Measurements of PAG cross section to low energy electrons

Steven Grzeskowiak,[a] Amrit Narasimhan,[a] Jonathan Ostrander,[a] and Jonathon Schad,[a] William Earley,[a] Robert L. Brainard,[a] Leonidas E. Ocola,[b] Mark Neisser,[c] and Greg Denbeaux,[a]

(a) CNSE
(b) Argonne National Laboratory
(c) Sematech

Resist TWG meeting
San Jose
February 22, 2015

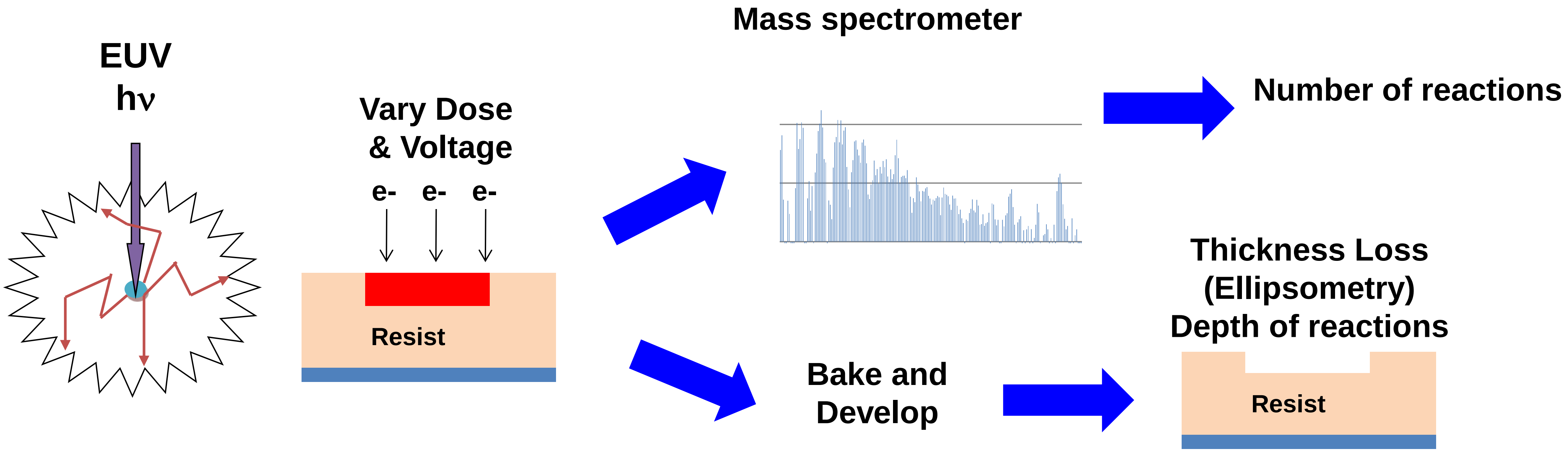
SEMATECH
Accelerating the next technology revolution.

SUNY POLYTECHNIC INSTITUTE

Overview

- EUV absorption is primarily atomic – composition and density sufficient for good understanding of EUV absorption
- EUV absorption generates primary photoelectrons near 80 eV, which are the primary cause of chemistry in exposed resists.
- Studying electron-PAG reactions and efficiencies will provide insight to help in development of improved resists

