"Radiation-induced processes on Ru surfaces: relevance to EUVL"

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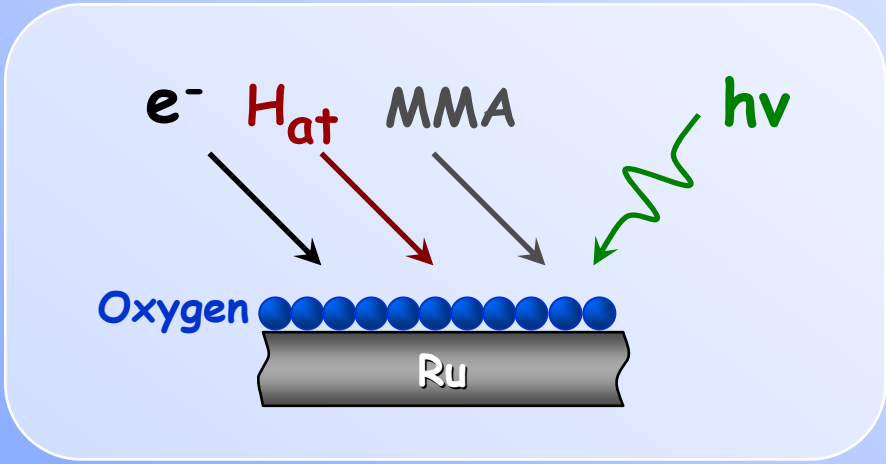
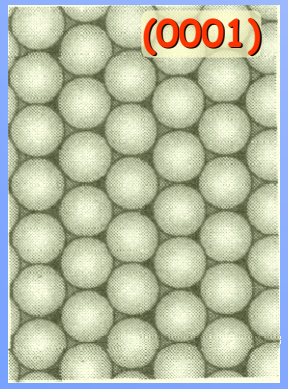
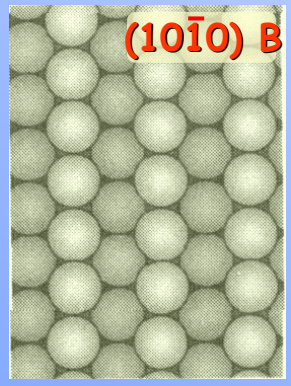
2006 EUVL Symposium

Outline





(close packed)



(atomically rough)

- Removal of O from Ru surfaces
- Electron stimulated desorption (ESD)
- H-atom reactions
- Reaction with MMA
- Secondary electron yields (Synchrotron radiation)
- clean, O-covered, C-covered Ru

The (0001) and (10$\bar{1}$0) faces of an ideal *hcp* crystal – possible surfaces in capping layers

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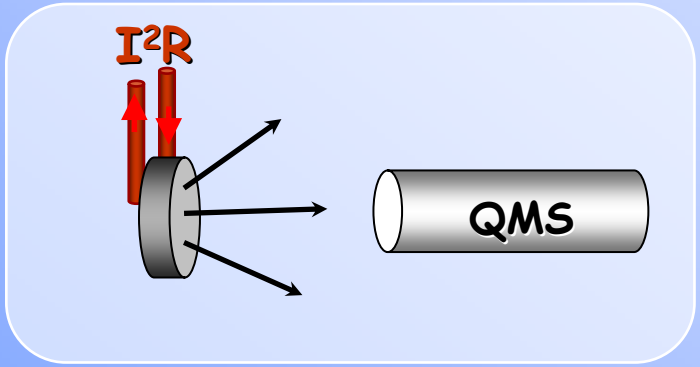
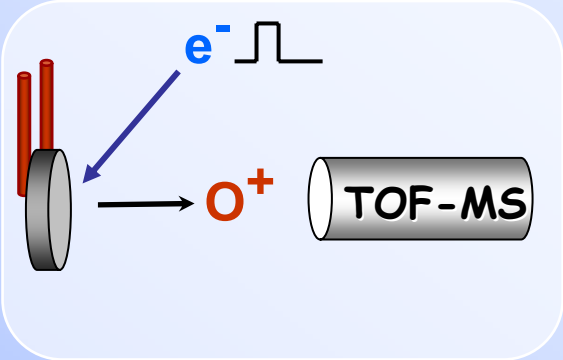
Methods

TPD: Temperature Programmed Desorption



ESD: Electron stimulated desorption



XPS: X-ray photoelectron spectroscopy

LEIS: Low energy ion scattering

Secondary electron yield (synchrotron radiation)

