US Regional Update

1. **Rutgers/Tulane/Fraunhofer/NIST/Intel Collaboration**
   a) **Rutgers/Tulane** - fundamental studies on model systems
      - Resonance effects on SEY
      - Measurement of parameters important for modeling:
        Surface coverage of HC species as function of pressure

        Measurements effective cross section of electron-stimulated transformation of MMA and benzene
      - **Carbon deposition rates on TiO_2 & Ru**
      - **Carbon removal from TiO_2**

   b) **Fraunhofer**
      - Lifetime tests with pulsed sources
      - Carbon removal
      - **Improved MLMs**

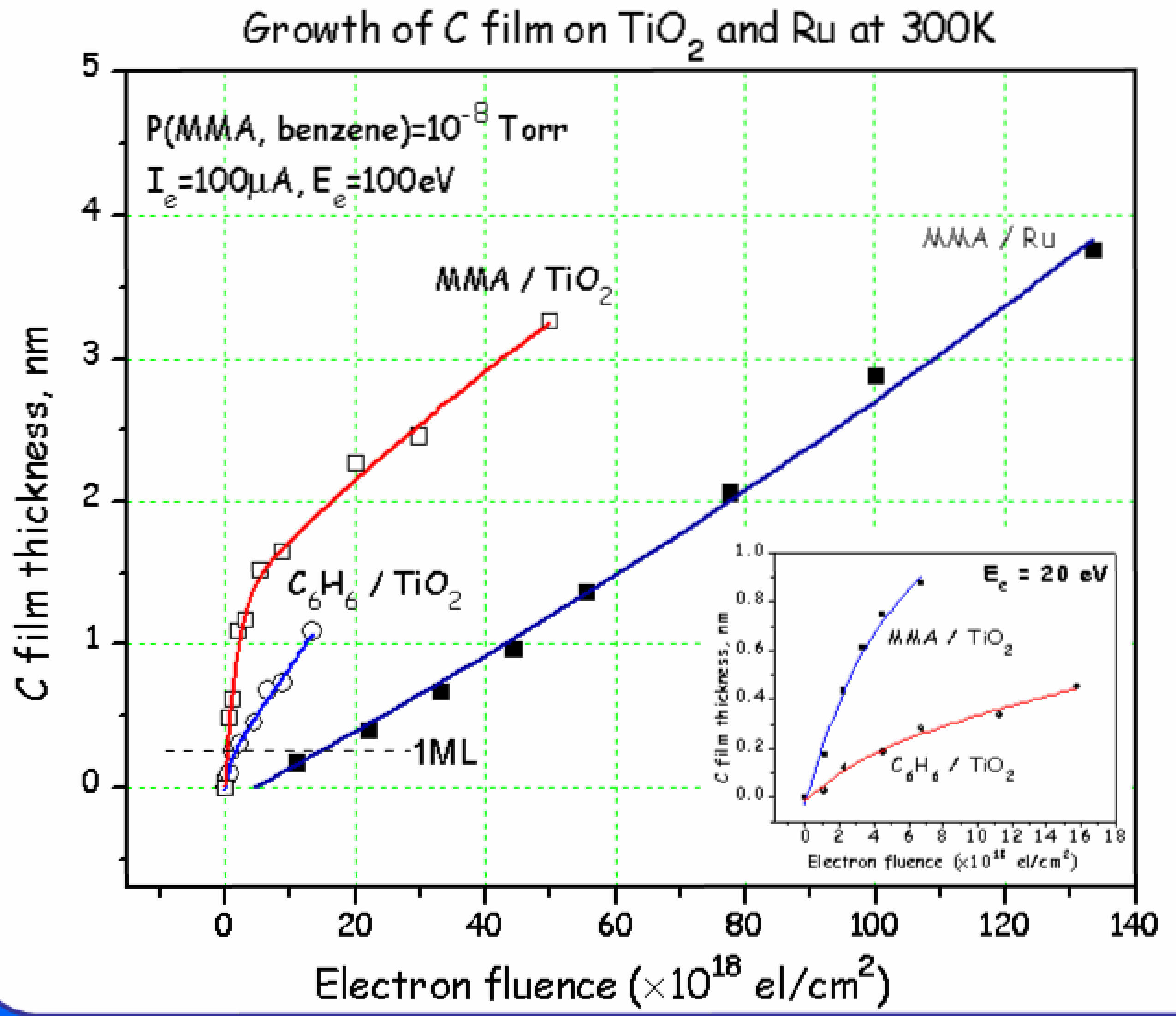
SPIE 2008 IEUVI Optics Contamination and Lifetime TWG

US Regional Update

1. **Rutgers/Tulane/Fraunhofer/NIST/Intel Collaboration (continued)**
   c) **NIST**
      - Lifetime tests & modeling
      - Contamination analysis in tools using cryotrapping and specialized GC/MS
      - **Total resist outgas measurements and outgas analysis using specialized GC/MS**

2. **CNSE SUNY Albany**
   - **“Injection” or controlled dose exposures with contaminants from resist outgassing and other sources**

