U.S. Regional Update

IEUVI Optics Lifetime/Contamination TWG

October 19th, 2006 **Barcelona, Spain**

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NIST Physics Laboratory

SEMATECH Coordinated Projects - 2006

- **Fundamental surface chemistry and physics: relevance to EUVL; Ted Madey, Rutgers:**
  - "Surface phenomena related to mirror degradation in EUVL, " Appl. Surf. Sci., in the press
  - "Alternatives to Ru for EUVL capping layers, " to be published
  - "Radiation-induced processes on Ru surfaces: relevance to EUVL"
- **EUV Resist Outgassing and Exposure Studies (EUV-ROX), Greg Denbeaux et al., SUNY,Albany.**
- **Analysis of contamination of illuminator optics in actual METs (planned).**
- **Collector optics lifetime/contamination; David Ruzic, et al. at the University of Illinois-Urbana Champaign.**

EUV-ROX Capabilities for Optics Contamination

(Greg Denbeaux et al., SUNY Albany)

- EQ-10M EUV source from Energetiq, which is a 10W into 2π in 2% bandwidth pulsed Xe plasma source

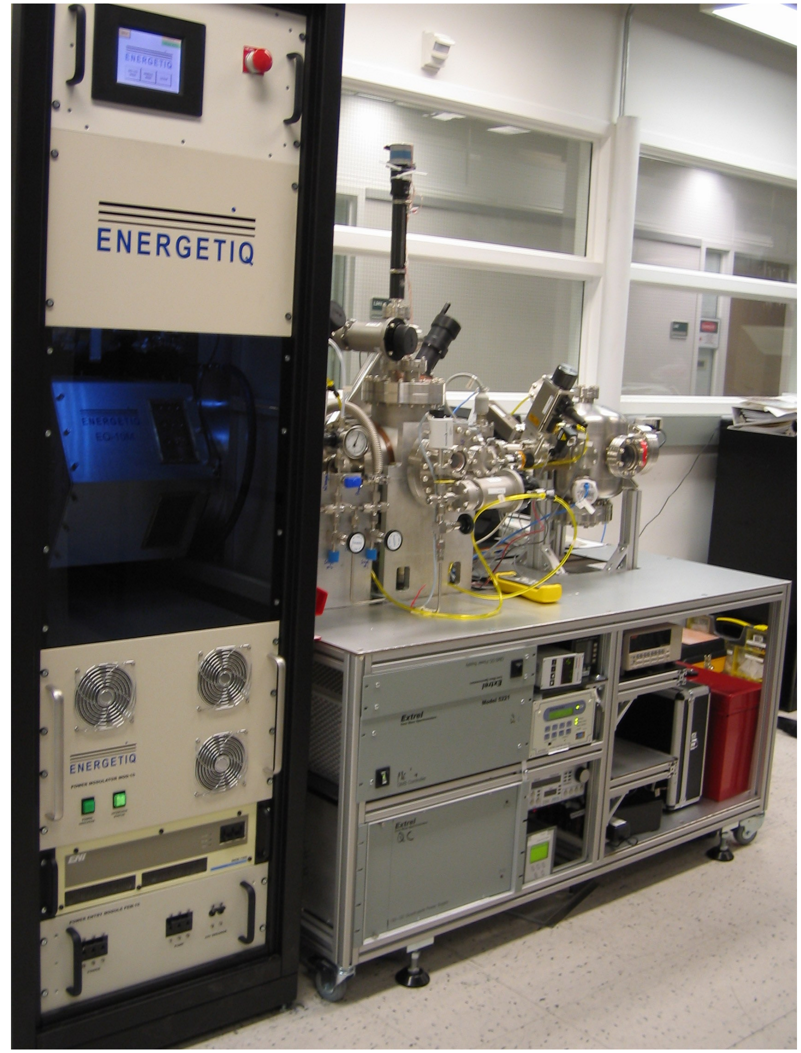
- Net spectra during exposure is between 10.5 to 15.5 nm wavelength, but can be reduced with multilayer mirrors

