Electrochromic investigation of dry lithiated MoO_3 thin films nanostructured by glancing angle deposition (GLAD)

Mathieu Boudreau

Supervised by Gisia Beydaghyan,Ph.D., and Prof. P.V. Ashrit

Thin Films and Photonics Research Group (GCMP)
Department of Physics and Astronomy
Université de Moncton
Moncton, N.B.

Table of contents

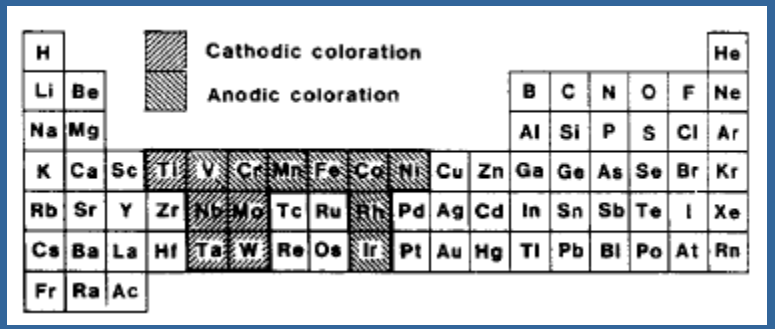
- Introduction
  - Electrochromism
  - GLAD technique
- Experimental method
- Results
  - Ellipsometer
  - AFM
  - Spectrophotometer

Introduction

- What is electrochromism?

$$\underset{\text{(transparent)}}{MoO_3} + Li^+ + e^- \leftrightarrow \underset{\text{(colored)}}{LiMoO_3}$$

- Which types of materials are electrochromic?



- Why is it important to study and develop electrochromic devices?

Technique

- **GLAD : Oblique angle deposition with a twist.**

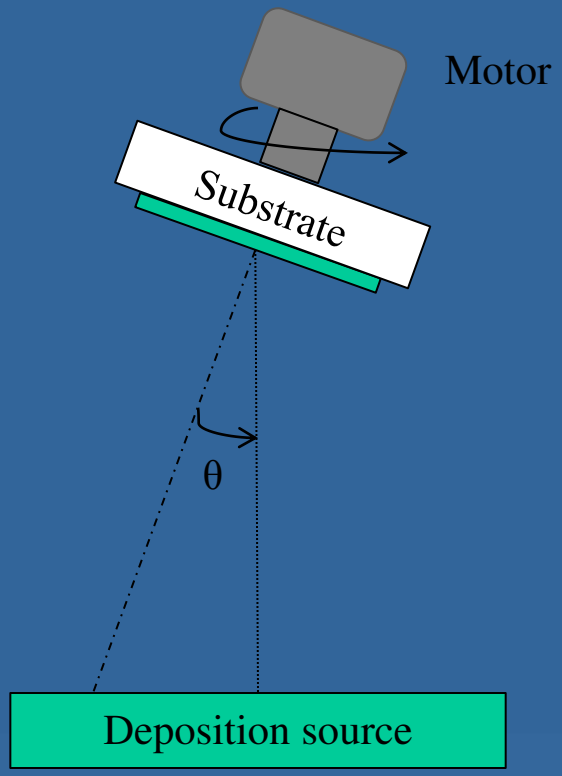
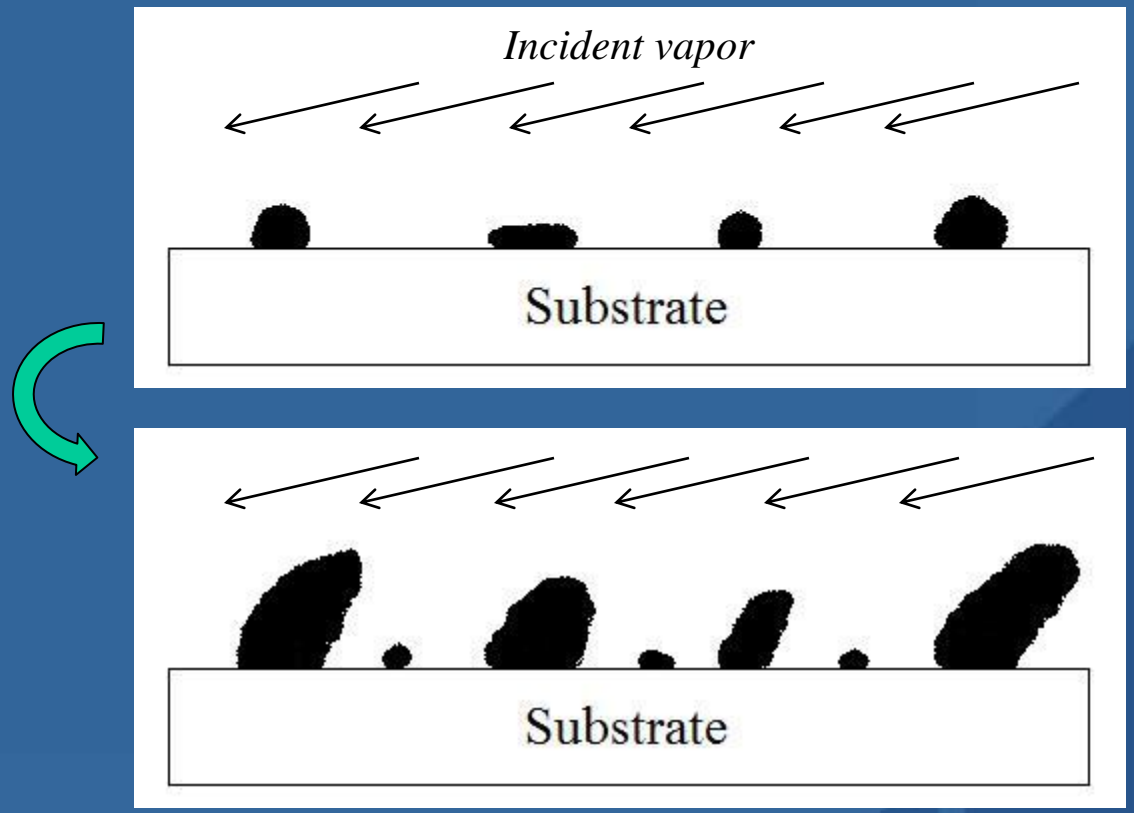


