A novel route to EUV resists design: Fundamental understanding of chemical processes

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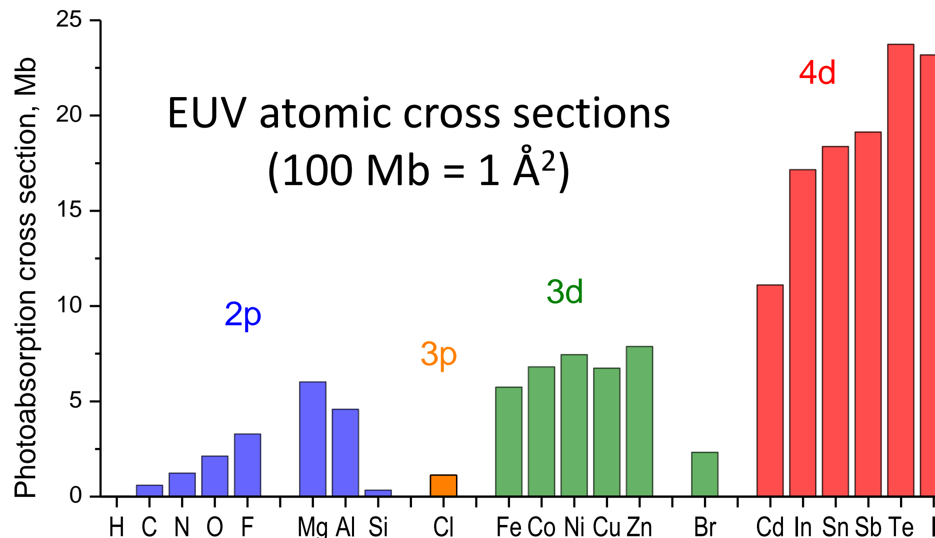
Motivation

- Increase sensitivity of EUV resist

30 mJ/cm^2 = 20 photons/nm^2

Table 1 Extreme Ultraviolet Absorption of Selected Materials

Material	Formula	Extreme Ultraviolet Absorption (50 nm film) (%)
Polypropylene	C_3H_6	11
Poly(methyl methacrylate)	$C_5H_8O_2$	24
Polyimide	$C_{22}H_{10}N_2O_5$	25
Teflon	C_2F_4	60
Hafnium oxide	HfO_2	30
Tin oxide	SnO_2	62



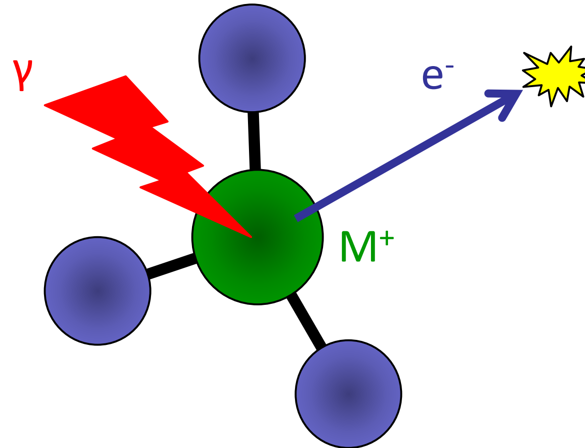
D.F. Ogletree, Frontiers of Nanoscience, **11**, 91 (2016)

Processes After EUV Photon Absorption

- Gain fundamental understanding

Step 1

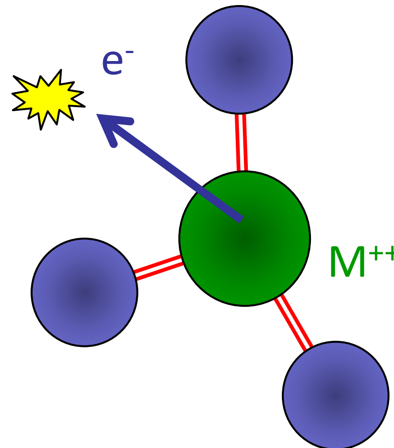
Photoionization



Step 2

Electronic Relaxation

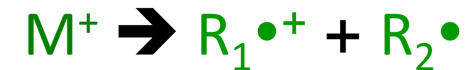
Auger process ?

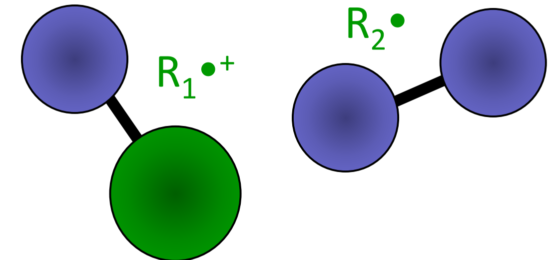


Step 3

Atomic Relaxation

Fragmentation?