- Net power at wafer lever can be varied between 0.8 – 3.5 mW/cm^2

- Exposure area is 4 cm^2

- Extrel MAX300 Quadrupole mass spectrometer for accurate vacuum measurements

- Resist outgassing measurements with Extrel mass spectrometer



Intel Coordinated Projects - 2006

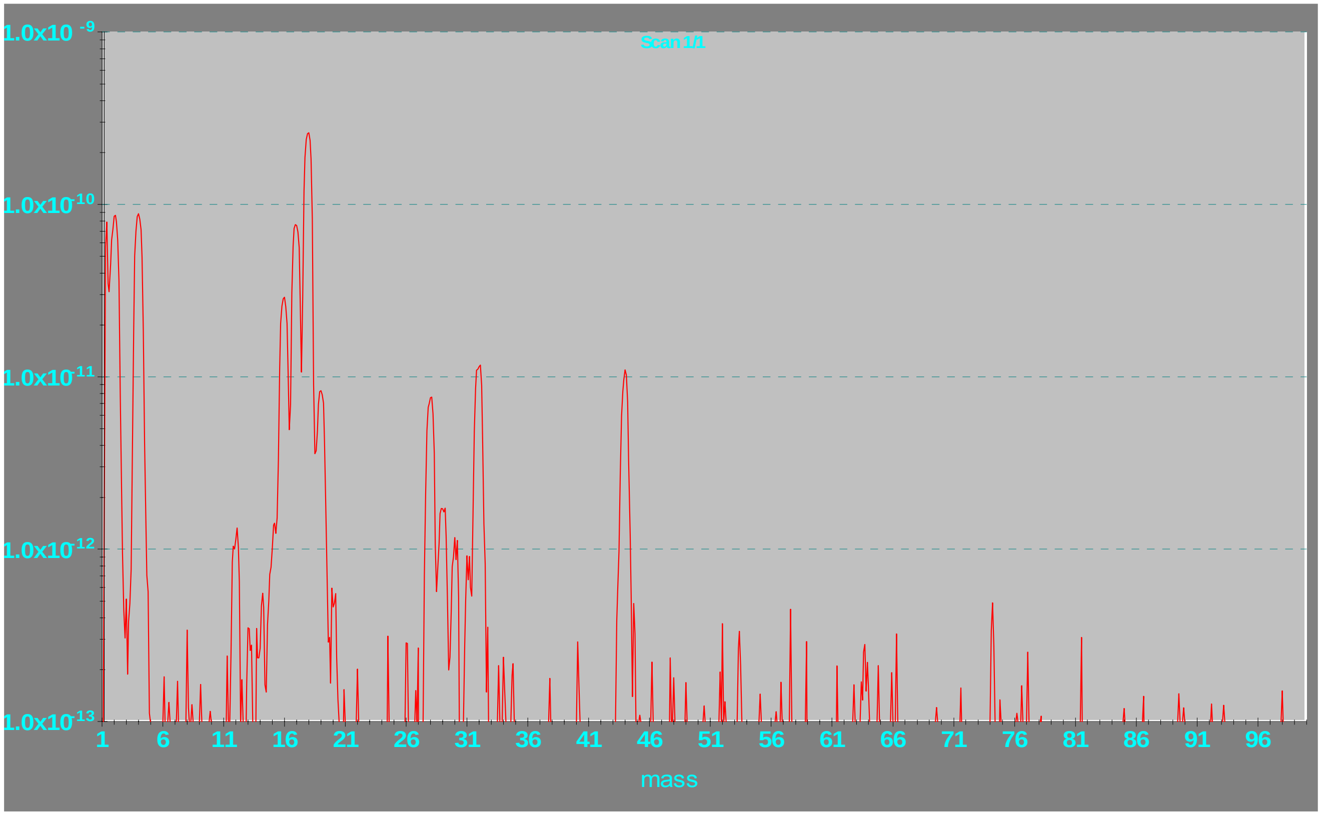
- **Cap layer development – Fraunhofer IOF**
- **Analysis of MET mirrors – Fraunhofer IOF**
- **Small spot reflectivity measurements – LBL - ALS**
- **CW EUV long-term exposure testing – NIST**
- **Pulsed EUV exposure testing – Denbeaux, SUNY Albany**
- **Fundamental Studies:**
  - **RuO_2 - Herbert Over, Justus-Liebig-Universität Gießen; Review Paper in JVSTB sometime in 2007.**
  - **TiO_2 – Ted Madey, Rutgers; Ulrike Diebold, Tulane; Project just started.**

