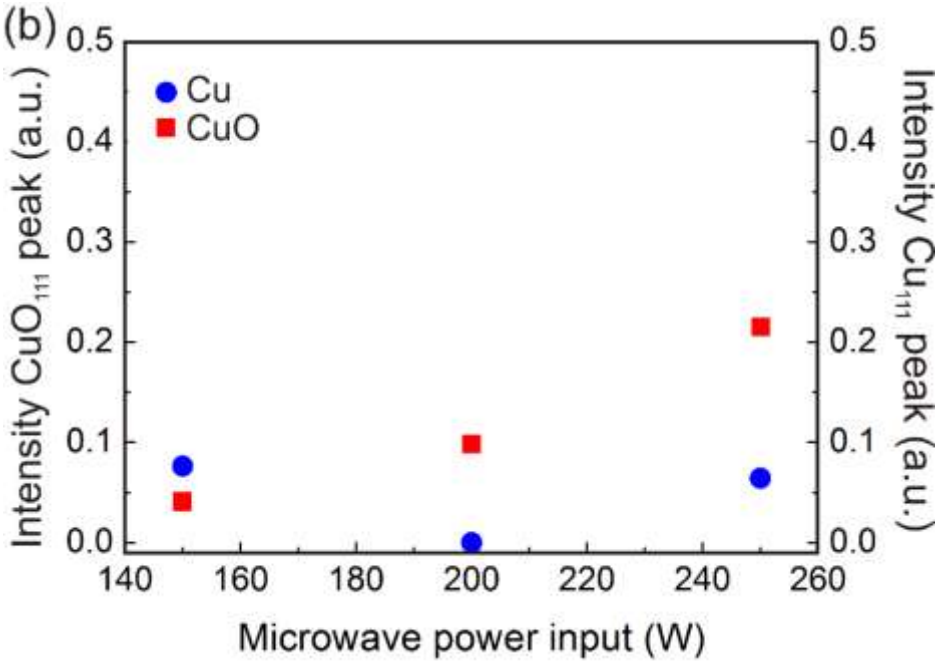


Microwave irradiation

Function of microwave power input

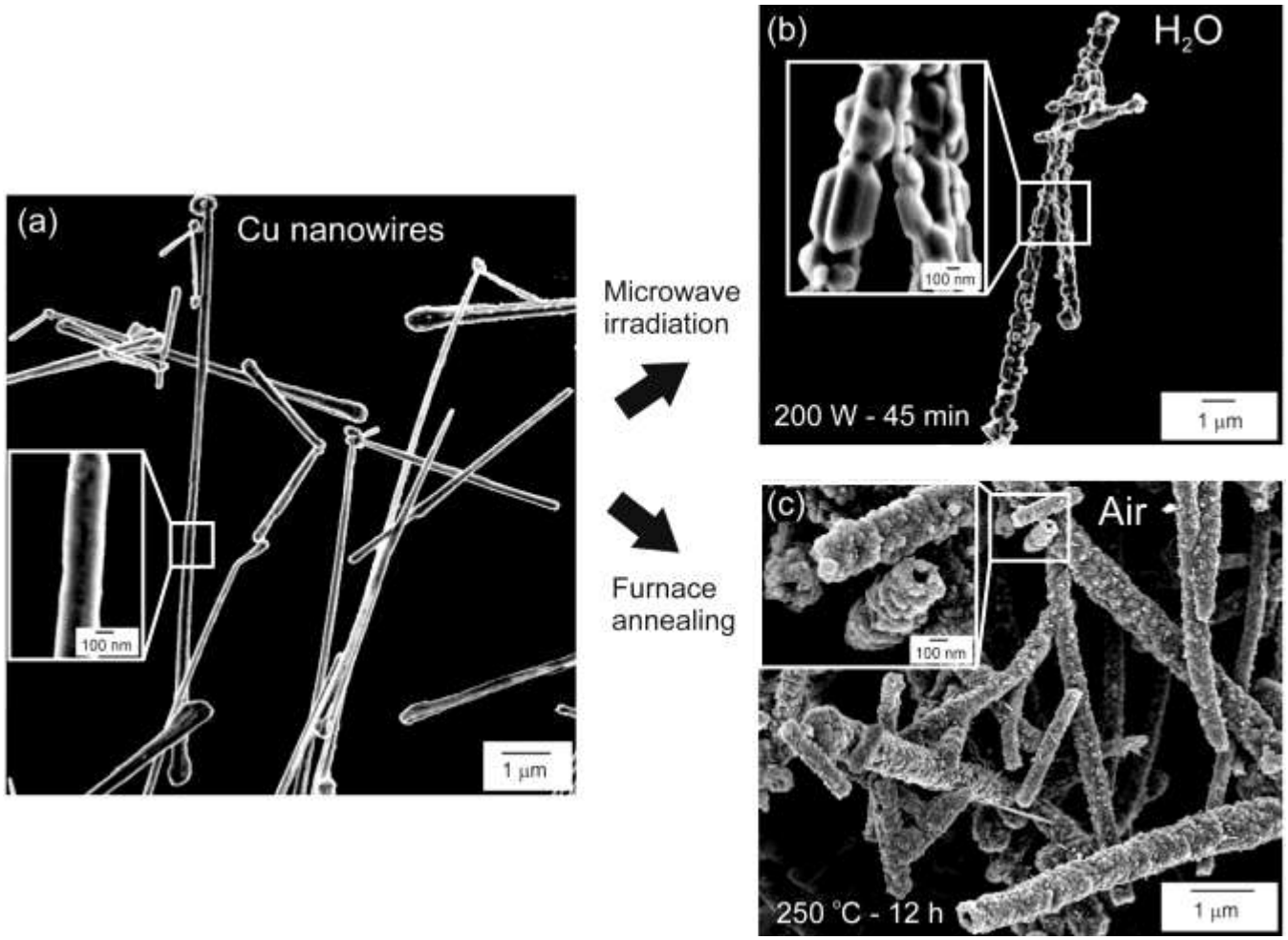
Best condition for Cu elimination: 200 W, 250 Psi and 45 min





