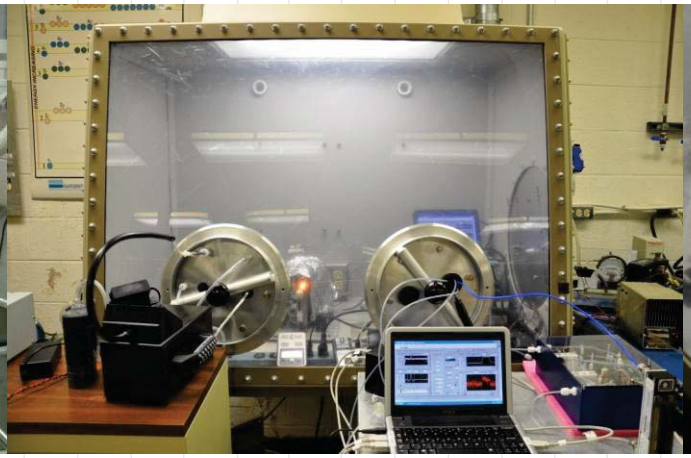
National Aeronautics and Space Administration


Materials Combustion Testing and Combustion Product Sensor Evaluations in FY12

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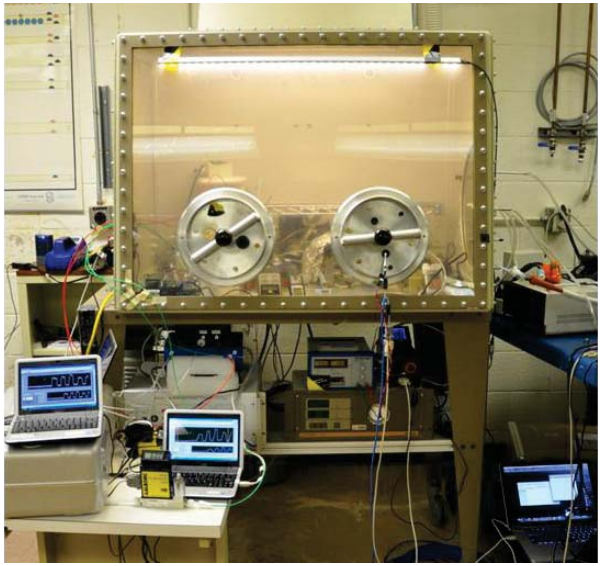
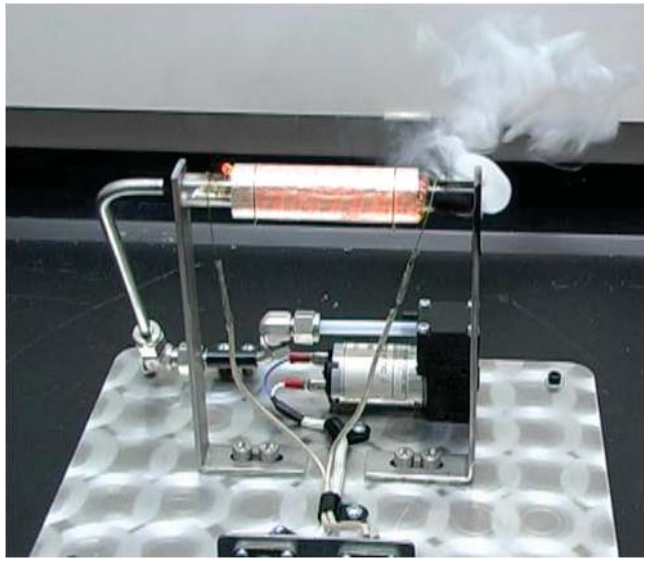
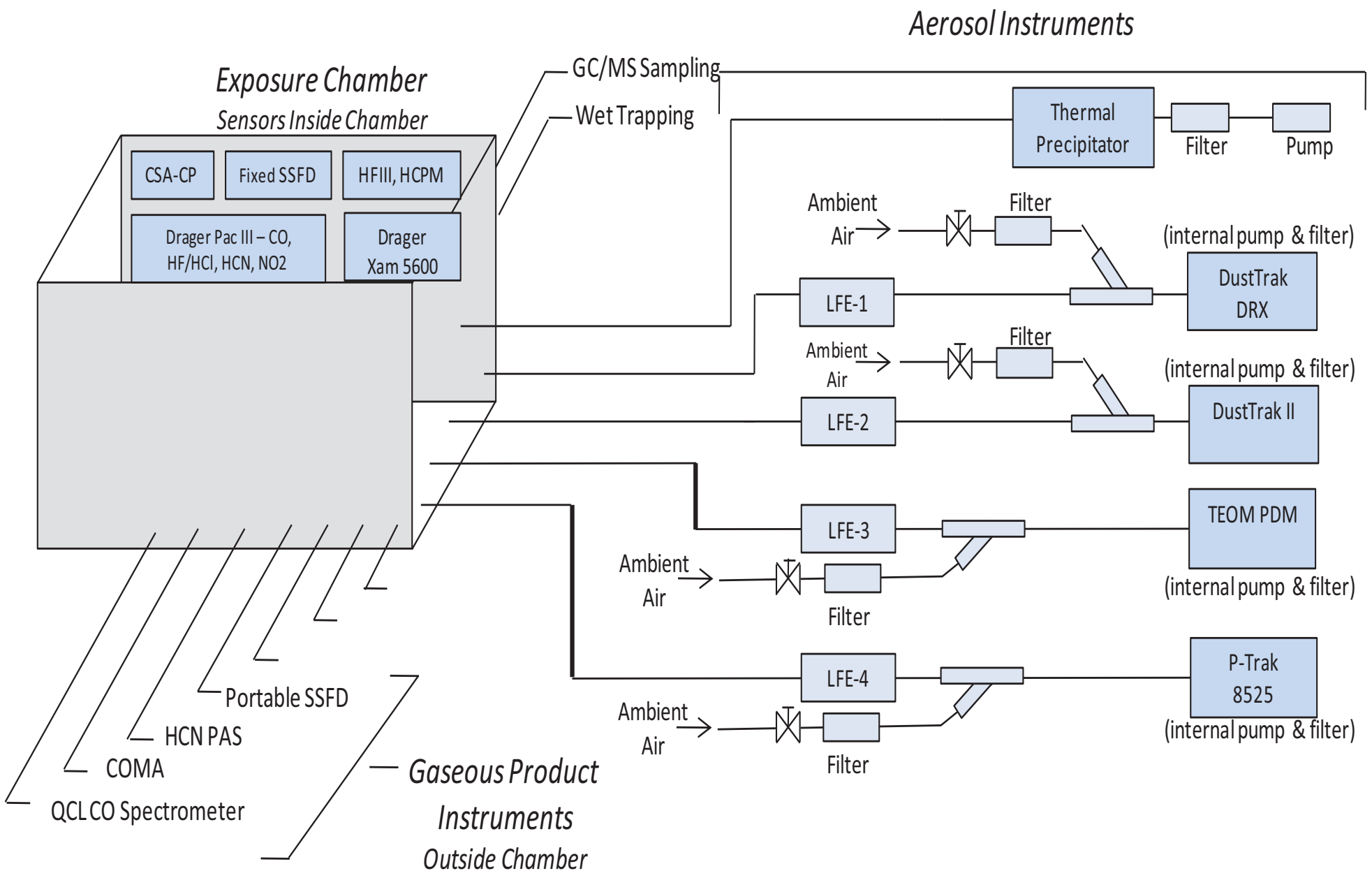
Background & Objectives

- Recent series of White Sands Test Facility materials combustion tests combined with combustion product sensor evaluations
- Objectives are to create realistic fire challenges for sensor evaluation and to better understand combustion signatures for modern spacecraft materials
- Paper presented at ICES 2011 reported first series of tests conducted in 2010
- Two series of tests were conducted in 2012 (Feb & Sep)
- New materials (fuels), better control of burn parameters, new sensor technologies
- Focus on smoldering regime without ignition
- Particulate and Chemical combustion product results presented & discussed





Experimental Setup: Instrumentation



Run Sequence

Step	Description
1	Load fuel, close up chamber, turn off purge vent, all instruments ON
2	Ramp furnace temperature up to target temperature
3	Turn furnace blower ON once target temperature reached (at t=3 min)
4	Hold furnace temperature for ~ 4min
5	Turn off furnace at t=7 min & stir chamber via muffin fan for 30 sec
6	5 to 10 min dwell/natural decay (occasionally longer)
7	Vent chamber, switch on purge duct fan
8	Remove and weigh ash

Series of Burns for the 2 tests (10 fuels each)