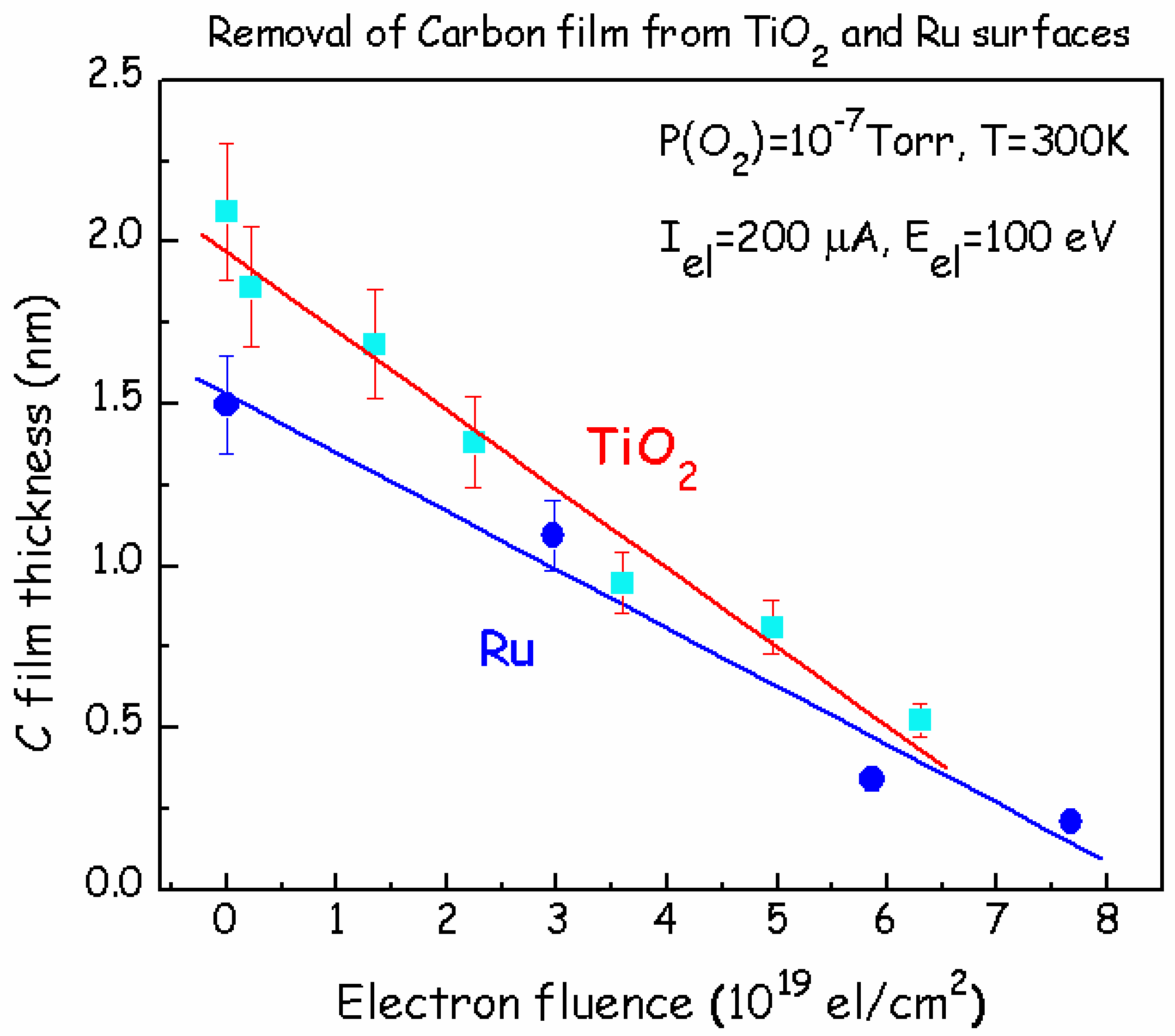
C growth under electron irradiation



Initial *C* growth rate on TiO_2 >> than on Ru;
limiting *C* growth similar for thicker films

Rutgers

Carbon film removal from TiO_2: electron bombardment + O_2



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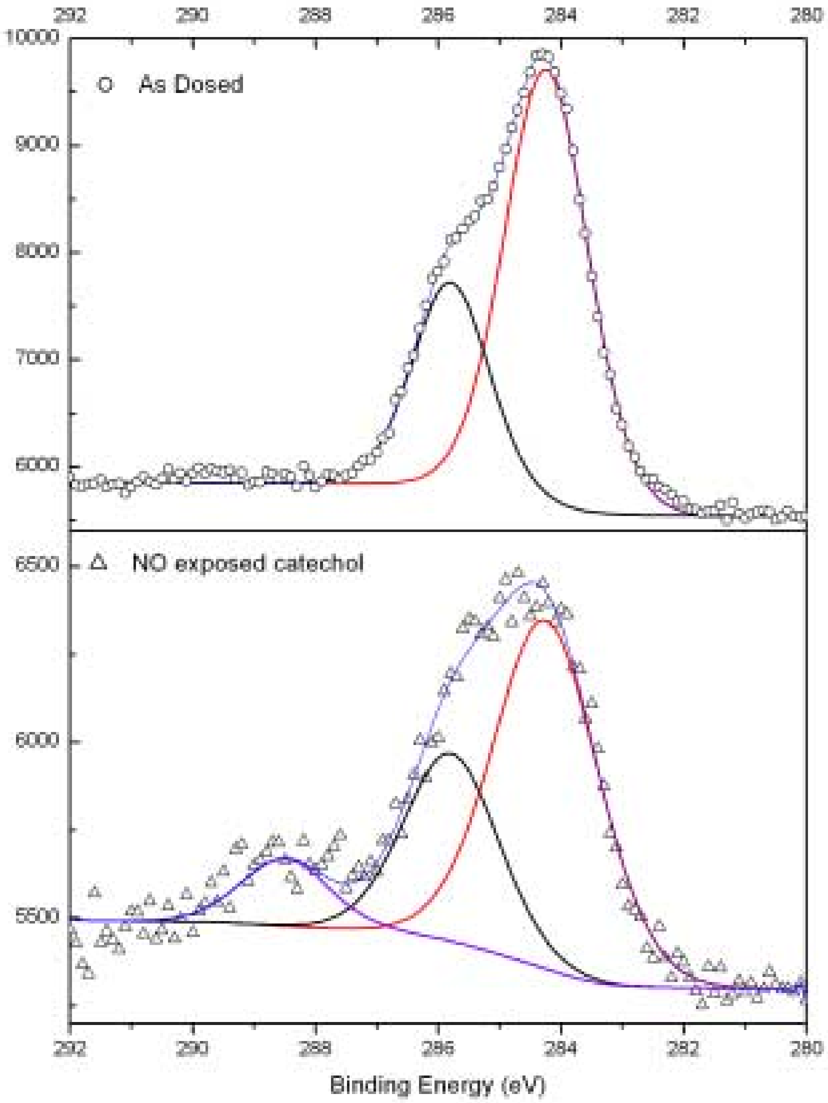
Photon Irradiation of adsorbed Catechol in Nitric Oxide (NO)



Ulli Diebold - Tulane

- C1s XPS spectrum of catechol as-dosed.

- after 90 minutes irradiaton in NO (1 x 10^{-6} mbar, KrF: 5 eV, 248 nm): substantial oxidation reactions. **70% of C removed**.