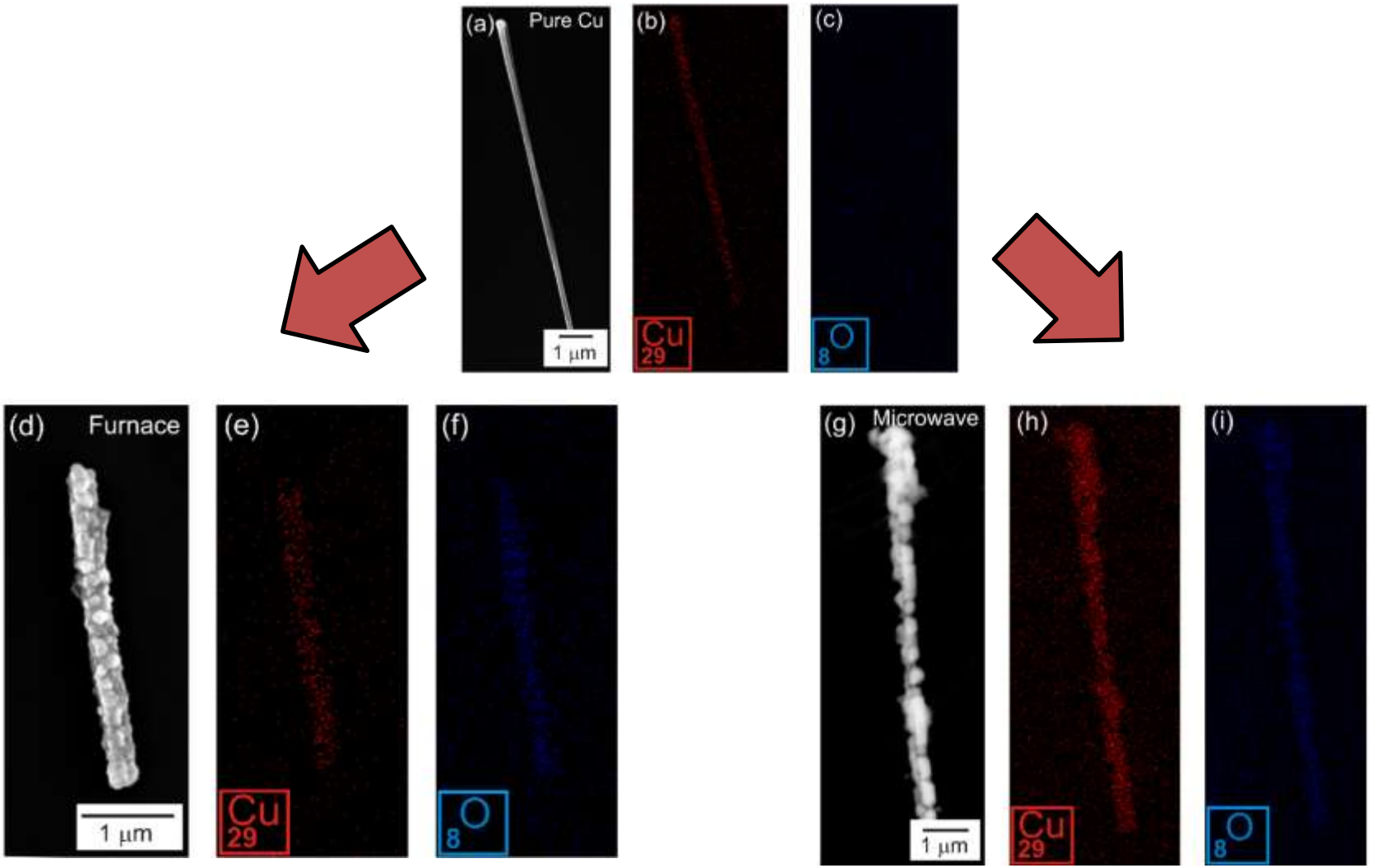
Furnace annealing *vs.* Microwave irradiation

