# Preparation by pulsed vacuum arc deposition and characterization of DLC/$MoS_2$ nanocomposite thin films

M.P. Delplancke-Ogletree*, O.R. Monteiro**

*Université Libre de Bruxelles, Industrial Chemistry Department

** Lawrence Berkeley National Laboratory

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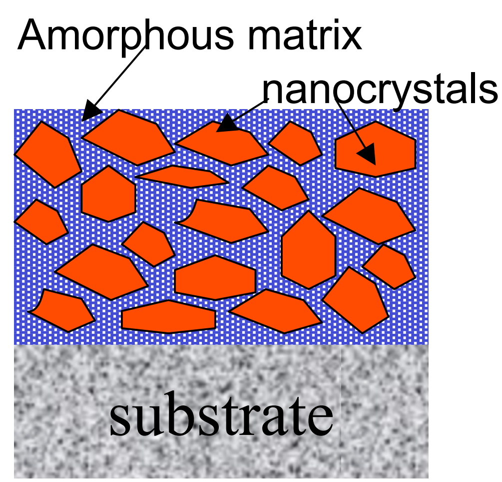
# Outline

- Why DLC + $MoS_2$ nanocomposites
- Set-ups
- Thermodynamics
- C + Mo + $CS_2$: bonding
- Mo + S:
  - Bonding and structure
  - Ball-on-disk tests under air and dry nitrogen
- Mo + S + C:
  - Bonding and structure
  - Ball-on-disk tests under air and dry nitrogen
- Comparison with other systems and conclusions

# Why DLC + $MoS_2$ nanocomposites

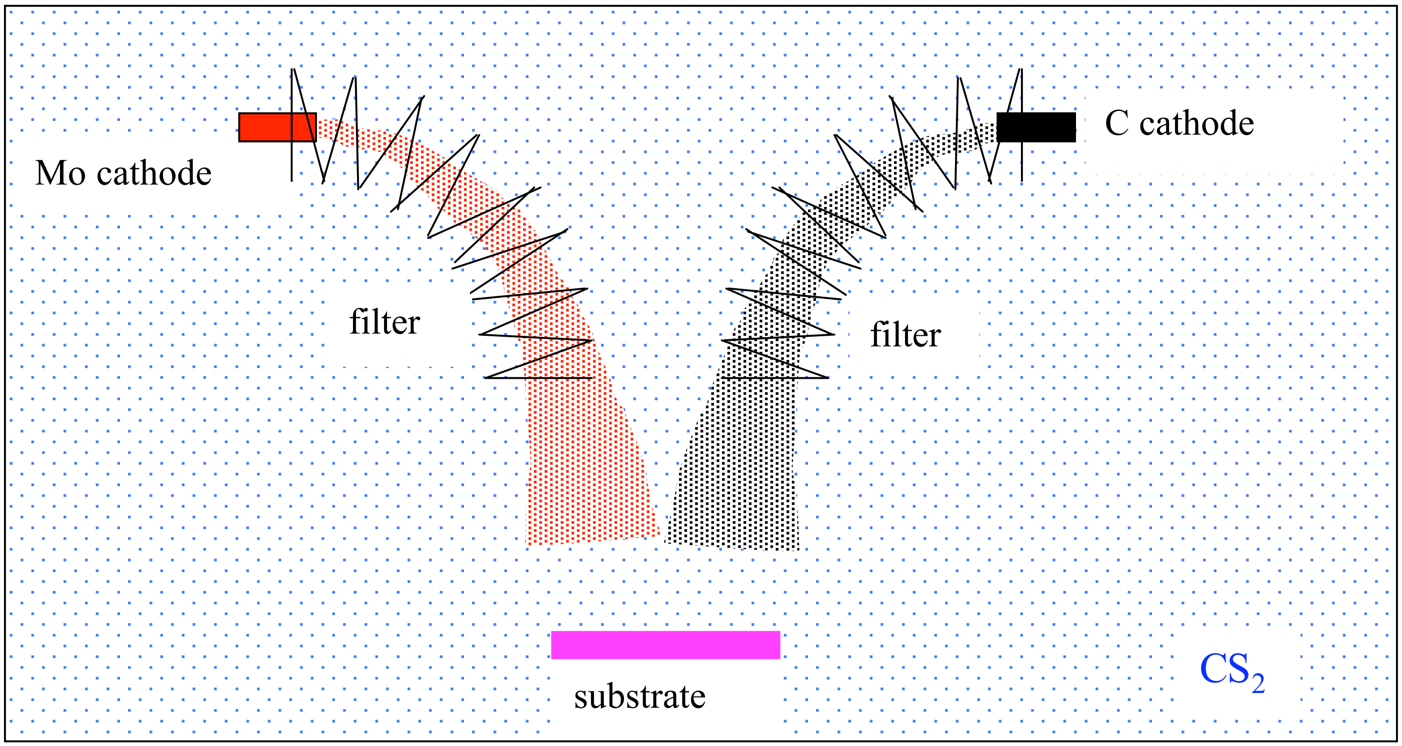
- Lubrication performances of non-hydrogenated DLC are limited in absence of moisture but good hardness and thoughness
- $MoS_2$ = good lubricant under dry conditions or under vacuum but low hardness, and oxydation in presence of $O_2$ or $H_2O$

=> idea: incorporate clusters of $MoS_2$ in a matrix of DLC to get a film with good performances under wet and dry conditions.