- no N on surface detected

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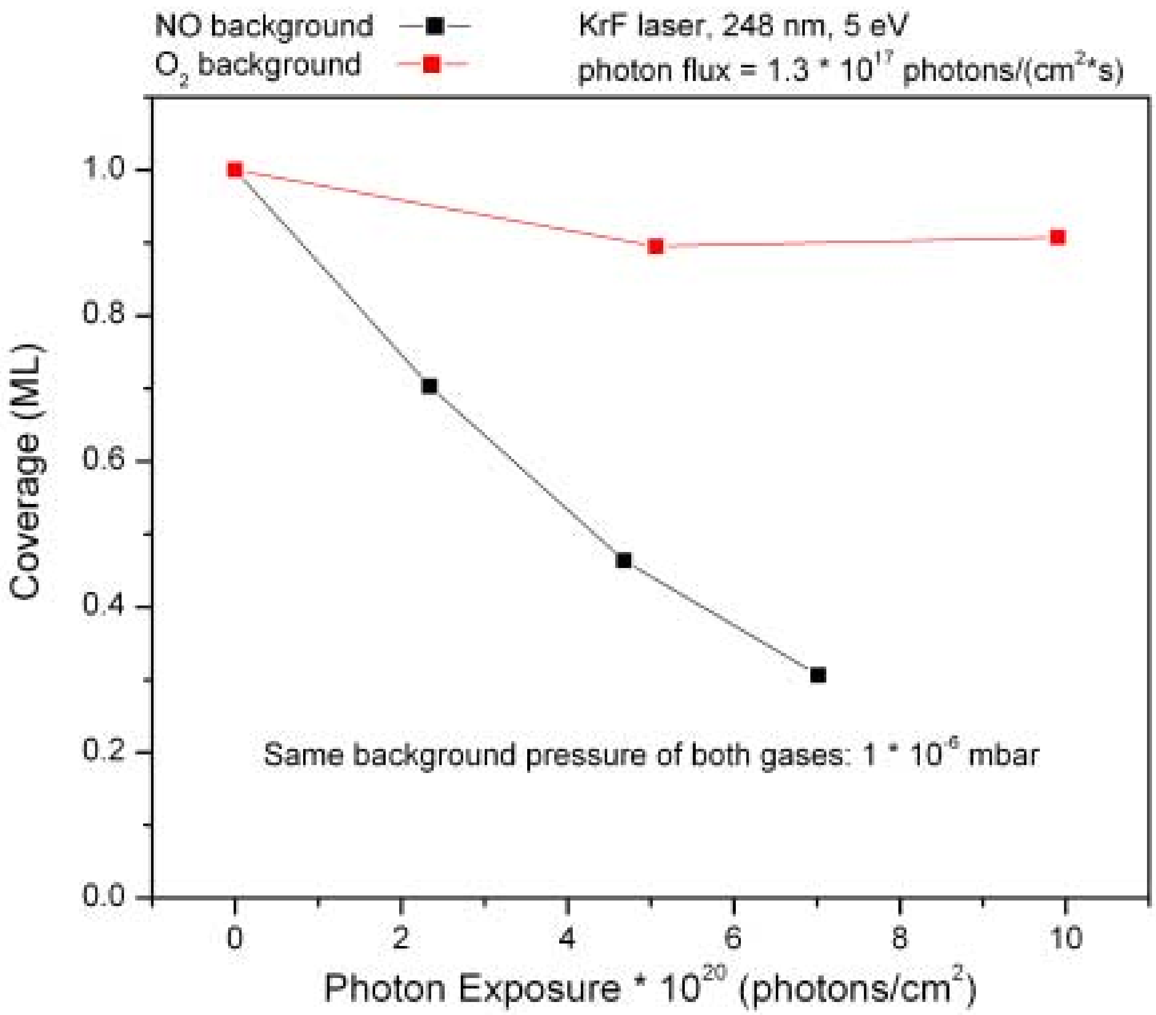
Photon irradiation of adsorbed Catechol Comparison NO vs. O_2 background gas

Ulli Diebold - Tulane



- Carbon removal highly dependent on reactivity of the background gas.
- NO background results in higher effective oxygen chemical potential
- Estimated quantum efficiency for carbon removal in NO: 6×10^{-7}

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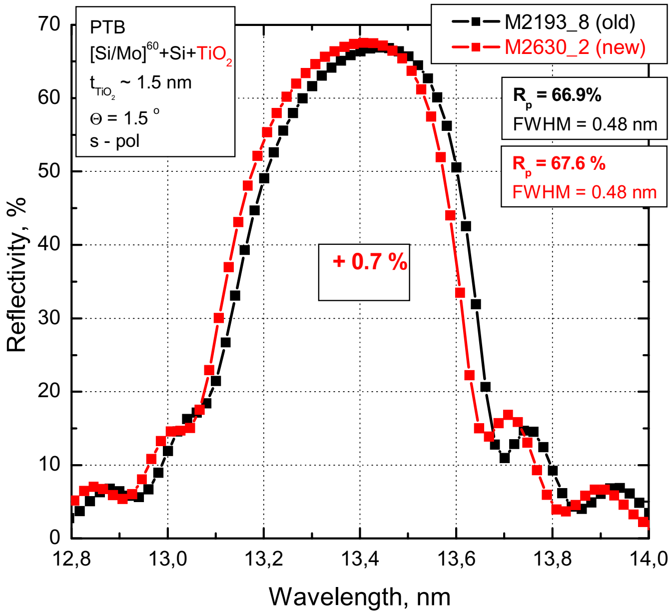
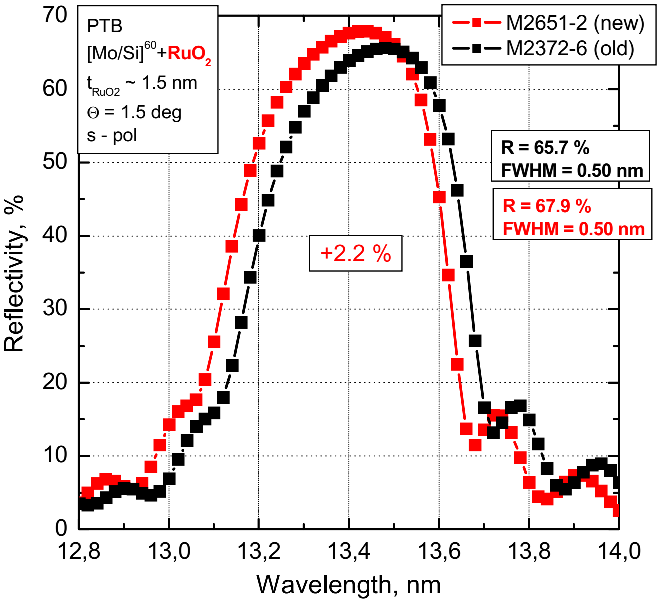
Enhanced reflectivity of TiO_2- and RuO_2- capped Mo/Si MLs

a. contact mitigation of oxygen (during deposition process)

Cap layer thickness is 1.5 nm !!!



