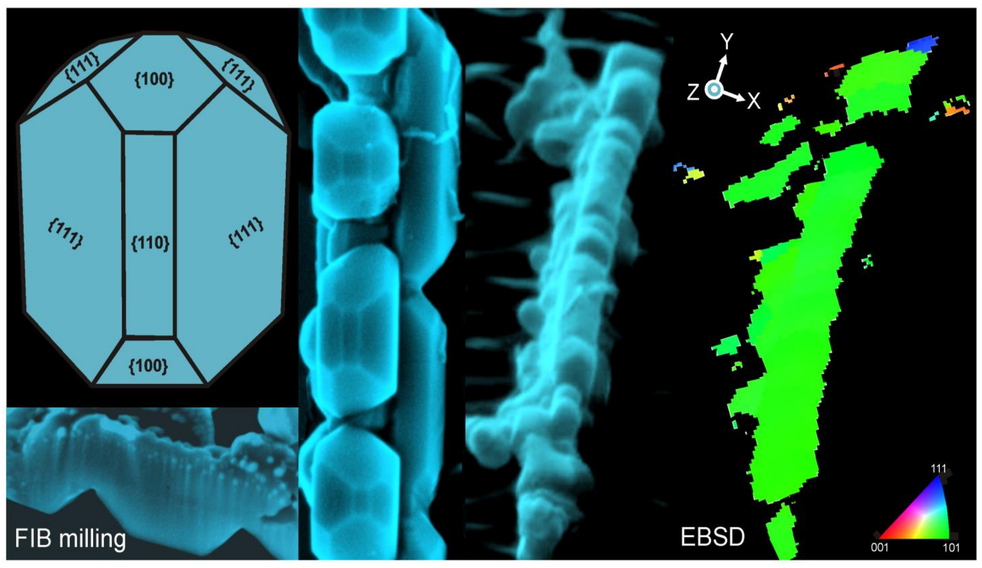
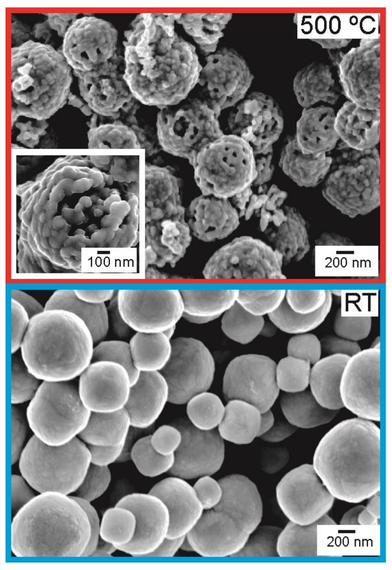
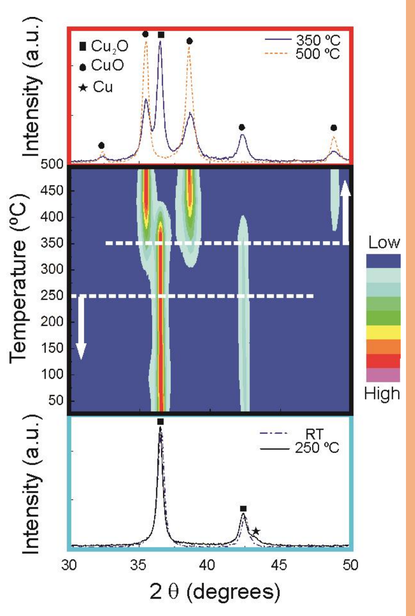
Design of new functional materials for electronics applications







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Objectives

The aim of my work is to develop and structurally characterize metal-oxide nanostructures. The study involves synthesis of materials ranging from nanowires to nanospheres, and in a final approach the formation of films where these nanostructures can be incorporated.

The goal is to study:

- Morphology;
- The effect of structural defects, and materials crystallinity;
- Investigate the differences in crystallite size and crystallographic orientation;
- The effect of contamination and presence of dopants;
- The effect of temperature.

All these parameters together control the physical properties and behavior of the studied materials. Moreover, to select synthesis techniques that are low cost, as well as with an enhanced efficiency/cost balance.