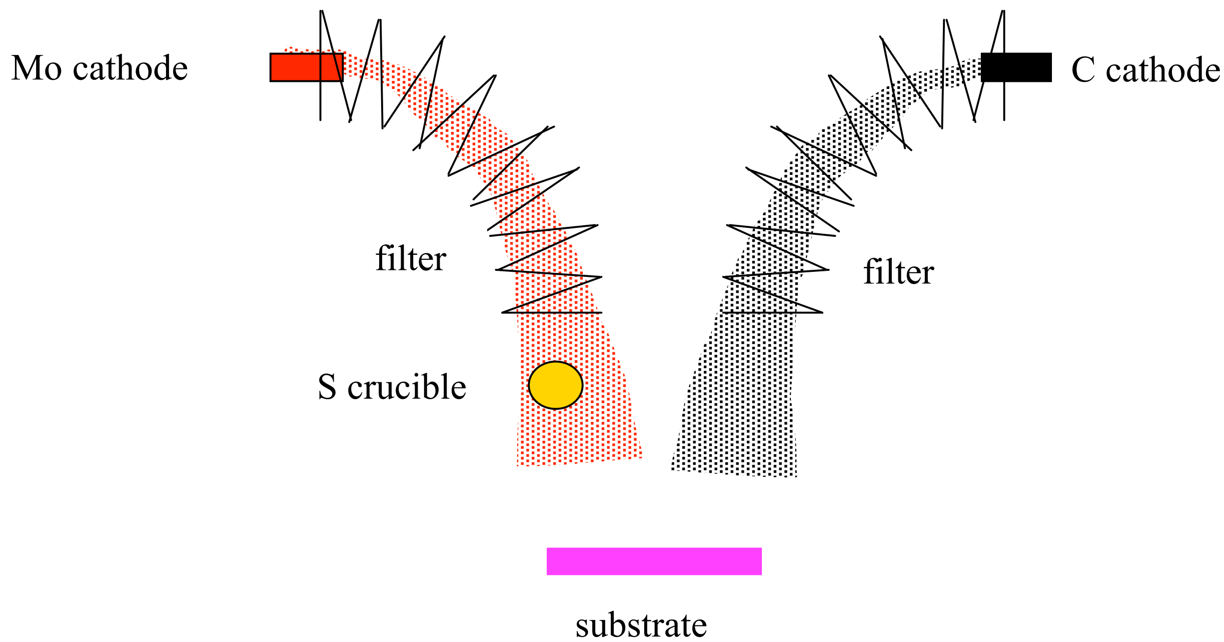
# Set-up: gaseous source of Sulfur

- Gaz source for S = $CS_2$



# Set-up : solid source of Sulfur

- Evaporation of solid sulfur in a crucible



# Thermodynamics

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|---|---|
| CompoundEnthalpy of formation (at 298 K)MoS2 solid-276.010 k | |
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# In absence of S source

- C pulse 4 ms at 270A,
  Mo pulse 6 ms at 100A

=> formation of
molybdenum carbide

# Films prepared with $CS_2$

- C pulse 4 ms at 270A,
  Mo pulse 6 ms at 100A
  1 Pa of $CS_2$

=> - very low incorporation of sulfur

- difficulty to control the Mo/C and S/C ratios

-sensitivity to contamination

# Mo + S synthesis: bonding

- sulfur is incorporated exclusively if Mo is present
- a bias on the substrate reduces the incorporation of sulfur in the film. Two factors:
  - preferential sputtering of sulfur under $Mo^{n+}$ ion bombardment
  - the bias attracts the $Mo^{n+}$ ions but as the ionization of sulfur is low, the bias is not attracting the sulfur
- the structure is not well ordered: wide peaks in XPS

# $MoS_2$ synthesis: mechanical properties

- Ball-on-disk tests in dry $N_2$, $Al_2O_3$ ball
  - life time increased by a factor of 4 in comparison with air tests
  - failure by delamination and intensive cracking

=> very brittle films

=> not satisfactory as lubricants even under dry $N_2$

# Mo + S + C: bonding

- S bonded mainly to Mo.
- No real proof of C-S bonds even in presence of an excess of S
- possible S-S bonds in presence of an excess of S
- in presence of an excess of Mo formation of $MoO_3$ at the surface and tendency to form Mo-C bonds in the bulk
- reduction of S incorporation in presence of bias

# Mo + S + C: mechanical properties

- Ball-on-disk tests with stainless steel and alumina balls in air
- Ball-on -disk tests with alumina balls in dry $N_2$

=> best resistance to abrasion in air and dry $N_2$ for low concentration of $MoS_2$ (doping).

=> at low concentration of $MoS_2$ (doping), better resistance to abrasion with a steel ball than with $Al_2O_3$ ball

=> performances are lower in air than pure DLC films

=> films with high $MoS_2$ concentration are brittle and don 't support the load: extensive cracking and delamination

**NO improvement of the tribological performances of DLC by the addition of $MoS_2$ in the deposition conditions investigated here.**

# Comparison with other systems and conclusions

- The $MoS_2$ / DLC system has been compared with W doped DLC and Ti doped DLC films prepared in similar conditions:

=> W and Ti additions reduce the intrinsic compressive stress of the hard DLC films and made them thougher.

=> addition of $MoS_2$ does not improve the performances of doped DLC films, it increases the brittleness: could be related to the bonding in the films.