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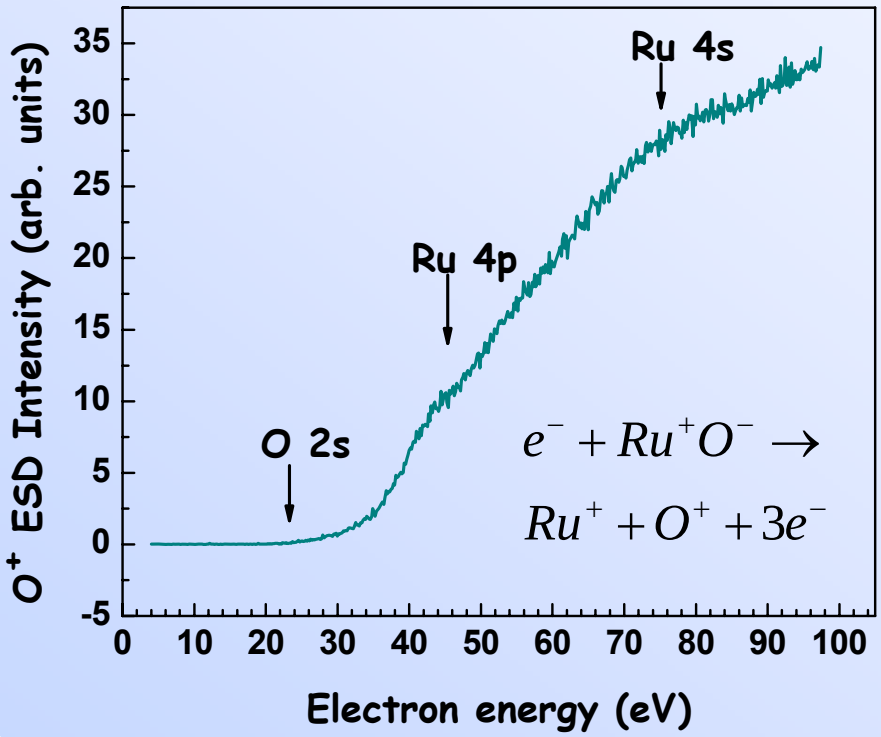
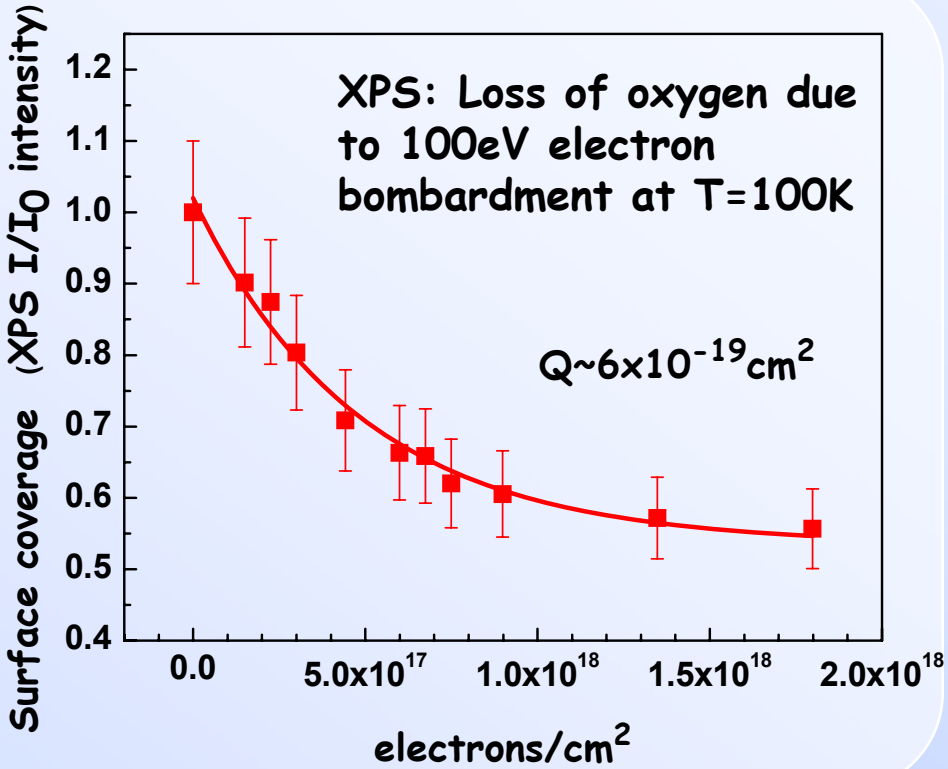
1. Electron-stimulated desorption of O^+, O from 1ML O/Ru (10$\bar{1}$0)





The implication:

since electrons excite desorption of O and O^+, via core excitation, 13.5nm photons can do so also:

