Metal-oxide nanostructures

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Titanium oxide nanotube arrays prepared by anodic oxidation

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Stage I) compact oxide layer formed on the metal surface

Stage II) Cracks on the surface due to field-enhanced dissolution of the oxide layer $\rightarrow$ diffusion of the electrolyte into cracks

Stage III) Current reaches a stable state $\rightarrow$ equilibrium pores formation/dissolution

Anodic oxidation of Titanium
TiO$_2$ nanotubes application

**DSSC**

**Water splitting**

**SERS substrate**

**Li-Ions Batteries**

**Supercapacitors**

**Memristor**
Conti et al. *Submitted to Nanotechnology* (2016)
Crystallographic phase can be selected after the growth!

Thermal crystallization...

TEM confirm the amorphous nature of the as grown TiO$_2$ NTs

- As-grown
- 450°C
- 650°C
Growth on different Ti substrates

Advanced Materials Technologies 1.2 (2016)
Decoration of TiO$_2$ nanotubes


Chemico/physical modification of TiO$_2$ nanotubes


Thermal treatment above 350°C → not compatible with flexible electronics
Low temperature crystallization $\rightarrow$ water can catalyze the crystallization reaction

Too long time 72 h

Hydrothermal condition
Mechanism water-assisted crystallization

**Crystallization**

1. Hydration
2. Dehydration
3. Combining the third octahedron
4. Formation of anatase unit cell

**Morphology evolution**

- **Top view**
  - Limited dissolution-precipitation
  - As-anodized TiO\textsubscript{2} NTs
  - Soaking in H\textsubscript{2}O at RT
  - Soaking time 15 - 25 h
  - Stage 1: Double-walled NTs
  - Soaking time 25 - 72 h
  - Stage 2: Wire-in-tube architectures
  - Long-term soaking (> 72 h)
  - Stage 3: Mesoporous NWs

- **Cross section**
  - Inner shell of tube walls
  - Outer shell of tube walls
  - Water
  - Mesoporous anatase TiO\textsubscript{2}
...why not water-vapor?
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Conclusions

❑ We demonstrated **for the first time** that amorphous TiO2 NTs can be crystallized into anatase phase after **exposure to water vapor** in ambient condition.

❑ Crystallographic conversion is complete after **only 30 minutes**

❑ Photocatalytic test reveals an improvement with respect to thermally treated samples

❑ Facile approach → **cost effective** integration in **flexible** and lightweight devices.
ZnO nanowire by anodic oxidation
ZnO by 2D templating

GO membrane → NCs/GO membrane → 1D Templated NCs

GO membrane
ZnO membrane

Additional images with SEM information:
- WD = 8 mm, Aperture Size = 20.00 μm, EHT = 5.00 kV, Mag = 50.00 K X
- WD = 4 mm, Aperture Size = 20.00 μm, EHT = 5.00 kV, Mag = 100.00 K X
MOx nanostructures for DSCs: spongelike ZnO

Deposition by RF magnetron sputtering
Thermal oxidation @ 380°C in air

MOx nanostructures for DSCs: spongelike ZnO

Near RT oxidation treatments

Optimization of the sensitization procedure through DoE

Investigation of the material in DSCs and LIBs

Figure 4. Coefficient plot for the CCF-DoE. $x_1$ is the dye loading time, $x_2$ is the dye solution concentration, and $x_3$ is the pH of dye solution.
Composite materials

Graphene/TiO$_2$ nanocomposite

TiO$_2$ NPs/NTs nanocomposite

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