Methods and techniques

Wet chemistry routes were used in this work, in which two different studies were performed. In the first one, Cu nanowires were produced using copper acetate and NaOH both dissolved in H_2O, followed by adding ethylenediamine (EDA) and hydrazine. The solution was placed in a water bath at 60 °C for 1 hour. Afterwards, the Cu nanowires were oxidized through furnace annealing or under microwave irradiation (Fig. 1). For the AFM experiments (Fig. 2), the nanowires were deposited on Si wafers with 100 nm of SiO_2. Contacts were patterned by conventional photo-lithography protocols, and a Mo film was sputtered and followed by lift-off procedures. The second study, investigated the effect of copper precursors on the formation of nanospheres, and it tested: copper acetate, sulfate, chloride, and nitrate (Fig. 3). The precursors were dissolved in H_2O, followed by adding NaOH, EDA and hydrazine. SEM observations used a Carl Zeiss AURIGA instrument equipped with an energy dispersive X-ray spectrometer (EDS). AFM measurements used a MFP-3D Stand Alone Asylum Research instrument.

Results

The Cu nanowires were oxidized under microwave irradiation or by furnace annealing in air, originating Cu_2O and CuO nanowires, respectively. The nanowires oxidized by furnace annealing displayed aggregates of nanoparticles with about 30 nm in size, while the nanowires oxidized via microwave irradiation consisted of larger Cu_2O polyhedral nanocrystals (Fig. 1). EFM showed that Cu nanowires displayed different energy levels of trap charges along their body (Fig. 2), moreover the presence of planar defects introduced trapped charges, acting as a different potential energy level in the nanowires. In EFM experiments, the existence of a bias generated an electrostatic field, giving indirect evidence of the ability of the nanowires to conduct current. The Mo sputtered film used as control indicated that the work function of the studied nanowires appears as CuO > Cu > Cu_2O, with clear KPFM contrast differences between them (Fig. 2).

Regarding the effect of precursors on the Cu_2O nanospheres, no morphology discrepancy has been detected, however a significant effect on the particle size was observed (Fig 3). Parallel studies revealed that the nanospheres consisted of aggregates of nanocrystals, which displayed distinct cathodoluminescence effects. Moreover, the thermal behavior of the nanospheres was investigated.

Publications

[1] D. Nunes, A. Pimentel, P. Barquinha, P.A. Carvalho, E. Fortunato, R. Martins, Cu_2O polyhedral nanowires produced by microwave irradiation, Journal of Materials Chemistry C, 2 (2014) 6097-6103.

[2] D. Nunes, L. Santos, P. Duarte, A. Pimentel, J.V. Pinto, P. Barquinha, P.A. Carvalho, E. Fortunato, R. Martins, Room temperature synthesis of Cu_2O nanospheres: optical properties and thermal behavior, Microscopy and Microanalysis, accepted for publication, MAM-14-118.R1.

[3] D. Nunes, T.R. Calmeiro, S. Nandy, J.V. Pinto, A. Pimentel, P. Barquinha, P.A. Carvalho, E. Fortunato, R. Martins, Mapping of localized charges on Cu-based nanowires, Nanotechnology, in preparation.

Fig. 1 – (a) Cu, (b) furnace annealed and (c) microwave irradiated nanowires.