E-beam Reaction rate and depth studies

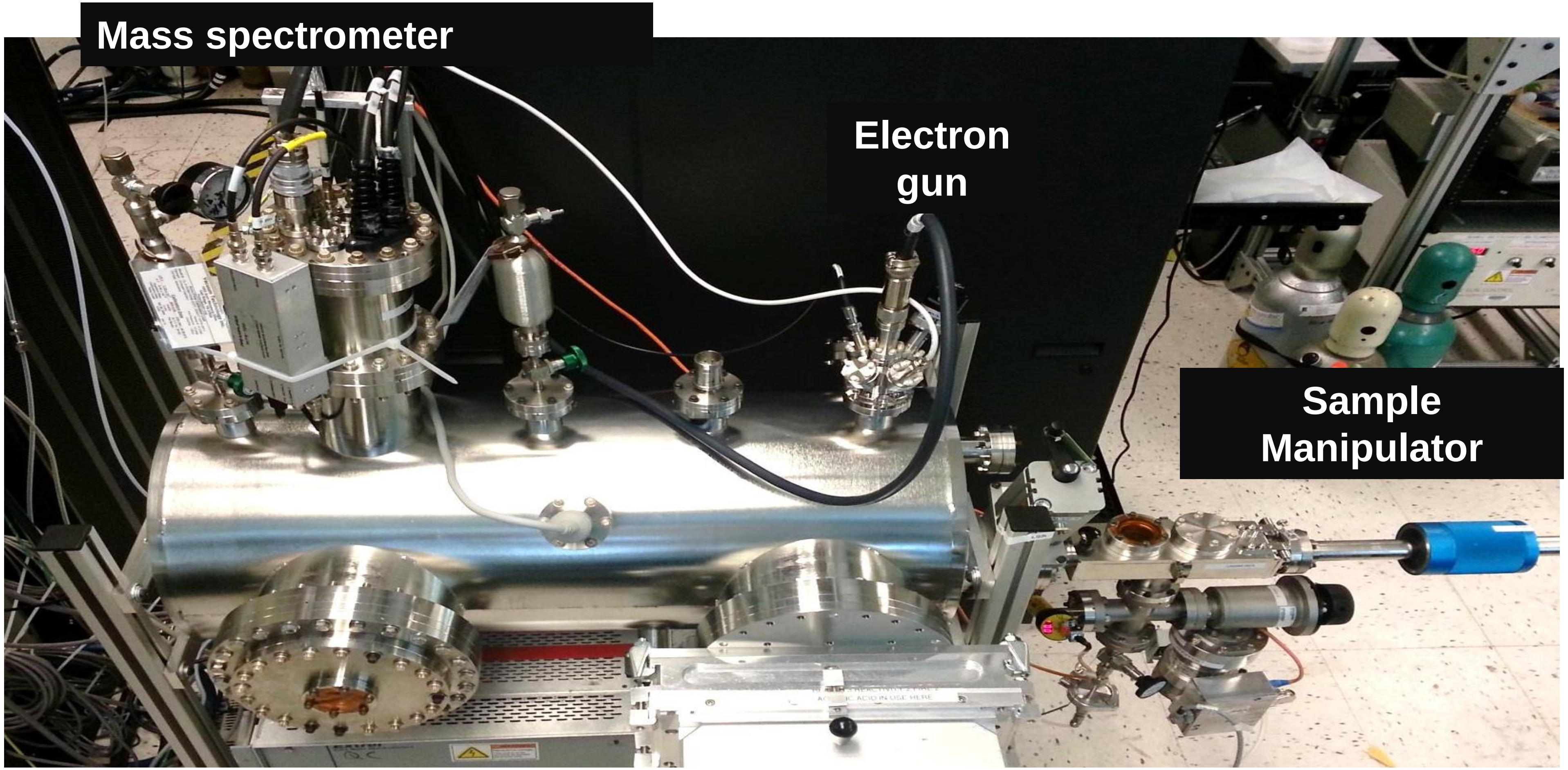


- From the central absorption event, there will be a maximum range of e- movement.
- We measure the range by top down exposures and measure the depth to represent the lateral electron travel away from the EUV absorption site.
- We measure number of reactions by mass spectrometry

