Optical memory effect in WO_3 and V_2O_5 electrochromic oxide films

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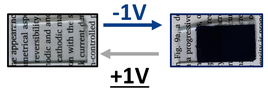
Introduction:

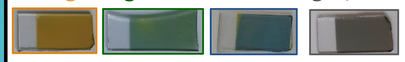
Electrochromism is the ability of a material to modify its optical properties under an applied voltage.
Applications: electrochromic displays, smarts windows.

Focus on two electrochromic oxides:

- **WO_3**: large optical modulation with a colour switch from transparent to dark blue.



- **V_2O_5**: multi-electrochromic coloration going from orange to green to blue and gray.



Unusual property: **memory effect**, corresponding to a colour persistence while no voltage is applied.

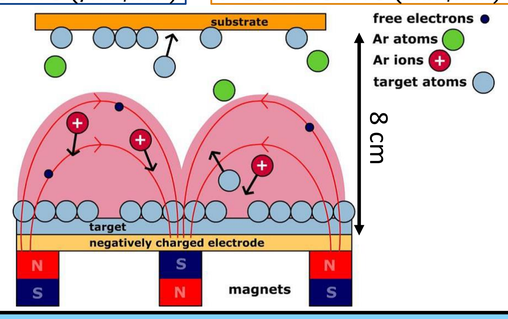
This specificity allows *ex-situ* characterisation in the different colour states.

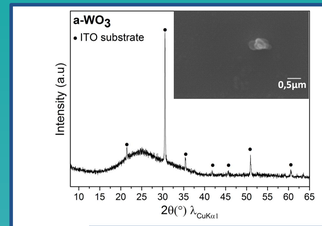
Origin of memory effect ?

Structural — Morphology — Electronic

Radio Frequency Magnetron Sputtering

WO_3	V_2O_5
WO_3 oxide target (3″) Power: 75W Total pressure: 2Pa Ar:O2 = 49:1 sccm **No heating** and **400°C** heating. t= 400nm on ITO (7nm/min)	V metal target (3″) Power: 200W Total pressure: 2Pa Ar:O2 = 45:5 sccm **No heating**. t= 200nm on ITO (2nm/min)



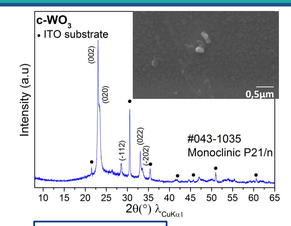


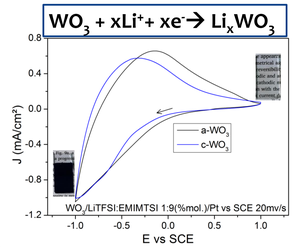
WO_3

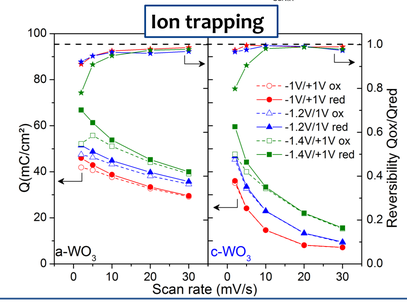
No heating

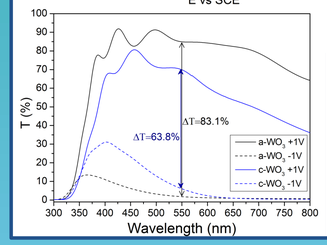
Substrate

400°C heating







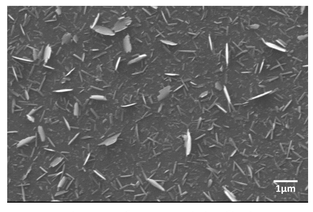


- a-WO_3 and c-WO_3: slower diffusion in oxidation during cycling.
- a-WO3: higher capacity and contrast

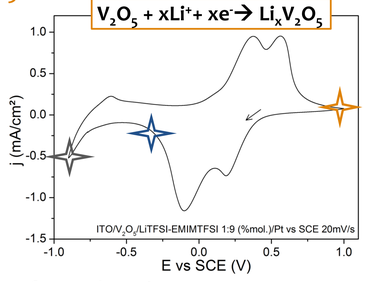
Color Efficiency=$\log(T_b/T_c)/Q$= **49,6** vs **36,6** cm²/C

- a-WO_3 : larger ion-trapping and lower stability than c-WO_3.