Fraunhofer Inst. Angewandte Optik und Feinmechanik

- **Joined effort in 2006**
- **Capabilities:**
  - State of the art deposition (both DC and RF sputtering)
  - Characterization by SAXR and XPS
  - Pulsed EUV source exposure system
  - Complete optics fabrication
- **Testing procedure for MLs:**
  - Coatings designed and fabricated at IOF
  - Exposure testing and micro XPS analysis at NIST
  - Reflectivity at ALS and PTB
- **Recent results:**
  - TiO_2
    - $R_{max} = 66.9\%$
    - $\Delta R = 66.9\% \rightarrow 66.3\%$ for 2 e-7 Torr H_2O and $D = 760 J/mm^2$
  - RuO_2
    - $R_{max} = 65.7\%$
    - $\Delta R = 65.7\% \rightarrow 66.0\%$ for 2 e-7 Torr H_2O and $D = 720 J/mm^2$
- **Future plans:**
  - Interface engineering – prevent diffusion of O_2 into Si and maximize peak reflectivity
  - Search for promising new capping layers
  - Investigation of photo-catalytic properties in collaboration with Ted Madey, Ulrike Diebold, Greg Denbeaux, and Herbert Over.

Long-term exposure testing NIST/Intel/IOF

- Second chamber on SURF III beamline operational; gold plated chamber with load lock; average intensity $5 mW/mm^2$
- Tests being done on Ru, TiO_2, and RuO_2 capping layers
- Tests done with H_2O, H_2, H, CO, CO_2, and methanol
- Excellent background vacuum:



Summary of findings – for Ru many questions, few answers

Ru (10hrs at ~ $5 mW/mm^2$):

- More water → less reflectivity loss → donut profile
- Filaments make a difference, but why? Is it that more water → more H, CO, and CO_2?
- However H_2, H, CO, and CO_2 do not mitigate reflectivity loss
- In fact, more H → more damage. (How to square with Madey's data?)
- Methanol prevents reflectivity loss at 1 part in 50 (and maybe less). Why?

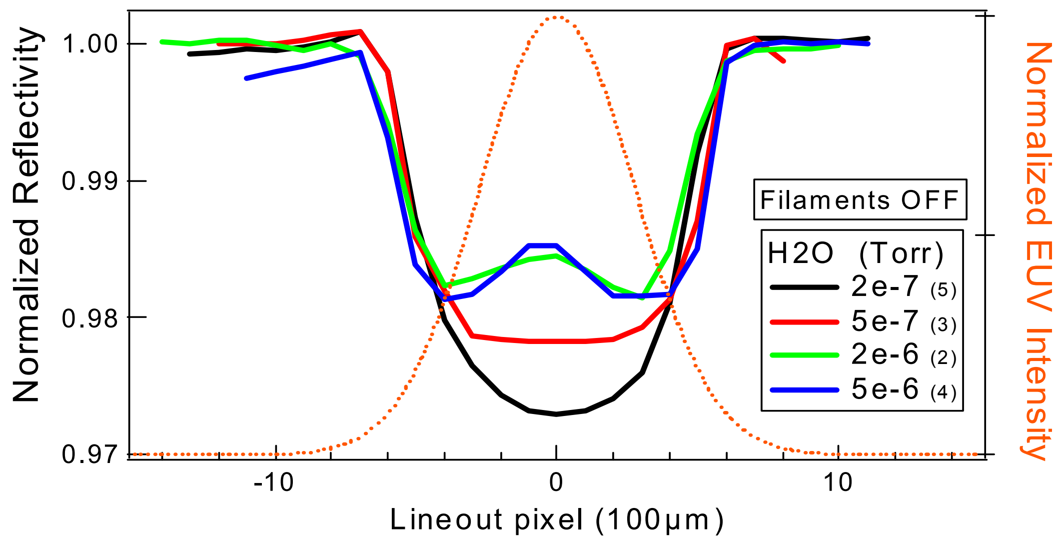
TiO_2 (IOF & LLNL) 40hrs; 5e-6 and 2e-7 H_2O respectively:

