Electrochemical properties of WO_3 coatings grown at low temperature

Harris S. Drosos

Mechanical Engineering Department,
School of Applied Technology,
Technological Educational Institute of Crete,
710 04 Heraklion, Crete, Greece

3rd International Scientific Conference on "Energy and Climate Change"

Outline of presentation

- **What are “smart windows”?**
- **Which are the conventional techniques used to develop electrochromic layers?**
- **Why solution growth?**

Aim of the work

This study aims to put forward growth strategies to be developed for “smart windows” in order to decrease their production cost and permit their successful commercialisation.

Smart windows

- **Thermochromism: Ability of substance to change color due to a change in temperature.**

- **Electrochromism: Phenomenon displayed by some materials of reversibly changing color when a burst of charge is applied.**

Thermochromic

Advantages

- ✓ Thermal performance is found to be excellent.
- ✓ In response to changes in the ambient temperature, clear thermochromic glazings become diffused.
- ✓ Allow the passage of sunlight into the home during cooler months => reduce the heating energy consumed by a household.

Disadvantages

- ❑ Reduce visible light transmission.
- ❑ No control over the opacity.
- ❑ Low color density.
- ❑ It cannot be adjustable according to the different countries and their ambient temperatures.

Electrochromic

Advantages

- ✓ Significantly greater access to outdoor views.
- ✓ Reduced need to use blinds and shades.
- ✓ Control of the amount of light and heat passing through.
- ✓ Significant lighting energy use savings if the window is zoned and controlled properly.
- ✓ Significant cooling load savings, depending on the usage patterns of manually-operated interior shades.

Disadvantages

- ✘ Cost.
- ✘ Safety.
- ✘ Practical sizes.

