Benchmarking test results on SEMATECH ML1 Ru-capped optics test sample

Comparison to TiO_2-capped MLs

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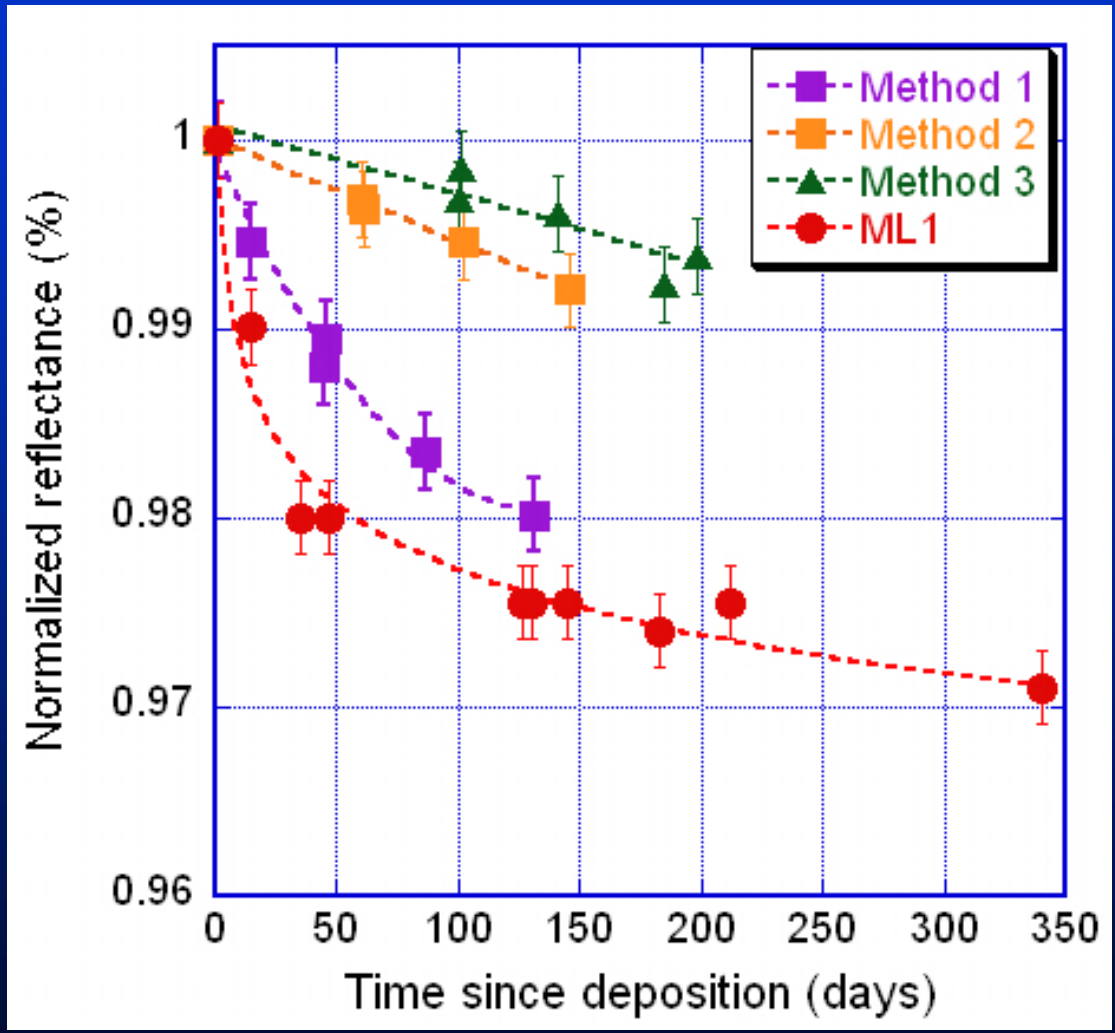
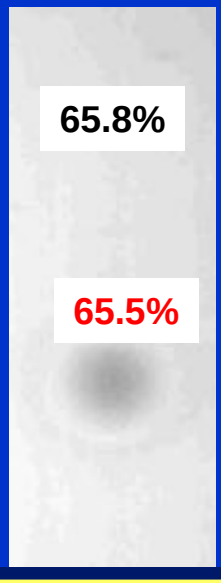
TiO_2-capped MLs show significantly better lifetime stability in the air when compared to ML1 (Ru-capped)



All TiO_2-capped MLs are of similar thickness (1.5 nm).