See Narasimhan talk
9422-7 4pm Monday

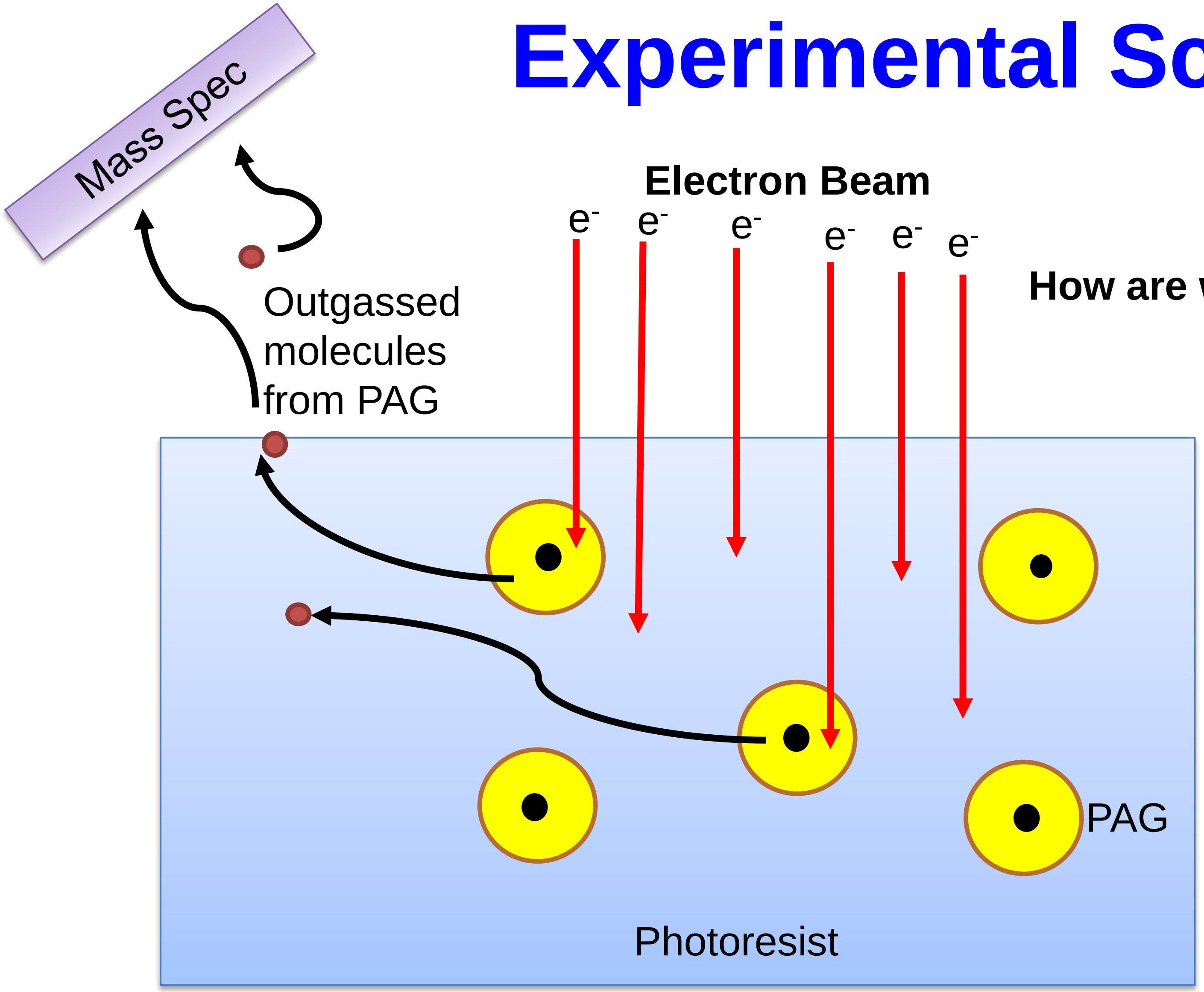
SEMATECH
Accelerating the next technology revolution.
SUNY POLYTECHNIC INSTITUTE

Electron Resist Interaction Chamber (ERIC)



- Expose EUV resist from 80-2000 eV across a wide range of doses and collect real-time outgassing information using mass spectrometry
- Bake and Develop, then measure the thickness lost with ellipsometry