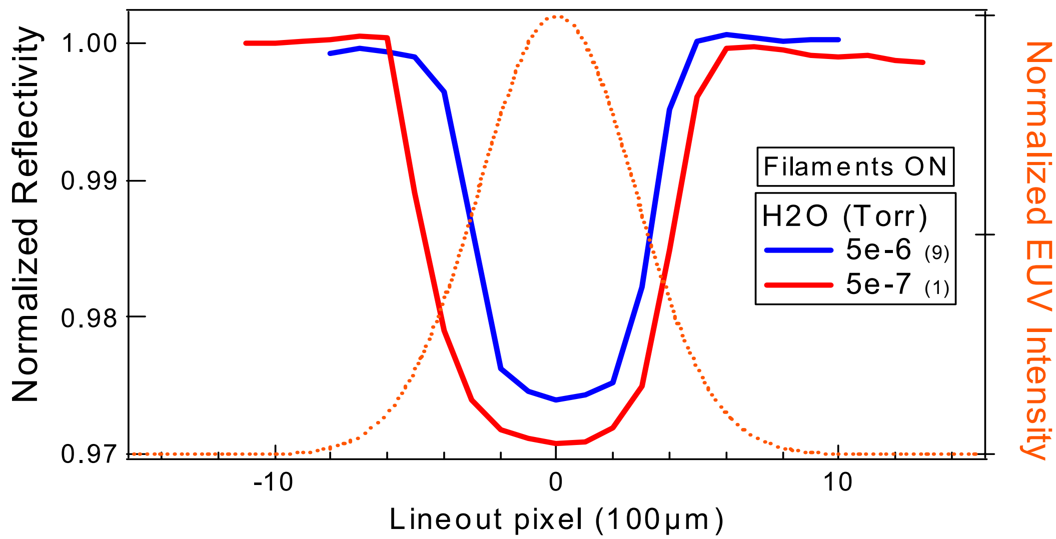
- Well designed TiO_2 show less loss than Ru

RuO_2 (IOF):

- No loss for best designed caps

M3-040415A1-L (BL1, 3/16-4/4/06)





