



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

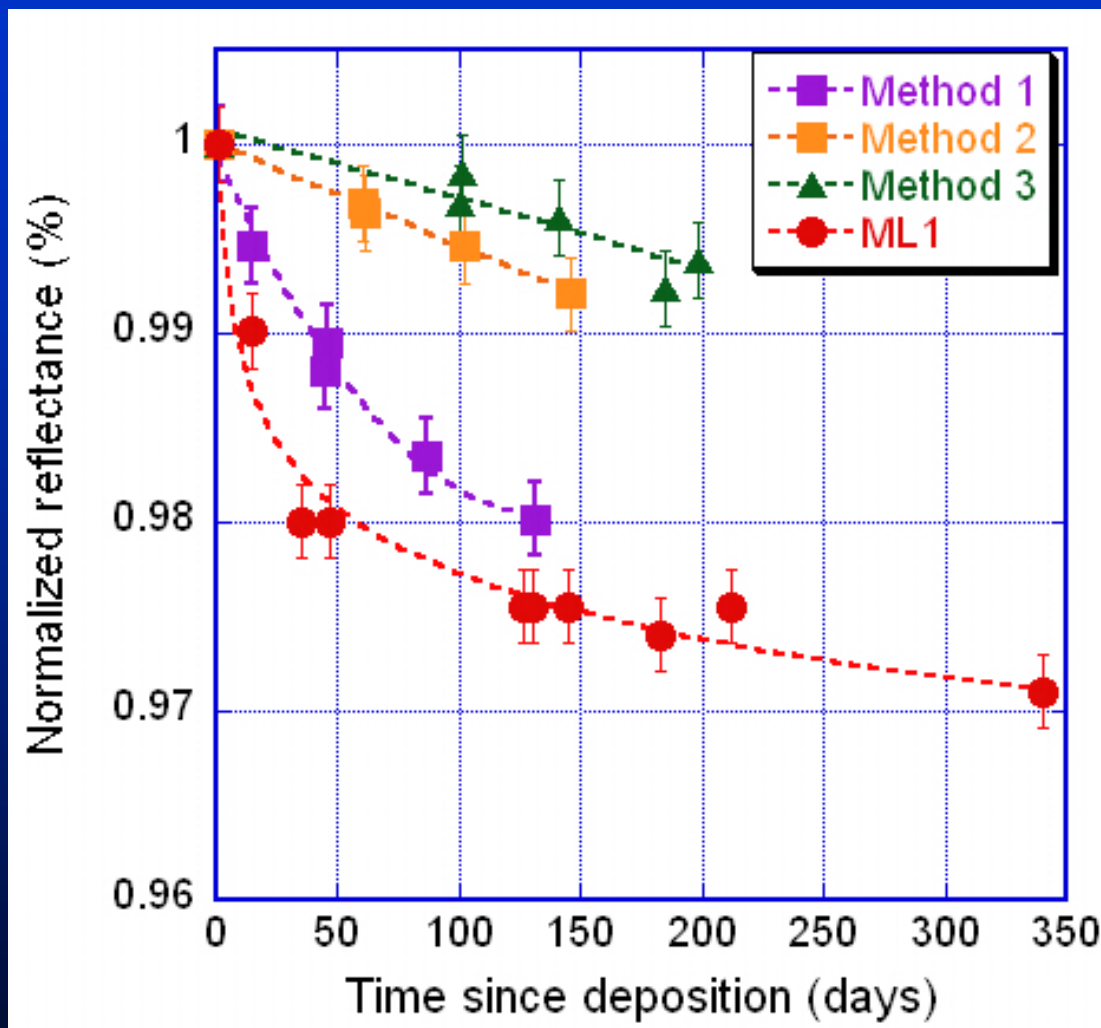
## Comparison to $\text{TiO}_2$ -capped MLs

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# TiO<sub>2</sub>-capped MLs show significantly better lifetime stability in the air when compared to ML1 (Ru-capped)

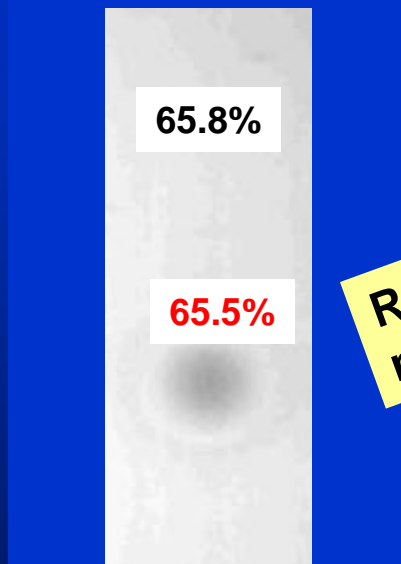


All TiO<sub>2</sub>-capped MLs are of similar thickness (1.5 nm).