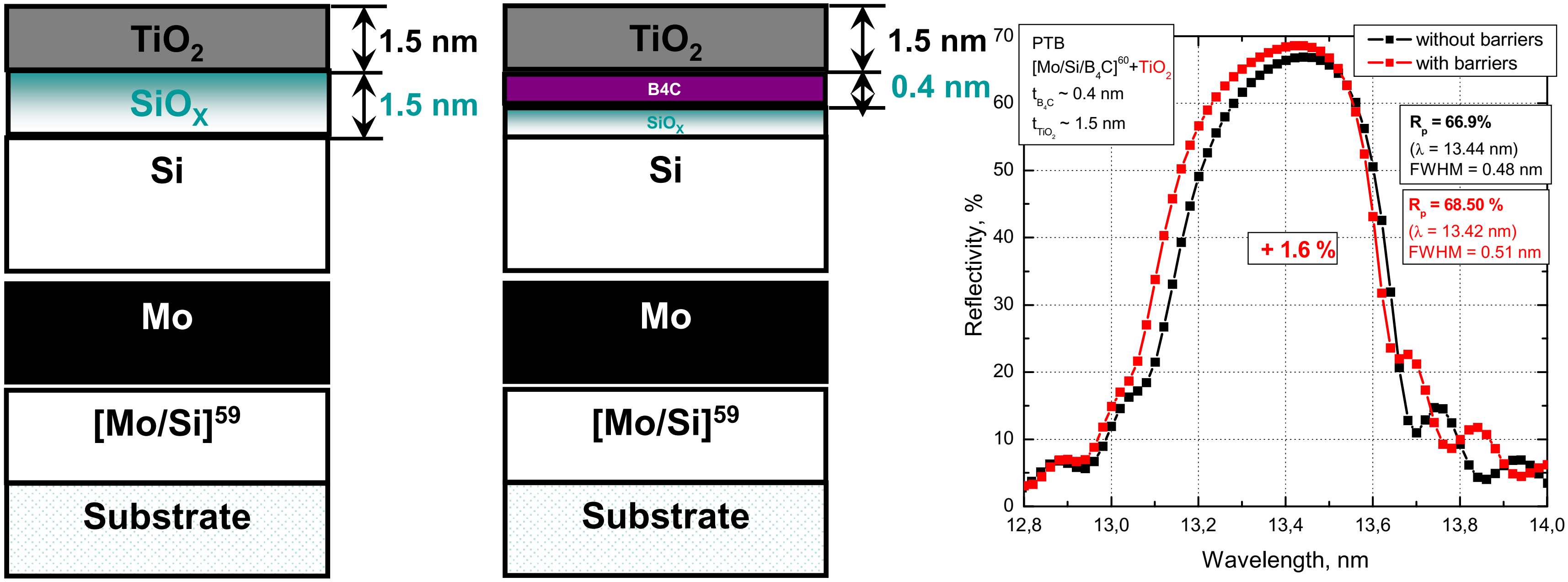


R = 67.6% @ 13.44 nm

R = 67.9% @ 13.45 nm

Enhanced reflectivity of TiO_2- capped Mo/Si MLMs

b. application of B_4C diffusion barriers



$[Mo/Si/B_4C]^{60}+TiO_2$: R = 68.5%

1. **Intermixing minimization (in stack)**
2. **Oxidation minimization (cap layers)**