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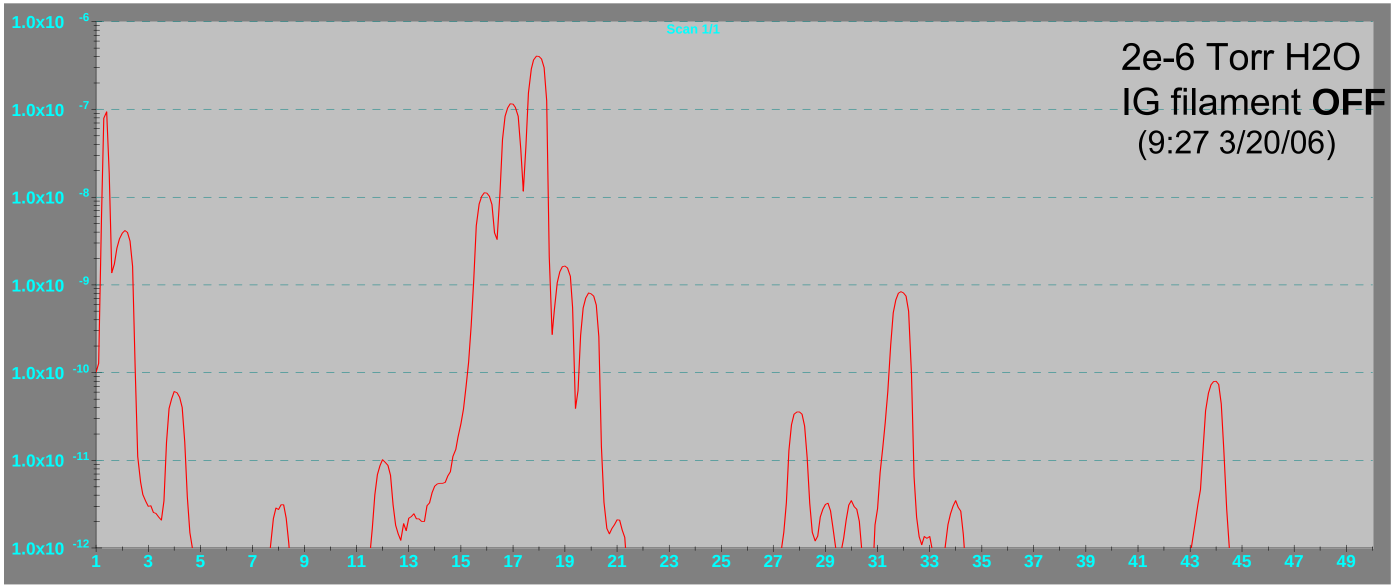
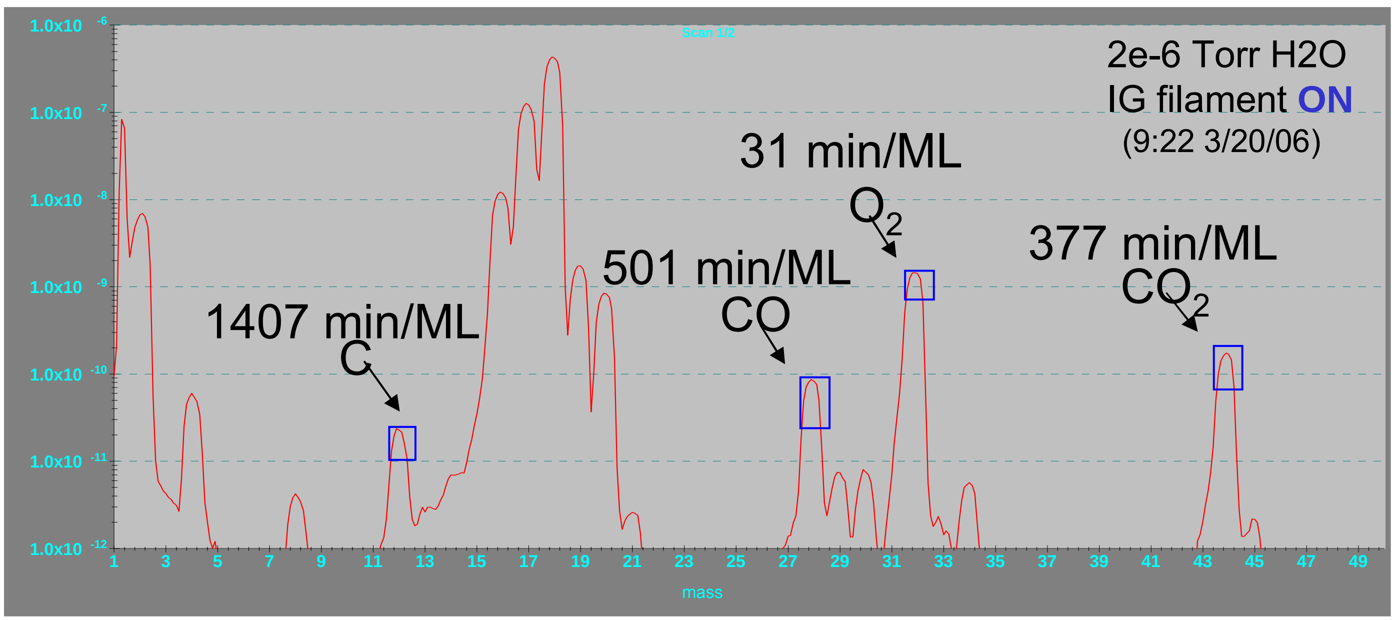

Scan 1/1
1.0x10 -6
1.0x10 -7
1.0x10 -8
1.0x10 -9
1.0x10 -10
1.0x10 -11
1.0x10 -12
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
2e-6 Torr H2O
IG filament OFF
(9:27 3/20/06)


Scan 1/2
1.0x10 -6
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1.0x10 -11
1.0x10 -12
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
mass
2e-6 Torr H2O
IG filament ON
(9:22 3/20/06)
1407 min/ML
C
501 min/ML
CO
31 min/ML
O2
377 min/ML
CO2