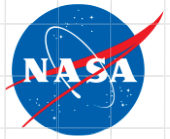


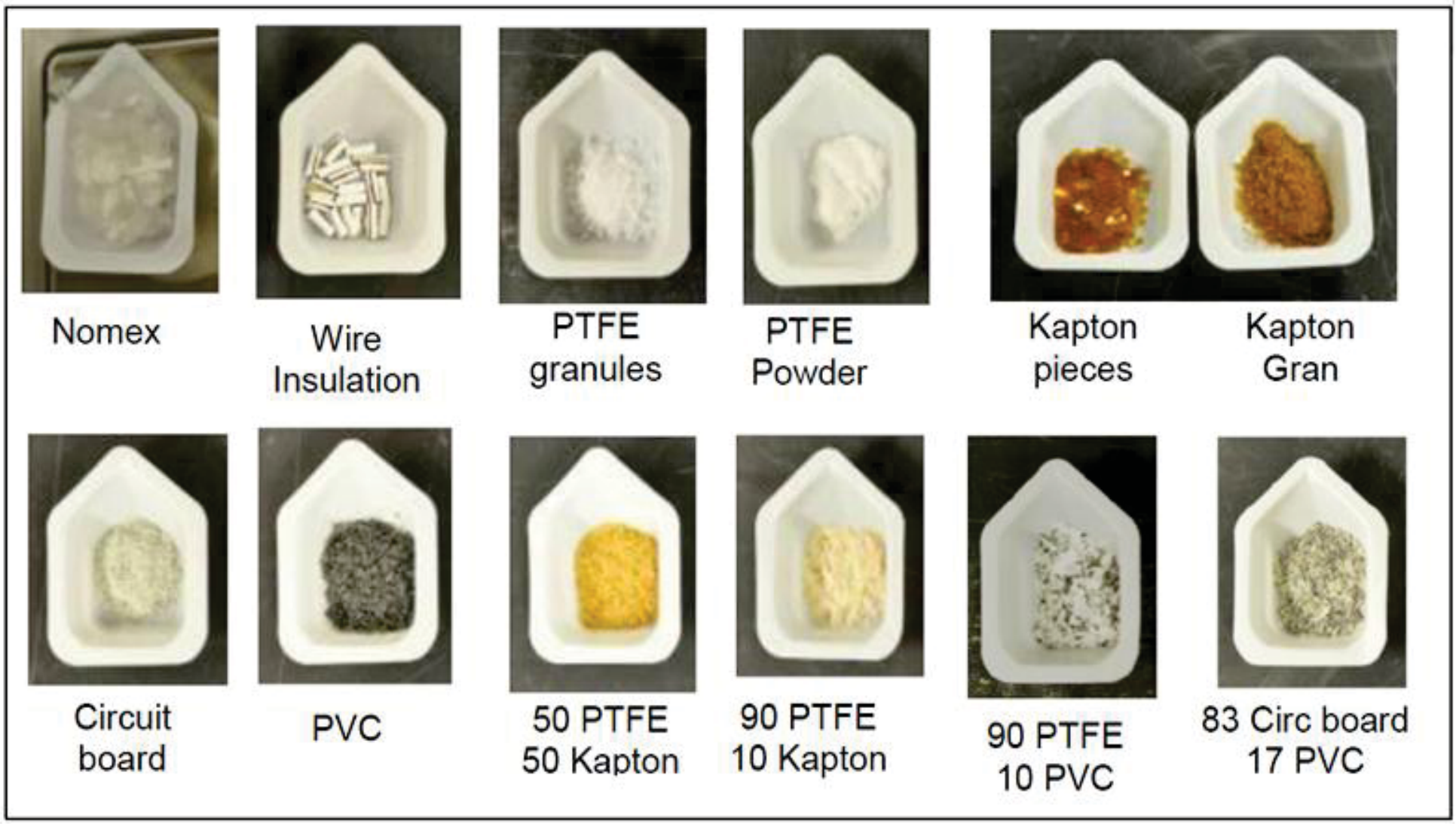
Table 1. Feb-Mar 2012 Burn Sequence (some ignition, total of 43 runs)

Material (0.5 g)	Furnace Temp/C	Ignite	Replicates	# Tests	Notes
Standard Mix	340,440,540,640	Yes	1-2	7	Granulated
Granulated Circuit Board	340,440,540	Yes	2-3	5	Populated, conformal coated
PFPI wire insulation	540,640	No	3-4	7	20AWG stripped
100% PTFE	540,640	No	2-3	5	Granulated
100% Kapton	540,640	No	2-3	5	Granulated
50:50 PTFE/Kapton mix	540,640	No	1-2	3	Mixtures of above
25:75 PTFE/Kapton mix	540,640	No	2	4	“
75:25 PTFE/Kapton mix	540,640	No	1-2	3	”
10:90 PTFE/Kapton mix	640	No	2	2	“
90:10 PTFE/Kapton mix	640	No	2	2	“

Table 2. Sep 2012 Burn Sequence (No ignition, total of 62 runs)

Material (0.5g)	Furnace Temp/C	Replicates	# Tests	Notes
Nomex	640	7	7	HT9040, natural, untreated
Nexans Wire Insulation	640	6	6	M22759/86 12AWG stripped
100% PTFE	640	8	8	4 Granulated & 4 powdered PTFE
100% Kapton	640	5	5	Granulated
PTFE/Kapton mixes	640	3-4	18	10/90; 90/10; 25/75; 75/25;50/50
Circuit Board (PCB)	340,440,540,640	2	8	Granulated
PVC	640	1	1	Granulated; for HCl production
PCB+PVC	640	3	3	0.5g PCB with 0.05g PVC “std addition”
PCB+PVC	640	2	2	0.5g PCB + 0.1g PVC
PTFE+PVC	640	1	1	0.4g PTFE + 0.1g PVC

Fuels used in the September 2012 Test Series



Fuel mass: 0.5g for majority of runs

Particle Instruments

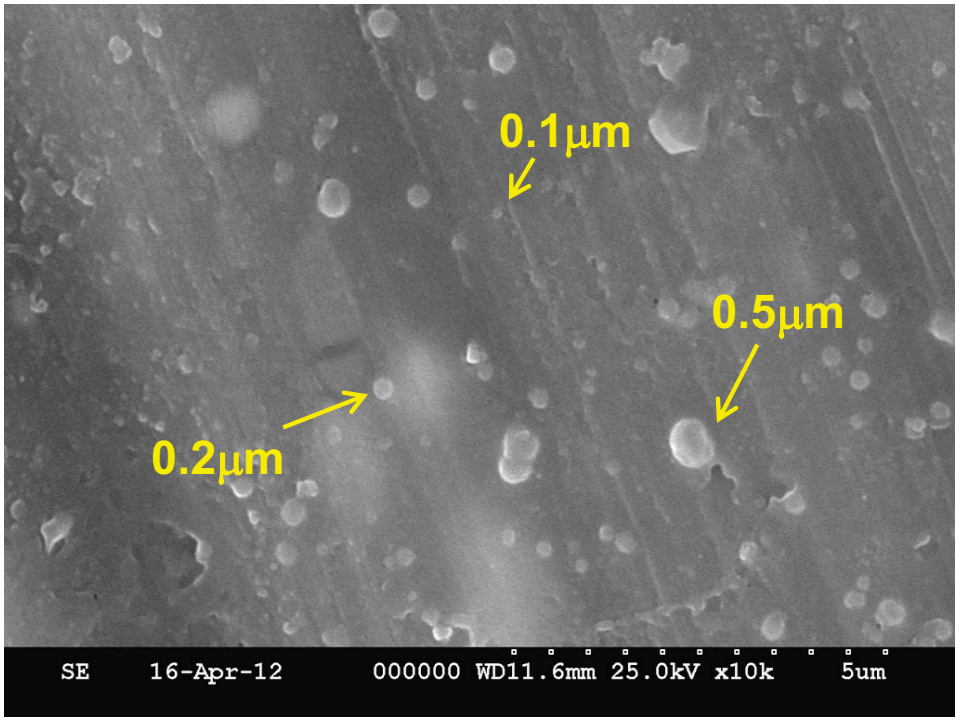
Instrument	Source	Core Technology	Target Parameter
Thermal Precipitator	Glenn Research Center	Particle Thermophoresis	Aerosol capture for microscopy
TEOM PDM	ThermoFischer	Gravimetry	Aerosol mass concentration
Dust Trak DRX	TSI Inc.	Laser Photometry with single particle counting	Aerosol mass concentration
Dust Trak II	TSI Inc.	Laser Photometry	Aerosol mass concentration
P-Trak 8525	TSI Inc.	Condensation/Light Scattering	Ultrafine particle concentration