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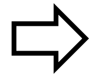
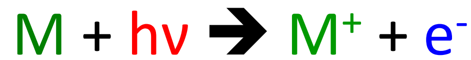
Our Approach

Gas-phase single molecule  Condensed material

Step 1 Photoionization



Step 2 Electronic Relaxation

Auger process ?

Photoelectron spectroscopy:

1. Electron kinetic energies
2. Electron yield

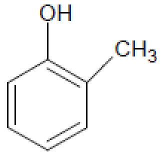
Step 3 Atomic Relaxation

Fragmentation?

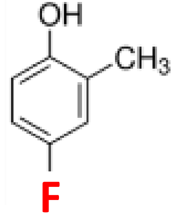
Mass spectrometry:

1. Fragmentation pattern after EUV photon absorption

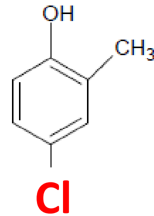
Samples



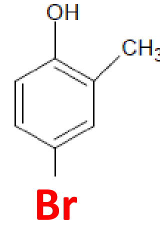
2-methylphenol



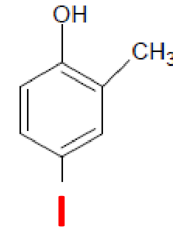
4-F-2-methylphenol



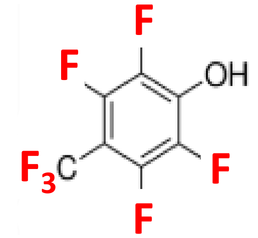
4-Cl-2-methylphenol