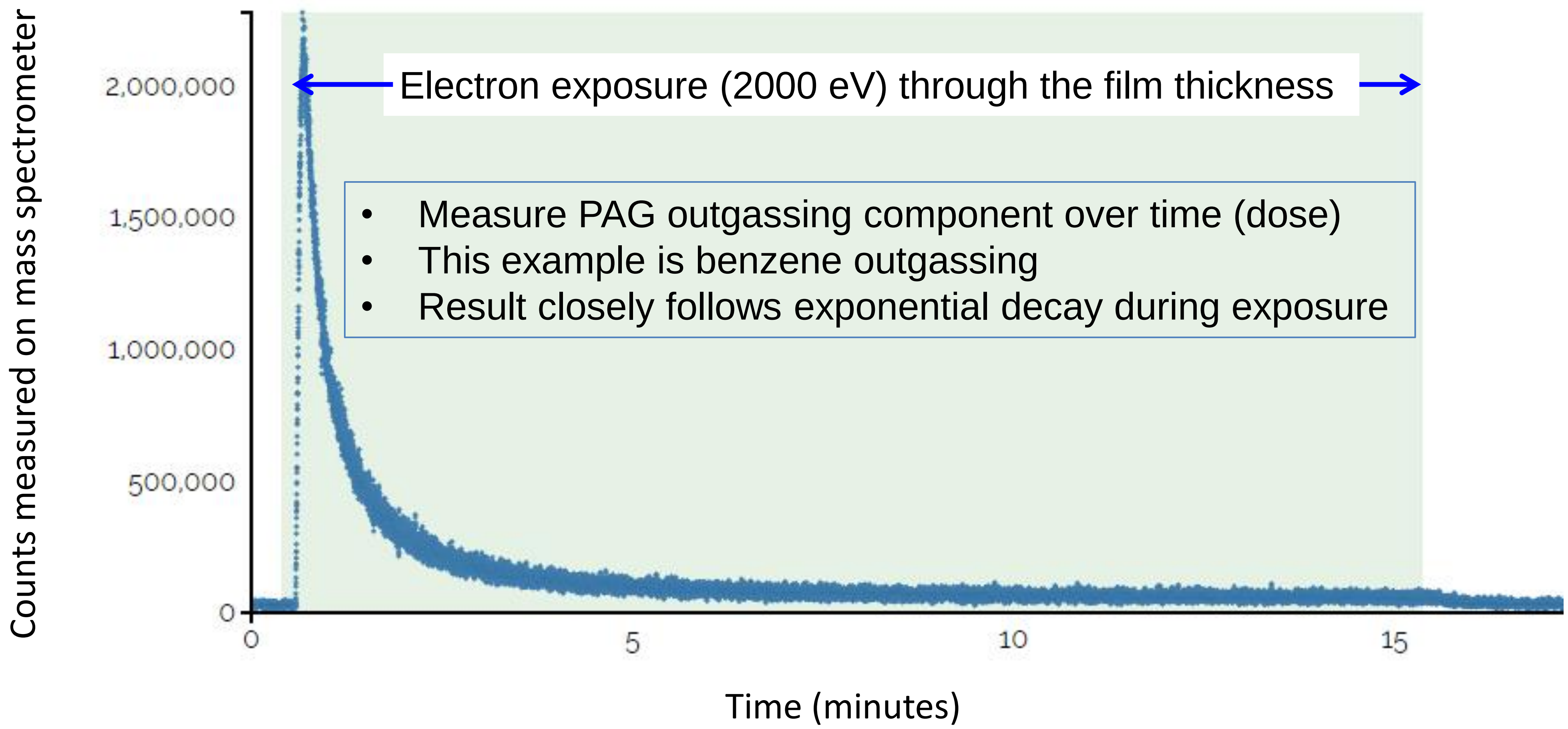
Experimental Schematic



How are we actually measuring #PAG rxns / # e$^-$?