- Thermal Precipitator provides information on
  - Particle morphology
    - SEM (scanning electron microscopy), TEM (transmission electron microscopy)
  - Chemical analysis of particles
    - EDS (energy dispersive x-ray spectroscopy)
    - Elemental mapping
  - Not intended for particle size distribution measurement
- TEOM PDM is a reference instrument for aerosol mass concentration
- P-Trak is an industrial hygiene aerosol instrument for number concentration

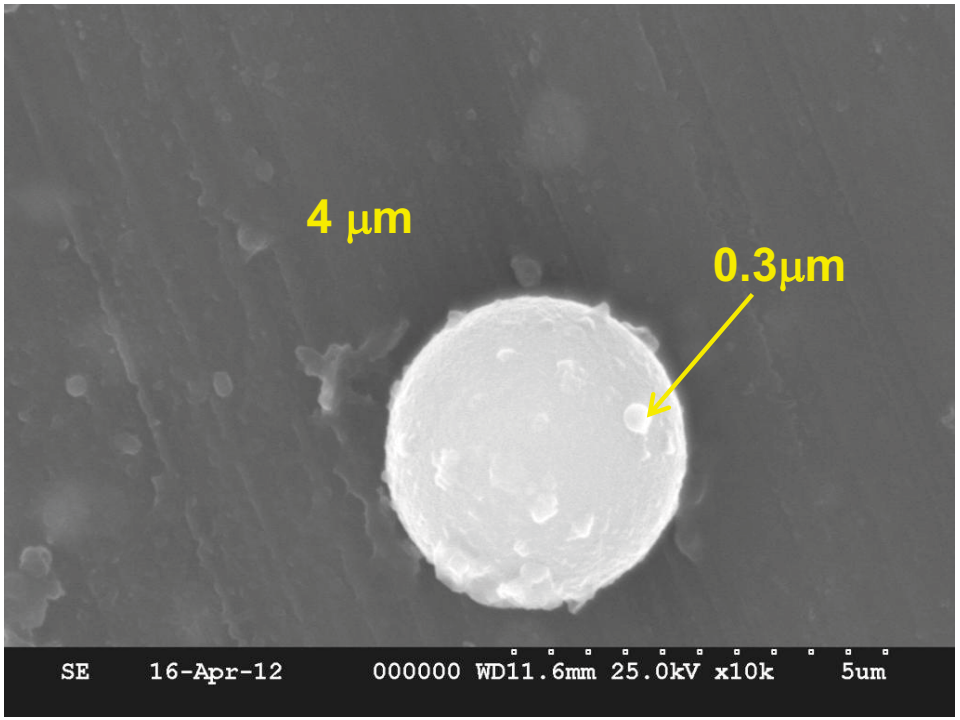
- *Certain commercial entities, equipment or materials may be identified in order to describe an experiment procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by NASA*