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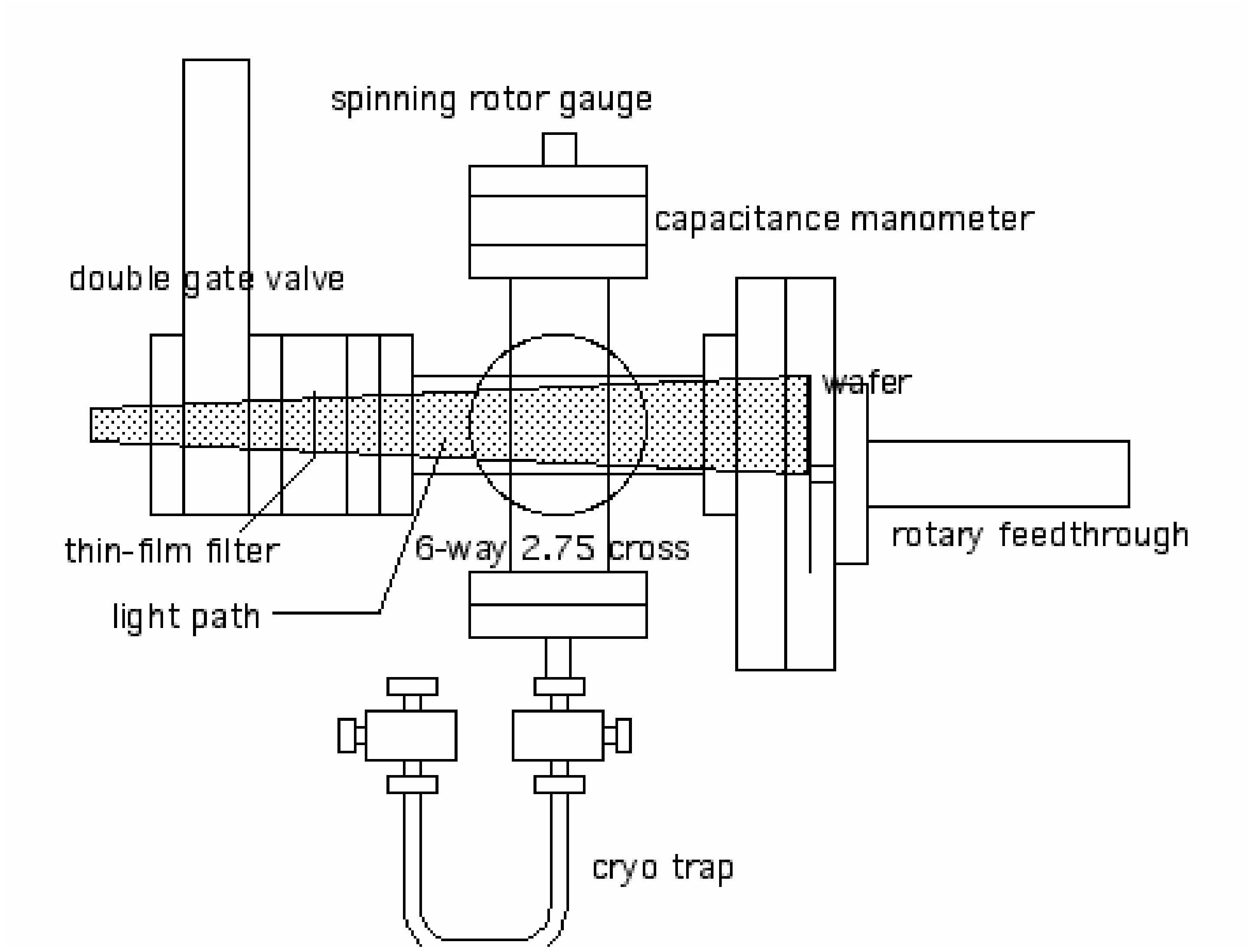
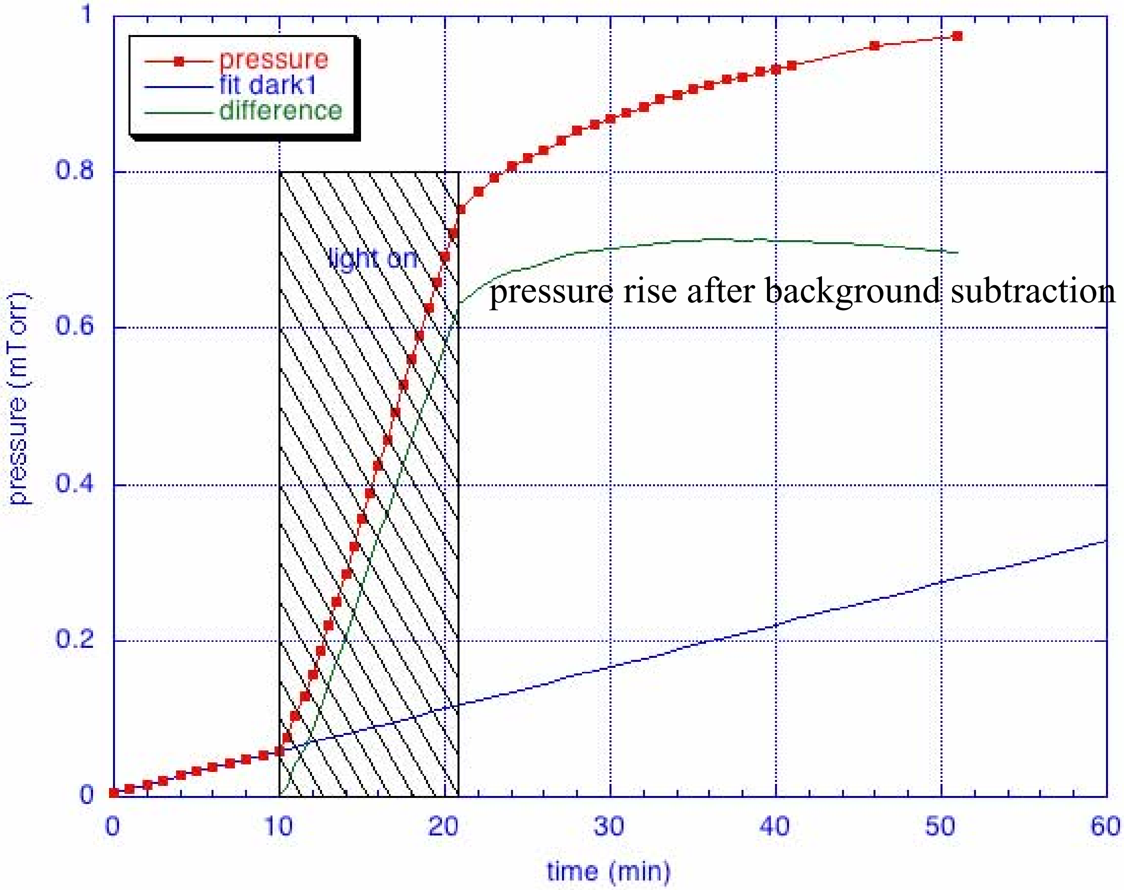
Chamber schematic