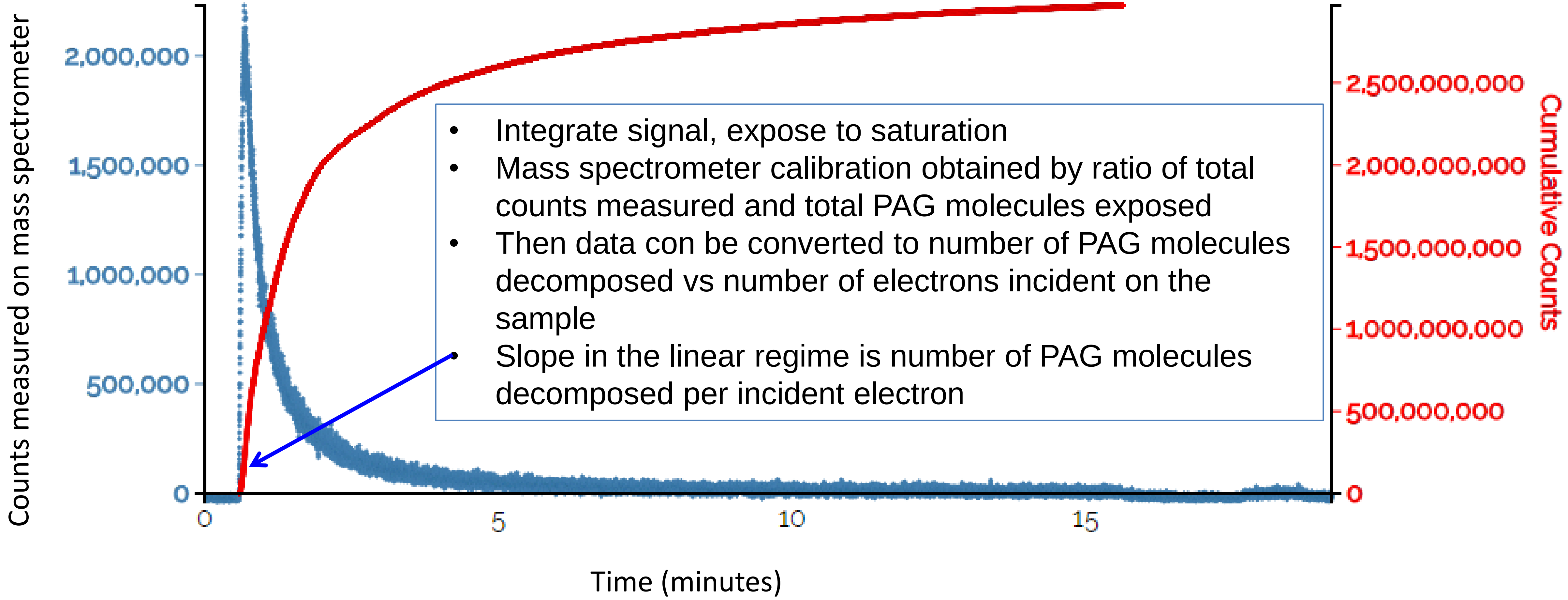
Top down electron exposure of photoresist. Molecules outgassed from electron-PAG interactions are monitored using mass spectrometry. (Figure is not to scale.)