$$e^-(\text{or } h\nu) + Ru^+O^- \rightarrow Ru^+ + O,\ O^{+}\uparrow$$

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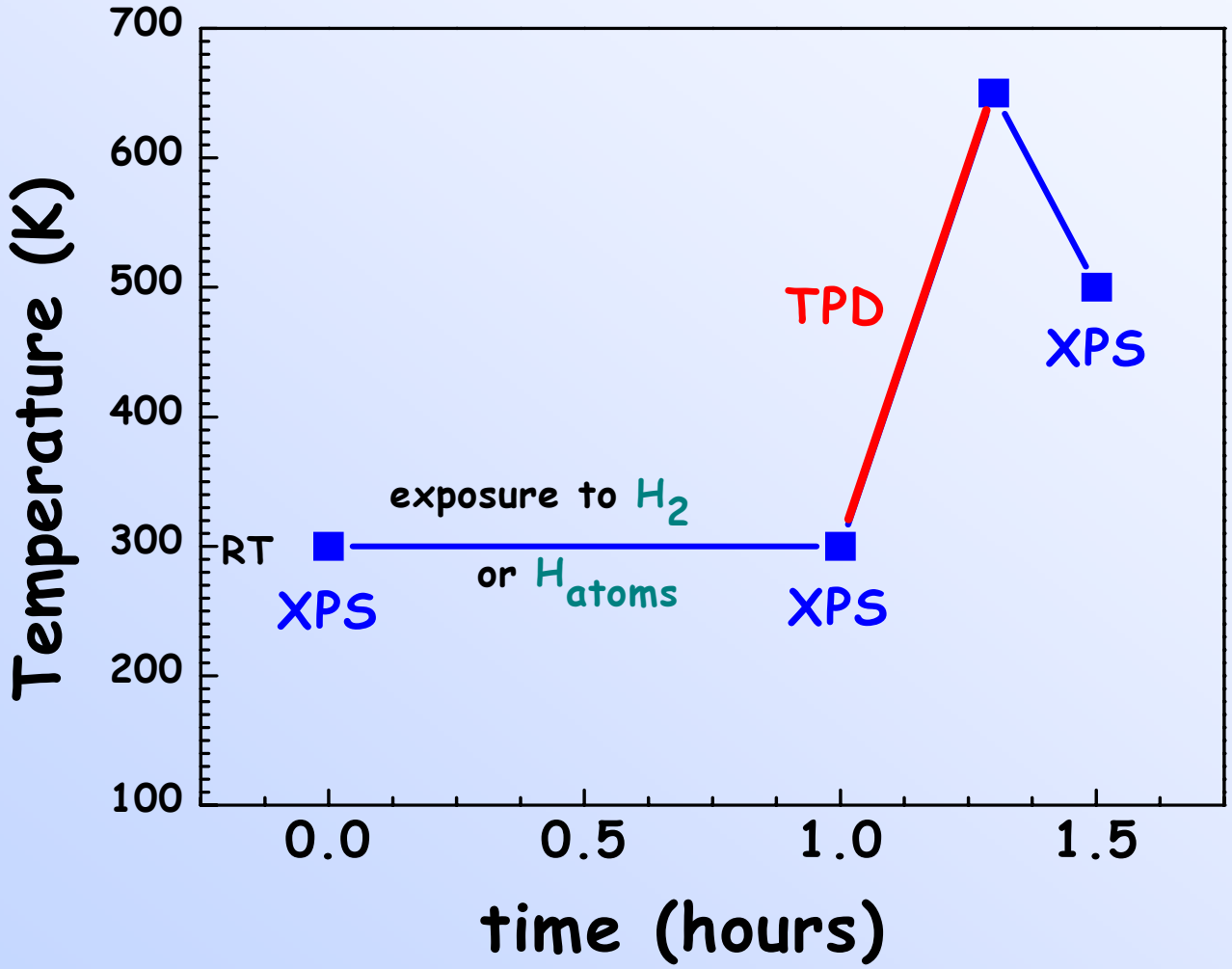
2. Temperature, time program for removal of O/Ru by H-atoms *(Make H atoms by cracking H_2 over hot W)*



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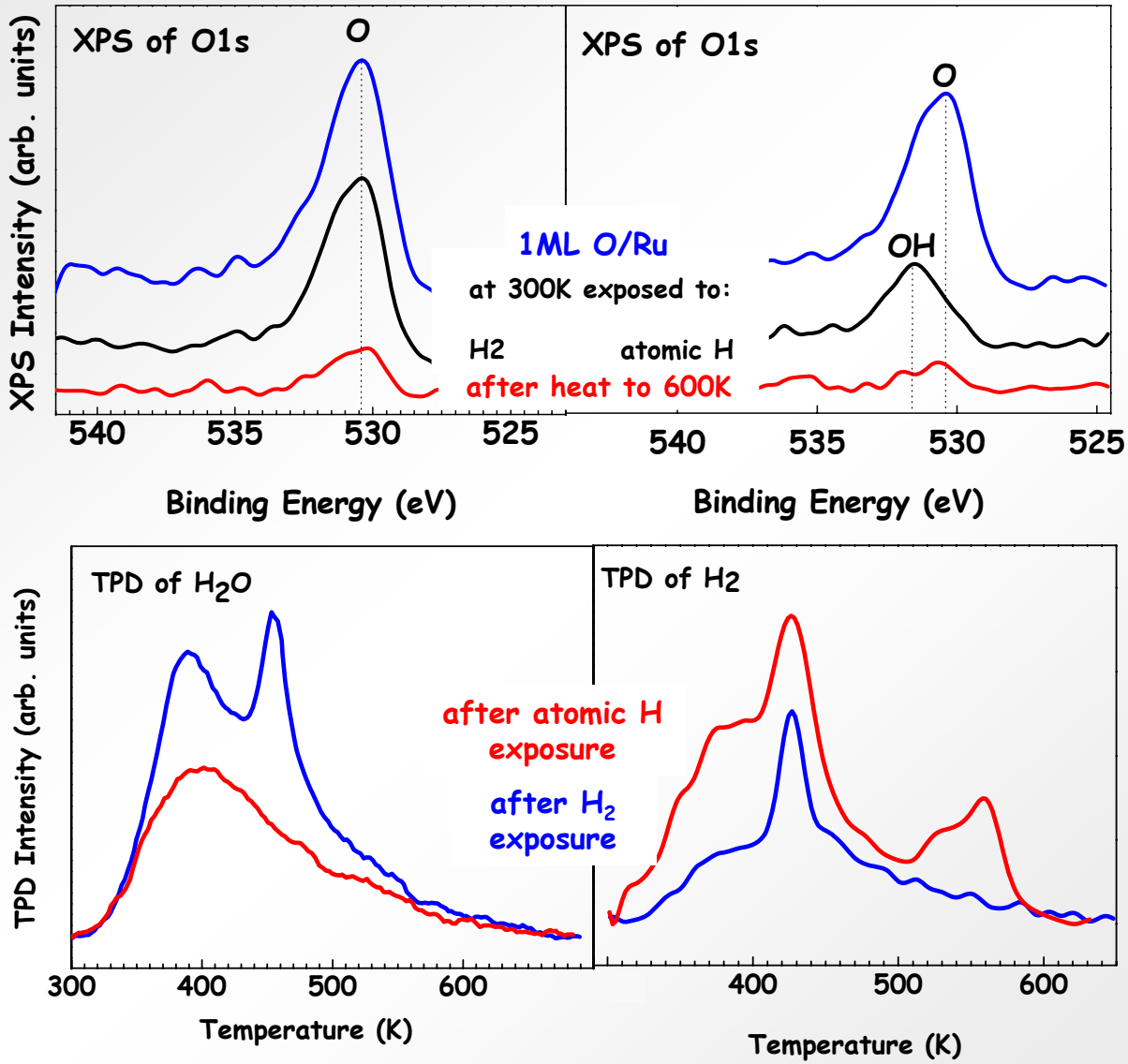
Reduction of 1 ML O/Ru(10$\bar{1}$0) by atomic and molecular hydrogen