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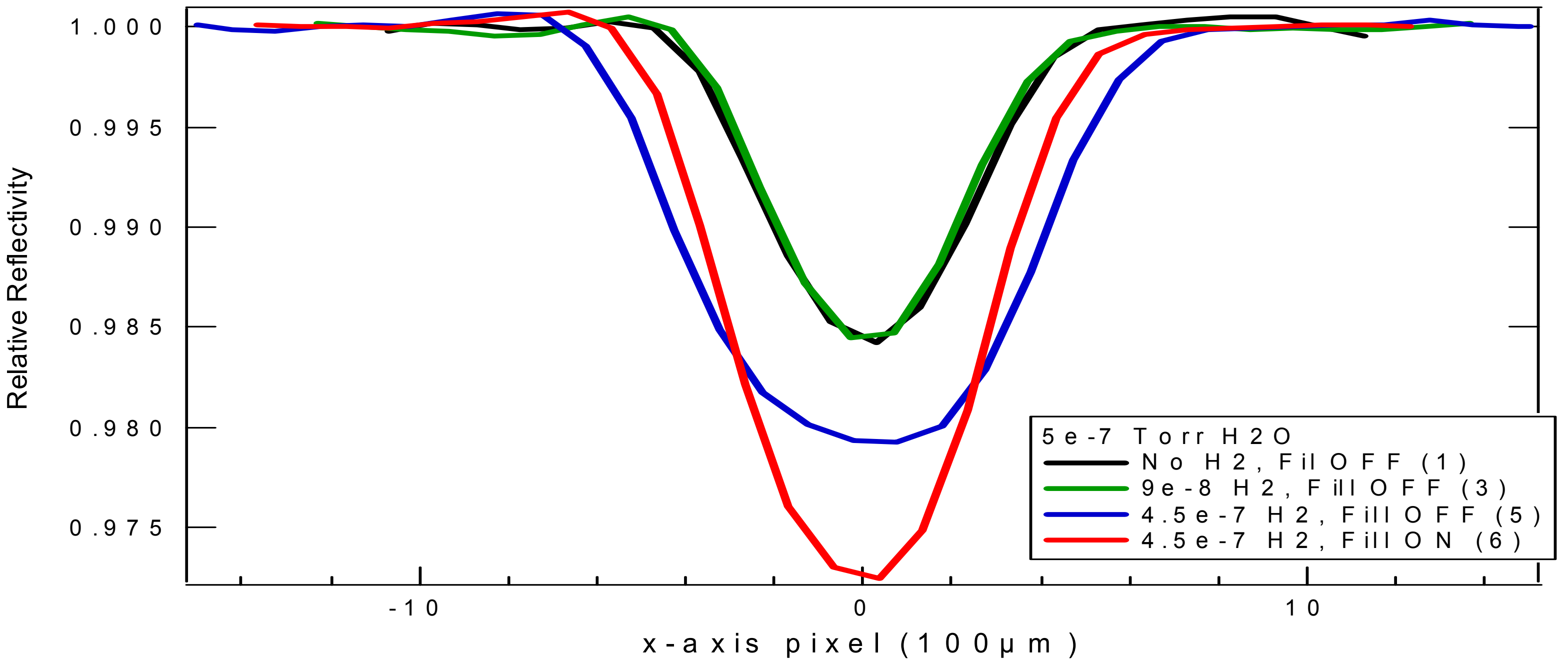
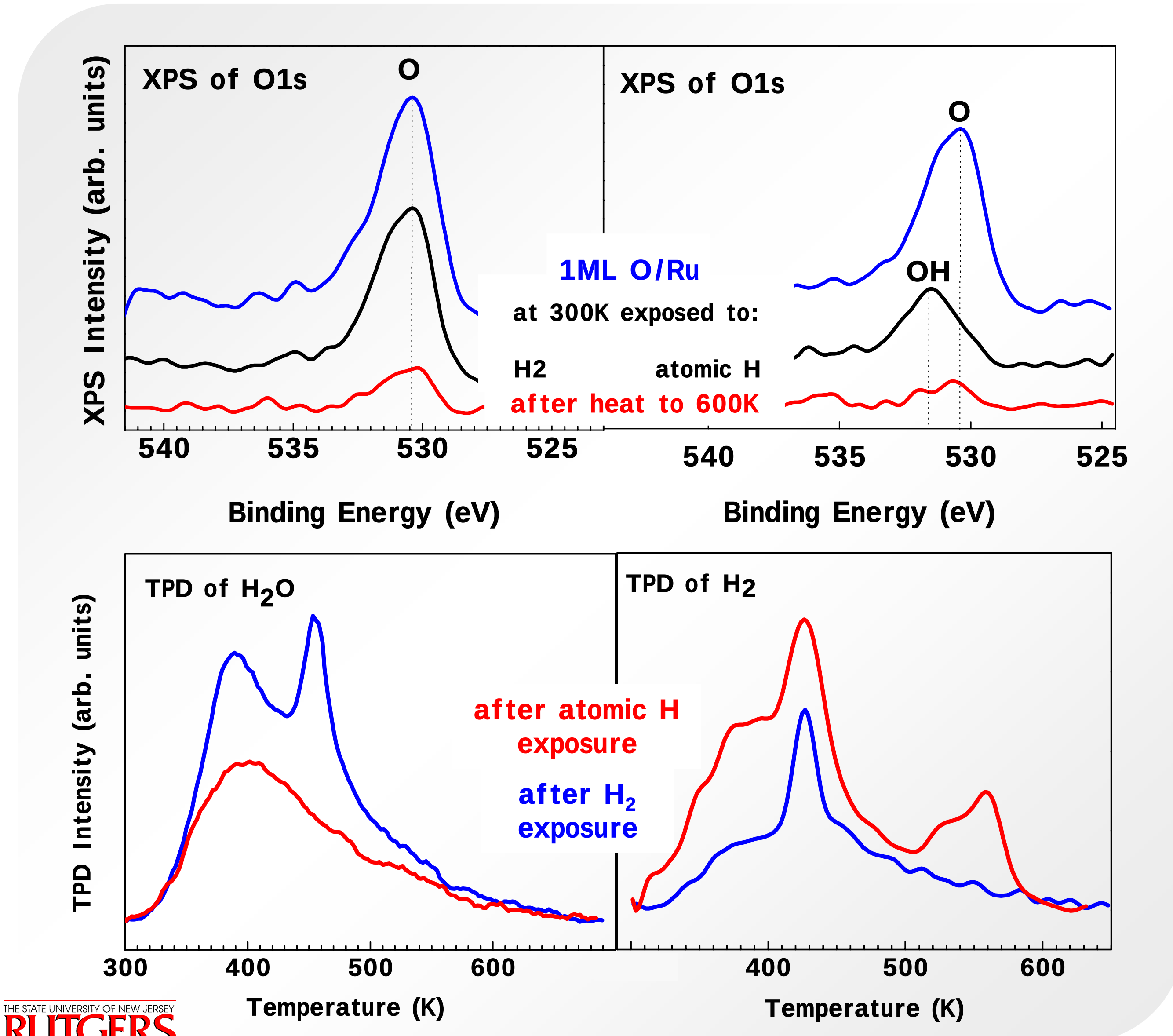
M3-050718A1-G (BL8)



Reduction of 1 ML O/Ru(1010) by atomic and molecular hydrogen



- Hydrogen dose: P=10^{-7}Torr for 1 hr
- Source of H atoms: hot W filament
- Atomic H effectively reduces Ru *even at 300K*
- Oxygen removal from H_2-exposed surface occurs through the associative desorption of H_2O upon heating

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Summary of findings – TiO_2 and RuO_2

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Summary

2006

- Fundamental surface chemistry of RuO_2
- Surface phenomena related to mirror degradation in EUVL
- Alternatives to Ru for EUVL capping layers
- Surface chemistry of methyl methacrylate (MMA) on Ru
- Preliminary resist outgassing and exposure studies
- Cap layer development: Ru, TiO_2, and RuO_2
- Long term testing of cap layers: Ru, TiO_2, and RuO_2

2007

- Continued lifetime tests and analysis of TiO_2 and RuO_2
- Fundamental surface chemistry of TiO_2
- Expanded set of resist studies
- Studies of mirror cleaning techniques?