Structural characterization



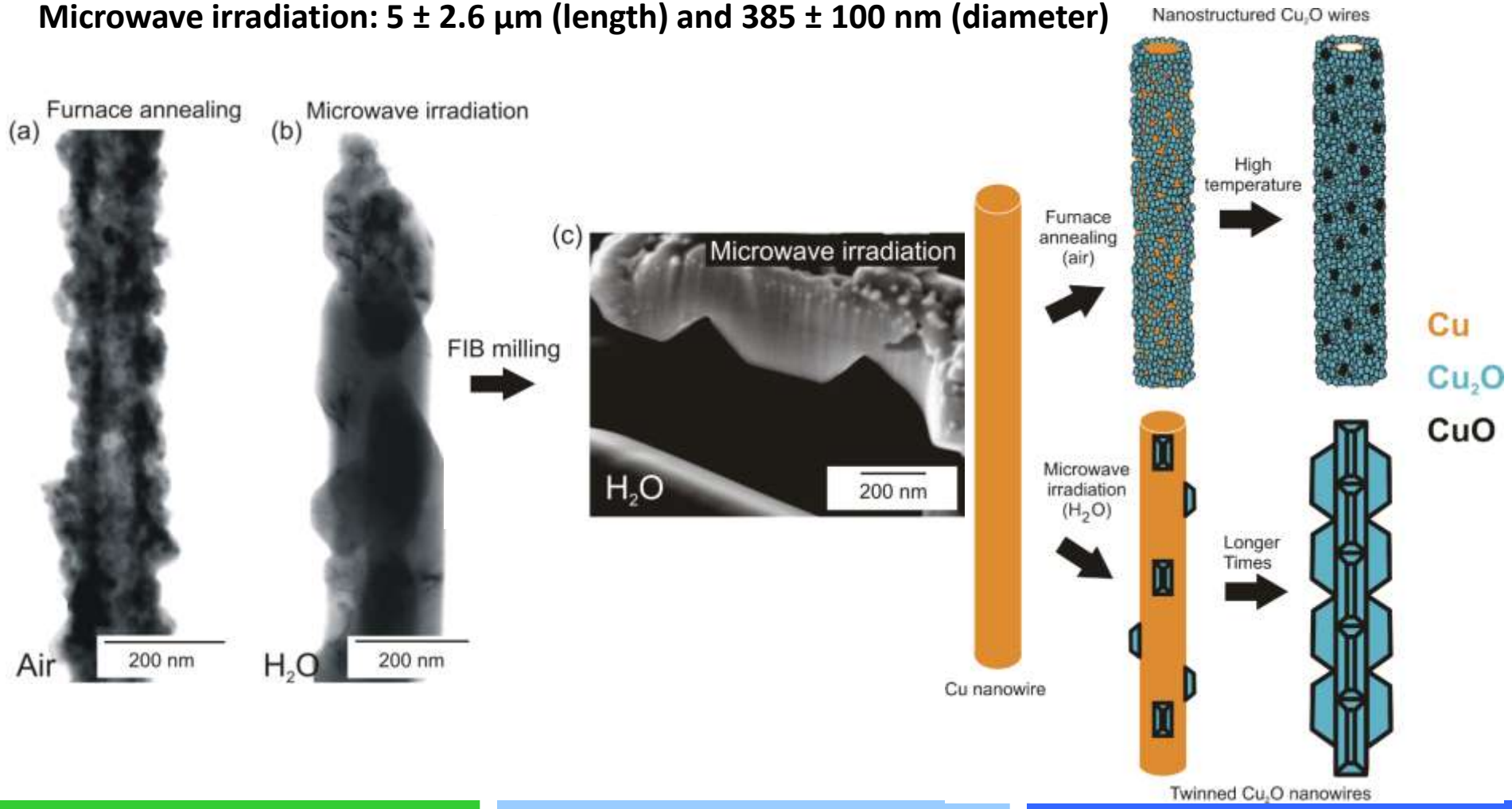
Furnace annealing *vs.* Microwave irradiation

