Boron Nitride Additive for Advanced Propellants

Insensitive Munitions and Energetic Materials Technology Symposium
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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Outline

- Introduction to pH Matter, LLC

- Background

- BN Nano-particle Characterization

- Dispersion Characterization

- Propellant Testing

- Coating Characterization

- Conclusions / Future Work

pH¹ Matter LLC

Develop innovative nano-materials for emerging applications in energy and defense.

- Founded in 2010

- Catalysts and related C and BN nano-materials

- In-house manufacturing equipment

- Ohio State University characterization facilities

- Army needs more powerful and balanced propellants

- Barrel wear and erosion is a problem

- BN is interesting because:

  - Hexagonal BN is lubricating

  - Boron doping of steel improves its hardness

  - Resistant to chemical attack
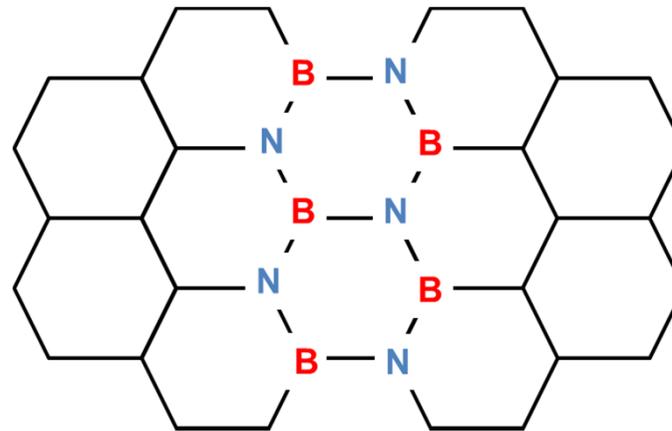
pH¹ Matter LLC

Approach:

Additive + Propellant → **Mix and extrude** → **Propellant Composite** → **Propellant Fired** → BN$_x$O$_y$ coating / B-doped Fe (dramatized image) **Coated and Hardened Barrel**

pH¹ Matter LLC
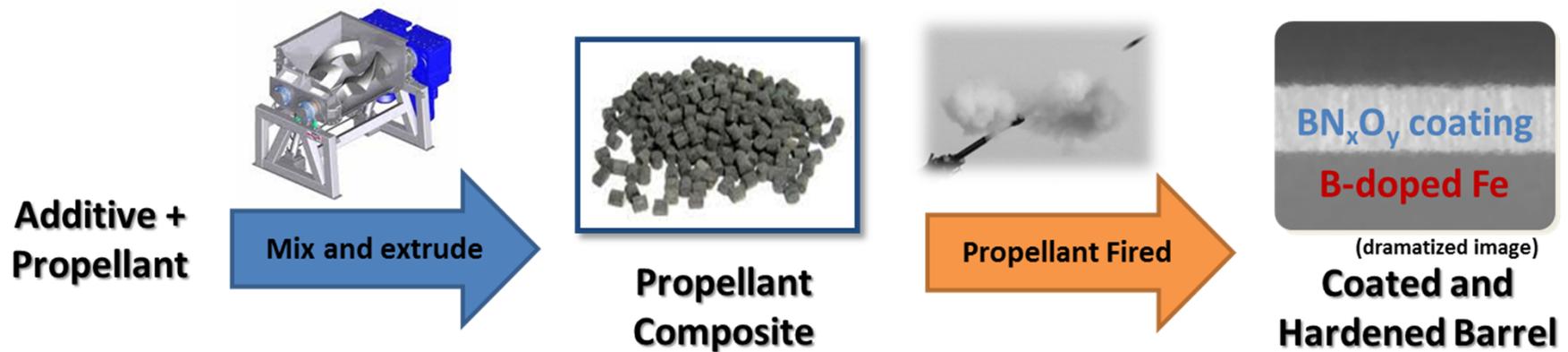
Particles Size / Surface Area Control