Electrochromic layer production techniques

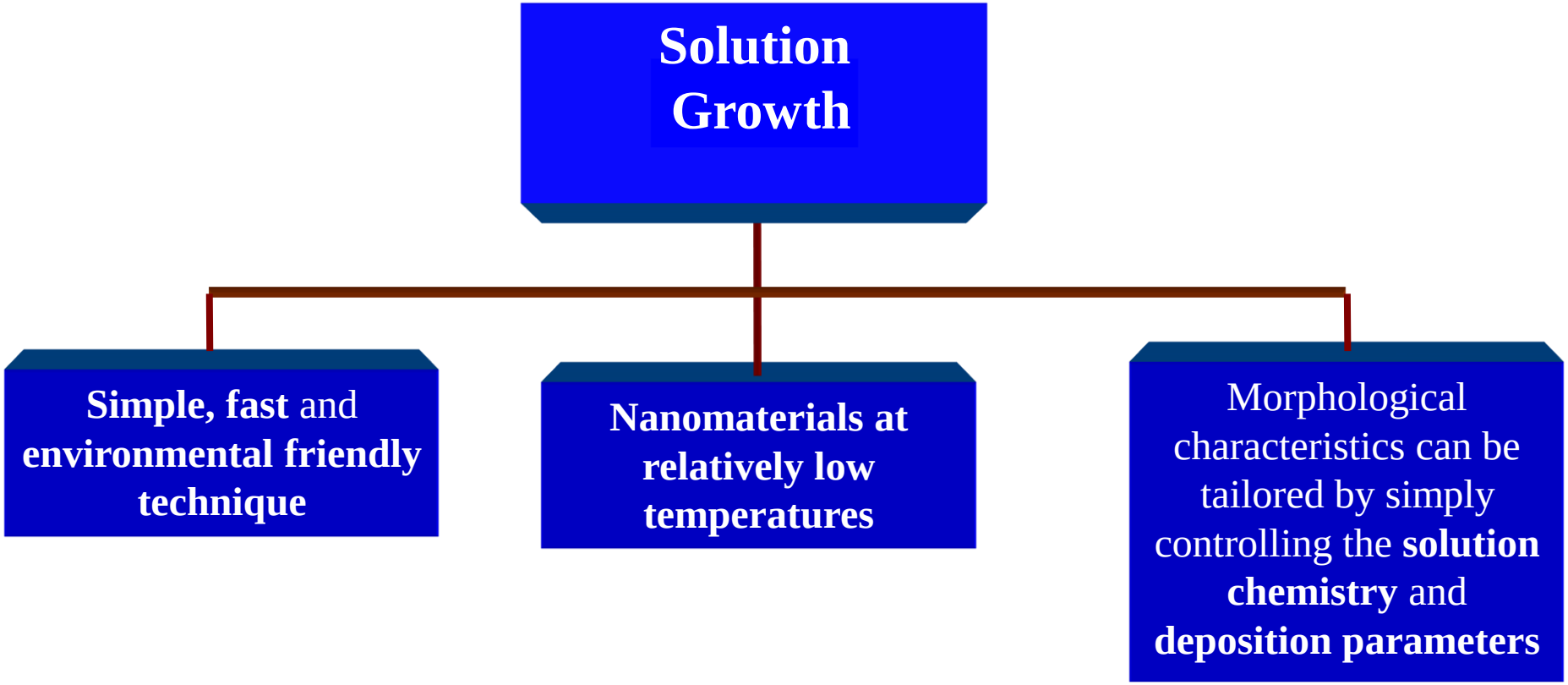
PVD →

- Reduced pressure and vacuum conditions
- Increase production costs

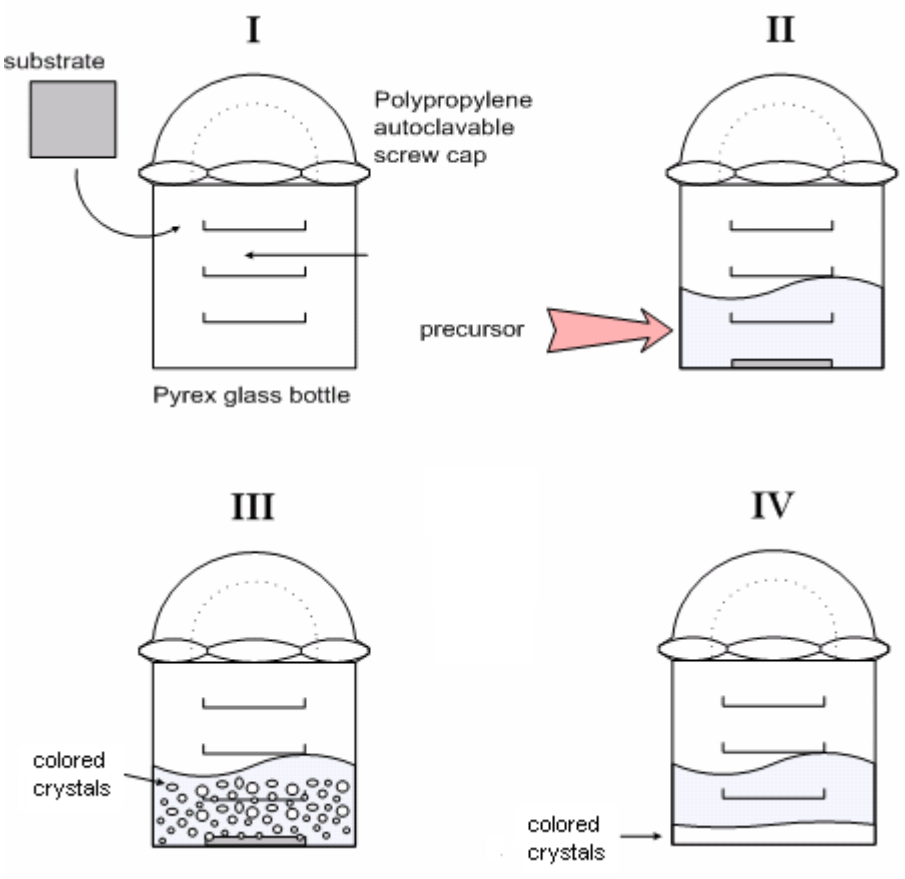
CVD →

- Toxic chemicals
- High deposition temperatures
- High degree of control

Why solution growth ?