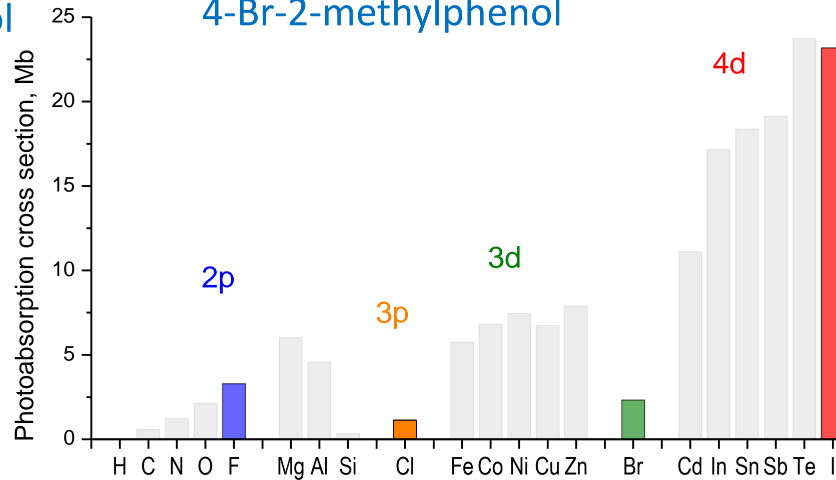
4-Br-2-methylphenol



4-I-2-methylphenol

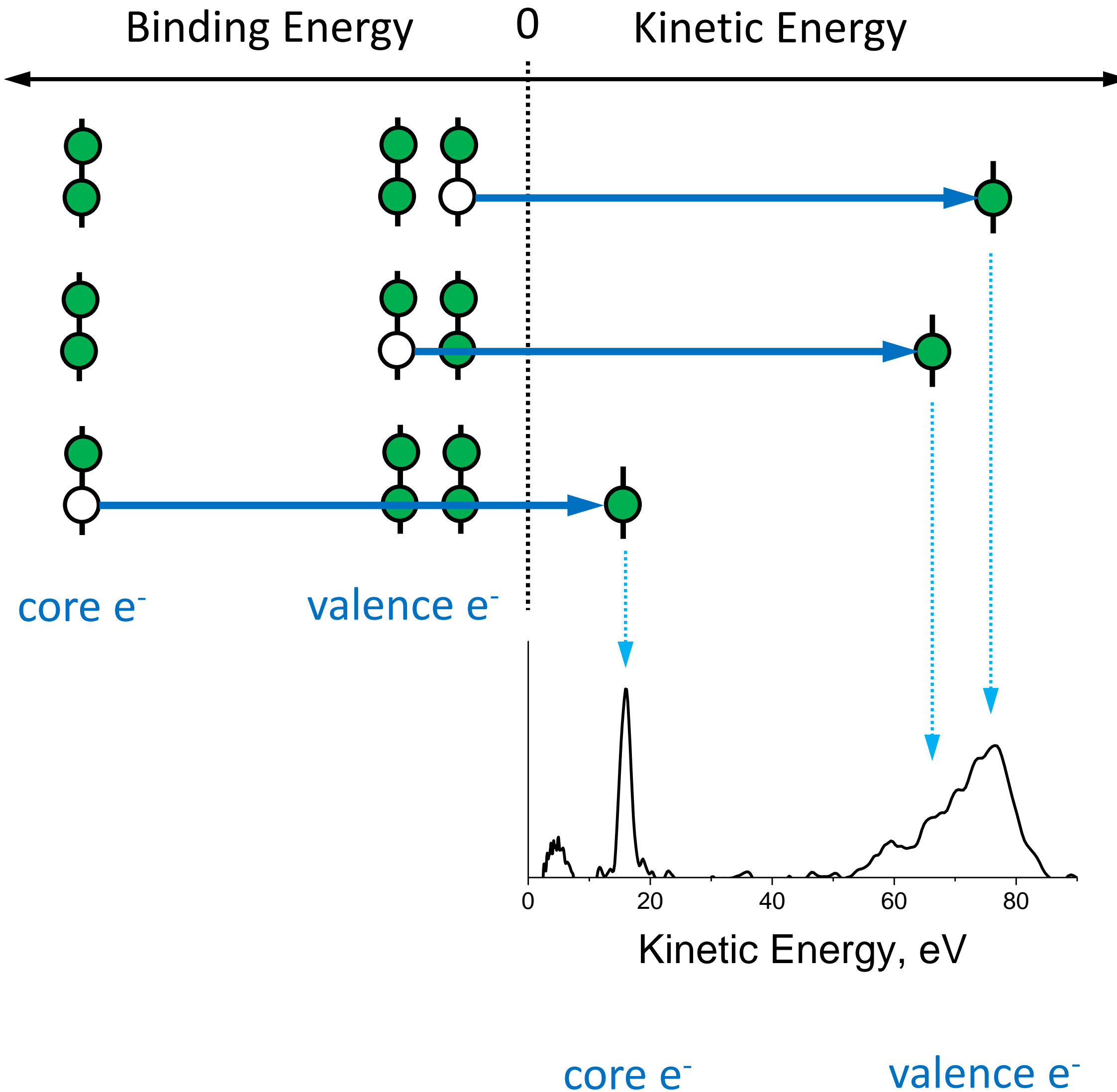


2,3,5,6-Tetrafluoro-4-(trifluoromethyl)phenol



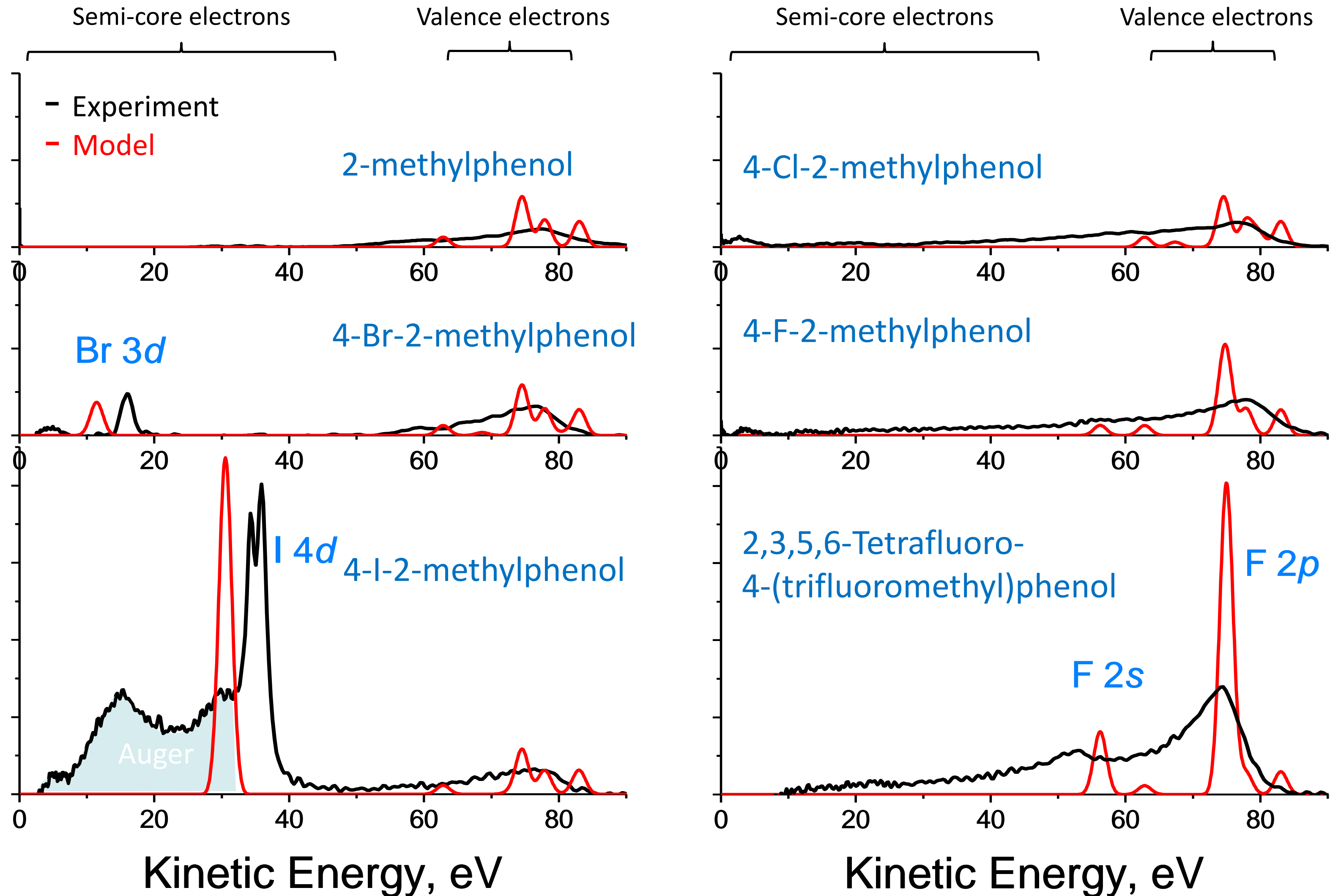
Compound	Absorbed EUV photons (50nm), %
2-Methylphenol	18
4-F-2-Methylphenol	25
4-Cl-2-Methylphenol	19
4-Br-2-Methylphenol	20
4-I-2-Methylphenol	51
2,3,5,6-tetra fluoro-4-(trifluoromethyl)phenol	48

