

Electromigration processes in the rapid synthesis of MoO_3 nanostructures

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What we know

Molybdenum trioxide is a wide gap semiconductor and one of the most promising 2D material with applications as catalyst, gas sensor, photochromic and electrochromic material and in Li-ion batteries.

Tungsten oxide with multiple crystal phases has potential applications as an important functional material for catalysis, photoelectrode, electrochromic device, and chemical sensors.

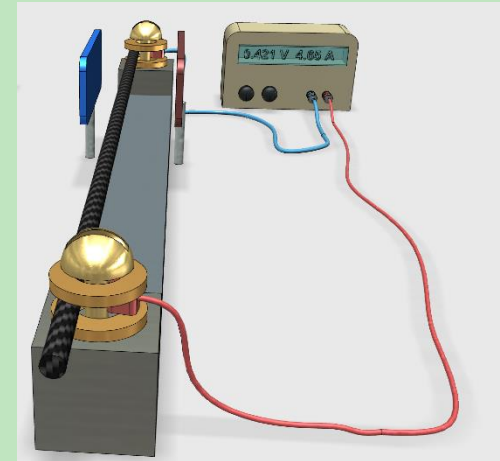
Among the thermal method of synthesis of low dimensional oxide structures, Joule heating of metallic wires has been found to be a rapid and effective way to obtain metal oxide nanostructures.

Objectives

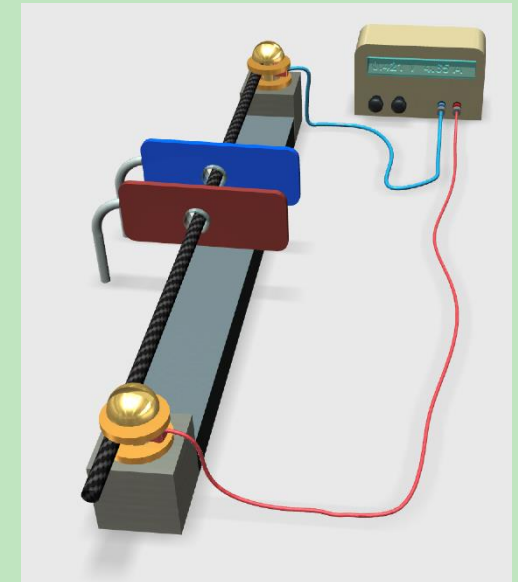
Thermal oxidation of metal substrates in air or other oxidizing atmosphere has been found to lead to the growth of nanostructures. Also, electromigration in temperature gradients has been considered as the mechanism to growth it. [1,2]

In this work, the role of thermal effects and electromigration processes in the growth of MoO_3 and WO_3 nanostructures during the Joule heating of wires has been investigated by conducting the Joule heating experiments under an external electric field by means of two parallel electrode plates.

Synthesis: Experimental set up



Electrodes parallel to the wire



Electrodes perpendicular to the wire

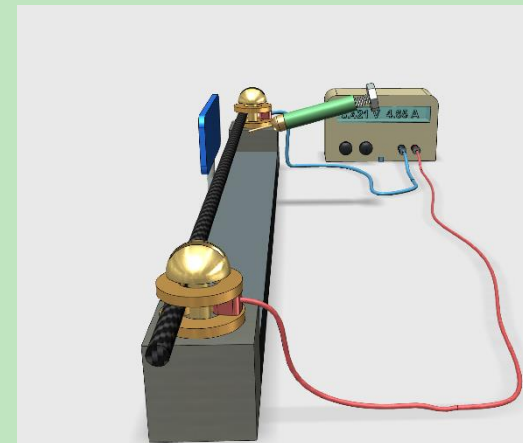
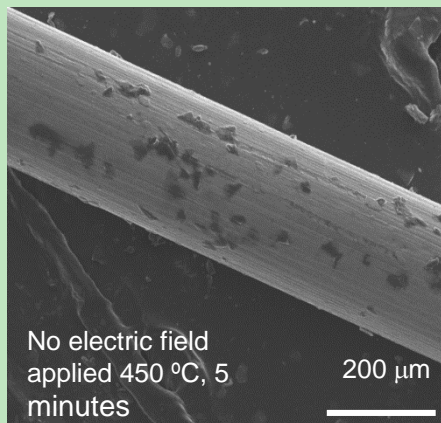


Plate and pointed electrodes to induce a local intense electric field on the wire