- 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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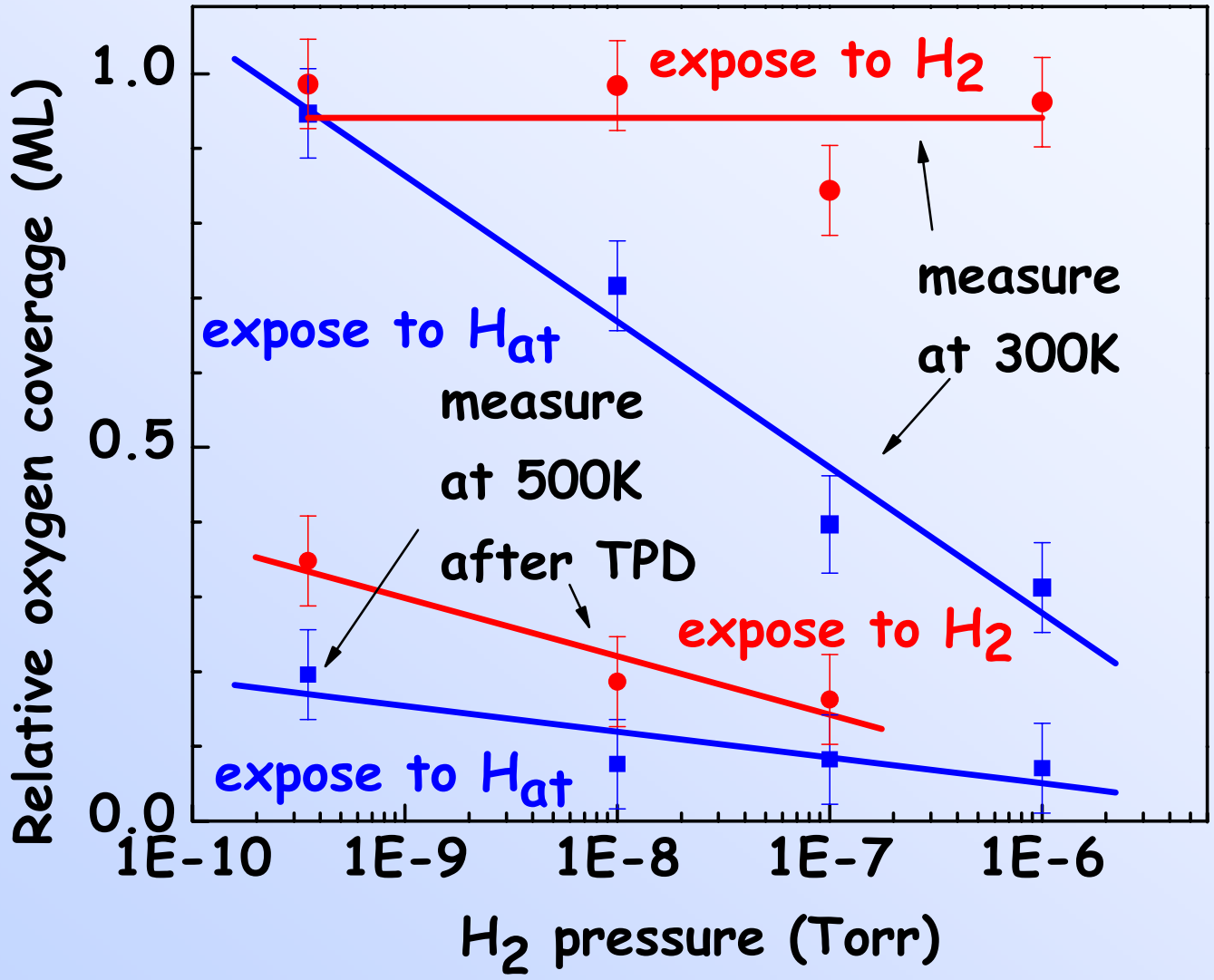
Effects of pressure on removal of O by H_2 and H-atoms