Fig. 1 GLAD setup

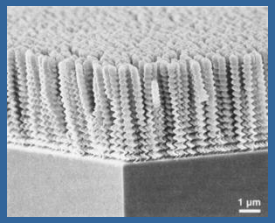
Technique

- Shadowing effect due to OAD



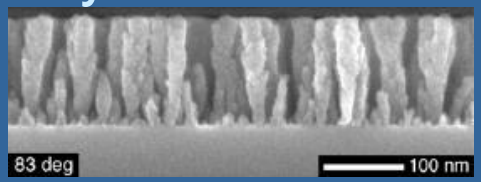
Technique

- Designing nanostructures with GLAD



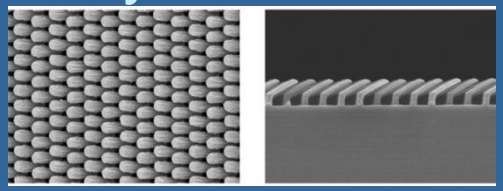
Robbie, K., Brett,M.J., *Nature*, Vol. **384**, p. 616, **(1996)**

- Controlled porosity of the film



Cristina Buzea *et al.*, *Nanotechnology*, Vol. **16**, p. 1986-1992 **(2005)**

- Improved uniformity of films



D-X Ye *et al.*, *Nanotechnology*, Vol. **16**, p. 1717-1723 **(2005)**

Methodology

- **MoO_3** films were deposited with Johnson VHV e-beam vacuum system
- Film thickness and refraction index were modelled data from ellipsometer scans
- Morphology of the films were measured using an atomic force microscope (AFM)
- Transmission and reflection spectrums were measure with a Cary 5000 spectrophotometer
- Lithium ions were injected by a dry lithiation method developed in our lab
- We studied both as-deposited and annealed films