Synthesis Condition	Surface Area (m²/g)	Calculated Particle Diameter (nm)
High Conc. A	20.0	143
High Conc. B	23.0	124
Intermediate Conc. A	37.8	76
Intermediate Conc. B	51.2	56
Low Conc.	77.4	37

BN Characterization
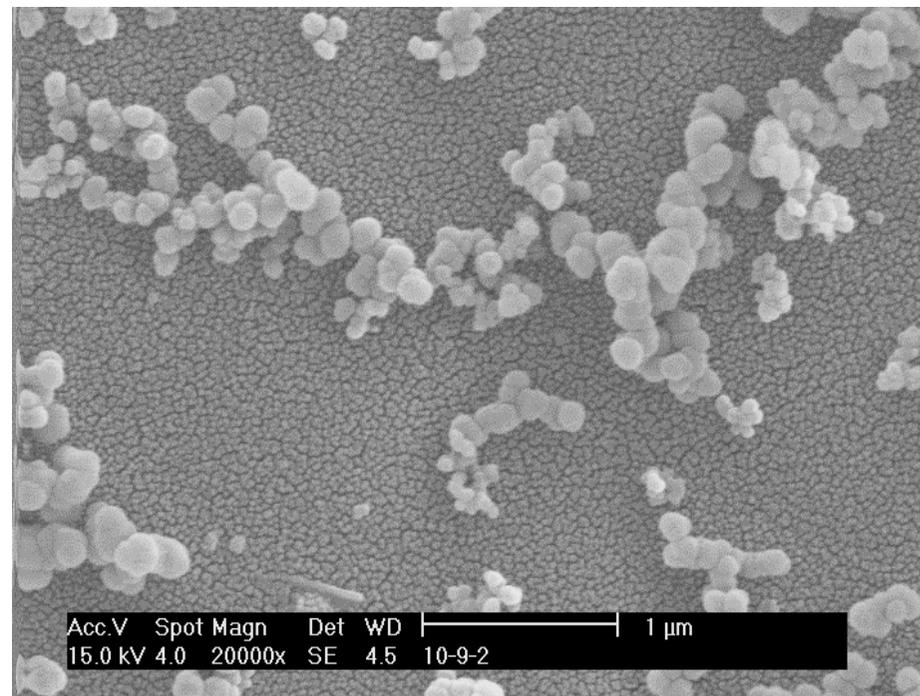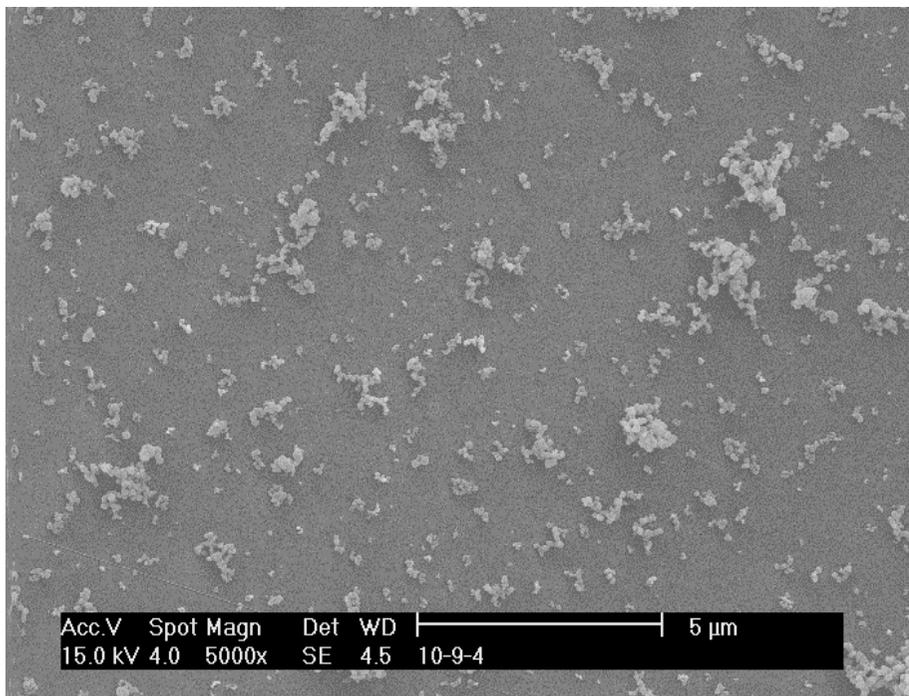
SEM Imaging