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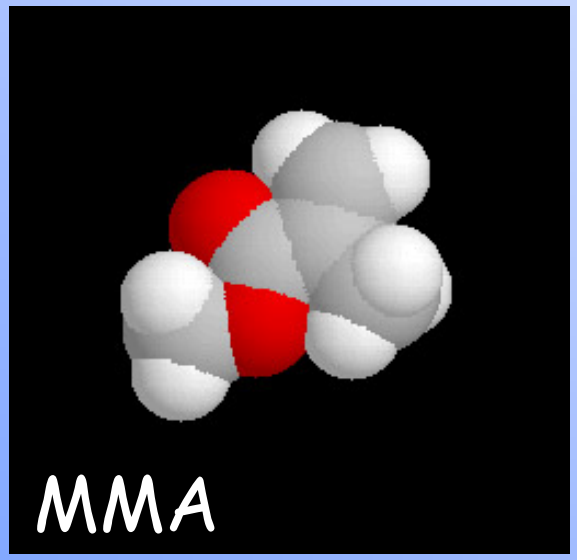
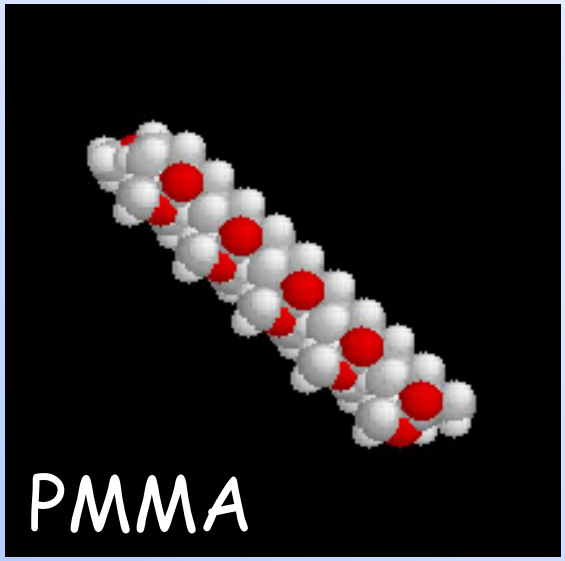
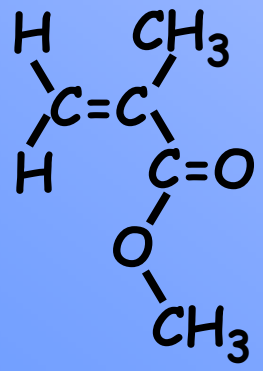
3. Surface chemistry of methyl methacrylate (MMA) on Ru

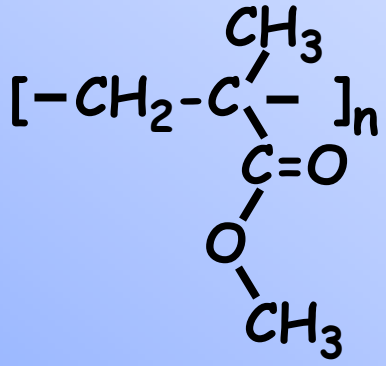






methyl methacrylate

$C_5H_8O_2$



poly(methyl methacrylate)