Thermal Precipitator Results—Particle Morphology

Wire Insulation 640° C



SEM stub —1 µm

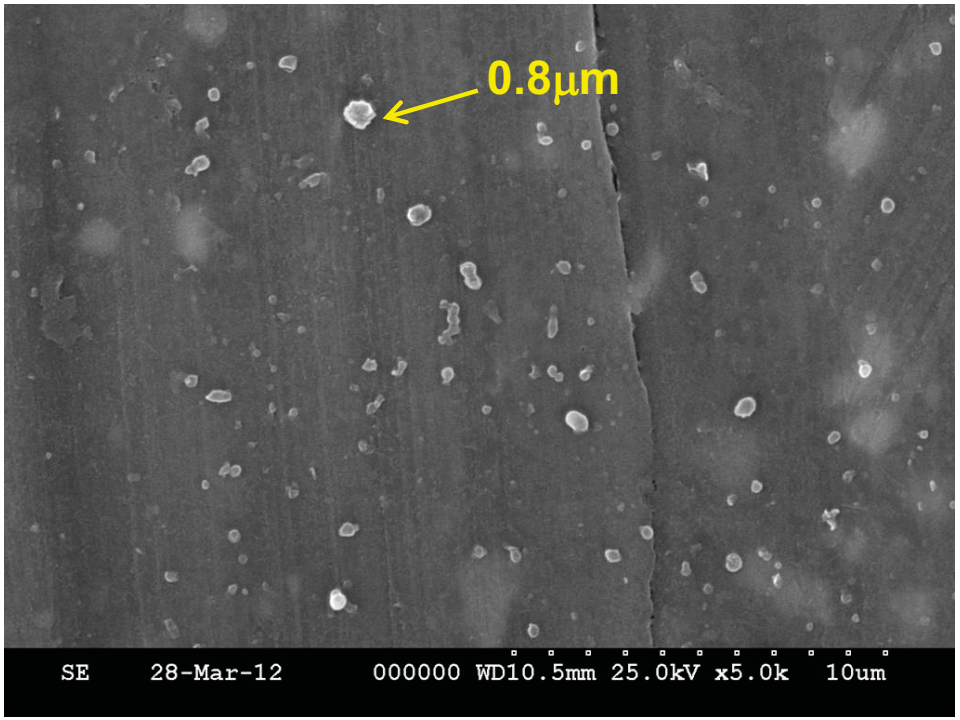


—1 µm

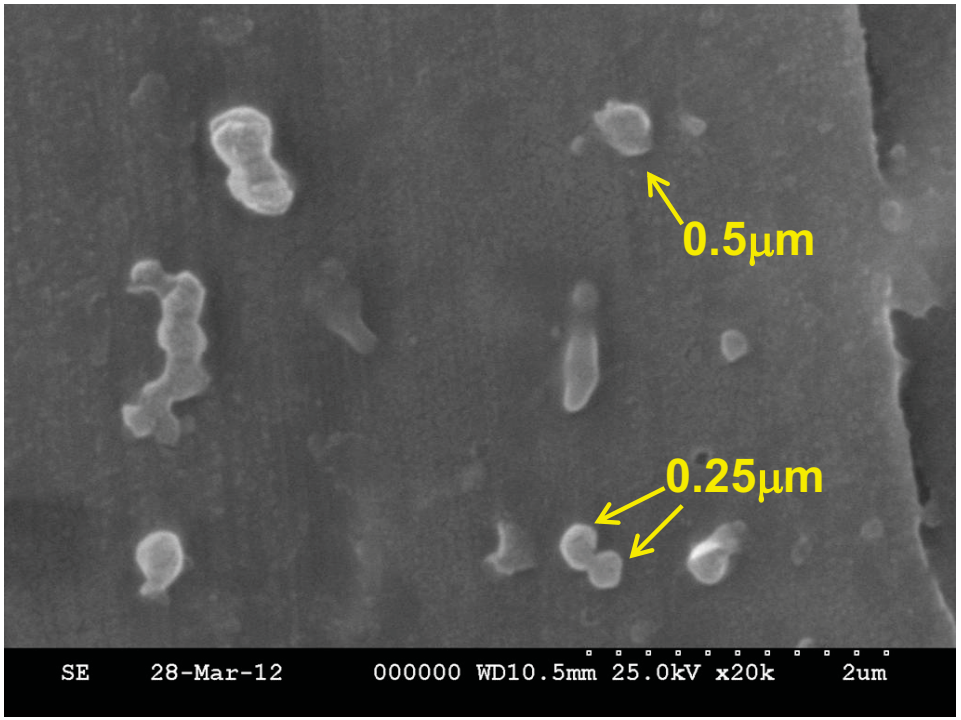
Microscopy by Victoria Bryg

Thermal Precipitator Results—Particle Morphology

Kapton 640° C



SEM stub — 2 µm

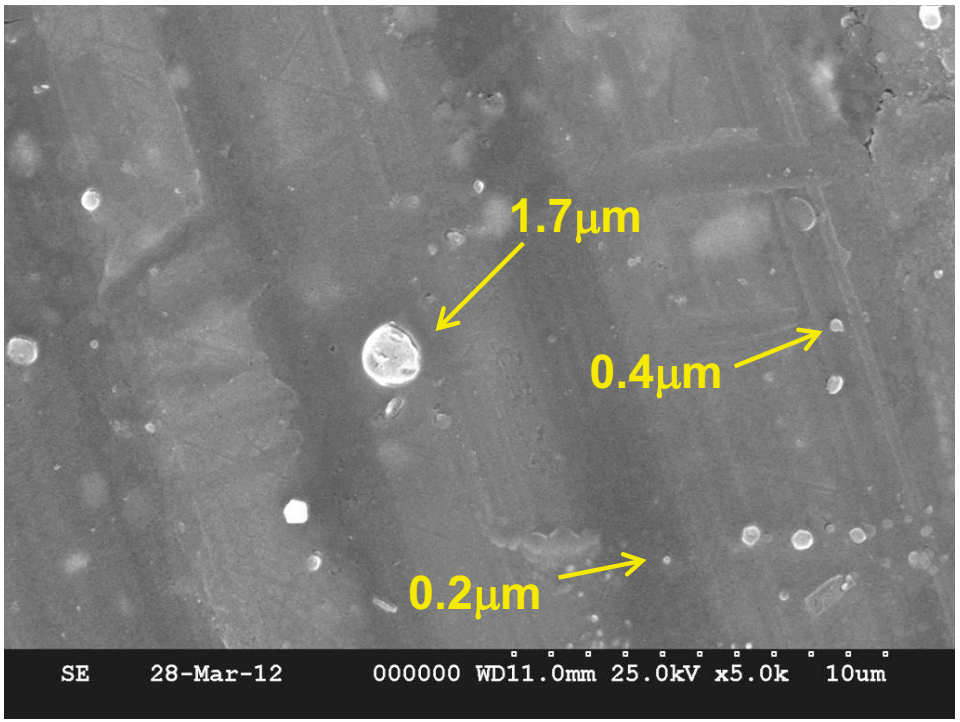


— 1 µm

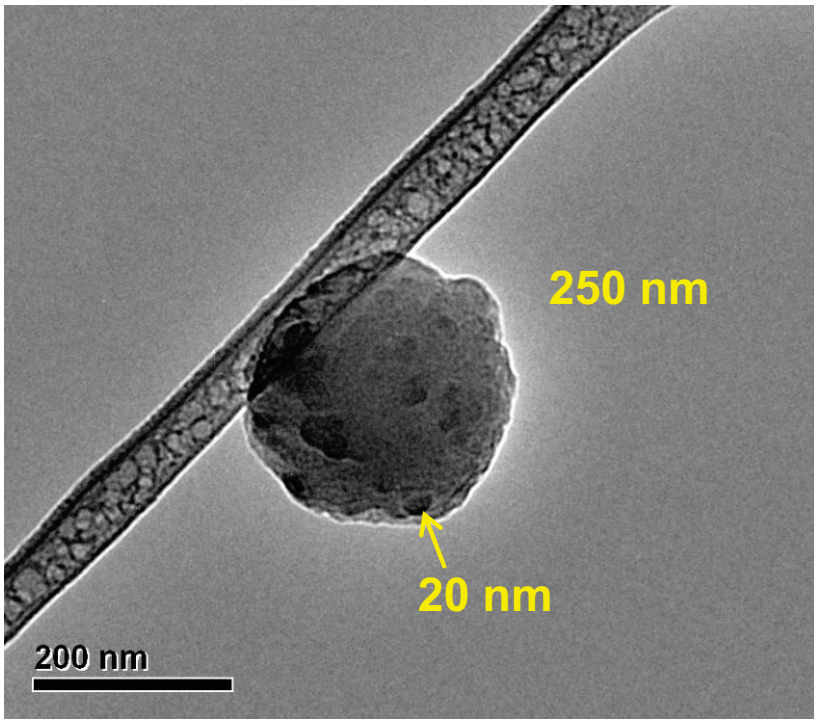
Microscopy by Victoria Bryg

Thermal Precipitator Results—Particle Morphology

Teflon 640° C



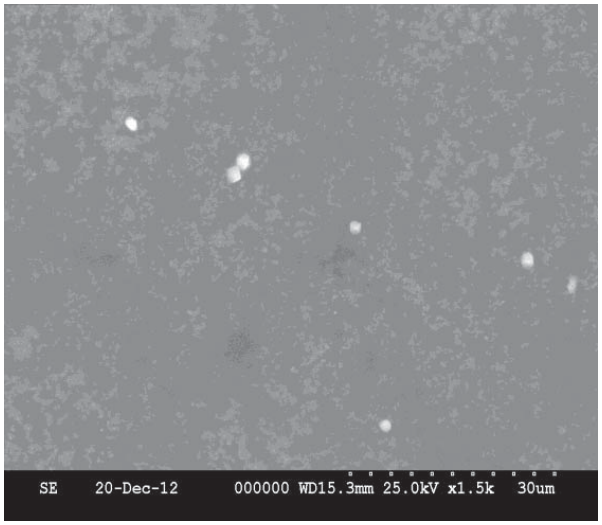
SEM stub —2 μm

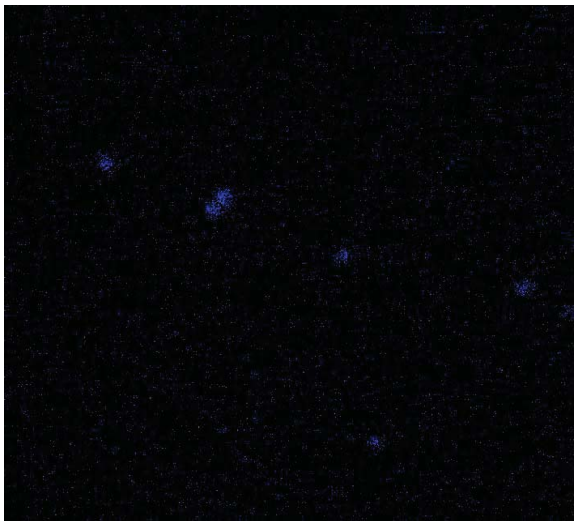


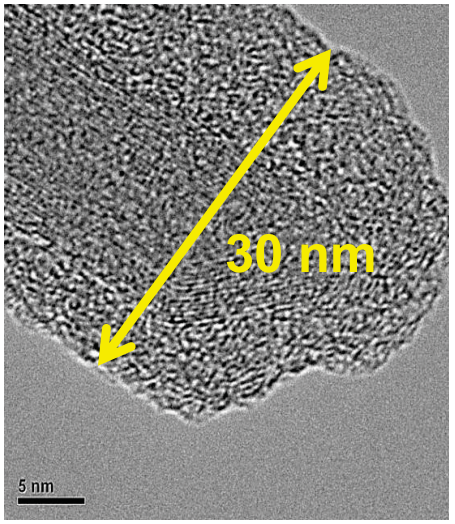
TEM grid

Microscopy by Victoria Bryg

Thermal Precipitator Results—Chemical Analysis





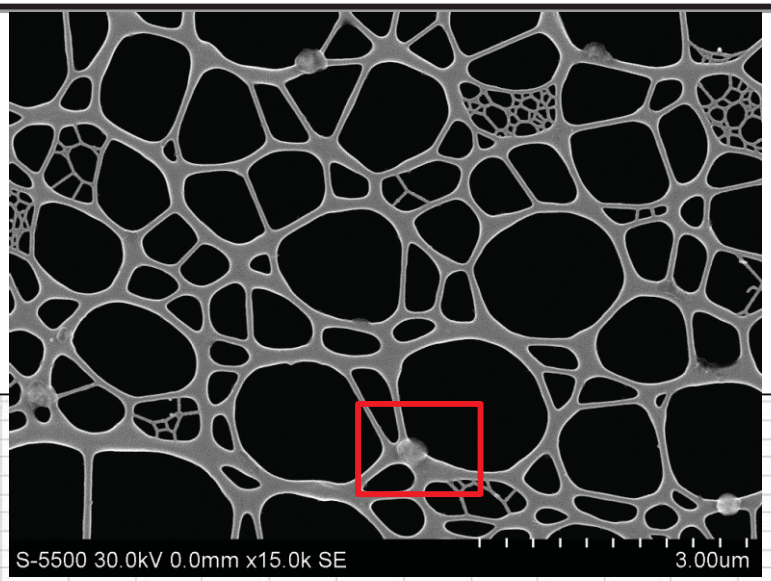


5 nm

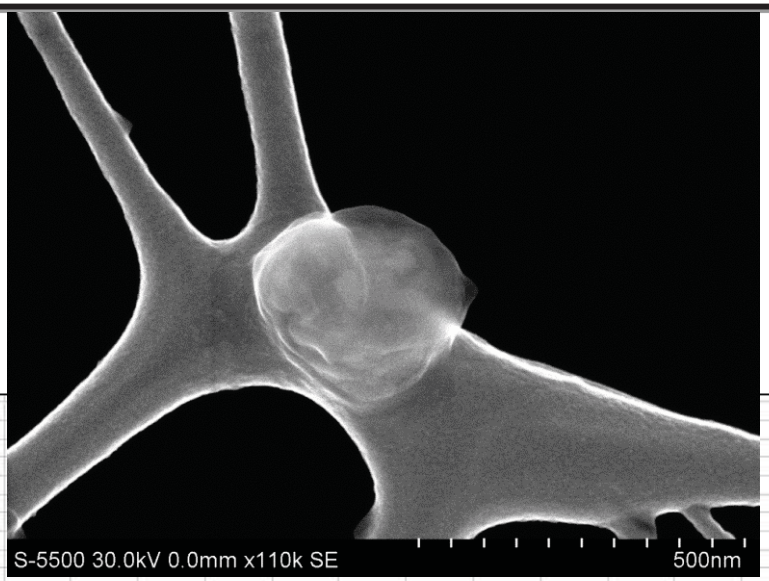
- Teflon particles are generally spherical
- Center image is an elemental map showing flourine (F) within the particles
- HRTEM image shows the Teflon particle has a crystalline interior with an amorphous coating