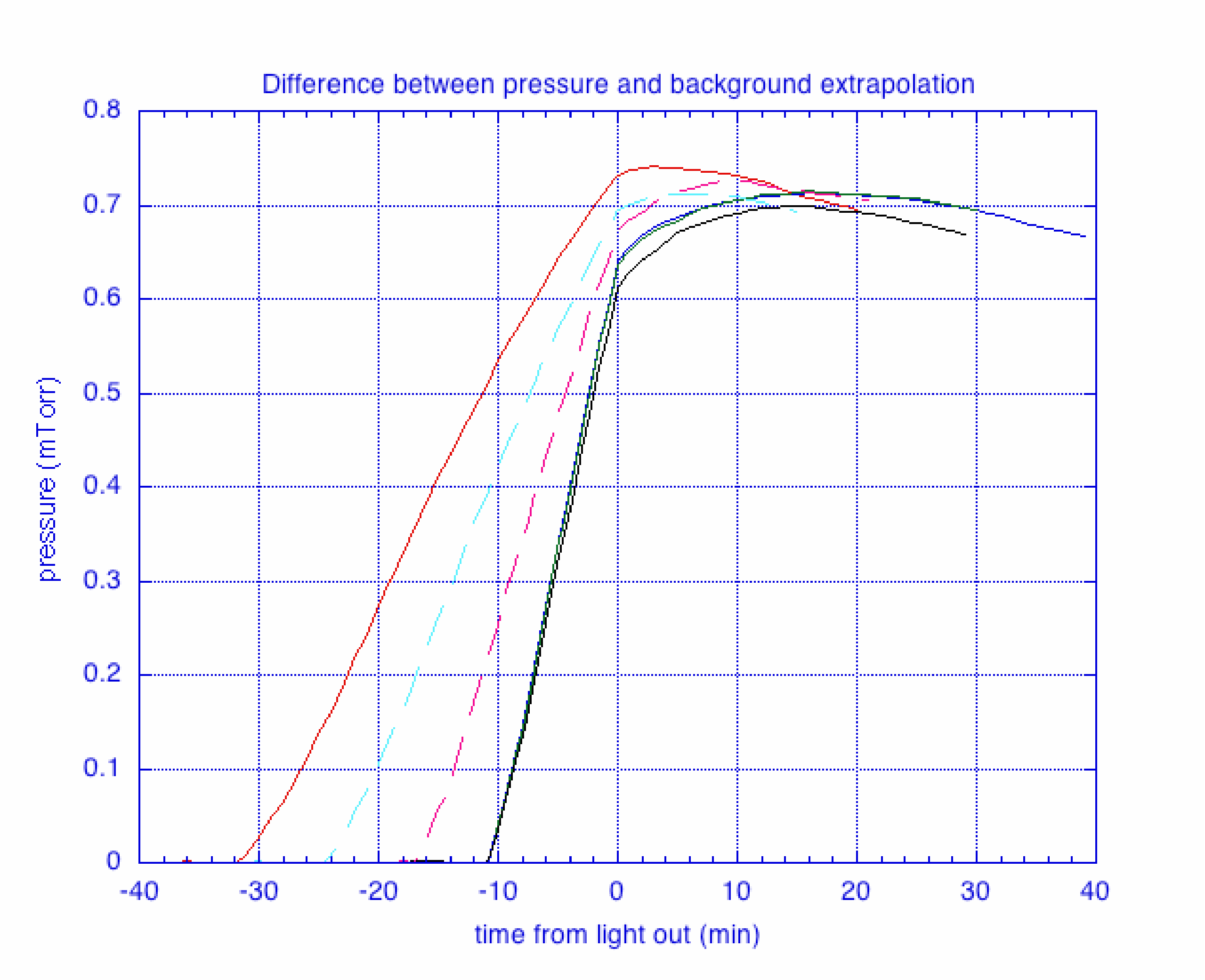


Data Analysis



Take data ~30 minutes after light-out, examine behavior for several runs under varying conditions, calculate outgassing at several times after illumination

Data Analysis



Data from several runs made under varying conditions (blue, green, and black are full intensity)

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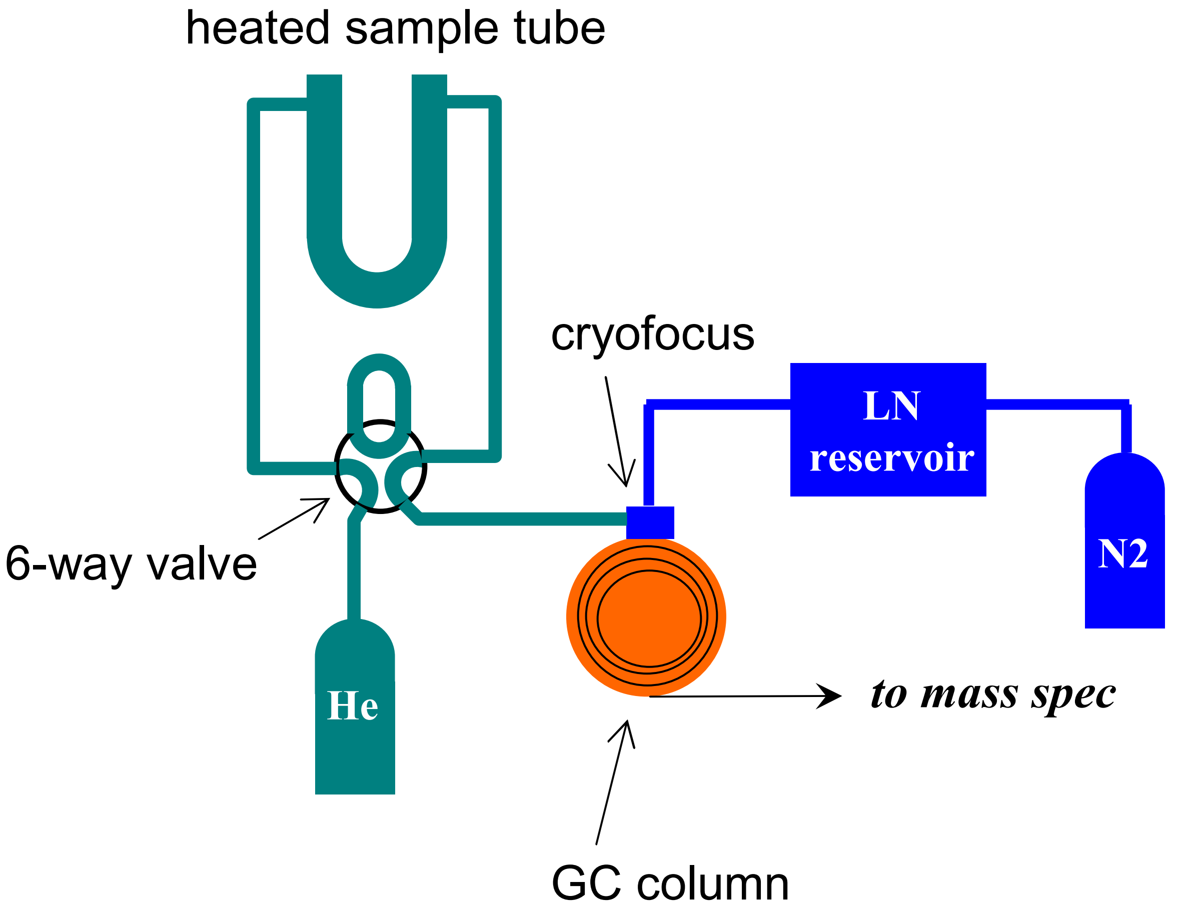
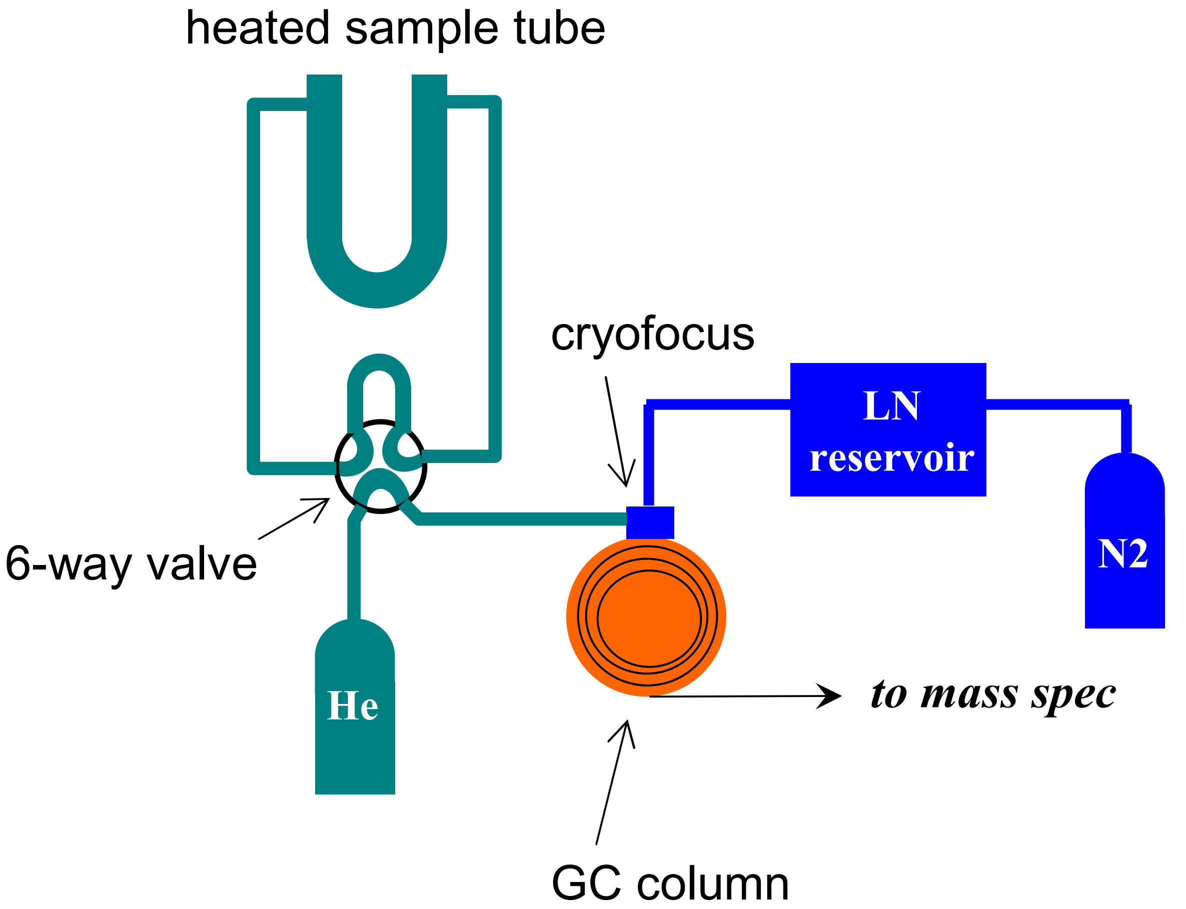
Data Analysis (10 runs)