Steps involved in solution growth



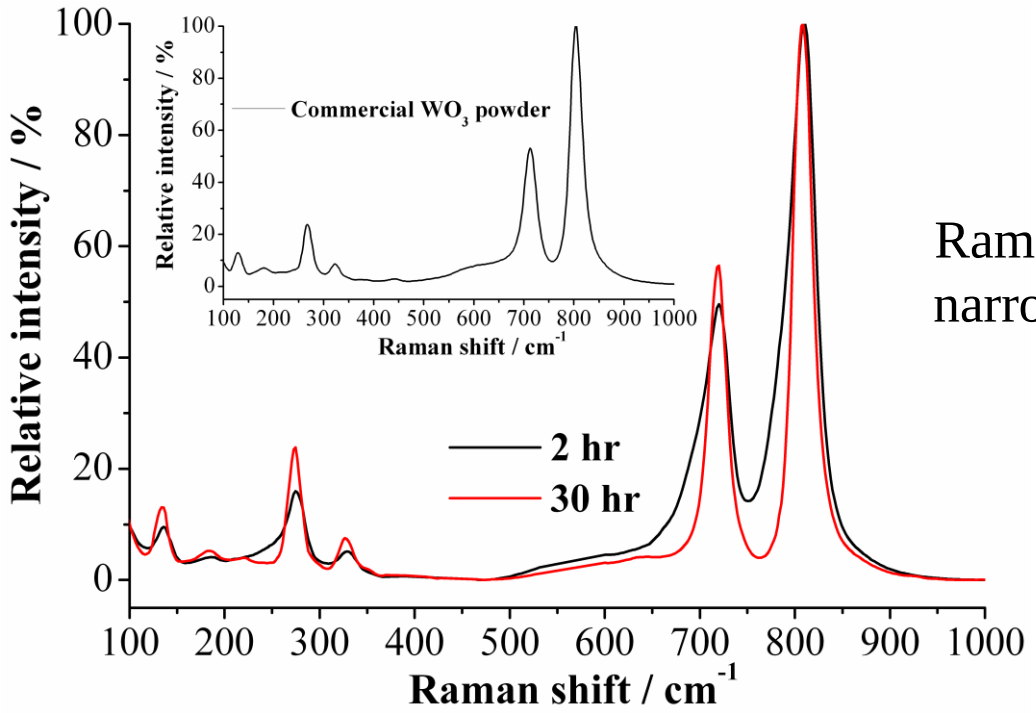
Experimental procedure

Substrate Microscope glass

- **Solution temperature** 95 ^{o}C.
- **Deposition time** 1, 2, 5, 10, 20 and 30 hr.

- **1st Stage:** **Cleaning procedure**
  Isopropanol, Acetone, MilliQ water and Dry with N_2
- **2nd Stage:** **Solution preparation**
  0.3 M, NaOH with 0.0021 M, WO_3
- **3rd Stage:** **WO_3 deposition**

Raman spectroscopy



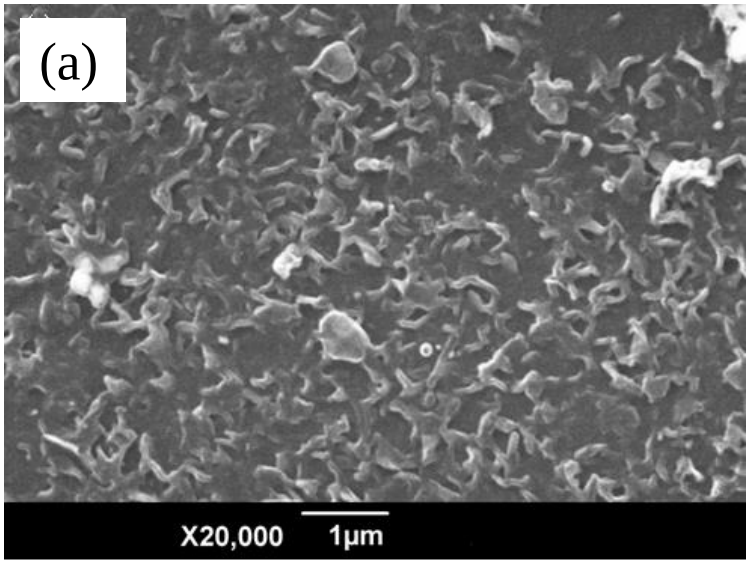
Raman peaks become more intense and narrow as the deposition time increased from 2 to 30 hrs.