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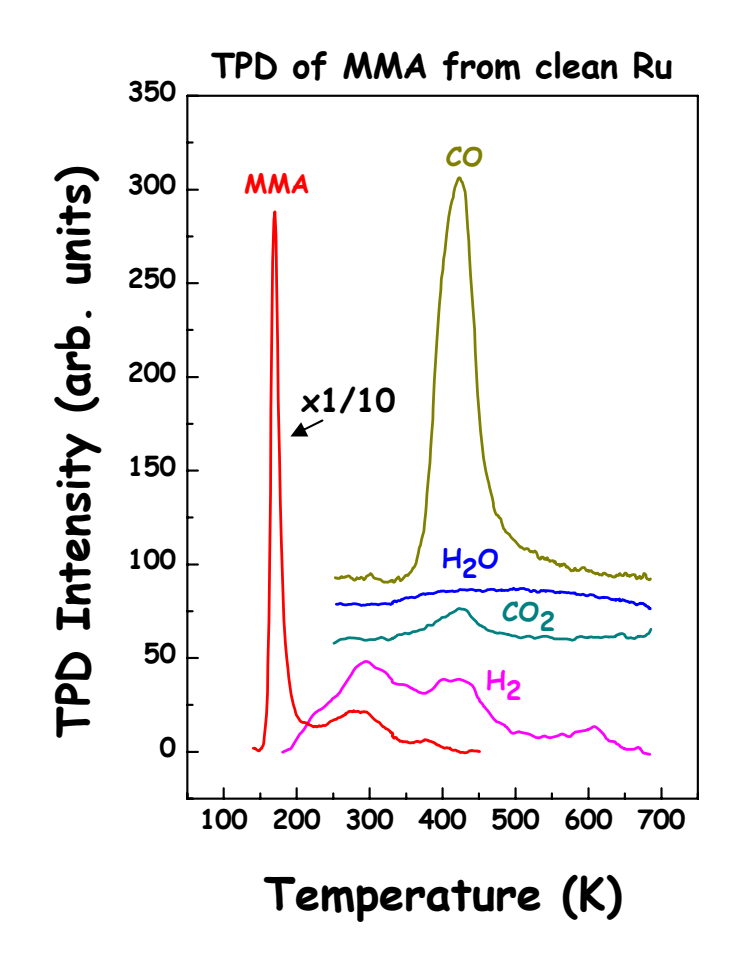
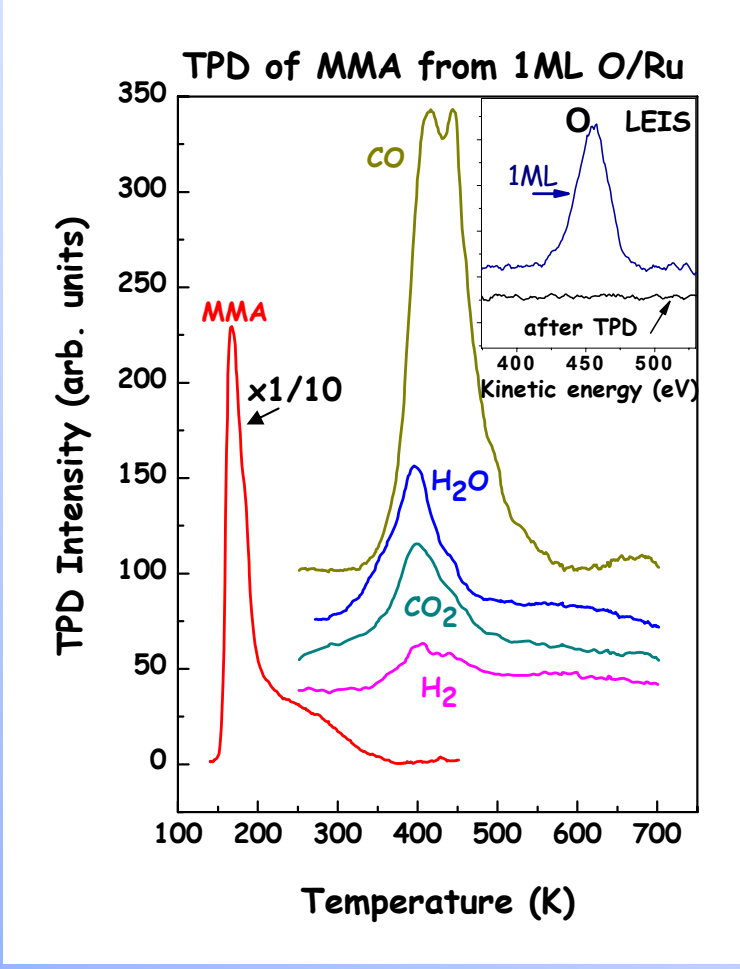
Thermal desorption of MMA and its reaction products, for clean Ru and O-covered Ru





- One monolayer of MMA dissociates on both surfaces.
- MMA reacts and completely removes adsorbed O monolayer upon heating.

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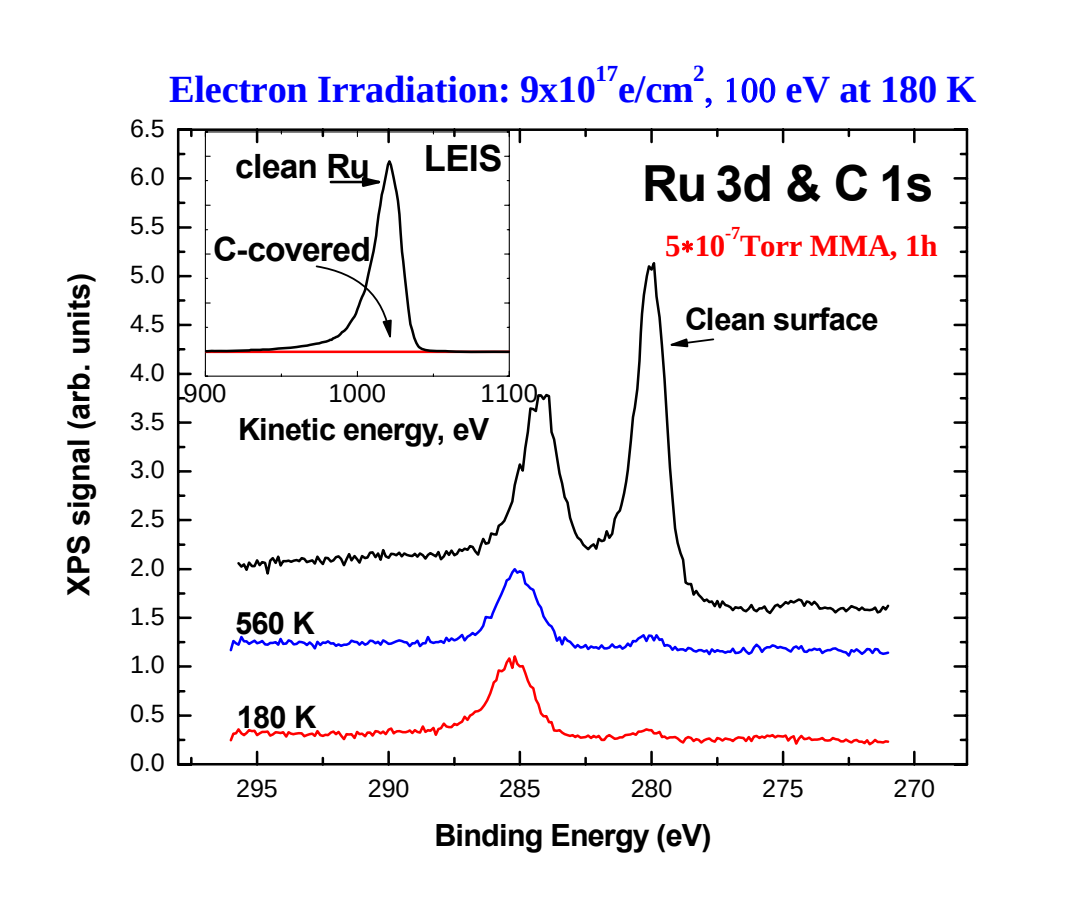
Electron irradiation of Ru(10$\bar{1}$0) at 180K, exposed to gas phase MMA