Microscopy by Victoria Bryg

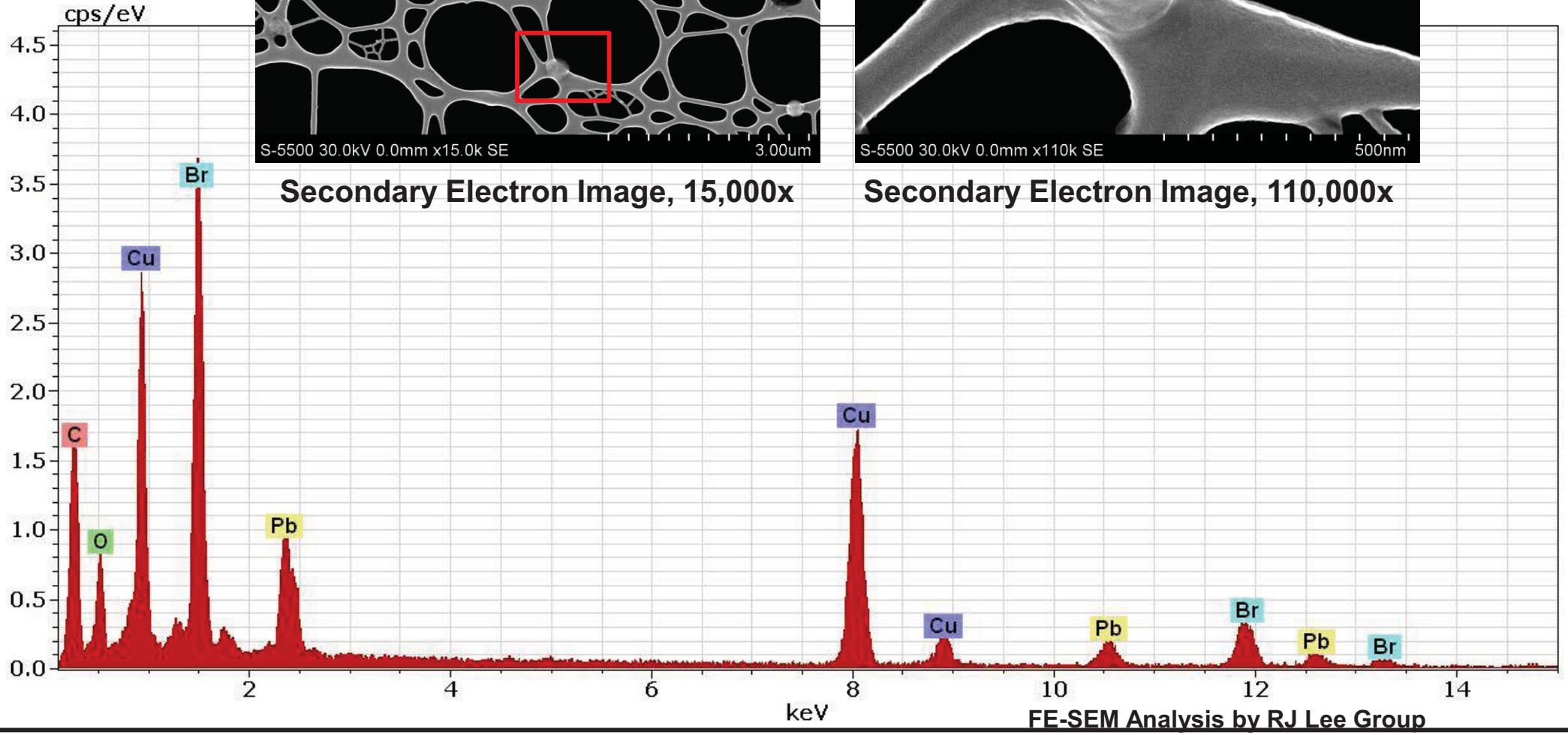
Chemical Analysis of Particles—FE-SEM Analysis, Circuit Card 540°C