TiO_2-capped multilayers (Method 3) show better oxidation resistance than Ru-capped multilayers

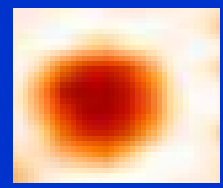
TiO_2-capped ML
ΔR = - 0.3%



Repeatable measurement

Exposure parameters:
40 hrs EUV light
~5 mW/mm^2
2 x 10^{-7} Torr H_2O

Ru-capped ML
ΔR = -3.1%



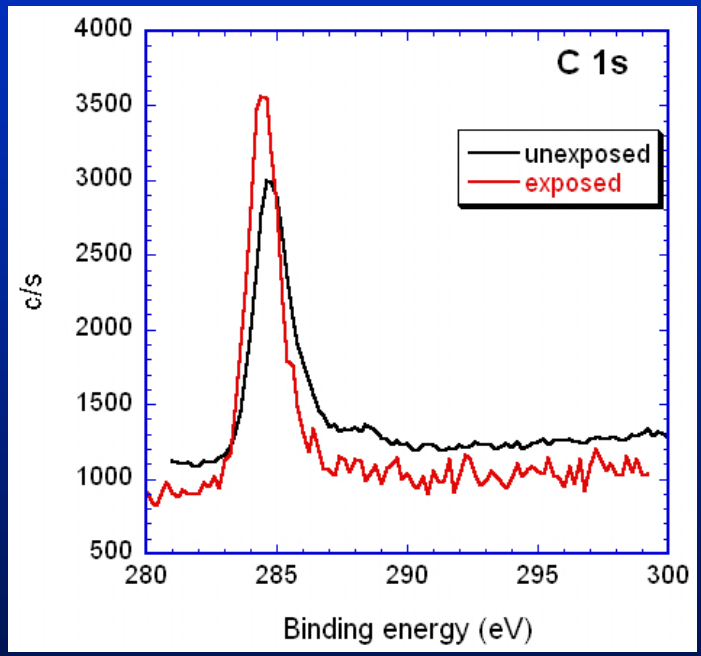
Exposure parameters:
38 hrs EUV light
~ 5mW/mm^2
7.5 x 10^{-8} Torr H_2O

(Pei-yang Yan et al., BACUS 05, 5992-135)

At least 10x better lifetime for TiO_2-capped MLs as compared to Ru-capped MLs (comparable EUV exposure in oxidizing environment).

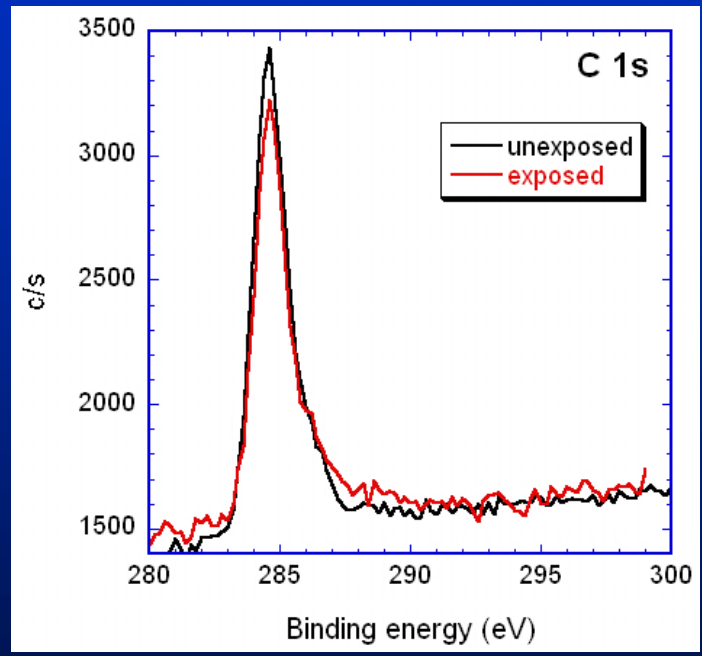
Preliminary XPS results show interesting differences in surface chemistry after EUV exposures (oxidizing environment)

Area exposed to EUV light + water vapor shows carbon growth for Method 1 sample and carbon removal for Method 3 sample



Method 1
Carbon growth

(30 at.% to 36 at.%)