post-exposure time (min)	average (10^{14} cm^{-2})	std dev (10^{14} cm^{-2})
0	2.77	0.20
5	2.99	0.13
10	3.11	0.06
20	3.20	0.18
30	3.11	--
Albany run 1	3.2	
Albany run 2	5.0	

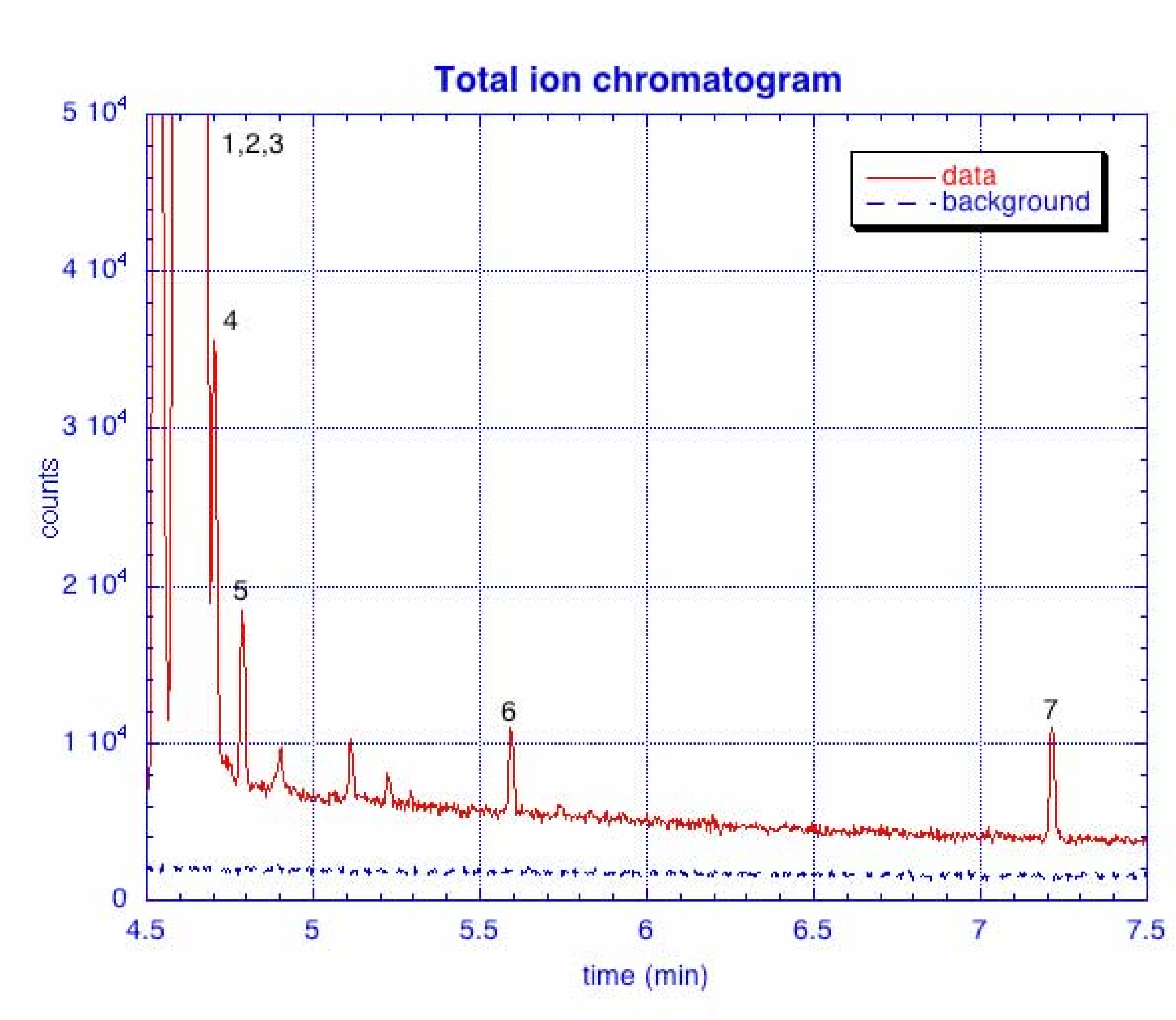
GC/MS with cryofocus: sample introduction