TEM Imaging
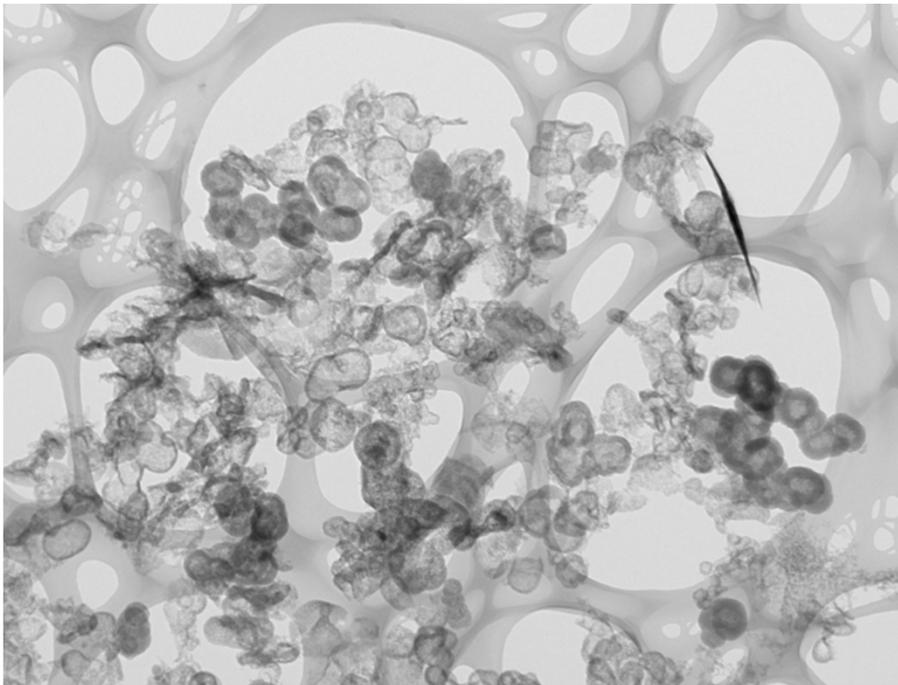
A4-01.tif
A4 - BN   500 nm
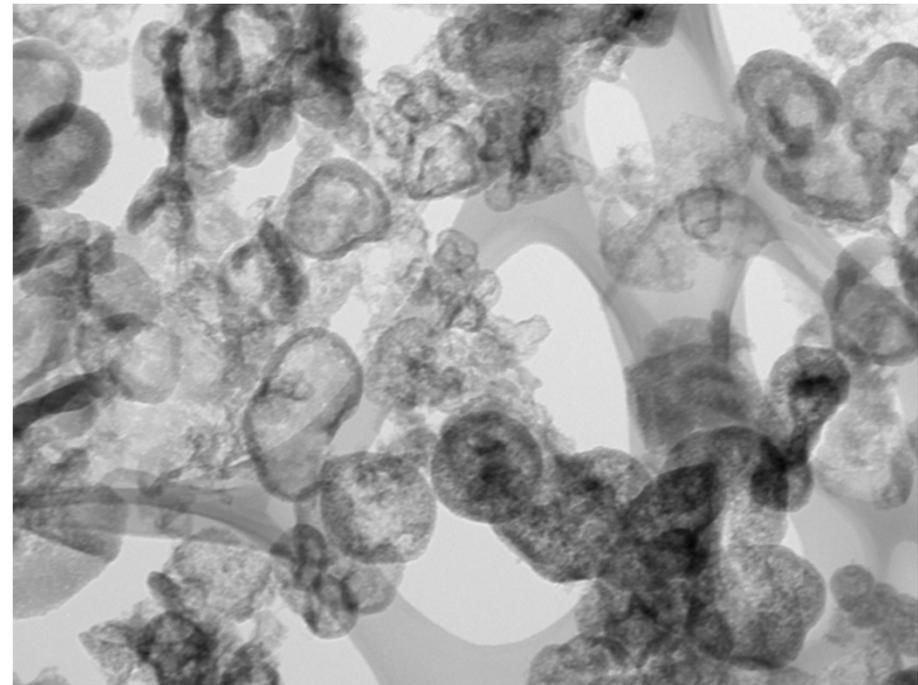
A4-02.tif
A4 - BN   100 nm