PAG reaction measurements



SEMATECH Accelerating the next technology revolution. SUNY POLYTECHNIC INSTITUTE

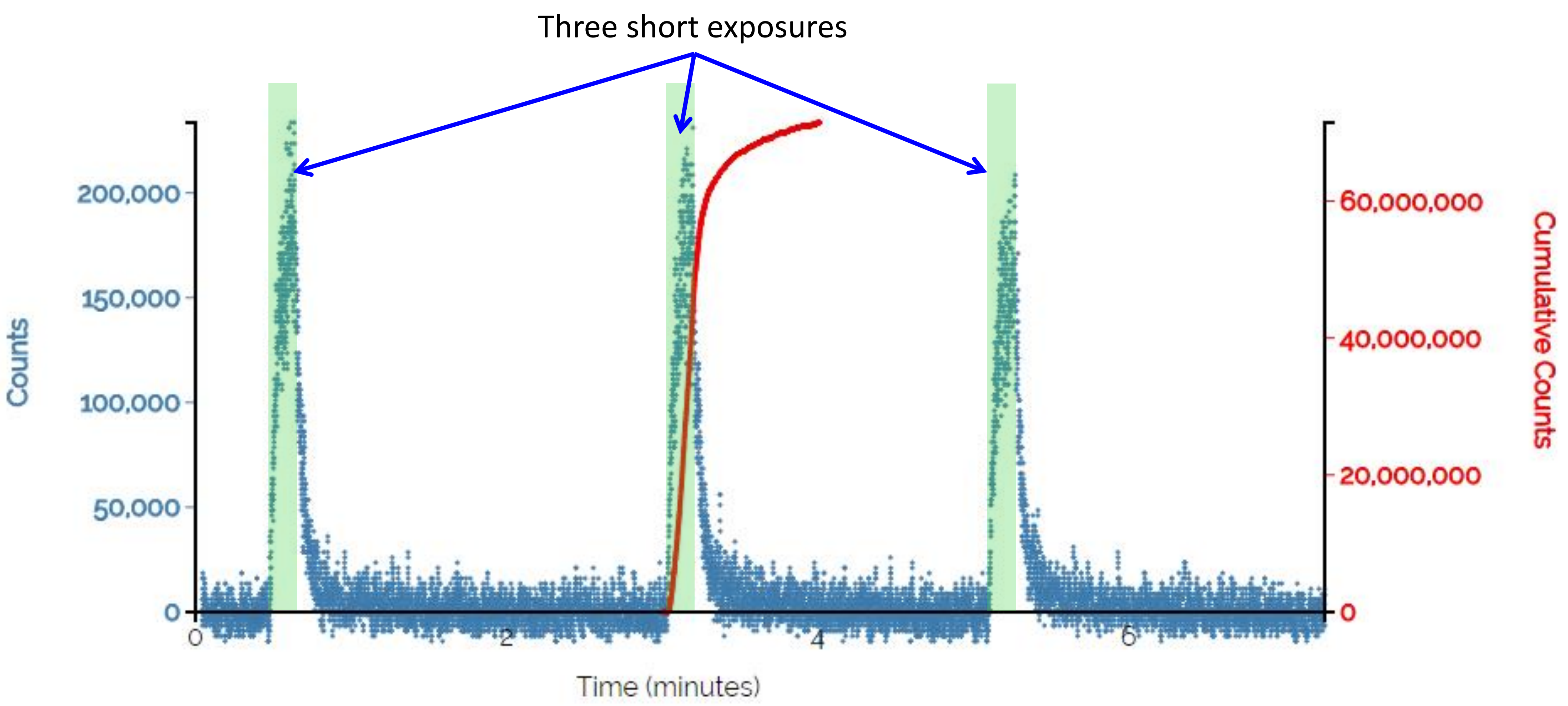
PAG reaction measurements



- Integrate signal, expose to saturation
- Mass spectrometer calibration obtained by ratio of total counts measured and total PAG molecules exposed
- Then data con be converted to number of PAG molecules decomposed vs number of electrons incident on the sample
- Slope in the linear regime is number of PAG molecules decomposed per incident electron

PAG reaction measurements

For improved accuracy, repeated measurements performed with multiple smaller exposures, each providing number of PAG decompositions per electron after applying the calibration

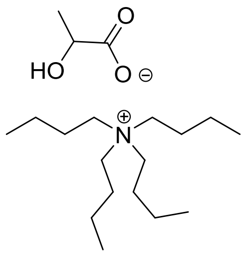


Resist Formulation and Preparation

Formulation (4 wt.% solids):
1.5 wt.% Base
15 wt.% PAG
83.5 wt.% Polymer

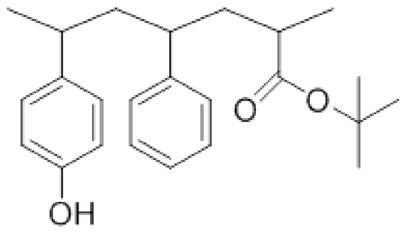
Spin Coat:
3700 RPM, 45s

Post Application Bake:
120 °C, 60s

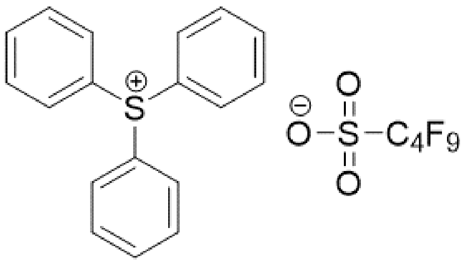
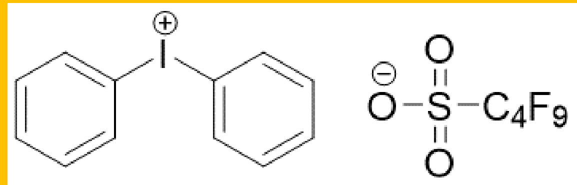
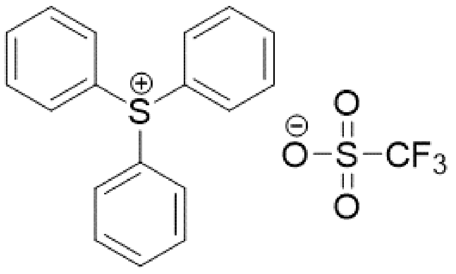
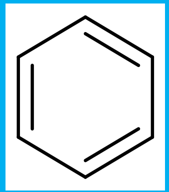