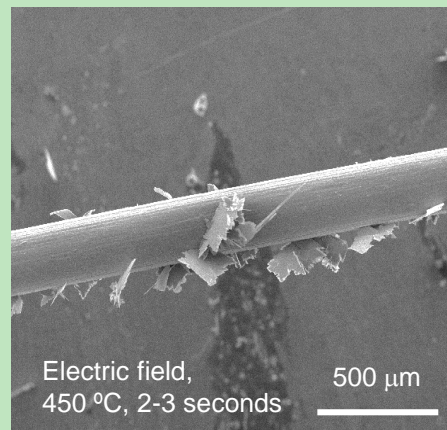
MoO₃ nanostructures

B. Rodríguez, P. Hidalgo, J. Piqueras and B. Méndez, RSC Adv., 2020, 10, 11892.

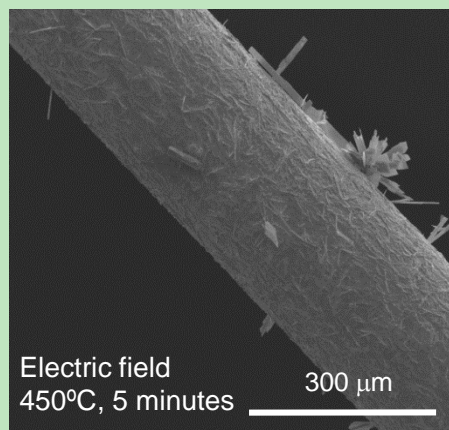
Structures formed on the Mo wire



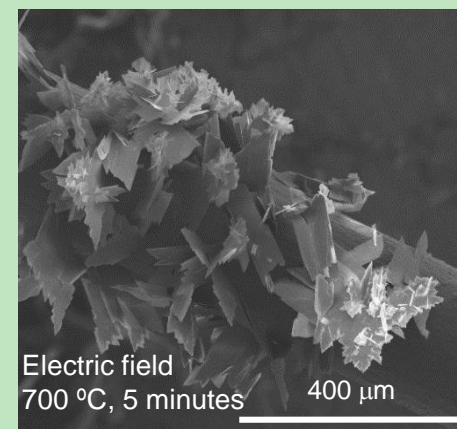
SEM image



SEM image

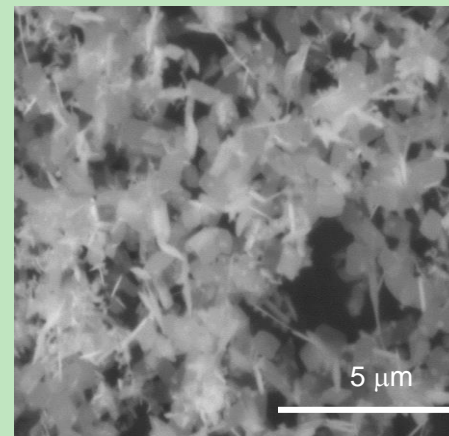


SEM image

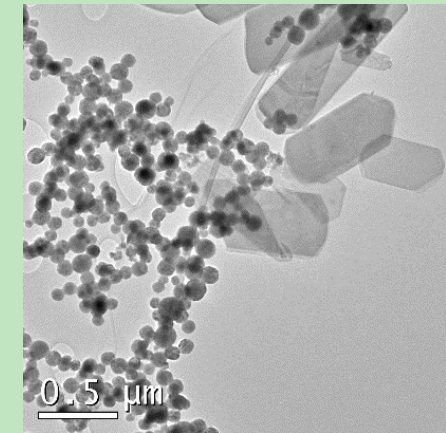


SEM image

Structures formed on the copper electrodes

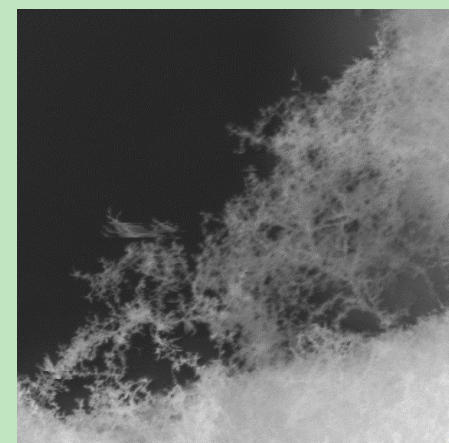


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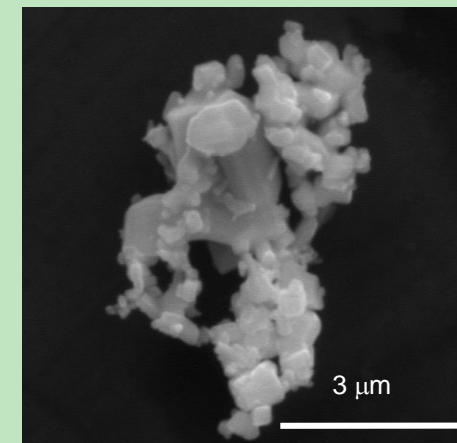