SEM/EDS

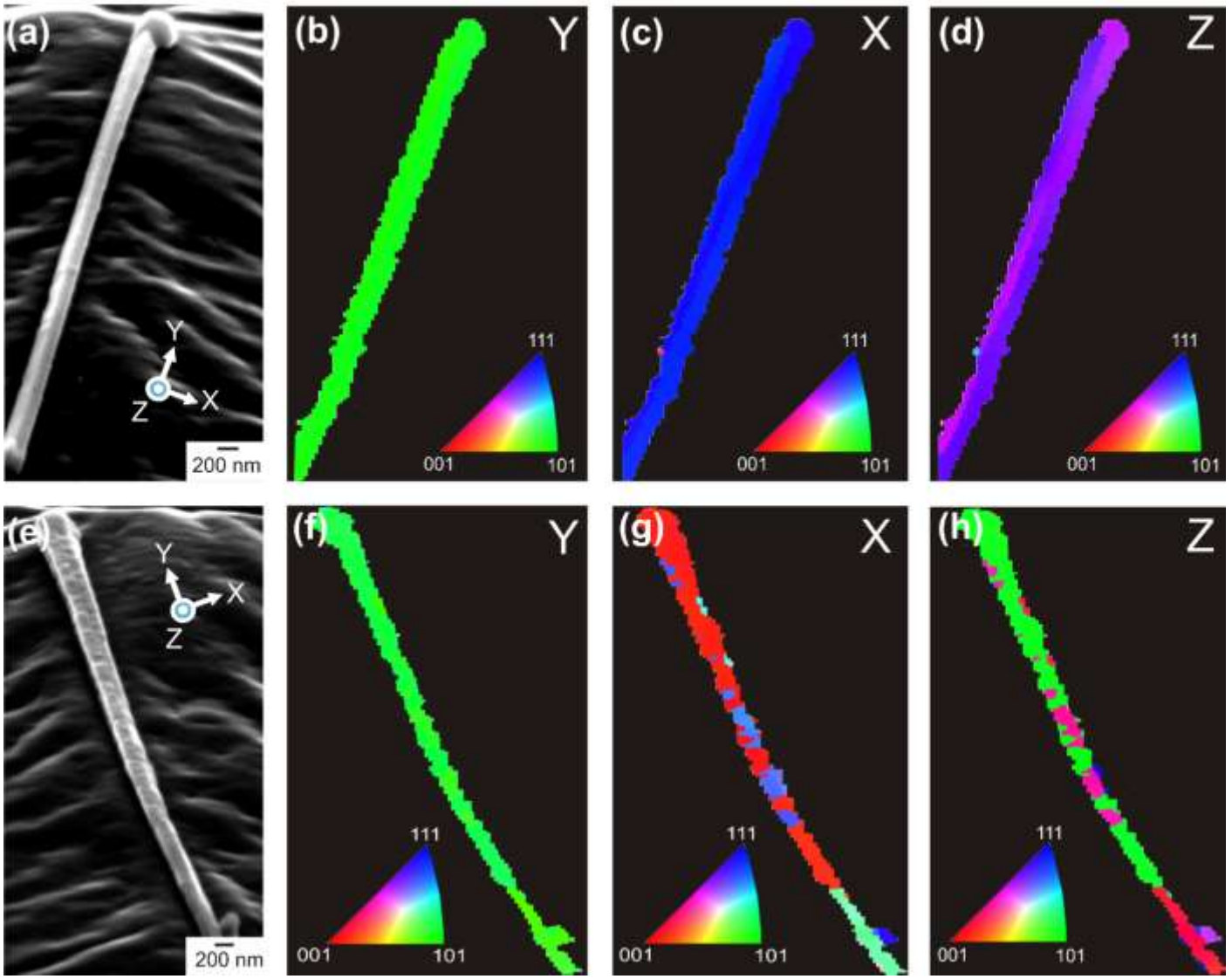


Furnace annealing *vs.* Microwave irradiation

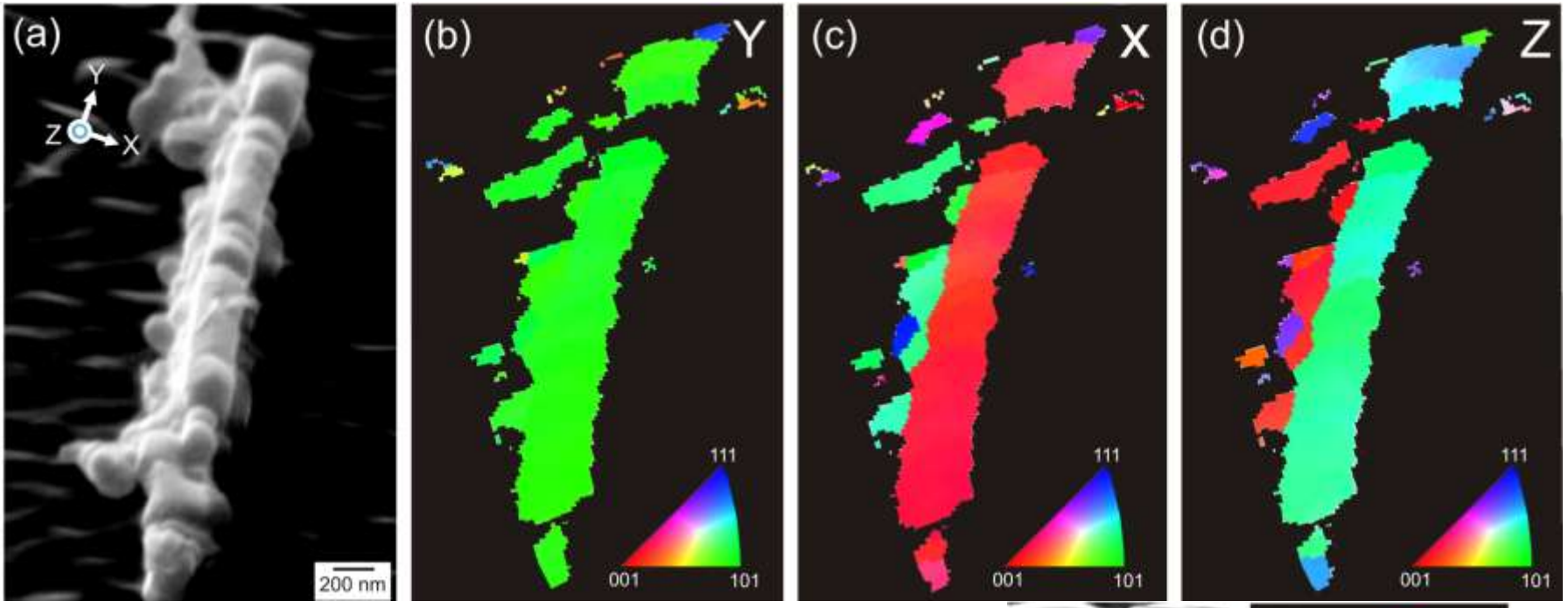
Cu nanowires: 10 ± 3.7 µm (length), 250 ± 90 nm (diameter)
Furnace annealing: 3.9 ± 1.4 µm (length) and 280 ± 90 nm (diameter)
Microwave irradiation: 5 ± 2.6 µm (length) and 385 ± 100 nm (diameter)