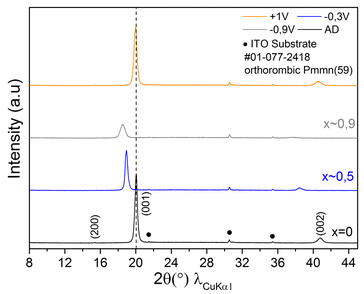
V_2O_5

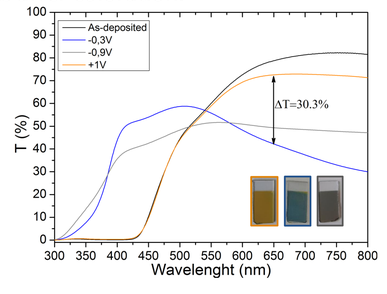


Rough surface with flakes.



Ex-situ measurements after coloration:

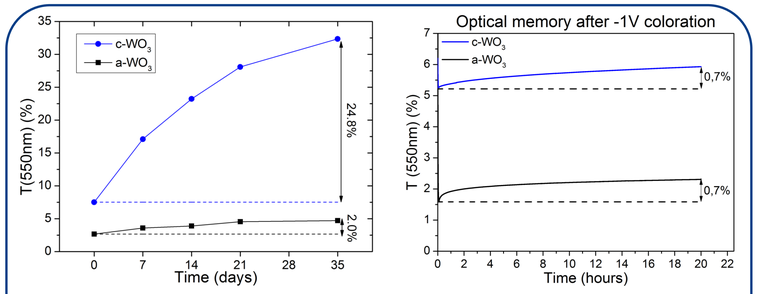




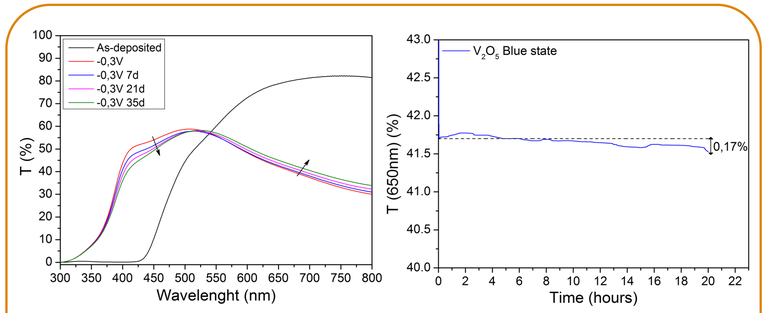
Intercalation/deintercalaltion mechanism with an increase of disorder during lithiation. Multi-electrochromism with a higher CE in the blue state(9,8 cm²/C).

Optical memory effect

Ex-situ (air) — *In-situ* (lithium electrolyte)



Discrepancies of memory effect between a-WO_3 and c-WO_3 linked to ion trapping behavior and their oxidation behavior during cycling.
In a lithium environment: good optical stability (ΔT_{550nm}= 0.7%) even for the crystallized one and faster self-bleaching compared to air.



High optical stability of V_2O_5 in blue state in air (ΔT_{650nm}= 2.8%) with a different behavior before and after 520nm.
Even in a lithium electrolyte, $Li_xV_2O_5$ self-bleaching present a minor change of ΔT_{650nm} about less than 0.2%.

Conclusion

By using RF-magnetron sputtering with an optimize set of parameters, thin films of V_2O_5 and WO_3 presenting a memory effect were grown.
Amorphous WO_3 film presents higher contrast and memory effect than the crystallized one. It is attributed to a more open structure and ion-trapping respectively.
V_2O_5 present a multi-electrochromism accompanied by an reversible intercalation mechanism and a high memory effect stability in air or in an lithium electrolyte.

Future work :

- Modifying sputtering conditions to tune the memory effect
- Study memory effect property in temperature/humidity controlled environment.

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