TEM image

Structures formed with the pointed electrode



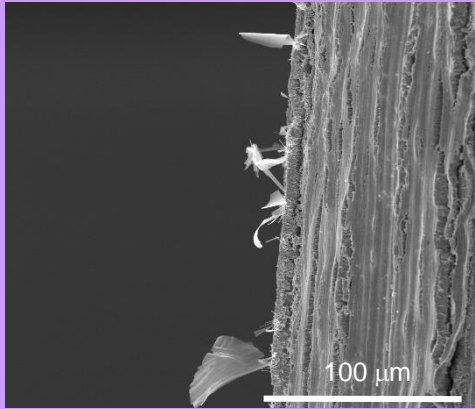
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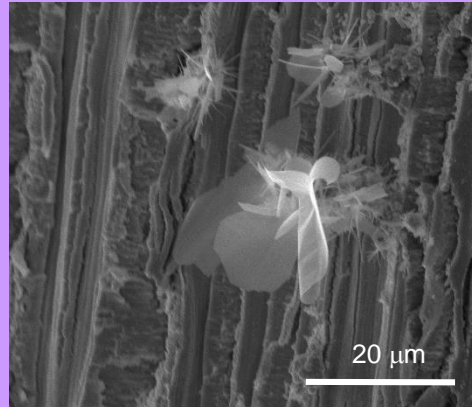
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WO₃

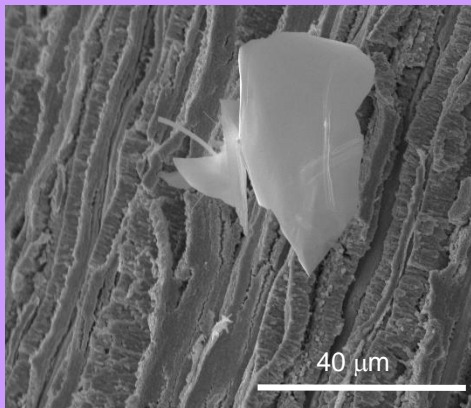
Structures formed on the W wire



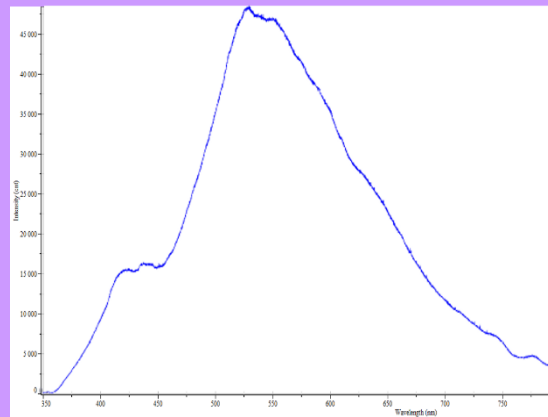
SEM image



SEM image



SEM image



Photoluminescence spectra of
WO₃ nanostructures

Conclusions

Application of an external electric field to a Mo wire carrying a high density electric current, induces a significant enhancement of growth rate of 2D MoO₃ nano- and microstructures.

The rapid growth is due to a thermally assisted electric mechanism involving diffusion of Mo ions toward the surface.

The electric contributions are electromigration in the metallic Mo wire during the Joule heating as well as the effect of the external electric field on the oxide layer.

The growth on the copper electrodes takes place only by application of the electric field.

References

- [1] A. F. Mallet, T. Cebriano, B. Méndez and J. Piqueras, *Phys. Stat. Sol. (a)*, 215, 1800471 (2018).
- [2] S. K. Lin, Y. C. Liu, S. J. Chiu, Y. T. Liu and H. y. Lee, *Sci. Rep.* 7, 3082 (2017).
- [3] **B. Rodríguez**, P. Hidalgo, J. Piqueras and B. Méndez, *RSC Adv.*, 2020, 10, 11892.