- A thick C film (~ 5 nm) is formed by electron bombardment of Ru exposed to gaseous MMA at T=180K

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MMA Summary

- MMA adsorbs molecularly on Ru below 200 K.
- Mainly dissociative chemisorption of MMA at temperatures > 200 K
- Electron bombardment of MMA/Ru causes dissociation and polymerization

4. Measurements of secondary electron yields (SEY) at beamline U4A, NSLS

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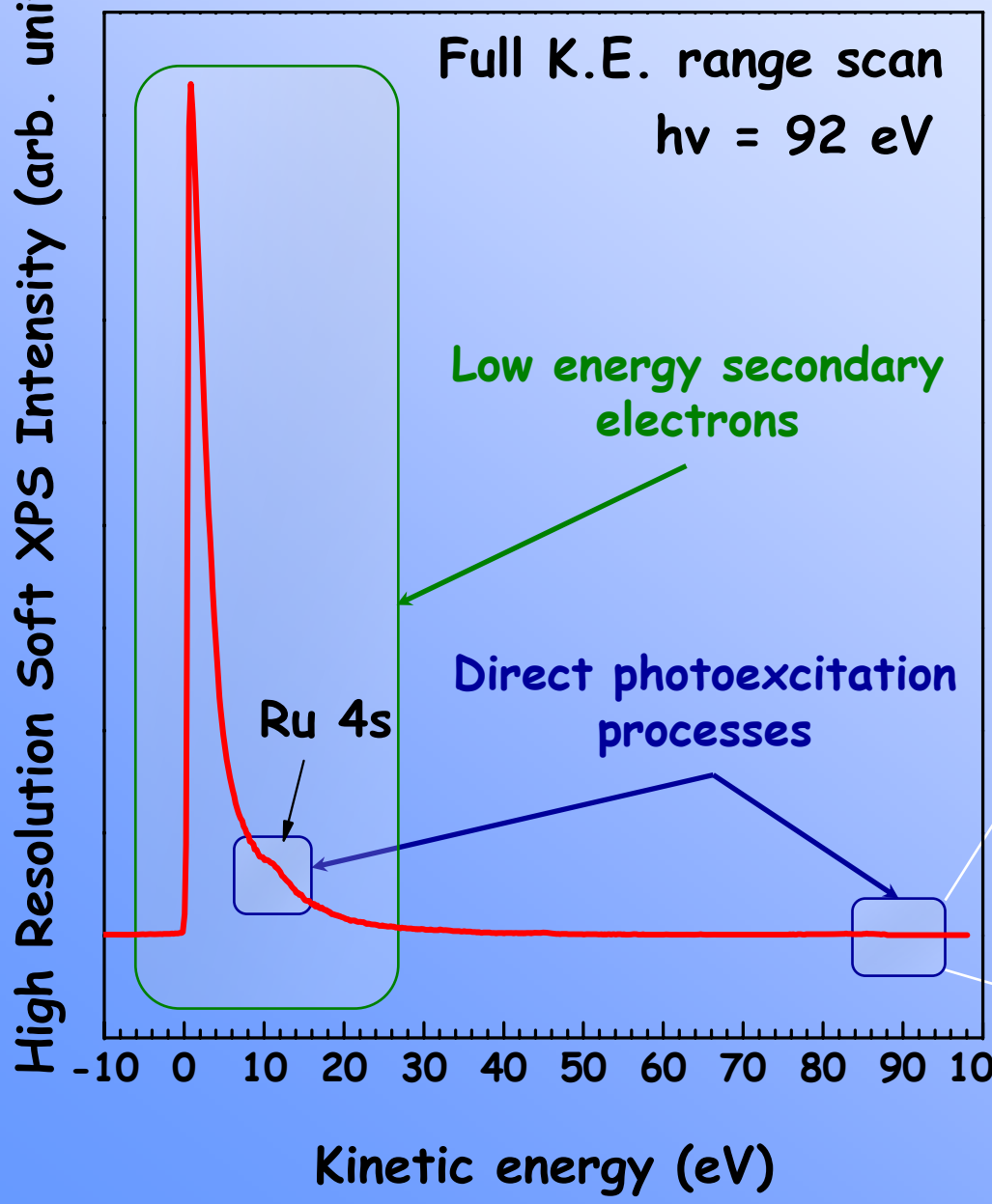
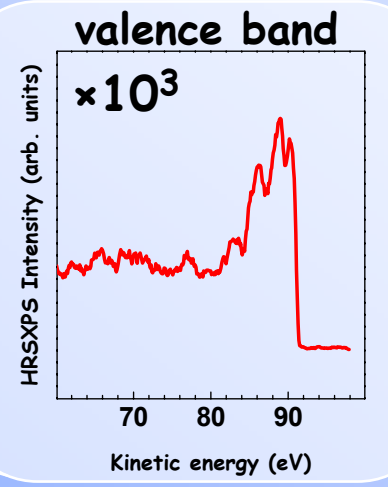
Typical SXPS spectrum of clean Ru surface