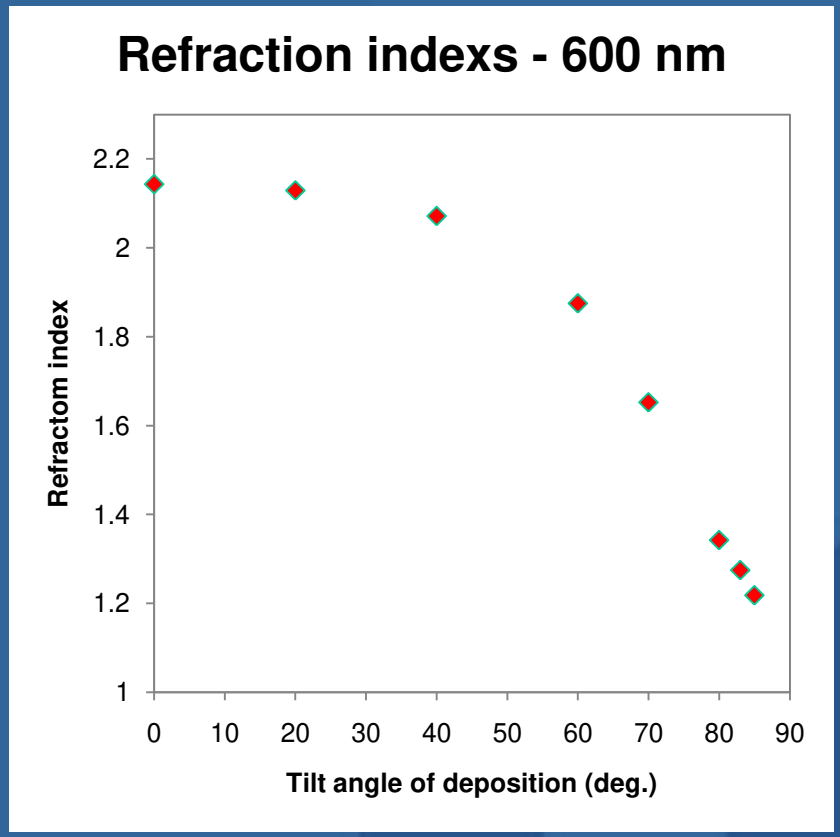
Experimental Parameters

Angle of deposition	0 to 85 degrees
Period of substrate rotation	3 s
Average base pressure	10^{-7} torr
Average deposition rate	5.0 ± 0.3 Å/s
Average thickness of the films	2000 Å
Recipe for annealing the MoO_3 films	400 C^o for 1 hour then cooled overnight

Results - Ellipsometer

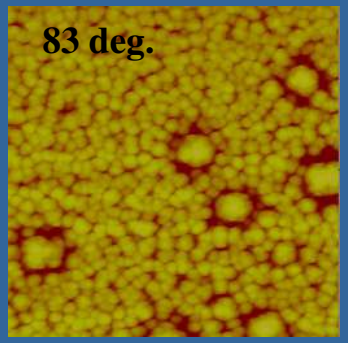
Remarks

- Decreasing optical indexes indicate increasing porosity
- Higher porosity means less material for coloration
- Increase in ion pathways is a consequence of higher porosity



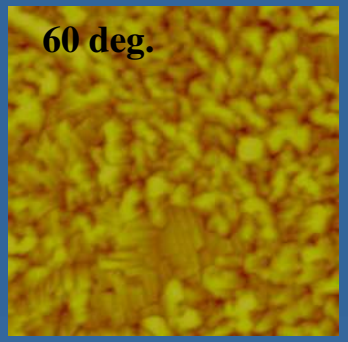
Results – AFM

(As-deposited)



2 um x 2 um

(Annealed)



5um x 5um 400 nm scale

(As-deposited films)

