Imaging ellipsometry of thermochromic materials : optical properties at the (sub)-micron scale

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Smart material : Vanadium dioxide VO_2

- **Reversible crystal-structural phase transition from monoclinic to tetragonal (rutile type) at 68°C.** Abrupt change in magnetic properties, electrical properties (from insulator to conductor) and optical properties
- Applications : thermal or optical switch, thermochromic smart windows,…
- 120 nm thick film deposited by DC reactive magnetron sputtering on atypical **stainless steel (SS) substrate** (Lafort et al., 2011)

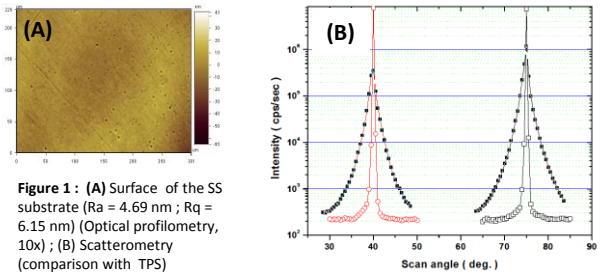


Figure 1 : (A) Surface of the SS substrate (Ra = 4.69 nm ; Rq = 6.15 nm) (Optical profilometry, 10x) ; (B) Scatterometry (comparison with TPS)

Imaging ellipsometry (IE)

Imaging ellipsometry : Non-destructive optical analysis technique based on the relative change of polarization of the *p*- and *s*- components of the light at the interface between two media characterized by different optical properties (Resolution : 1 µm / pixel – Magn. 10x)

$$\rho = \frac{R_p}{R_s} = \tan\Psi\, e^{i\Delta} \quad \textit{with} \quad \tan\Psi = \frac{|R_p|}{|R_s|} \quad \textit{and} \quad \Delta = \delta_p - \delta_s$$

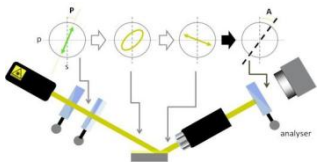


Figure 2 : Polarized light reflected on the substrate gives light polarized in another direction in the s and p space. The analyzer rotates to extinguish the beam.

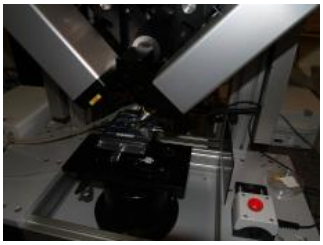
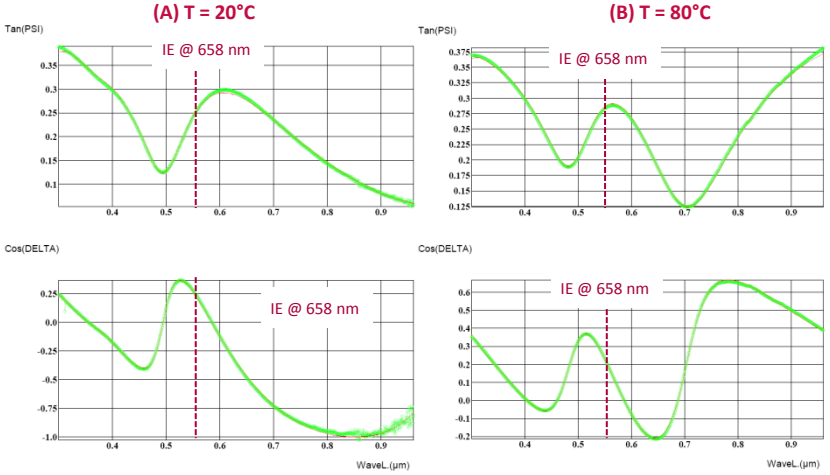


Figure 3 : Experimental setup - Imaging ellipsometer with Linkam heating stage

Imaging (IE) and spectroscopic (SE) ellipsometry results

SE data : 119 nm-thick VO2 film on stainless steel

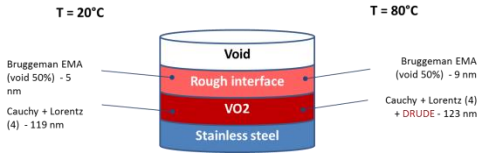
(A) T = 20°C **(B) T = 80°C**



OPTICAL PROPERTIES AND MODELLING

Spectroscopic ellipsometry on a SOPRA GESP5 and a SOPRA FTIR ellipsometers (infrared data not shown)

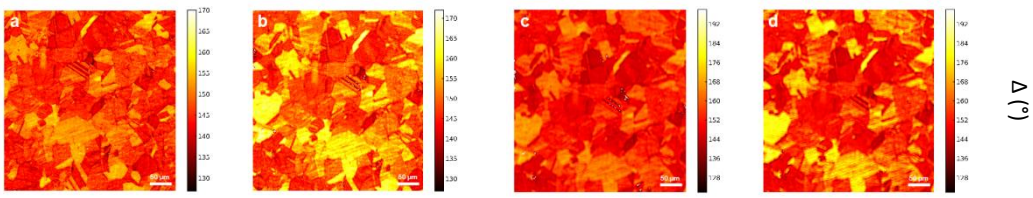
- Optical properties available from 300 nm to 16.6 µm



Figures 4 : SE data (green) and model results (red) for the 119nm-thick VO2 film

Figure 5 : Δ maps of the 119 nm –thick VO_2 at different temperatures.

Abrupt increase of Δ at **69°C**.
Slow increase of Δ from 68°C to 65°C and from 69°C to 100°C .



T = 20°C **T = 68°C** **T = 69°C** **T = 100°C**

Conclusion and acknowledgements

- **Imaging ellipsometry allows observation of the abrupt change of the optical properties of V02 at ≈ 69°C and of the polycrystalline nature of the layer**
- **Temperature to monitor the phase transitions and their consequences on optical properties**
- **Importance of combining STRUCTURAL and OPTICAL data and of defining new strategies for (S)IE data processing**

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