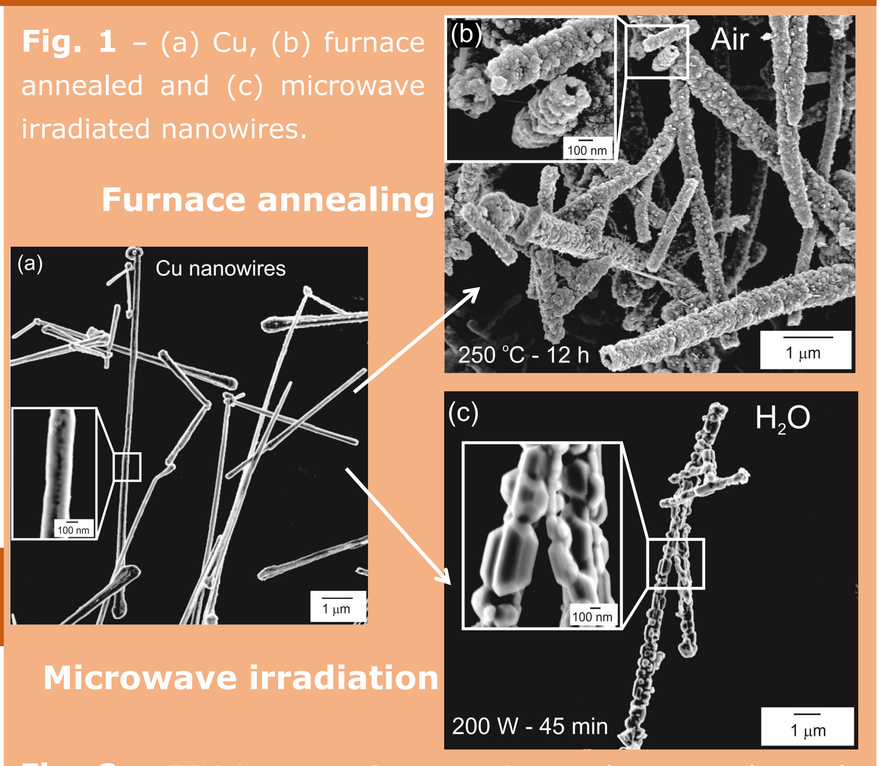


Fig. 2 – EFM image a Cu nanowire, and topography and KPFM images of the oxidized nanowires.

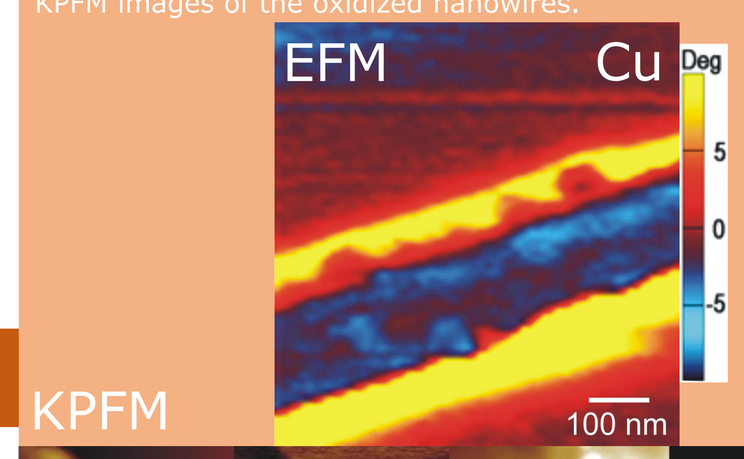
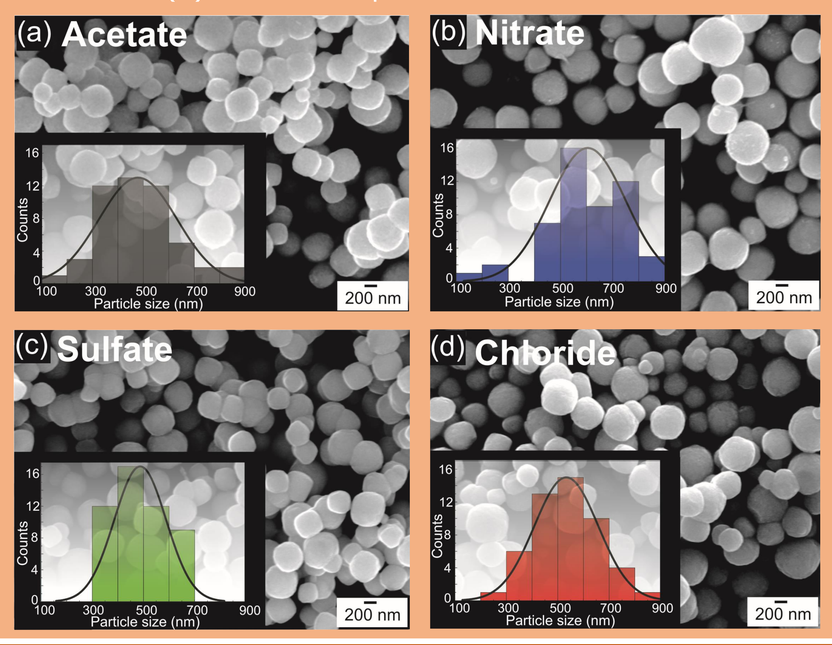


Fig. 3 – SEM images and size distribution of the Cu_2O nanospheres synthesized using (a) acetate, (b) nitrate, (c) sulfate and (d) chloride as precursors.



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