Photoelectron Spectroscopy

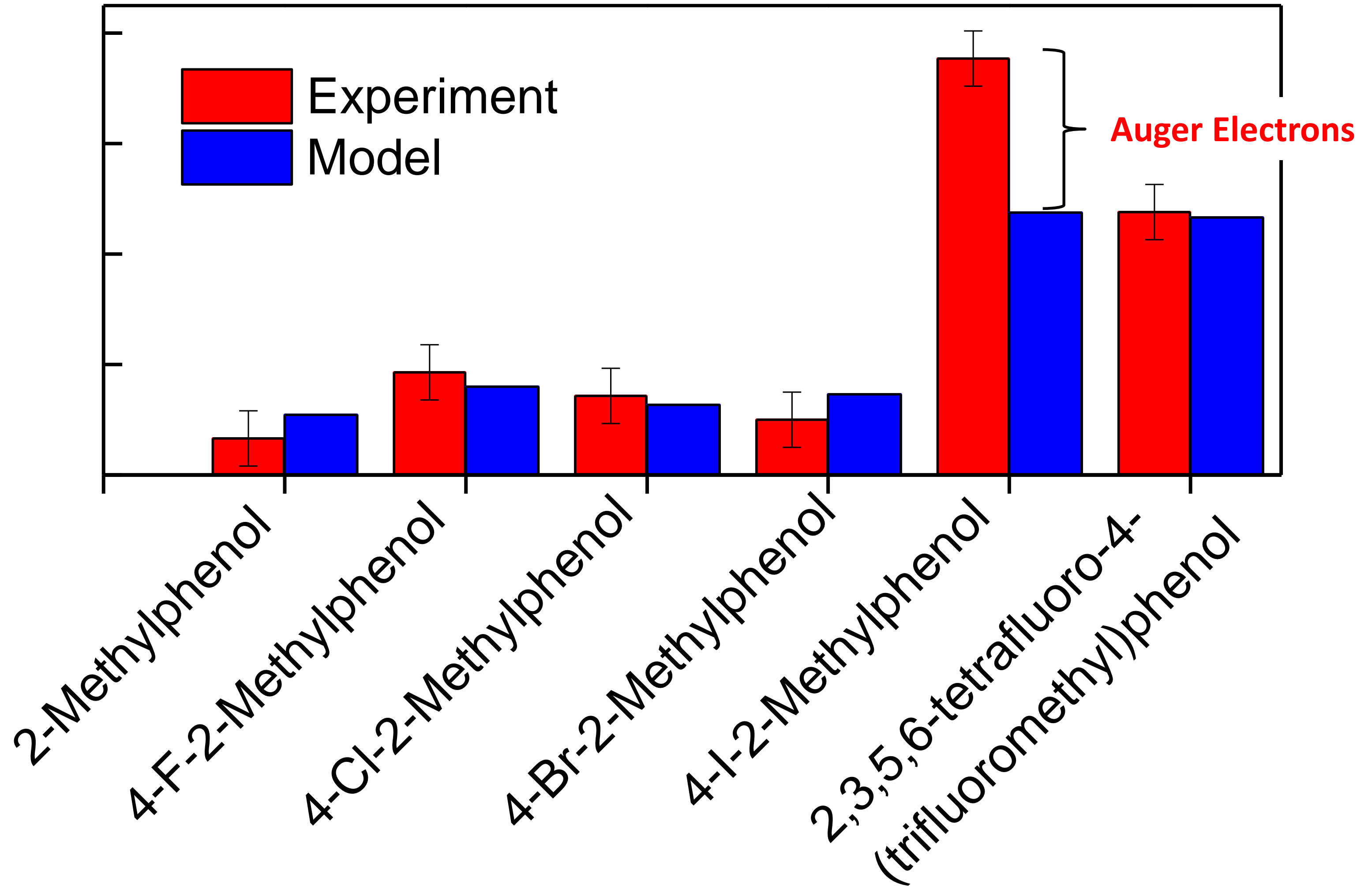


Photoelectron Spectroscopy

Step 1-2. Electron kinetic energies

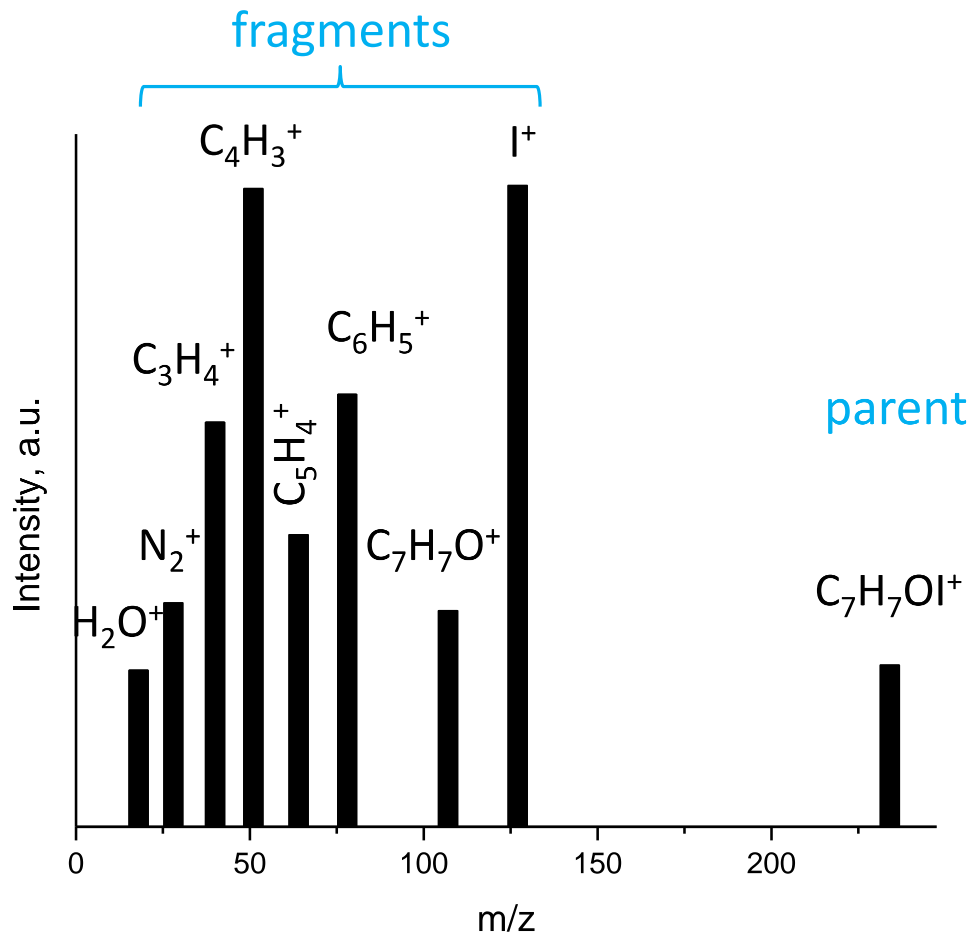


Relative Electron Yield

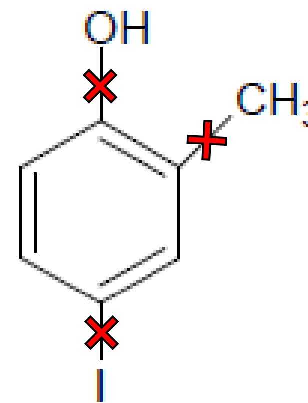


Mass Spectrometry: Photons

Step 3. Atomic relaxation

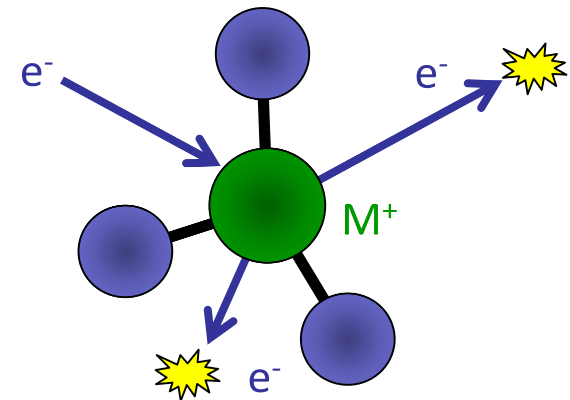


4-I-2-methylphenol



Condensed Resist?

- Photoabsorption, photoemission and Auger relaxation processes are almost unchanged
  - dielectric environment reduces binding energies ~ 4 eV
  - sharp lines are broadened
- Molecular fragmentation changes
  - fragments are trapped in polymer matrix, may recombine or generate secondary reactions…
- Inelastic electron scattering
  - electrons interact with molecules



Step 4 Inelastic Scattering

and more steps…

Mass spectrometry:

1. Fragmentation pattern after e^- collision

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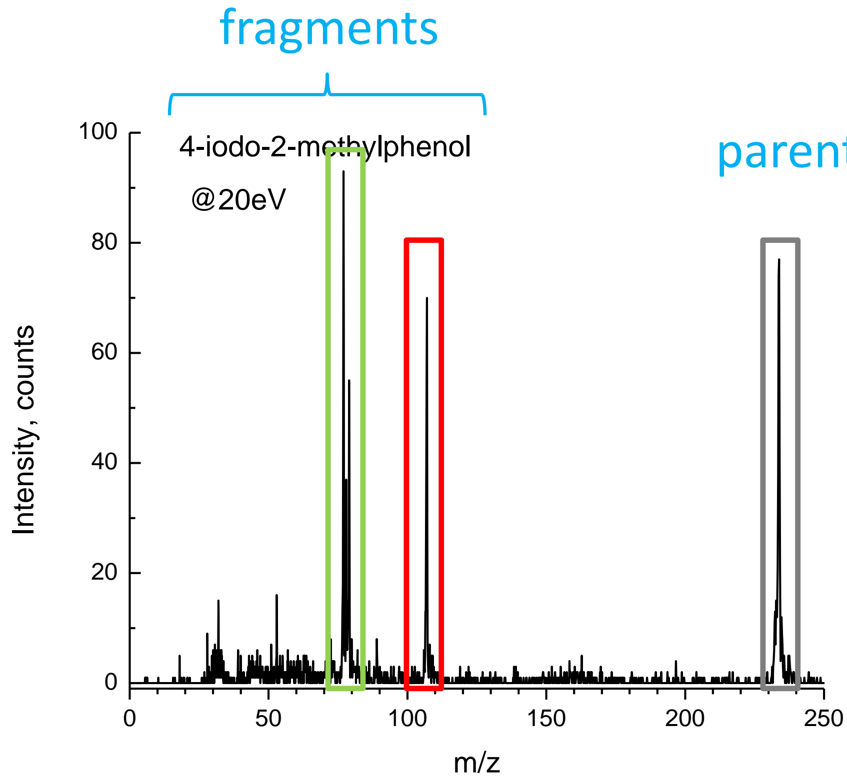
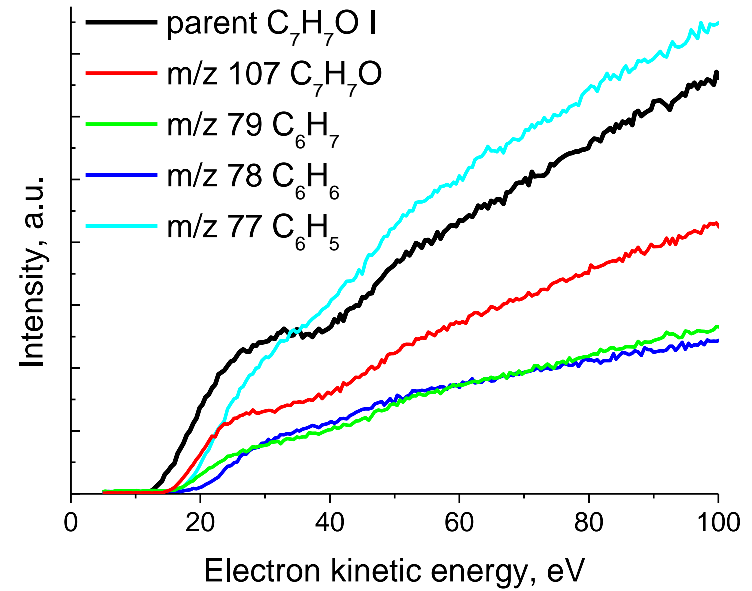
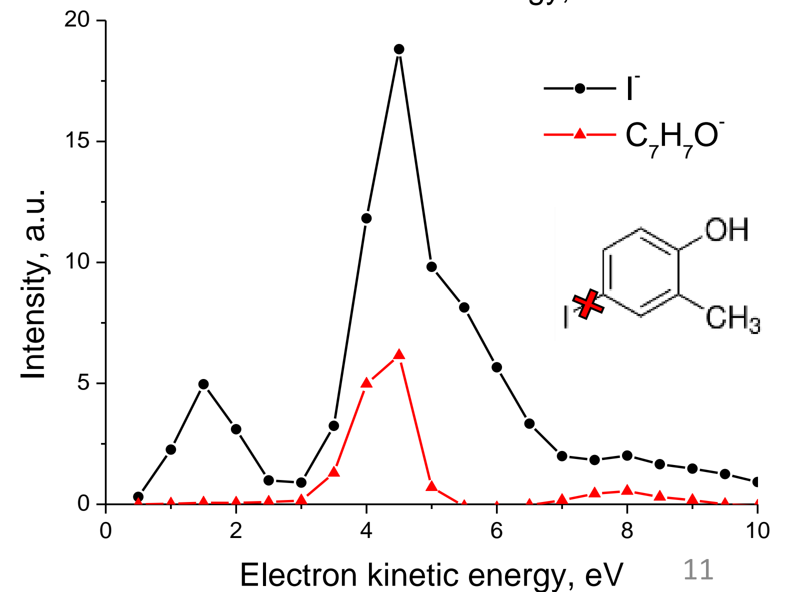
Mass Spectrometry: Electrons