GC/MS: analysis mode

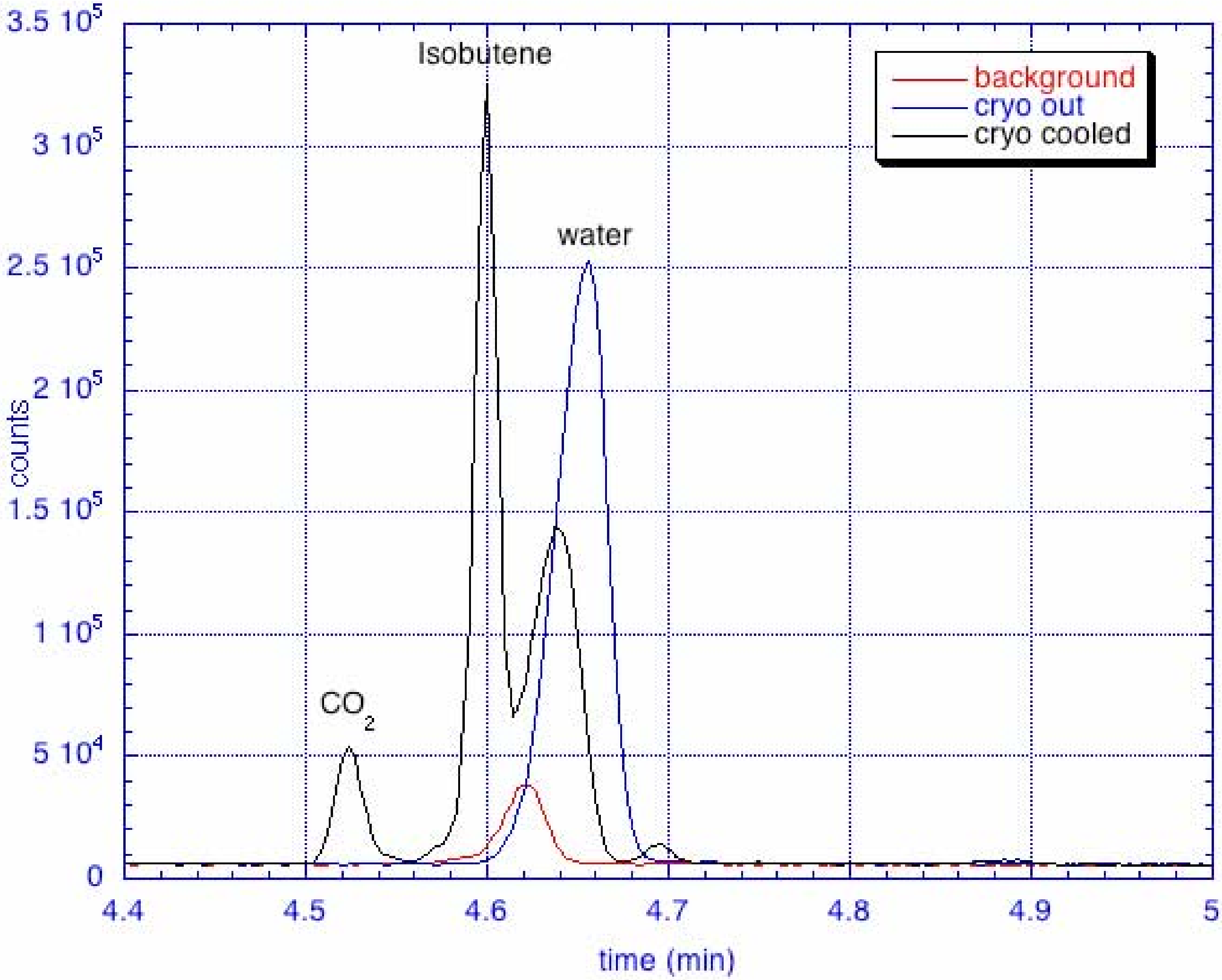


GC/MS analysis

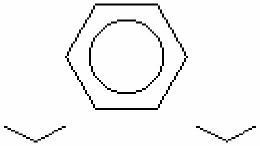
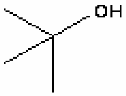
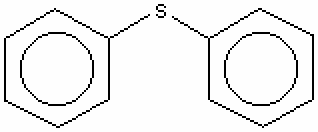


1 - CO_2
2 - isobutylene
3 - water
4 - acetone
5 - CS_2
6 - toluene
7 - tert-butylbenzene

GC/MS analysis



Chosen species for injection and exposure of mirrors to measure contamination

Contaminants	Formula	Structure	Molecular weight (amu)	Boiling point (^{0}C)
Benzene	C_6H_6		78	80.1
Tert-butanol	$C_4H_{10}O$		74	82
Diphenyl Sulfide	$C_{12}H_{10}S$		186	296.2

Intended to represent known or similar structures that may outgas from resists

Reflectivity results due to contamination from these species

Chamber Conditions	**Chamber Pressure (Torr)**	**Exposure time (hours)**	**Total Dose (J/cm^2)**	**Number of pulses (millions)**	**Reflectivity drop ($\Delta R/R$%)**
Clean (background)	2.5×10^{-8}	8	29	36	0.35
Benzene	1×10^{-6}	8	29	36	0.35
Tert-Butanol	3×10^{-6}	8	11.5	36	-0.09
Diphenyl Sulfide	1×10^{-6}	4.2	15	19	0.1
Diphenyl Sulfide	1×10^{-6}	3.6	13	16	-0.23
Diphenyl Sulfide	1×10^{-6}	2.9	42	13	0.1

No significant reflectivity loss for these species at these pressures and doses

What causes optics contamination – if it is not typical resist components?

Material Tested	**Measurable Effect**
Apiezon vacuum grease	No
Heated Apiezon vacuum grease	No
Neoprene	No
Heated neoprene	No
Carbon conductive tape	No
Heated carbon conductive tape	Yes!

- For modest doses and times, most materials don't cause a measurable contamination on EUV optics
- Carbon conductive tape for SEM sample mounting does cause an effect when heated
- A 3.5 hour exposure at 2 mW/cm^2 intensity (total 25 J/cm^2) caused 18 nm of carbon on the mirror surface!
  - Instead of ~ ½ nm or less from other components tested at similar doses, the hot carbon tape provides 1-2 orders of magnitude more contamination