majority of photoemitted electrons are low energy secondaries



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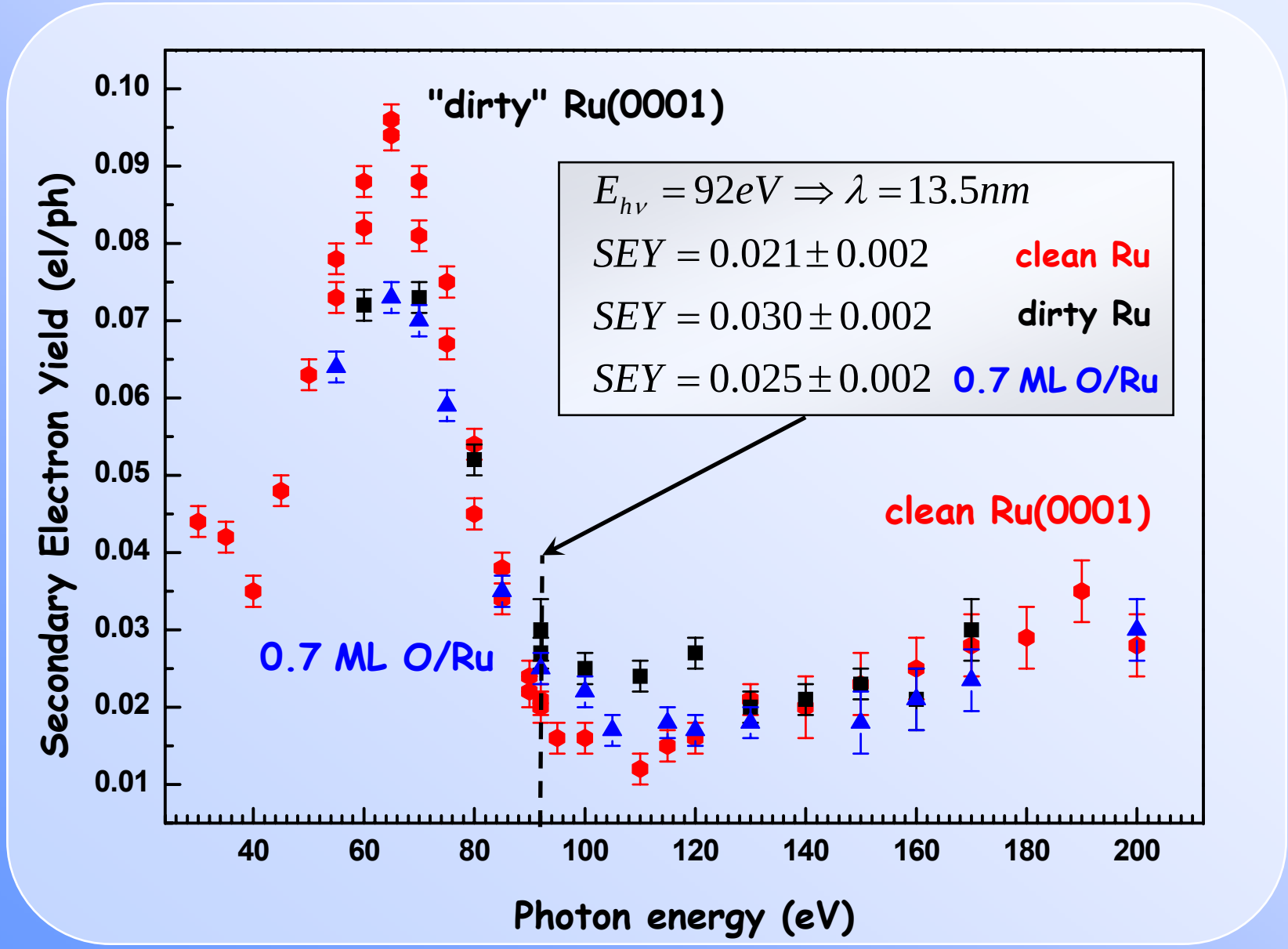
Secondary Electron Yield of Ru(0001)



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Summary

Oxygen can be removed from Ru($1\bar{0}10$) surfaces

*Electron stimulated desorption (ESD), by O & Ru core level excitations
*H-atom reactions
*Reaction with MMA (CO, CO_2, H_2O desorb)

Secondary electron yields (SEYs), Synchrotron radiation

*SEYs of clean, O-covered, C-covered Ru, & multilayer mirror all about 0.02 at 13.5 nm

+ Models

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Review

Surface phenomena related to mirror degradation in extreme ultraviolet (EUV) lithography

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