Base - TBAL

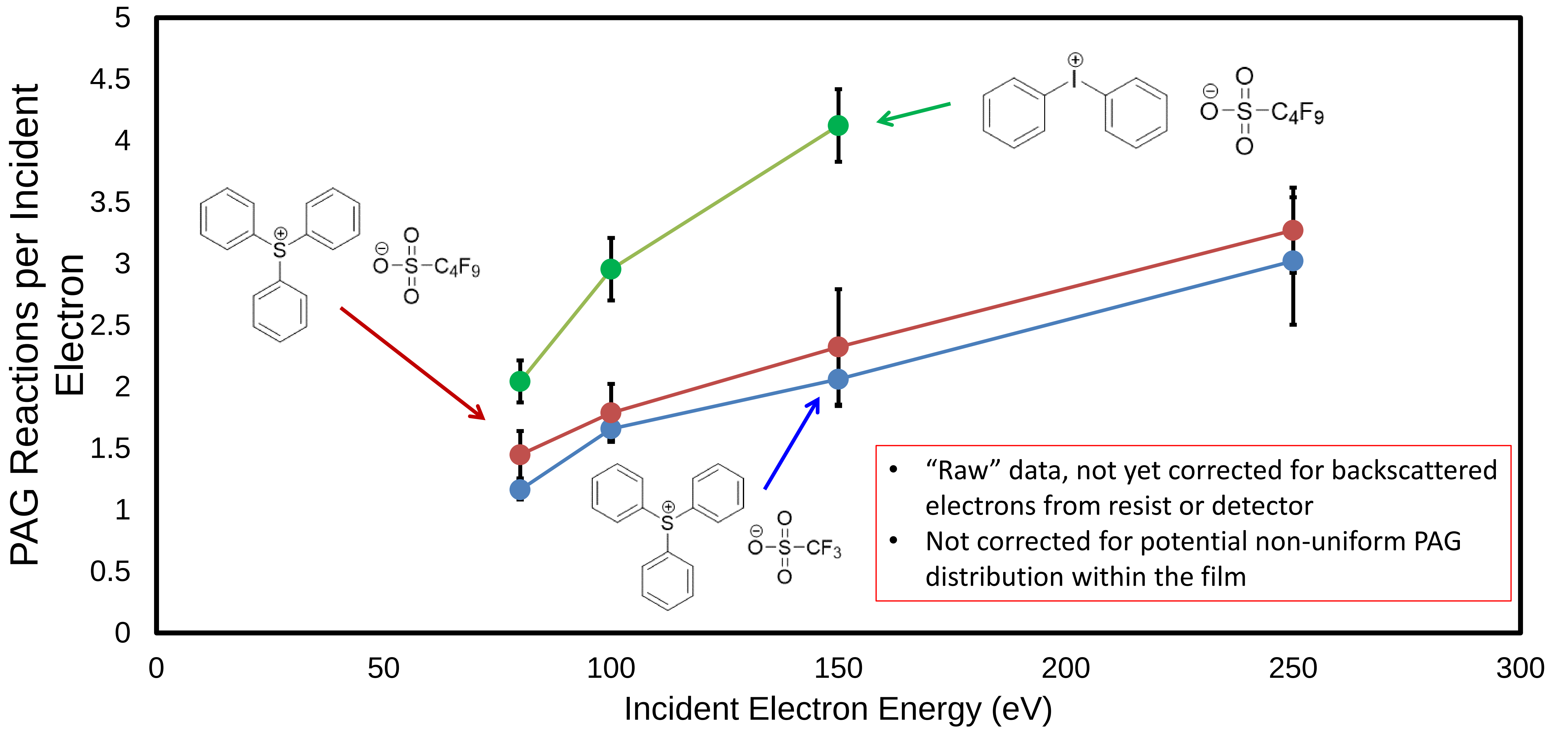
ESCAP



65%/20%/15%

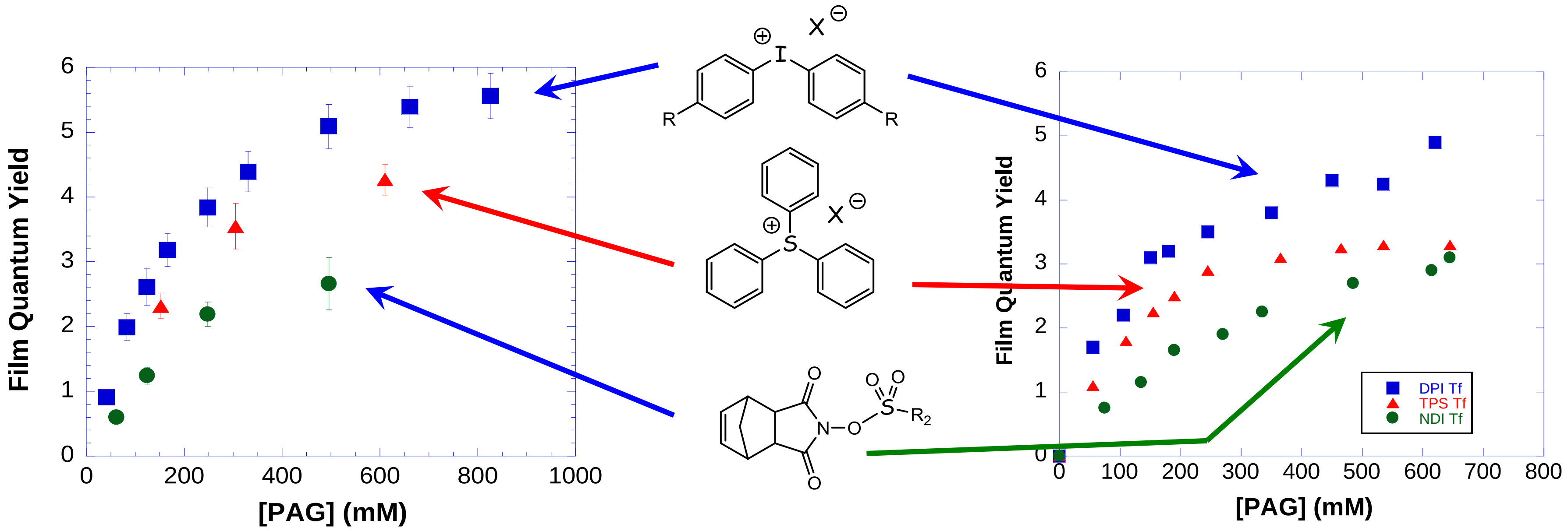
	Sulfonium	Iodonium
Nonaflate		
Triflate		All 3 outgas benzene 

Electron-PAG Reaction Efficiency



II. PAG Reaction Mechanisms in EUV

2008: Is it possible to "Titrate" the number of e- using PAG?



Higgins & Brainard[1]

Max H^+ Φ = 5.6

Kozawa & Tagawa[2]

Max H^+ Φ = 4.9

Prior work also showed iodine based PAG more efficient than sulfur

- ***Two PAG-Loading studies agree: Quantum Yields of 5-6 H^+/Photon are possible.***
- ***Higher Quantum Yield gives better Z-Parameter[1]***

1. *Higgins & Brainard SPIE 2008 and JJAP 2011 V. 50*
2. *Kozawa & Tagawa JJAP 2010 V. 49*

Brainard 2013 SPIE

SEMATECH Accelerating the next technology revolution.

SUNY POLYTECHNIC INSTITUTE

Future Work

- Incorporate penetration depth to calculate cross-sections, not just reactions per electron for each PAG
- Incorporate electron backscattering measurements to the raw data to improve accuracy of results
- Gather data at lower electron energies
- Expand study to non-ionic PAGs and PAGs with non-benzene outgassing products

Acknowledgements

Project Funding By:

Accelerating the next technology revolution.

DuPont Electronic Materials:

Supplying Polymers

Brainard and Denbeaux Groups:

Ryan Del Re

Jodi Hotalen

Mihirkant Upadhyaya