BN Characterization

EELS Analysis


Legend:
- Spectrum
- Background
- Signal
- X–section
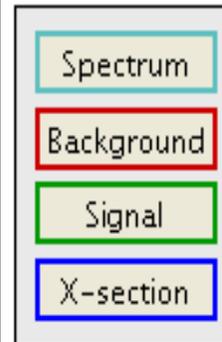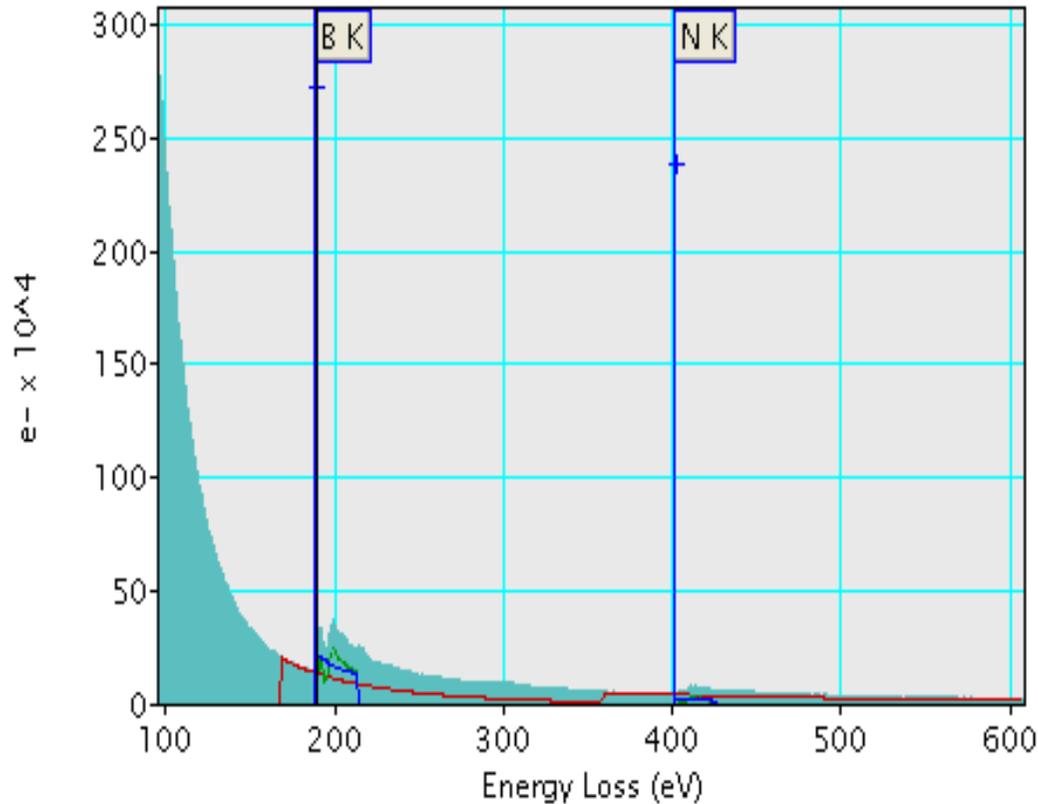
Experimental Conditions

Beam Energy: 200 keV
Convergence Semi-Angle: 5 mrad
Collection Semi-Angle: 1.5 mrad

Composition Information

Elem.	Atomic ratio (/B)	Percent content
B	1.00 ± 0.000	52.37
N	0.91 ± 0.129	47.63