# TiO<sub>2</sub>-capped multilayers (Method 3) show better oxidation resistance than Ru-capped multilayers



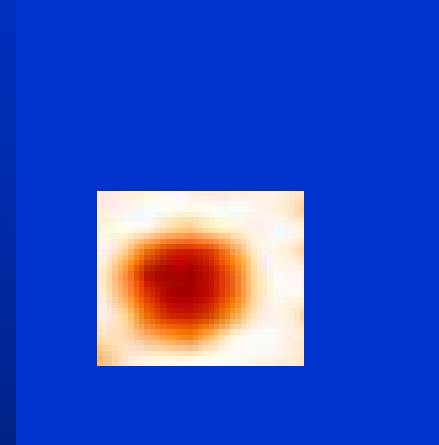
TiO<sub>2</sub>-capped ML  
 $\Delta R = -0.3\%$



Repeatable  
measurement

Exposure parameters:  
40 hrs EUV light  
~5 mW/mm<sup>2</sup>  
2 x 10<sup>-7</sup> Torr H<sub>2</sub>O

Ru-capped ML  
 $\Delta R = -3.1\%$



Exposure parameters:  
38 hrs EUV light  
~5mW/mm<sup>2</sup>  
7.5 x 10<sup>-8</sup> Torr H<sub>2</sub>O

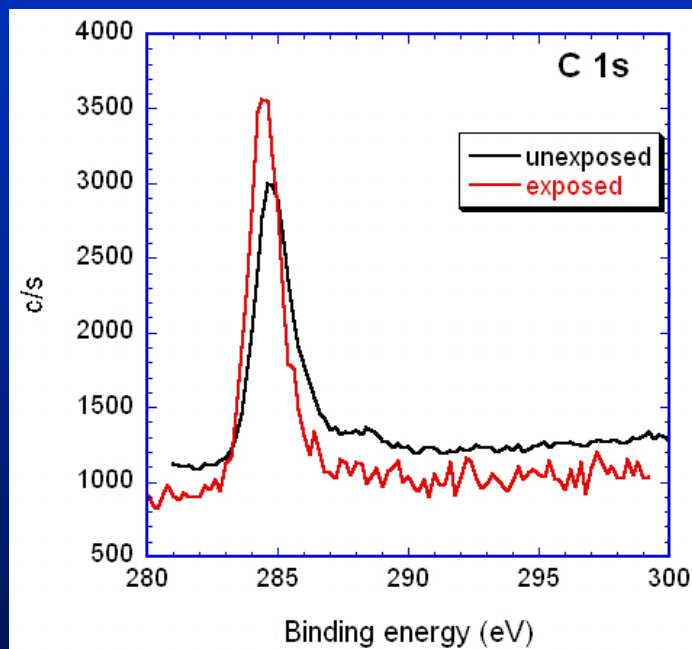
(Pei-yang Yan et al., BACUS 05, 5992-135)

At least 10x better lifetime for TiO<sub>2</sub>-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)

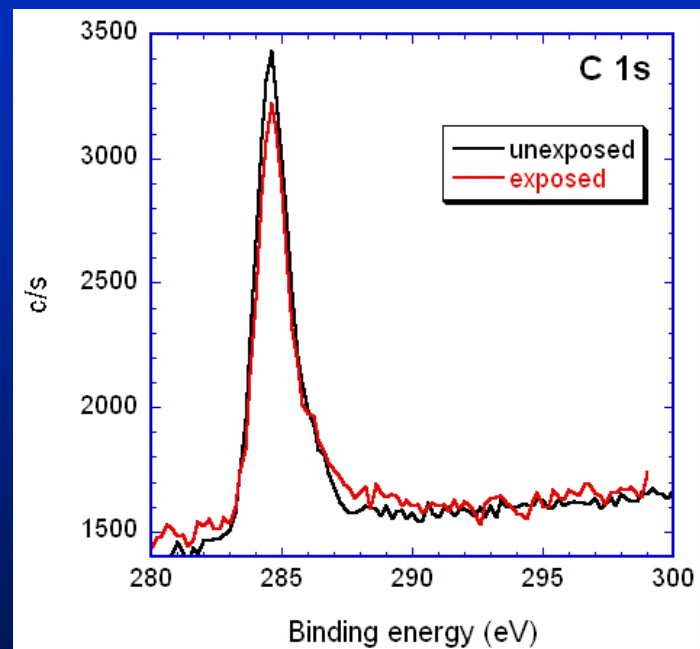


Area exposed to EUV light + water vapor shows carbon growth for Method 1 sample and carbon removal for Method 3 sample