Step 4. Inelastically scattered electrons





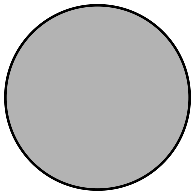


Low energy electrons:
dissociative electron attachment

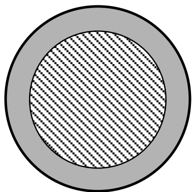
How to Study Condensed Resist

Gas-phase single molecule ⇨ Condensed resist

Nanoparticles:
uniform

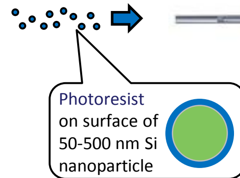


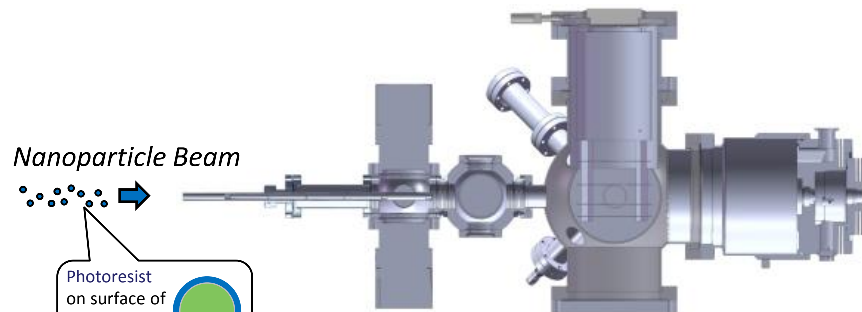
core-shell



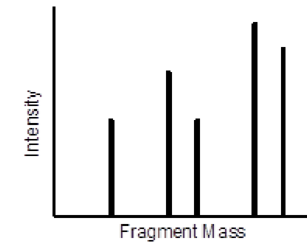
50-500nm

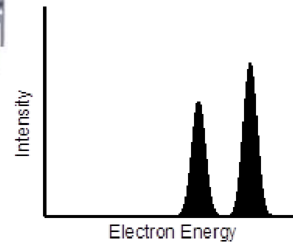
Nanoparticle Beam





TOF-MS for chemical characterization of desorbed species

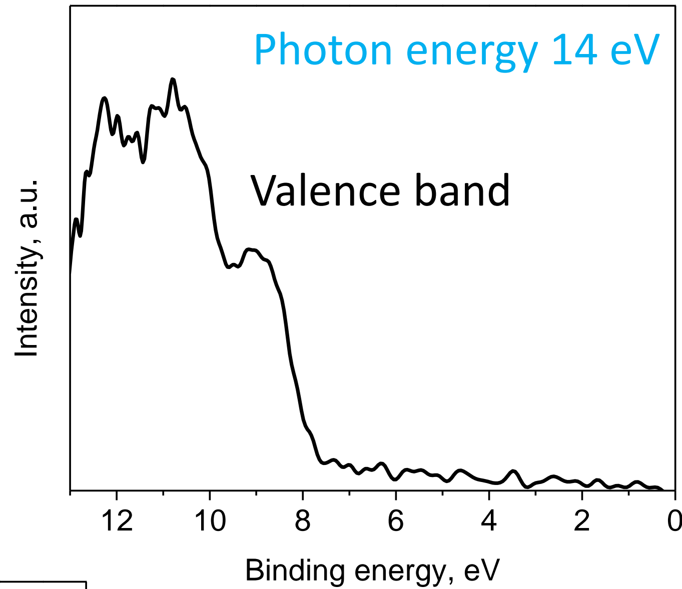


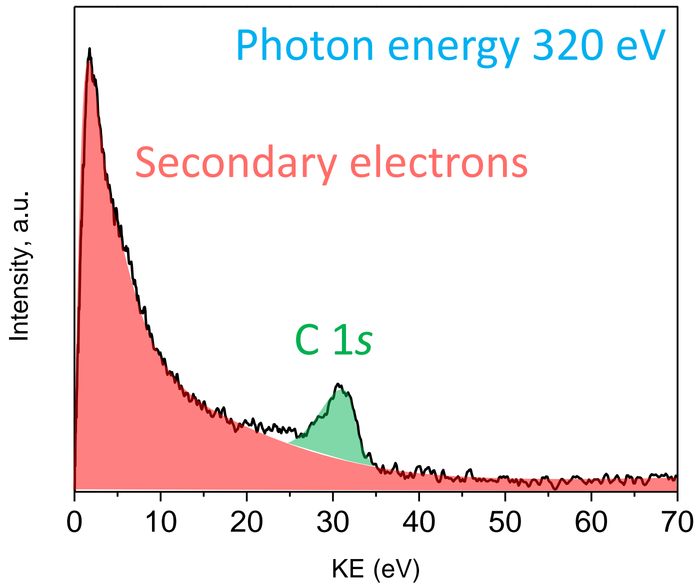


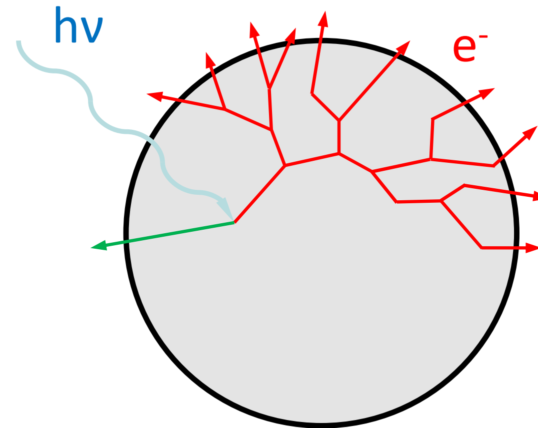
Velocity map imaging (VMI) for photoelectron energies and angular distributions

Photoelectron Spectra of Condensed Resist

E-beam resist:
4-Methyl-1-Acetoxycalixarene







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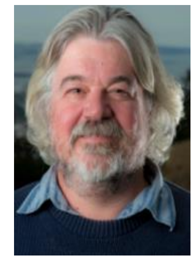

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