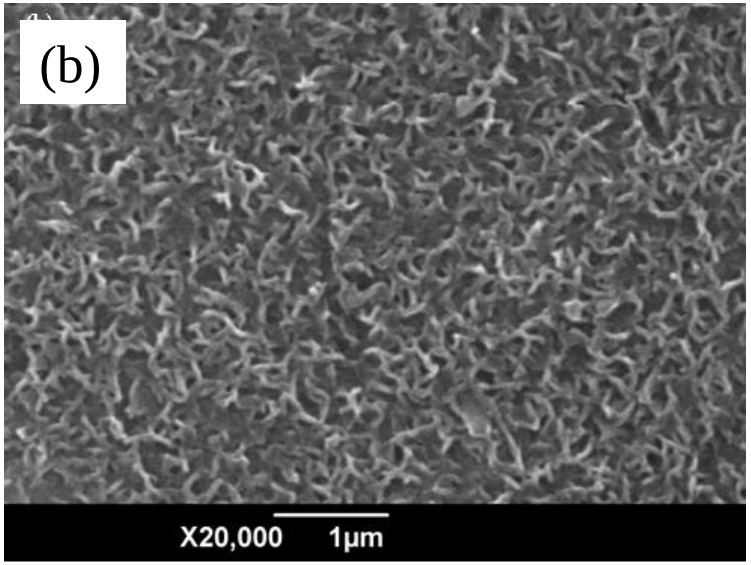
Growth conditions

Deposition time, 2 and 30 hr, Deposition temperature, 95 ^{o}C

Precursor, 0.3 M NaOH with 0.0021 M WO_3

Scanning electron microscopy





- Wall-like structures are formed with a relatively porous morphology.
- Their density (mainly) and size (secondarily) increase with deposition time.

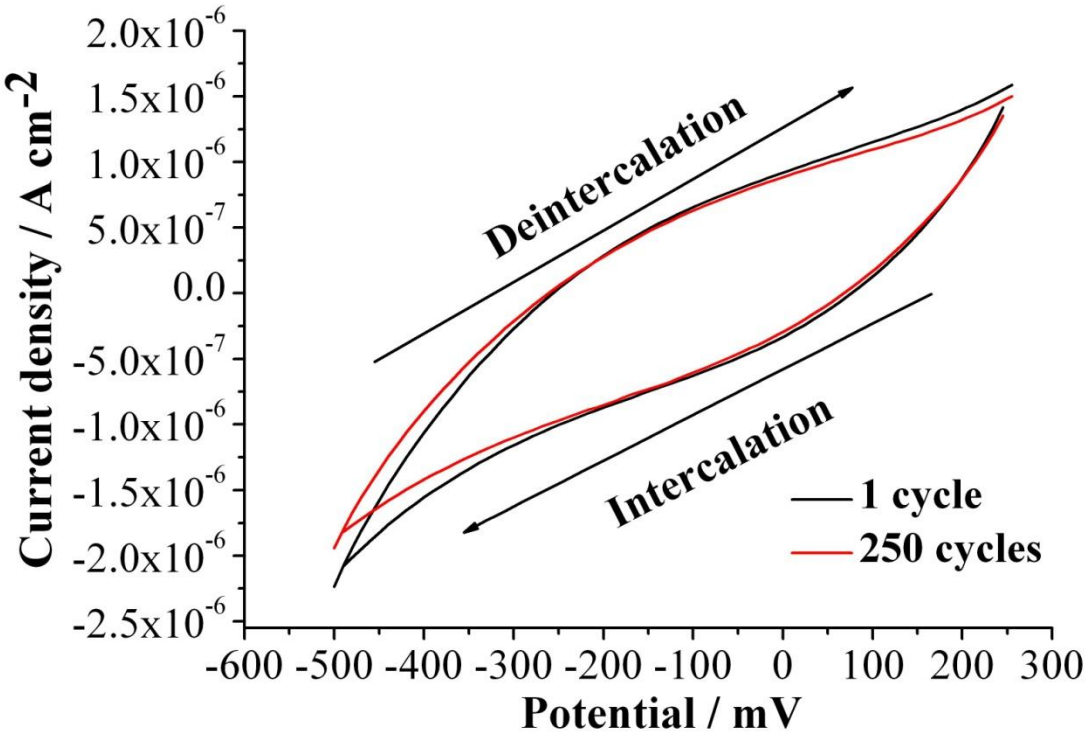
Growth conditions

Deposition time, 2 (a) and 30 hr (b)

Deposition temperature, 95 ^{o}C

Precursor, 0.3 M NaOH with 0.0021 M WO_3

I – V measurements



- **Typical amorphous WO_3 character since sharp peaks do not appear for either reduction or oxidation.**
- **No significant long-term degradation => 30 hr as–deposited sample.**
- **A decrease by one degree of the current density => samples prepared at shorter deposition times.**