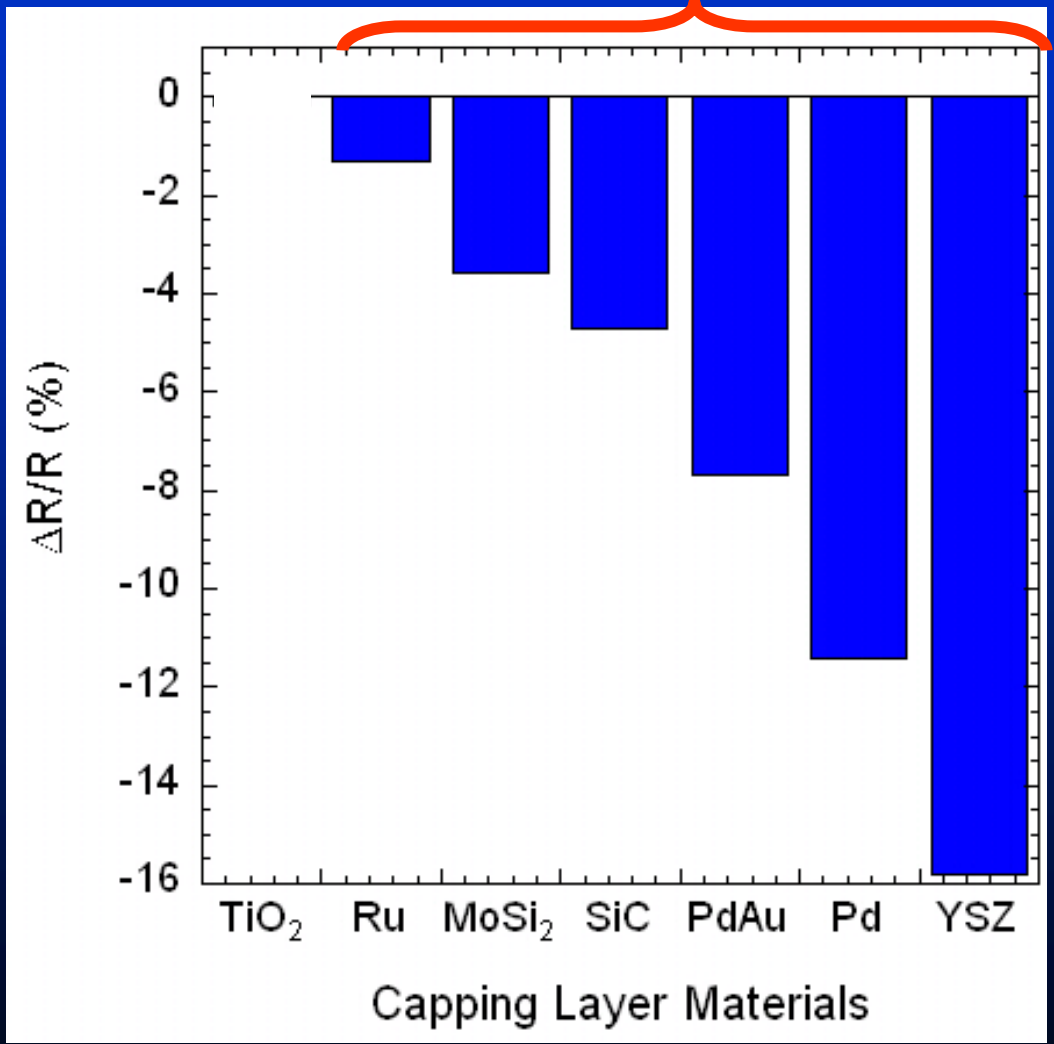


Method 3
Carbon removal

(32 at.% to 25 at.%)

Reflectivity loss as a function of material under oxidizing conditions for e-beam exposures

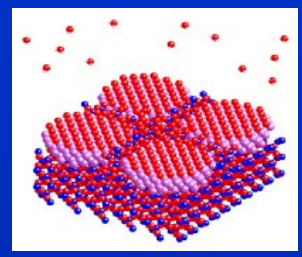
SEMATECH (LITH 160)

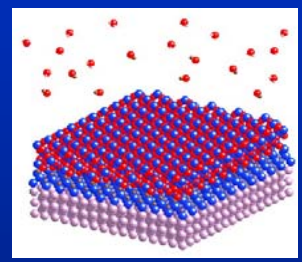


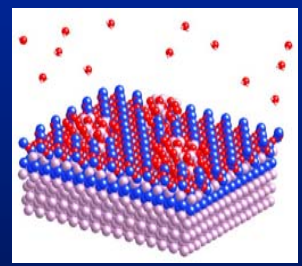
40 hrs e-beam exposures
~5 μA/mm²
2 x 10^{-7} Torr H_2O

Possible degradation mechanisms were identified

- Oxidation of incompletely covered surfaces
- Oxygen diffusion into the capping layer and subsequent chemical reactions
- Oxidation via defects (pesting)





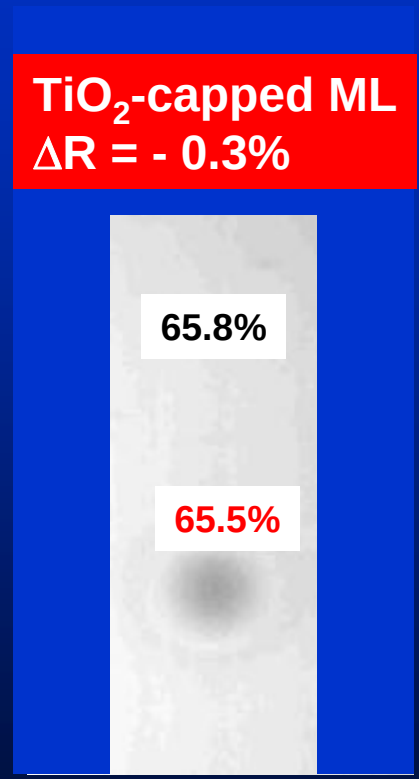


Physical Processes :

- **Transport**
  - to the surface
  - through the capping layer
- **Reaction**
  - on the surface
  - inside the capping layer
  - below the capping layer

Summary

- Compared to Ru-capped MLs TiO_2-capped MLs show:
  - comparable reflectivity for comparable thickness (>65%)
  - superior oxidation resistance (10x better)
  - better aging in the air



However:

- There are still several unknowns:
  - Basic knowledge on the formation of stoichiometric TiO_2
  - Lifetime stability as a thin layer
  - The effect of thickness and microstructure on lifetime stability
  - Photo-catalytic performance as a thin layer under EUV light