**Method 1**  
**Carbon growth**

**(30 at.% to 36 at.%)**



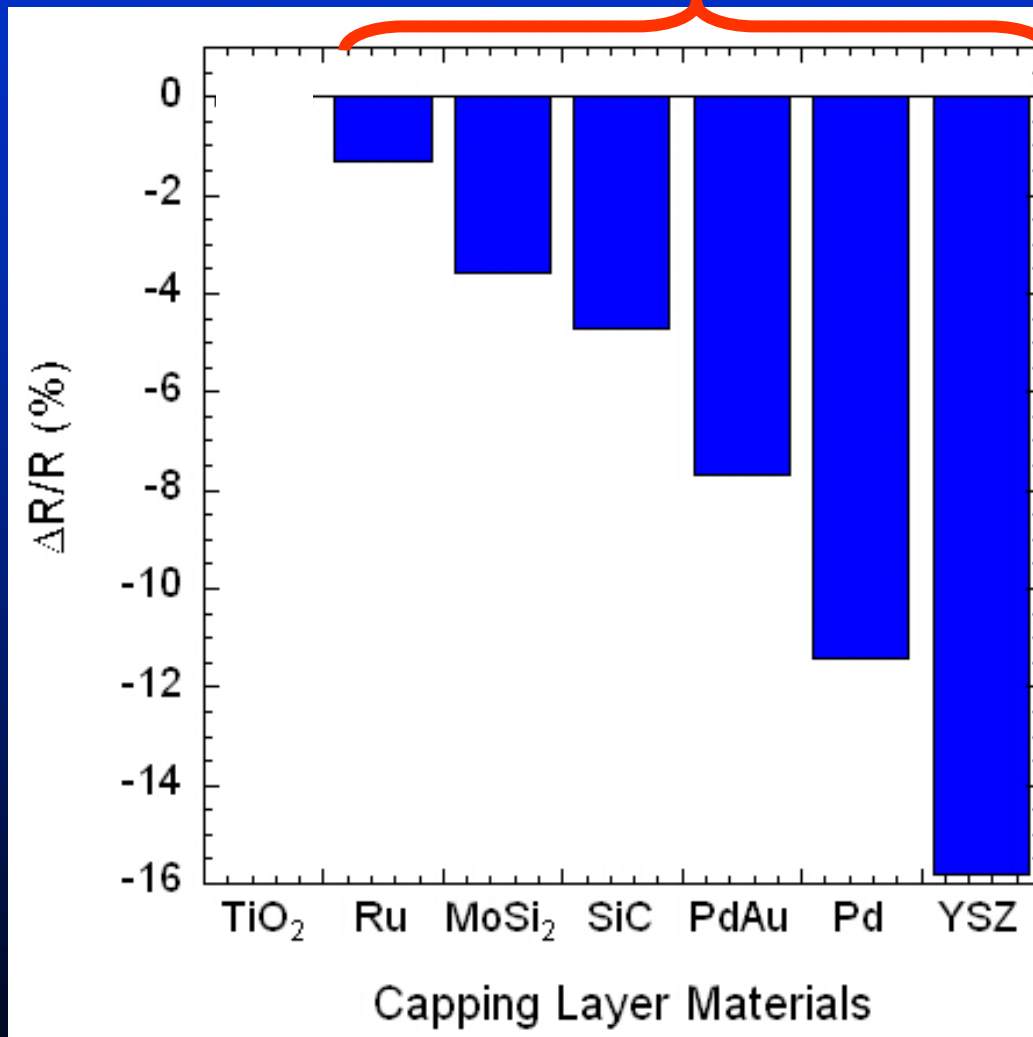
**Method 3**  
**Carbon removal**

**(32 at.% to 25 at.%)**

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



SEMATECH (LITH 160)

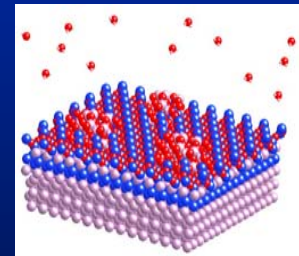
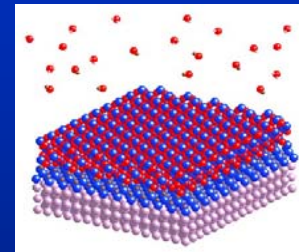
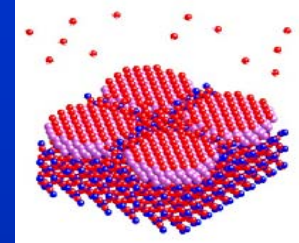


40 hrs **e-beam** exposures  
 $\sim 5 \mu A/mm^2$   
 $2 \times 10^{-7}$  Torr  $H_2O$

# Possible degradation mechanisms were identified



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



## 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<sub>2</sub>-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<sub>2</sub>**
  - **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**

**TiO<sub>2</sub>-capped ML**  
**ΔR = - 0.3%**

65.8%

65.5%