Secondary Electron Image, 15,000x

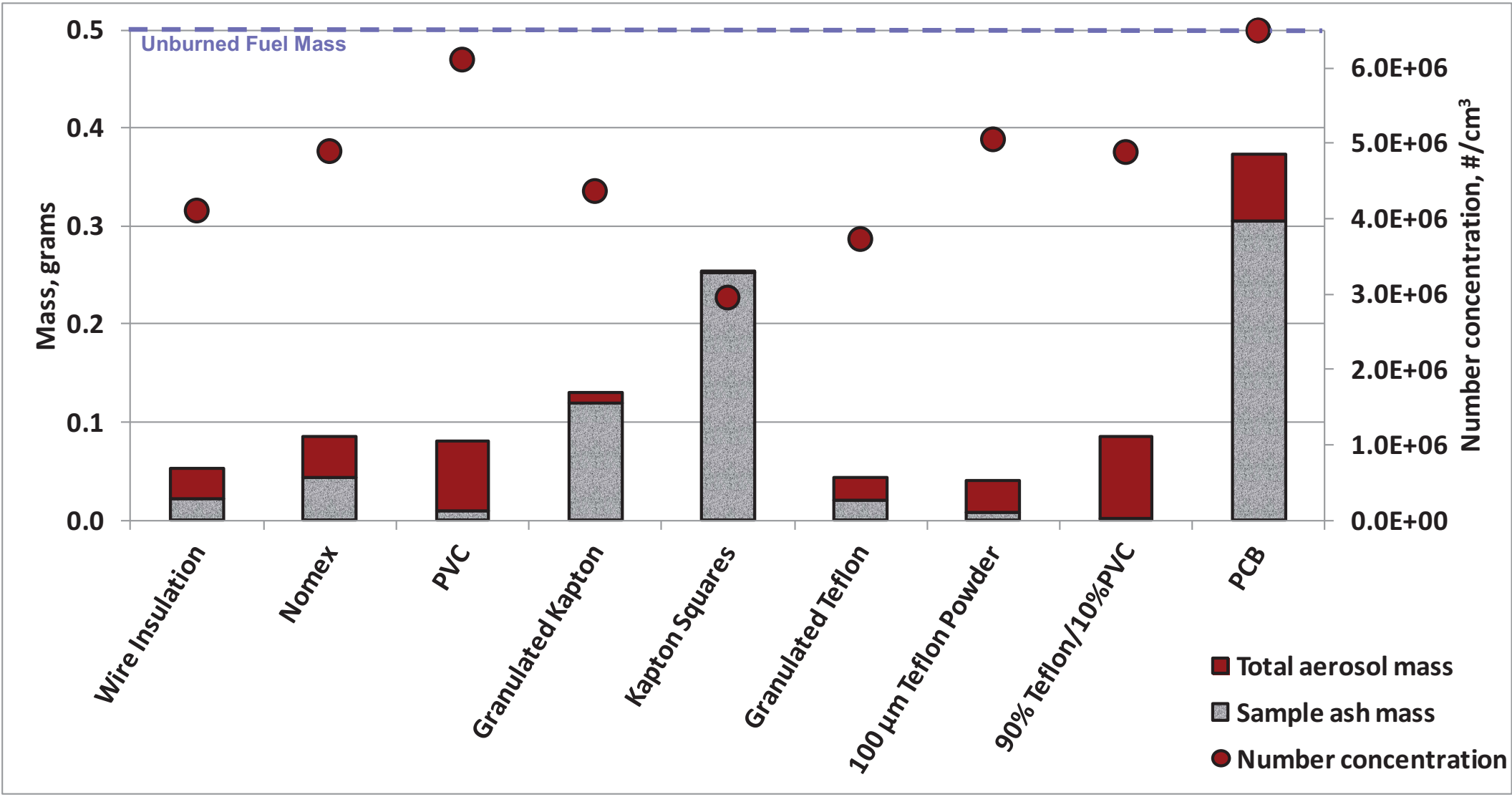


Secondary Electron Image, 110,000x

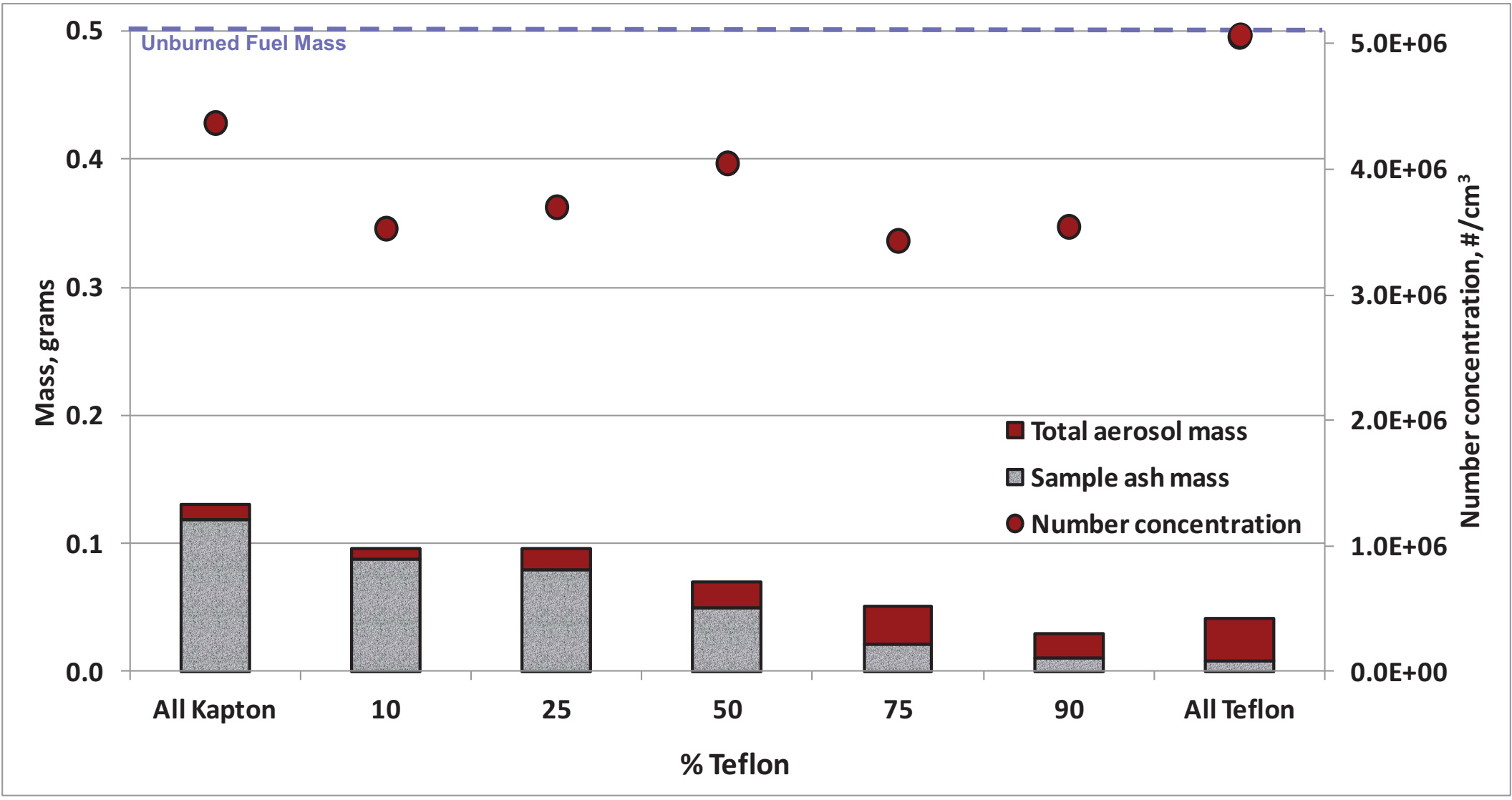


FE-SEM Analysis by RJ Lee Group

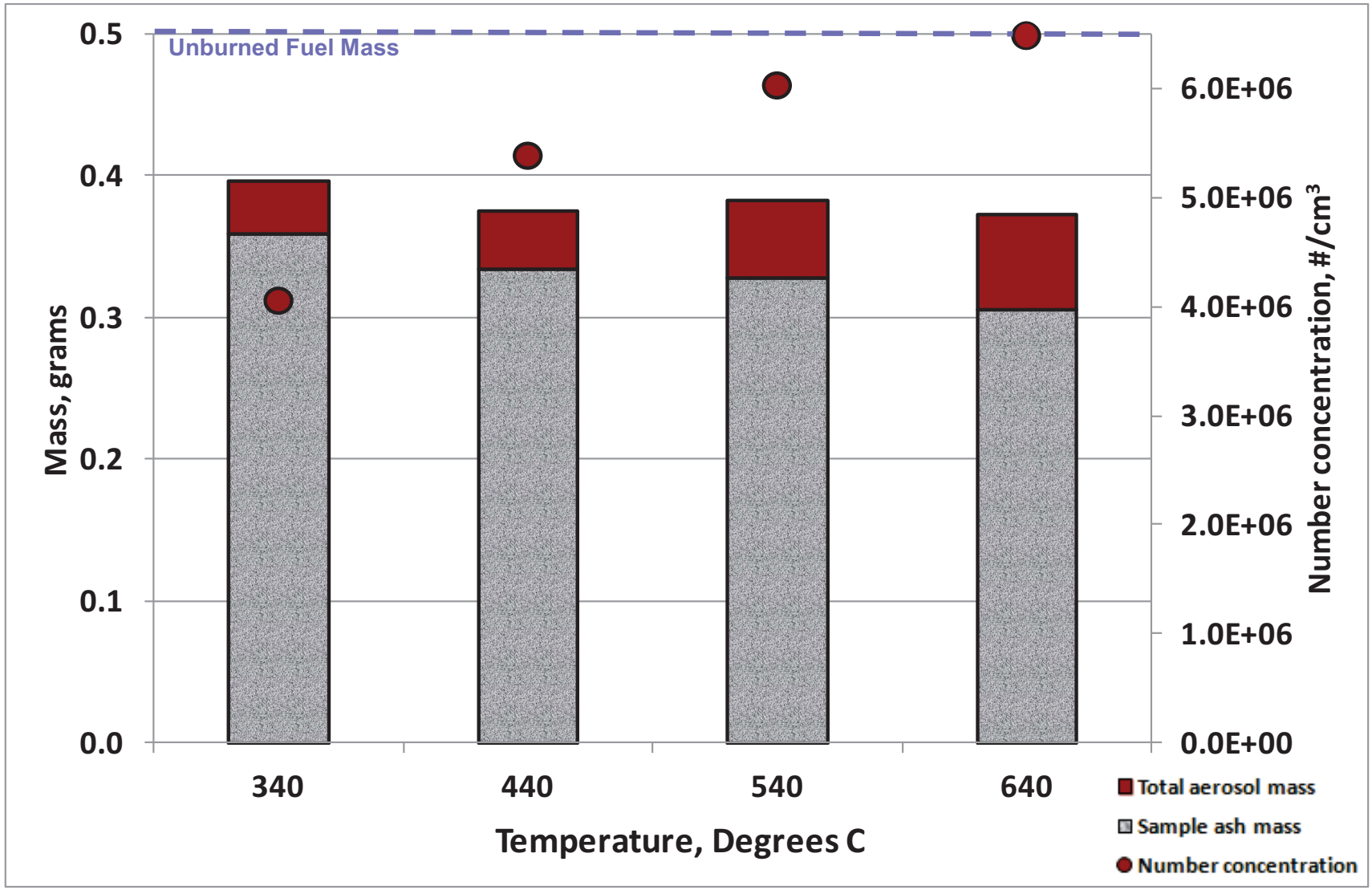
Smoke Aerosol Signatures, 640°C



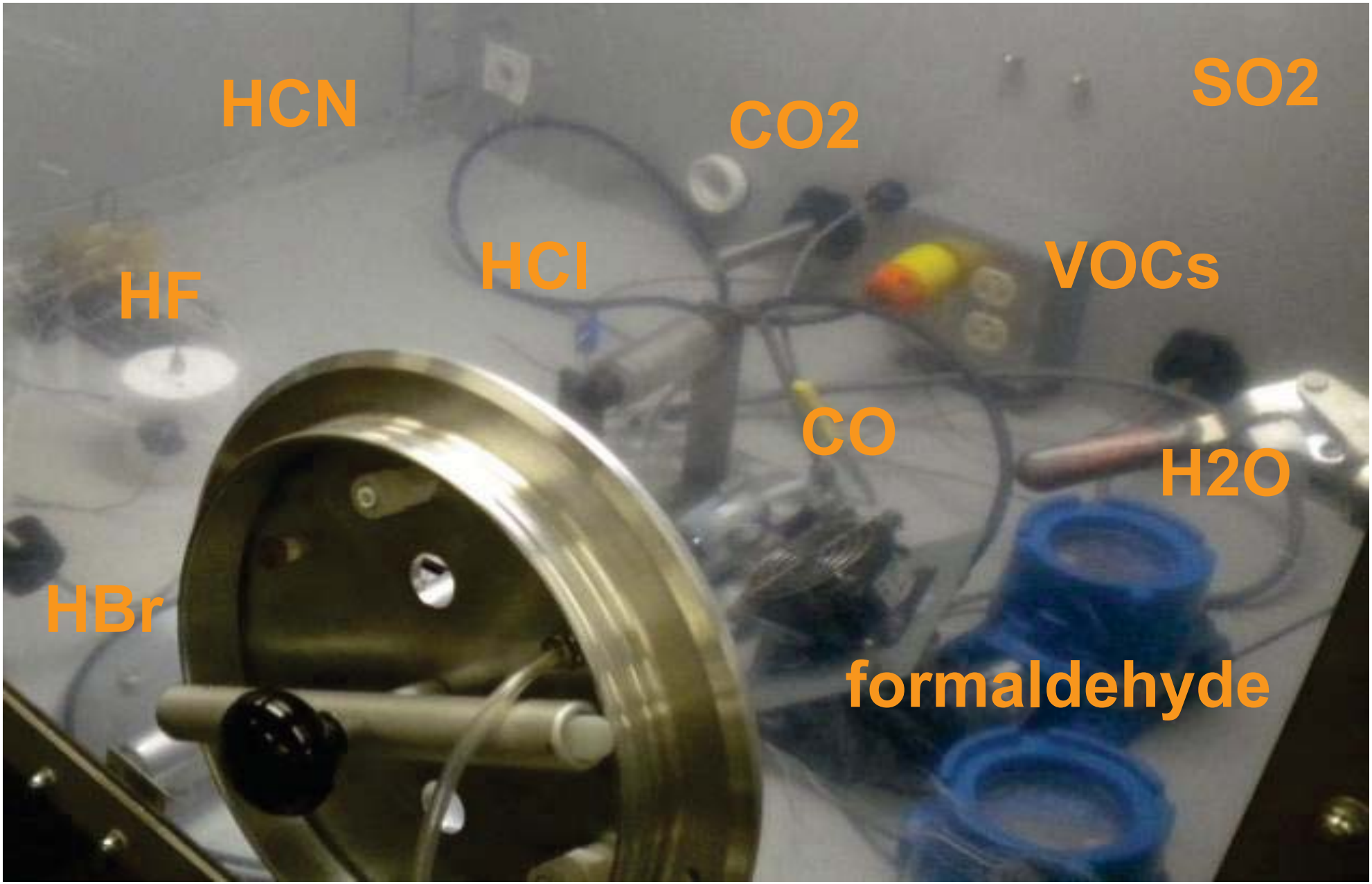
Aerosol Signatures—Teflon/Kapton Mixtures



Aerosol Signatures—Circuit Card vs. Temperature



Chemical Products of Incomplete Combustion



Chemical Combustion Product Measurements

Target	Device	Source	Core Tech
CO	CSA-CP	ISC/JSC	Electrochemical cell
CO	Xam-5600	Draeger/JSC	Electrochemical cell
CO	Vista COMA	Vista Photonics	Multipass Tunable Diode Laser Spectroscopy
CO	Fixed & Portable SSFD	Makel Engrg/GRC	Solid State Sensor