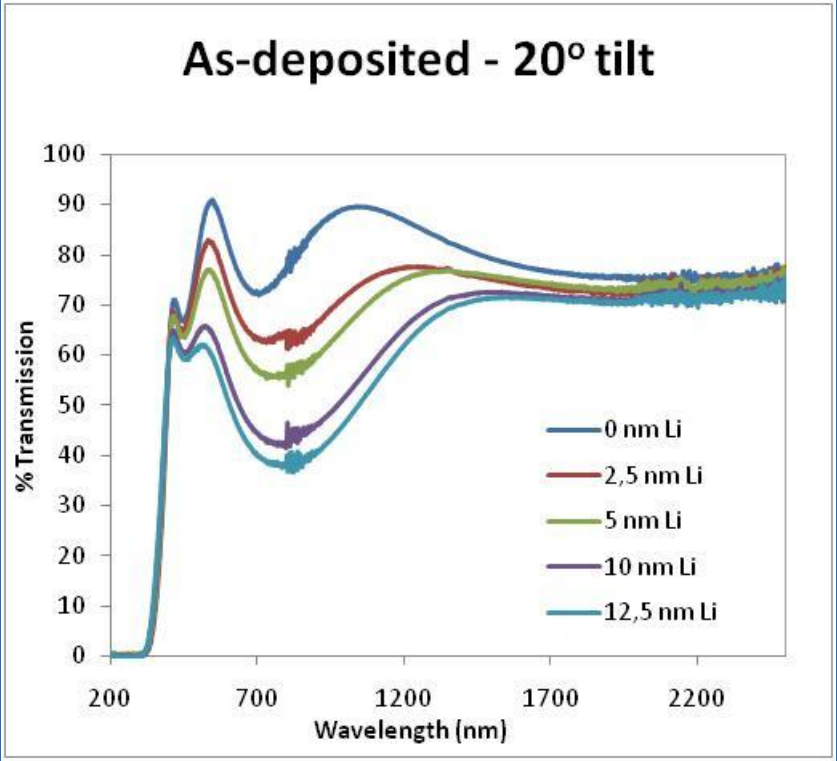
- Nanostructured films are present
- Angles near glancing angle (>80 deg.) have visible increase in porosity
- Some clustering seems occur at very high angles

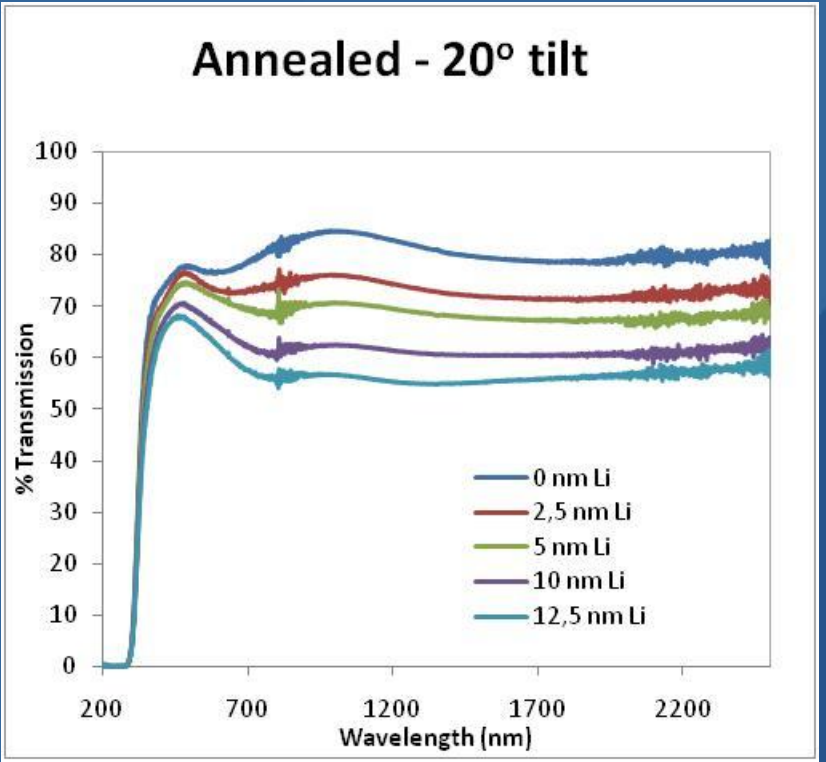
(Annealed films)

- Polycristalline structure emerges after heating
- The size of clusters seem to be of the order of visible light or larger