Growth conditions

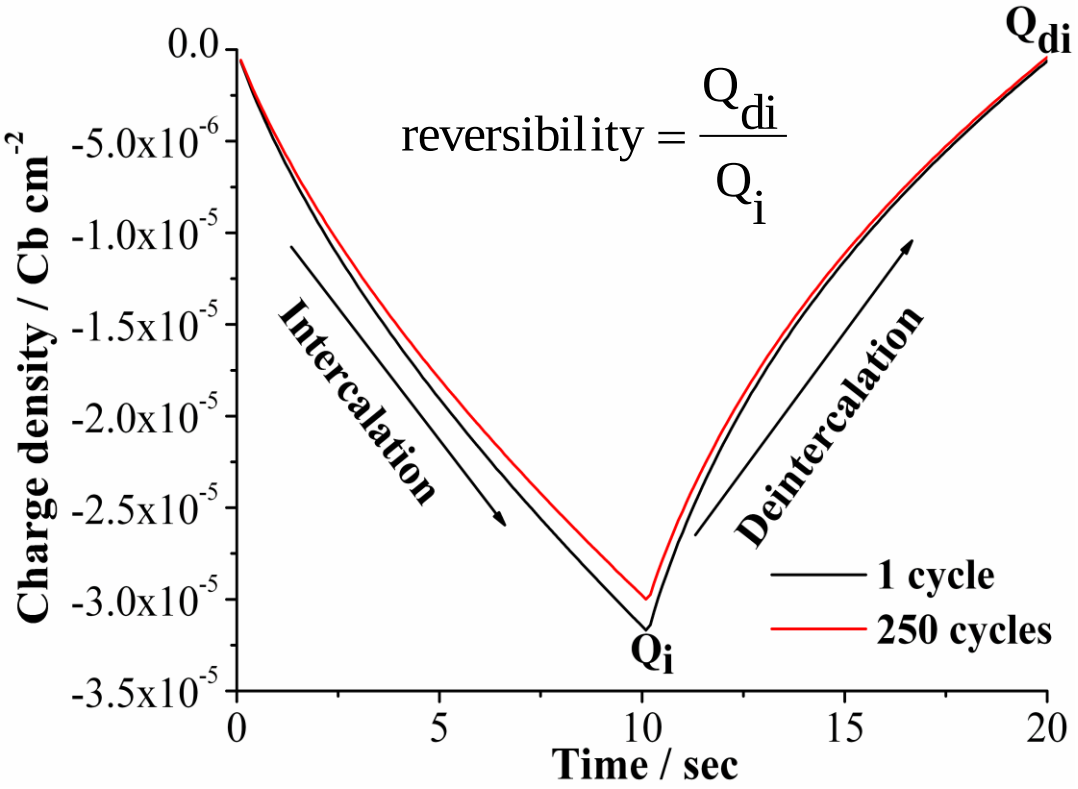
Deposition time, 30 hr, Deposition temperature, 95 ^{o}C

Precursor, 0.3 M, NaOH with 0.0021 M WO_3

Parameters

Number of scans 1 and 250, Scan rate 10 mV sec^{-1}, Electrode active area, 1 cm^2, Electrolyte 1 M $LiClO_4$ / polypropylene carbonate.

Chronocoulometry



For long term measurement, the intercalated charge density was

1st cycle, 3.15 x 10^{-5} C cm^{-2}
250th cycle, 2.97 x 10^{-5} C cm^{-2}

The intercalated / deintercalated charge ratio was
1st cycle, 1.0
250th cycle, 1.0

Parameters

Number of scans 1, 200, 500, Electrode active area, 1 cm^2, Potential step -0.5 V and +0.25 V, time step 10 s, Electrolyte, 1 M $LiClO_4$ / polypropylene carbonate.

Growth conditions

Deposition time, 30 hr, Deposition temperature, 95 ^oC and Precursor, 0.3 M, NaOH with 0.0021 M WO_3.

Conclusions

- Porous WO_3 thin films may be deposited at 95 ^oC by solution growth,
- Raman spectroscopy has revealed that the peaks are narrower and higher in intensity as the deposition time increases,
- SEM images indicated the formation of wall-like structures with porous morphology,
- Higher deposition times promote significant electrochemical response, which is reversible when the bias is inverted and repeatable with minimal degradation at least for 250 times,
- Hydrothermal synthesis thus seems to be a promising technique for the preparation of tungsten oxide coatings with intricate patterns and interesting properties that could serve in a range of applications.

Acknowledgements

- Dimitra Vernardou
- Emmanouil Spanakis
- Emmanouil Koudoumas
- Constantinos Savvakis
- Nikolaos Katsarakis