HCl	CSA-CP	ISC/JSC	Electrochemical cell
HCl	Vista HCPM	Vista Photonics	Enhanced Tunable Diode Laser Spectroscopy
HF	Vista HCPM & HFiii	Vista Photonics	Enhanced Tunable Diode Laser Spectroscopy
HCN	CSA-CP	ISC/JSC	Electrochemical cell
HCN	Xam-5600	Draeger/JSC	Electrochemical cell
HCN	Vista PAS	Vista Photonics	Photoacoustic spectroscopy
HCN	Pac III	Draeger/WSTF	Electrochemical cell
Anions	Wet trap/IC	WSTF	Ion chromatography
VOCs	GC/MS	HP/WSTF	Gas chromatography/mass spectrometry

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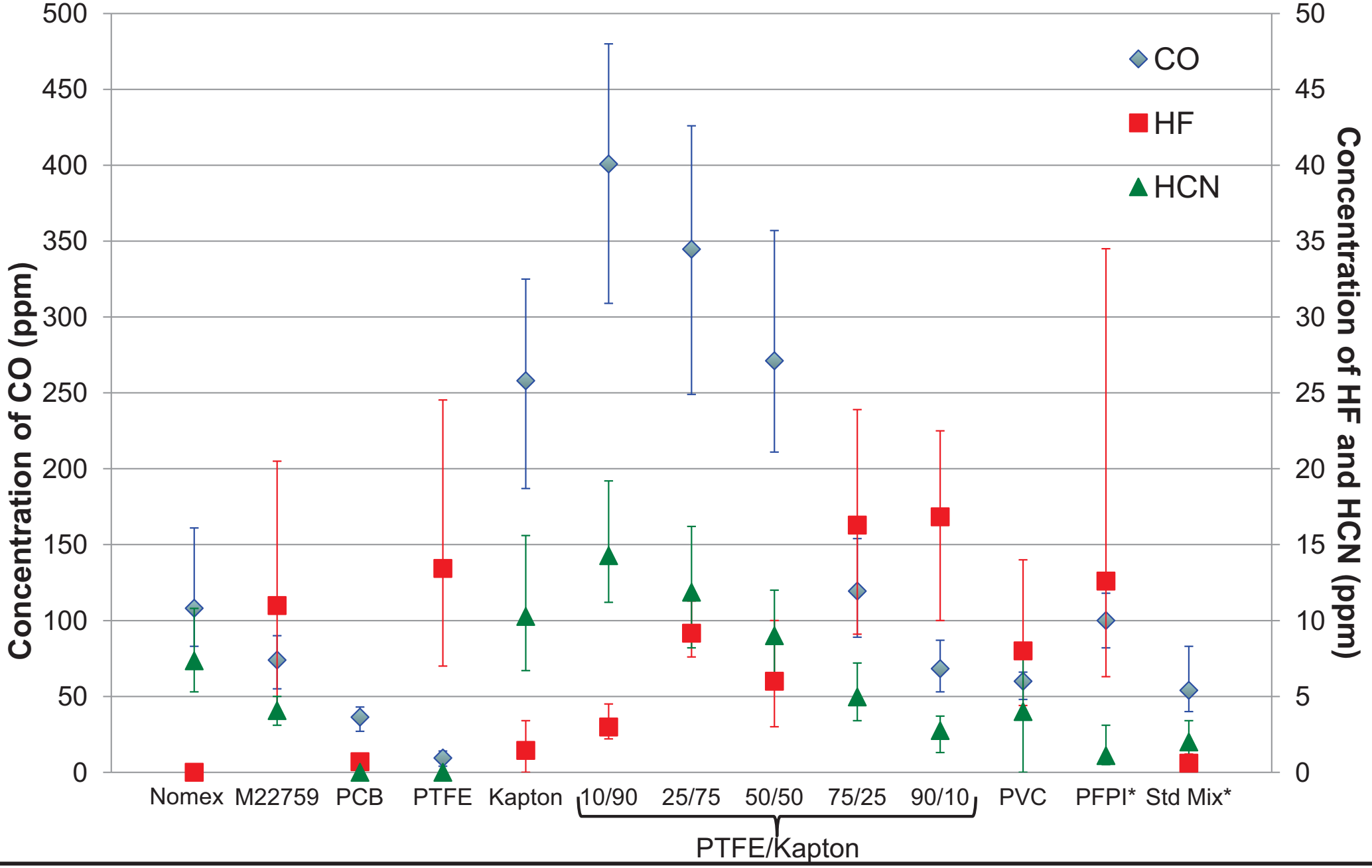
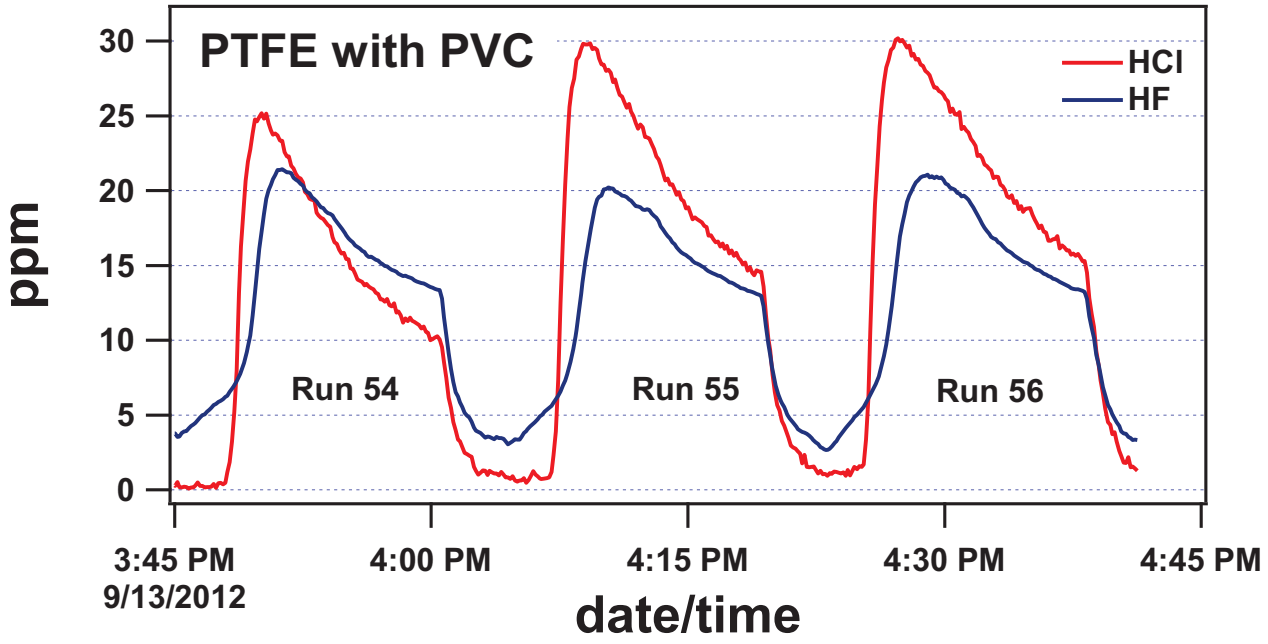
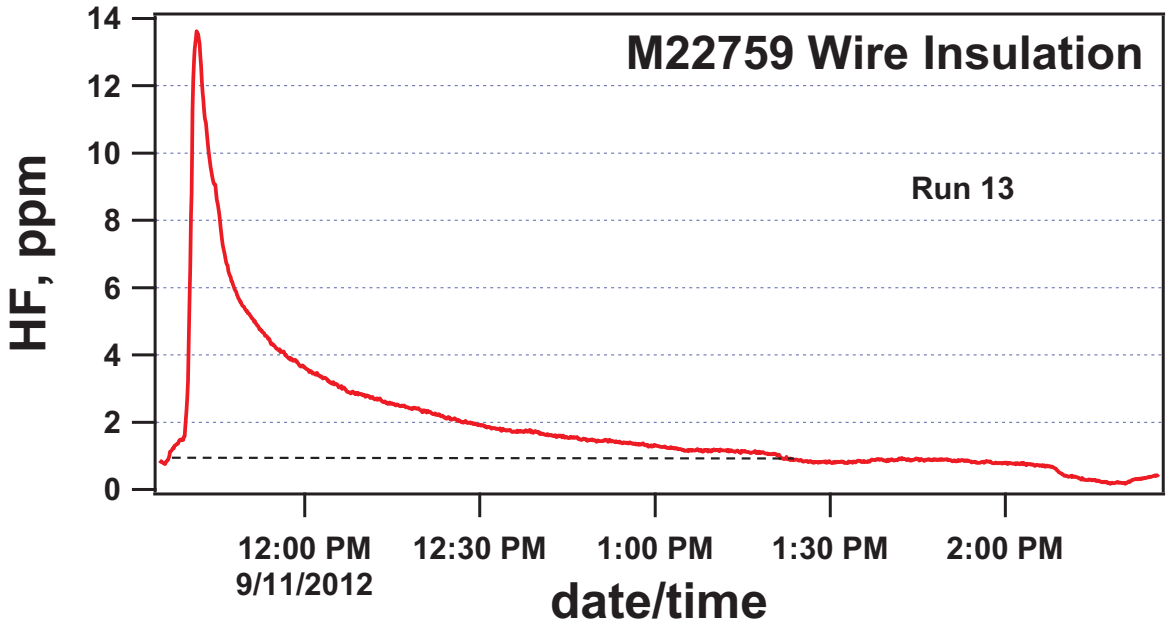
Peak Gas Production vs. Material at 640C