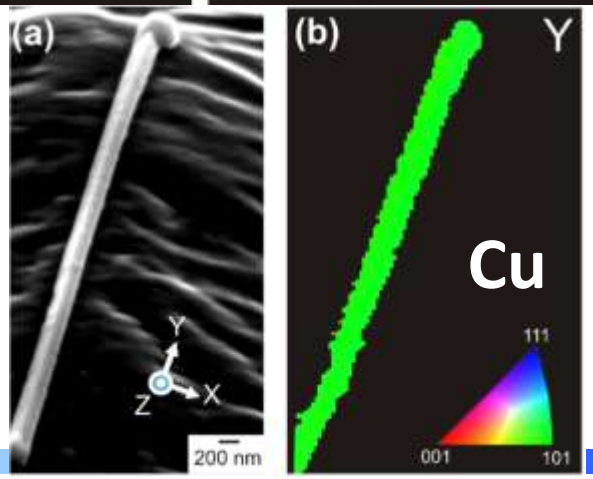
Cu nanowires



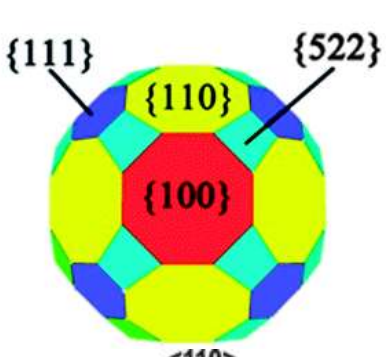
Microwave irradiation

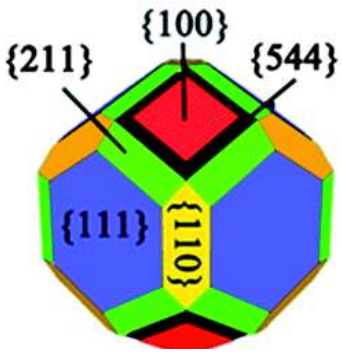


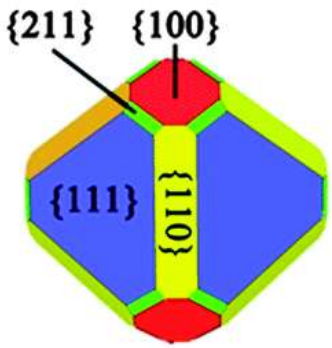
- Cu nanowires with axes (Y) parallel to <110>
- Oxidation of the metal nanowires resulted in the growth of polyhedral Cu_2O crystals arranged in twinned configurations around the nanowire axis.
- Axes (Y) parallel to <110> and are related by a 90° rotation around the nanowire axis.