Results - Spectrophotometer

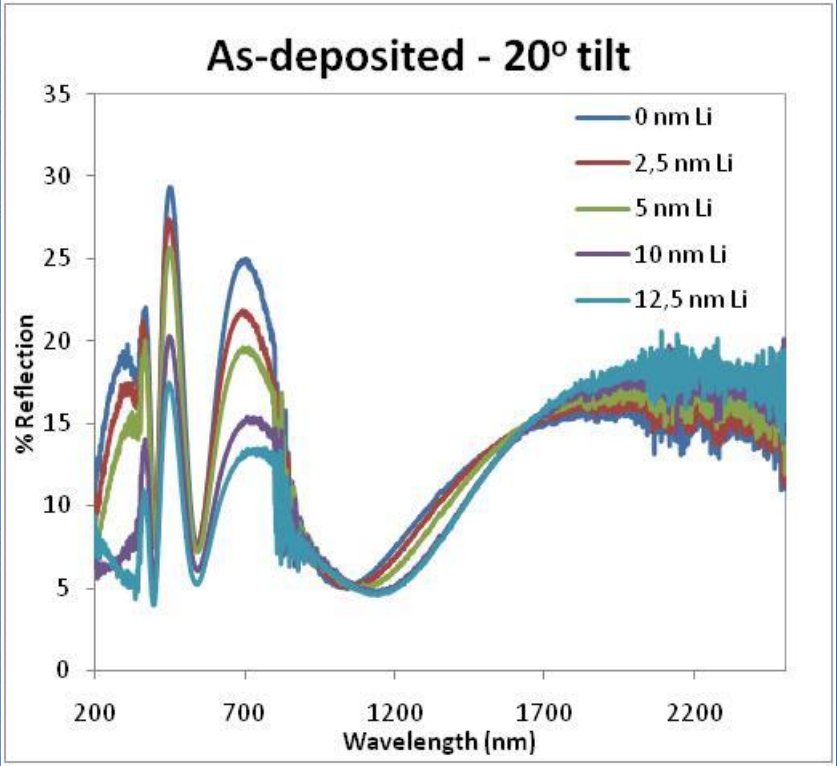
Total Transmission

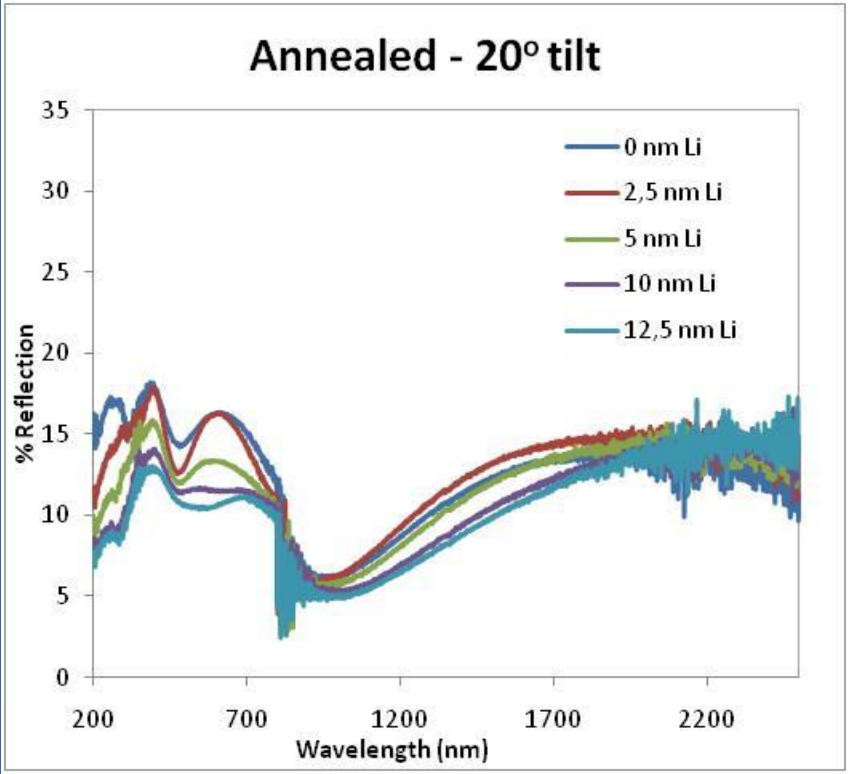




Results - Spectrophotometer

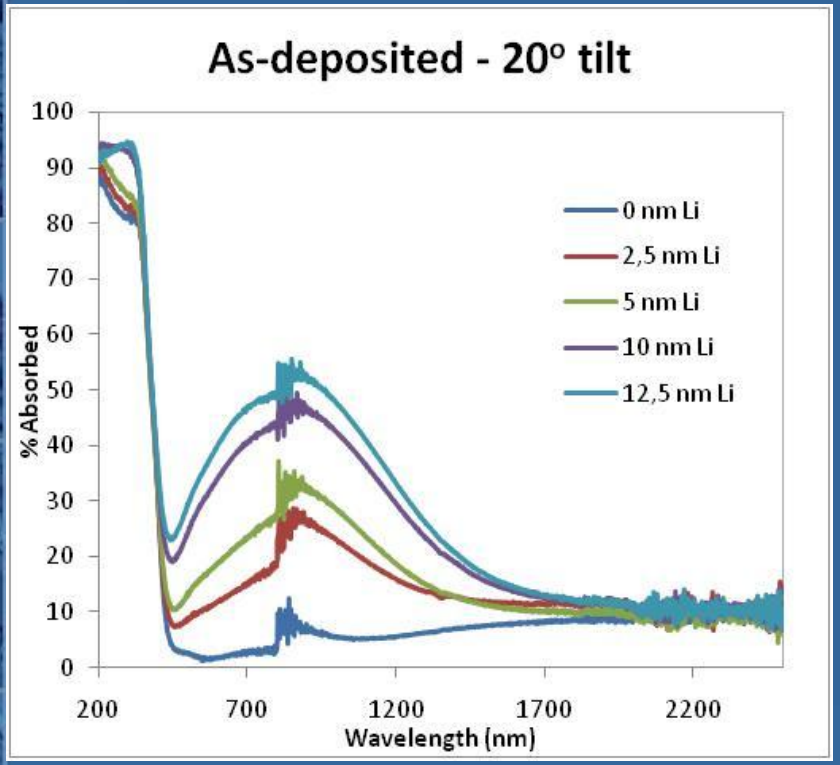
Total Reflection

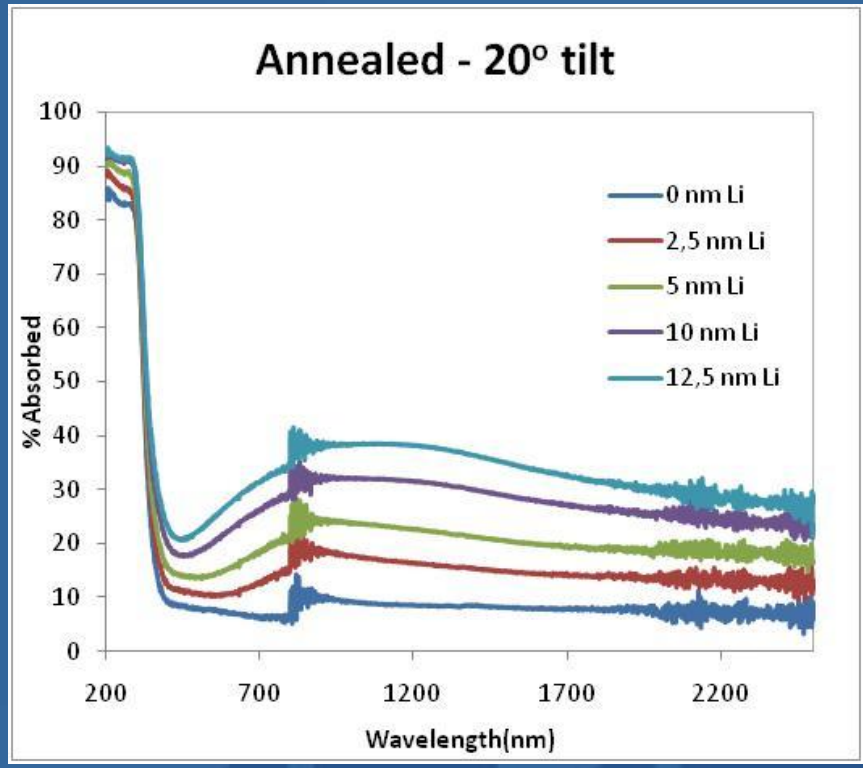




Results - Spectrophotometer

Absorption





Conclusion - Spectrophotometer

As-deposited films

- Electrochromic coloration is present
- Reduced transmission in high infra-red region due to increase in reflexion
- Coloration in visible region is due to absorption

Annealed films

- Electrochromic coloration is present
- Reduced transmission in the visible and through the infra-red region due to absorption
- Diffusion in the visible region due to Mie scattering of the light by large clusters of material

Future research

- Full and half electrochromic devices
- Coloration speed
- Investigation of the coloration efficiency, solar transmission and photopic transmission
- Bragg mirrors

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