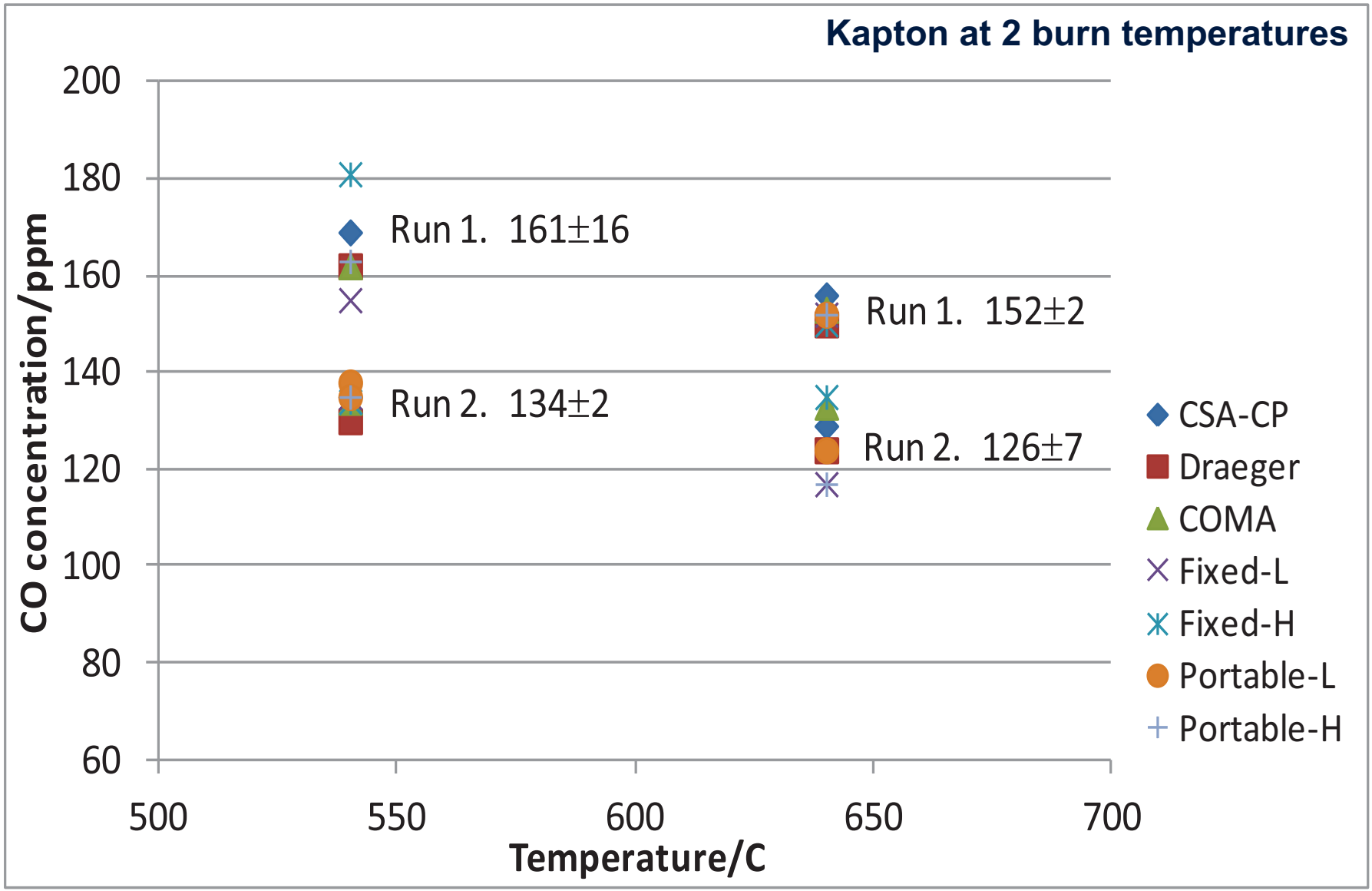
Production and Decay of Acid Gases



SMAC	HCl	HF
1 hour	5 ppm	5 ppm
24 hour	2 ppm	2.5 ppm



CO Sensor Comparison (example)



Summary and Future Work

- Most recent study indicates we have a better handle on variables and reproducibility, but some autoignition occurs
- Acid gases are produced from certain materials in significant quantities and persist for 10's of minutes in the chamber
  - This result indicates acid gases may persist for hours in a spacecraft
  - This result is rationale for adding HF to the short list of monitoring targets
  - Acid gases HCl and HF simultaneously measured via TDLS technology
- Future research is needed for minimally processed fuels (native state)
  - e.g. Determine lowest temperature at which we can detect particles
- Forward work to include more detailed study of 2-3 select materials, single temperature, improve reproducibility
- Study acid gas production and decay
- Explore effect of ignition on acid gas production

Team Photos