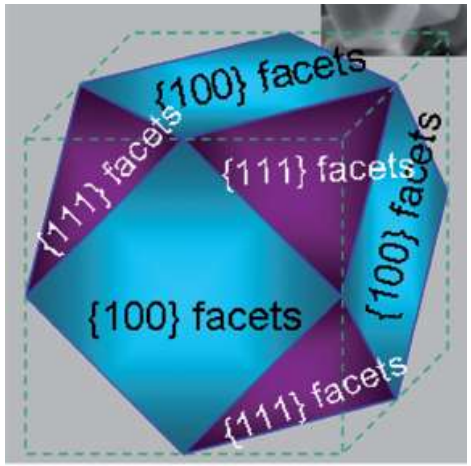


Cu_2O faceted structure

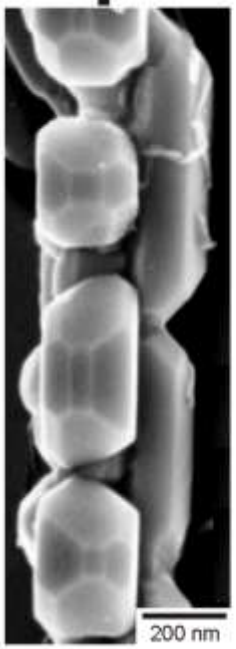




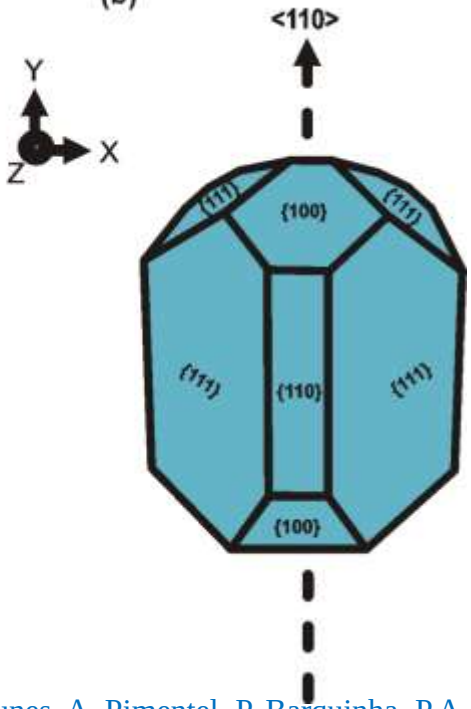


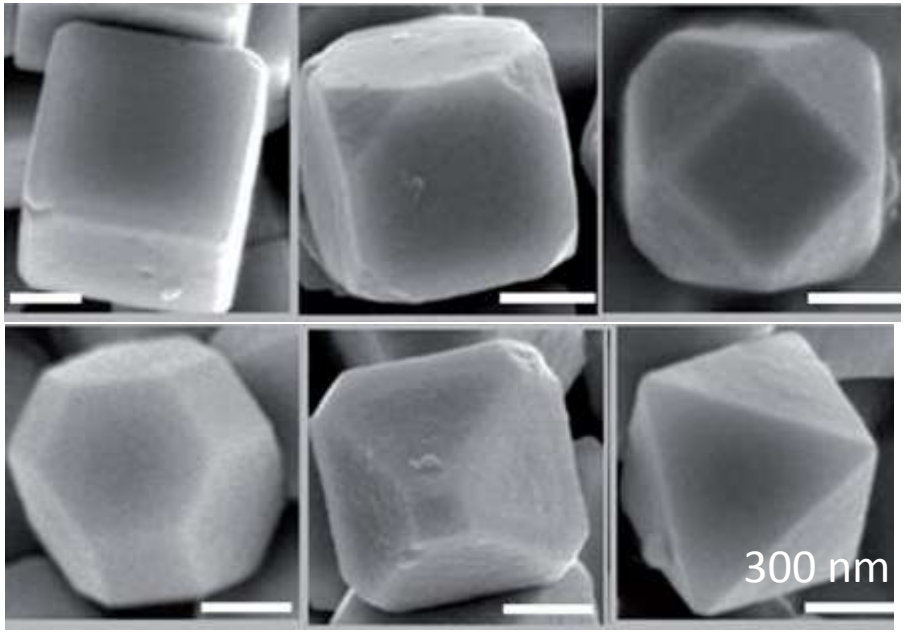


(a)



(b)

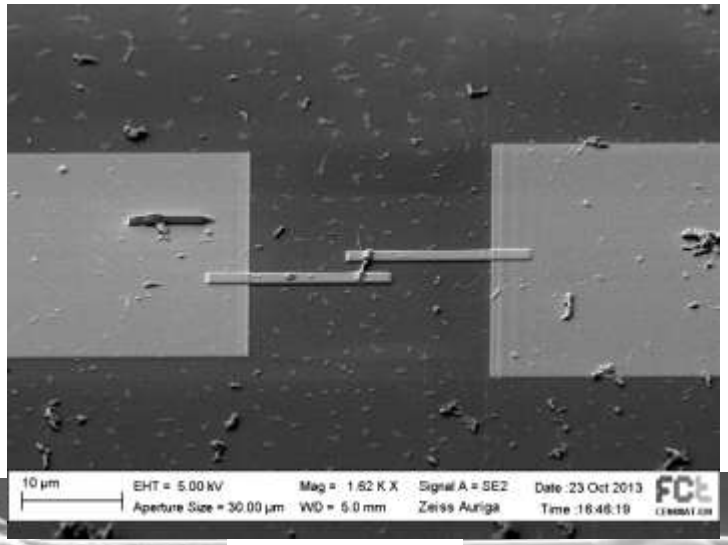


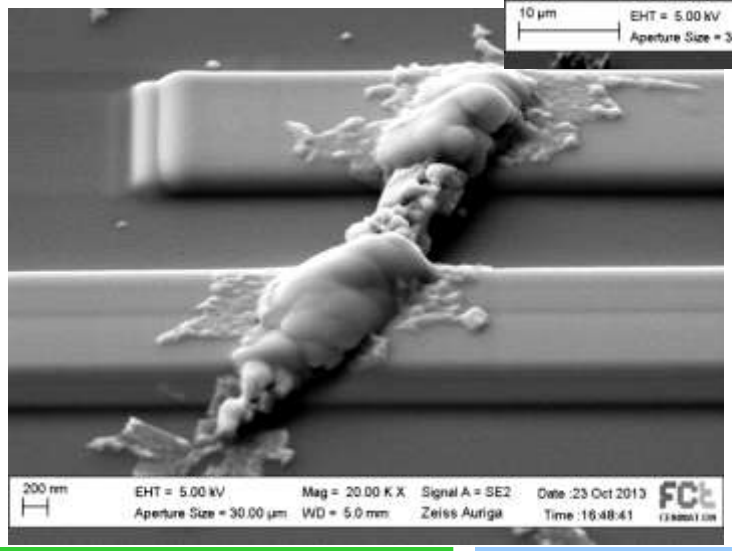


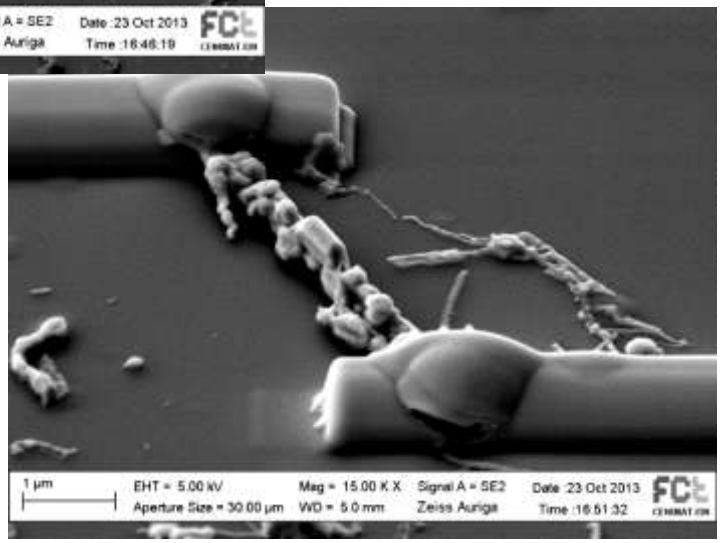
D. Nunes, A. Pimentel, P. Barquinha, P.A. Carvalho, E. Fortunato, R. Martins, Journal of Materials Chemistry C, (2014).

Single crystal TFTs

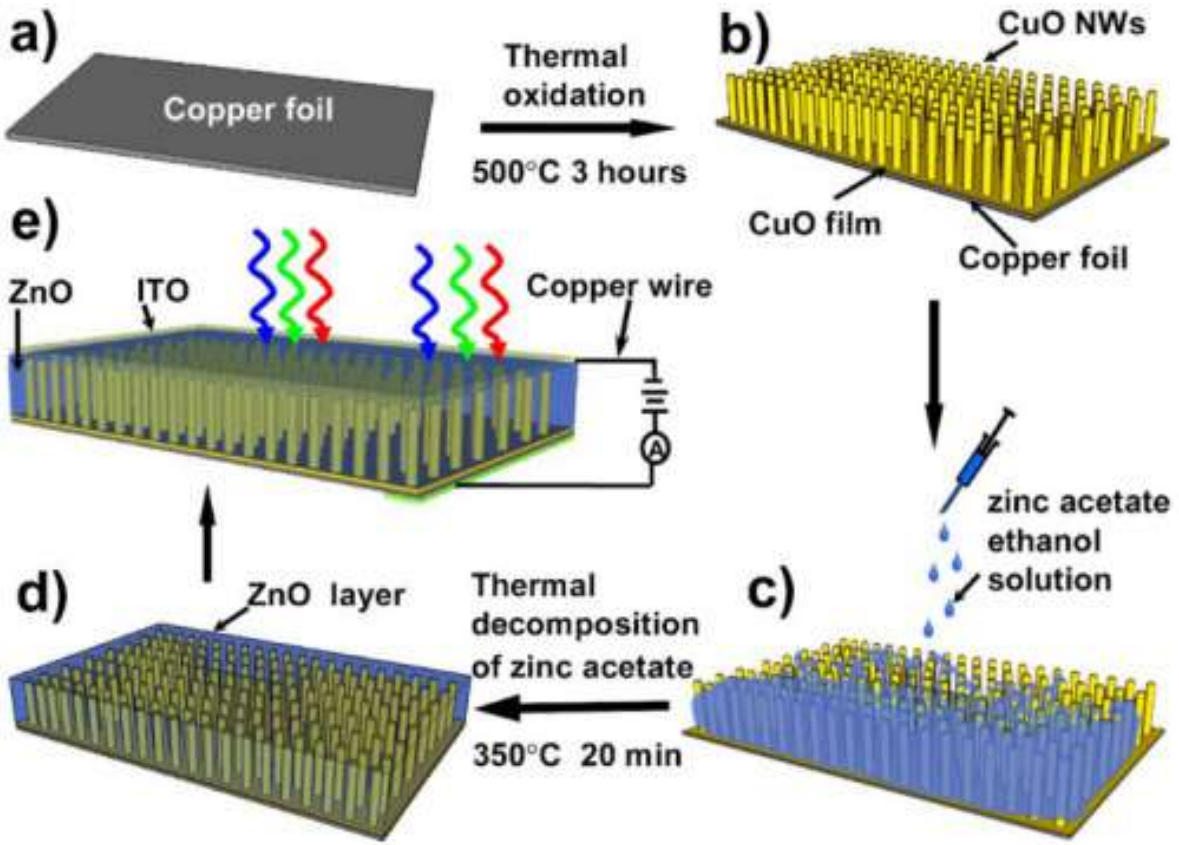
Microwave nanowires with Pt contacts deposited by FIB







Photovoltaic applications



Nanowire-based heterojunctions by coating the p-CuO nanowire arrays in an n-ZnO layer

http://www.opticsinfobase.org/oe/fulltext.cfm?uri=oe-19-12-11271&id=214265

Thank you for your attention ☺

and also to my dear co-workers…