XPS Analysis – N 1s Region

BN Characterization
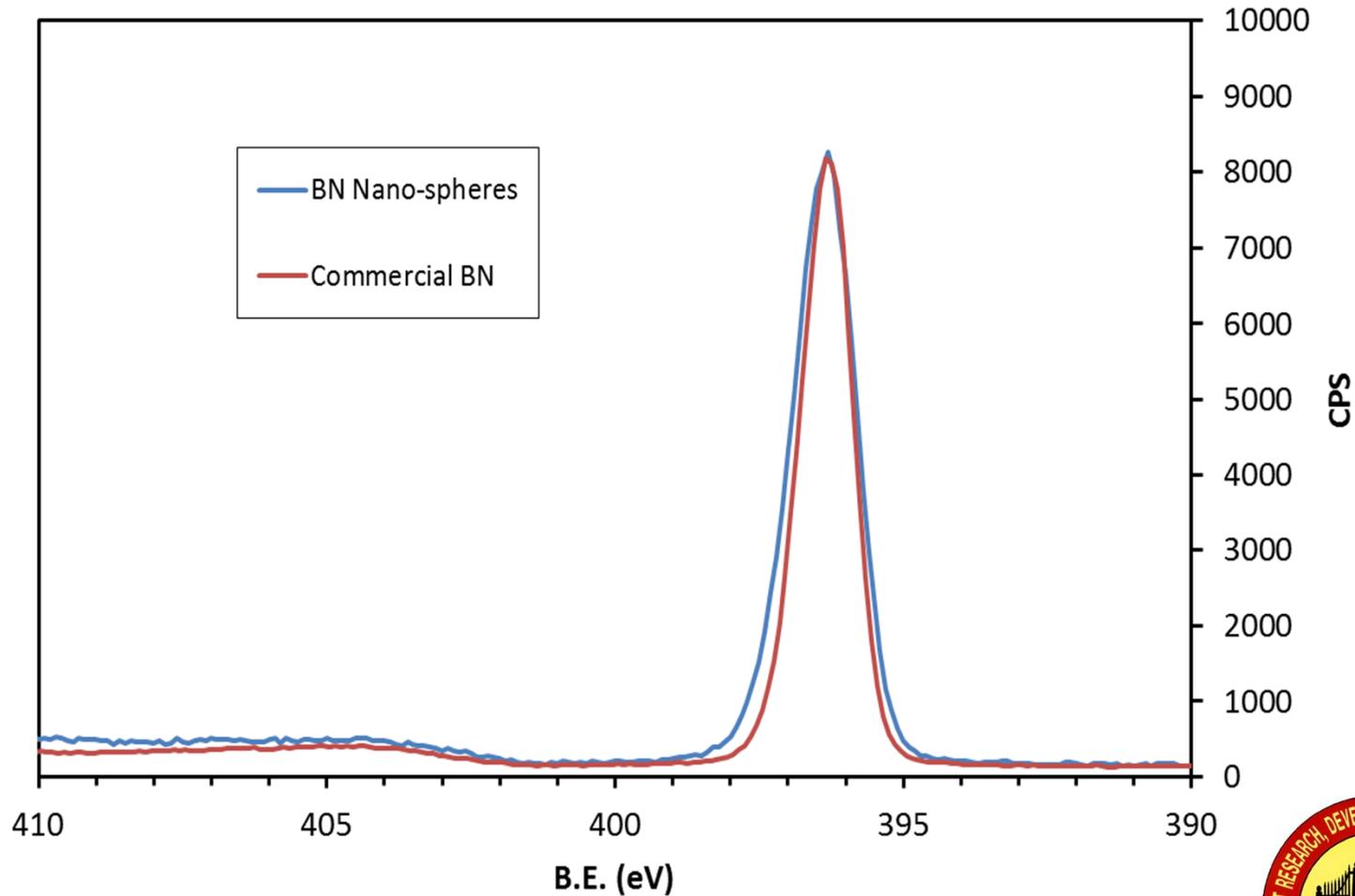
XPS Analysis – B 1s Region
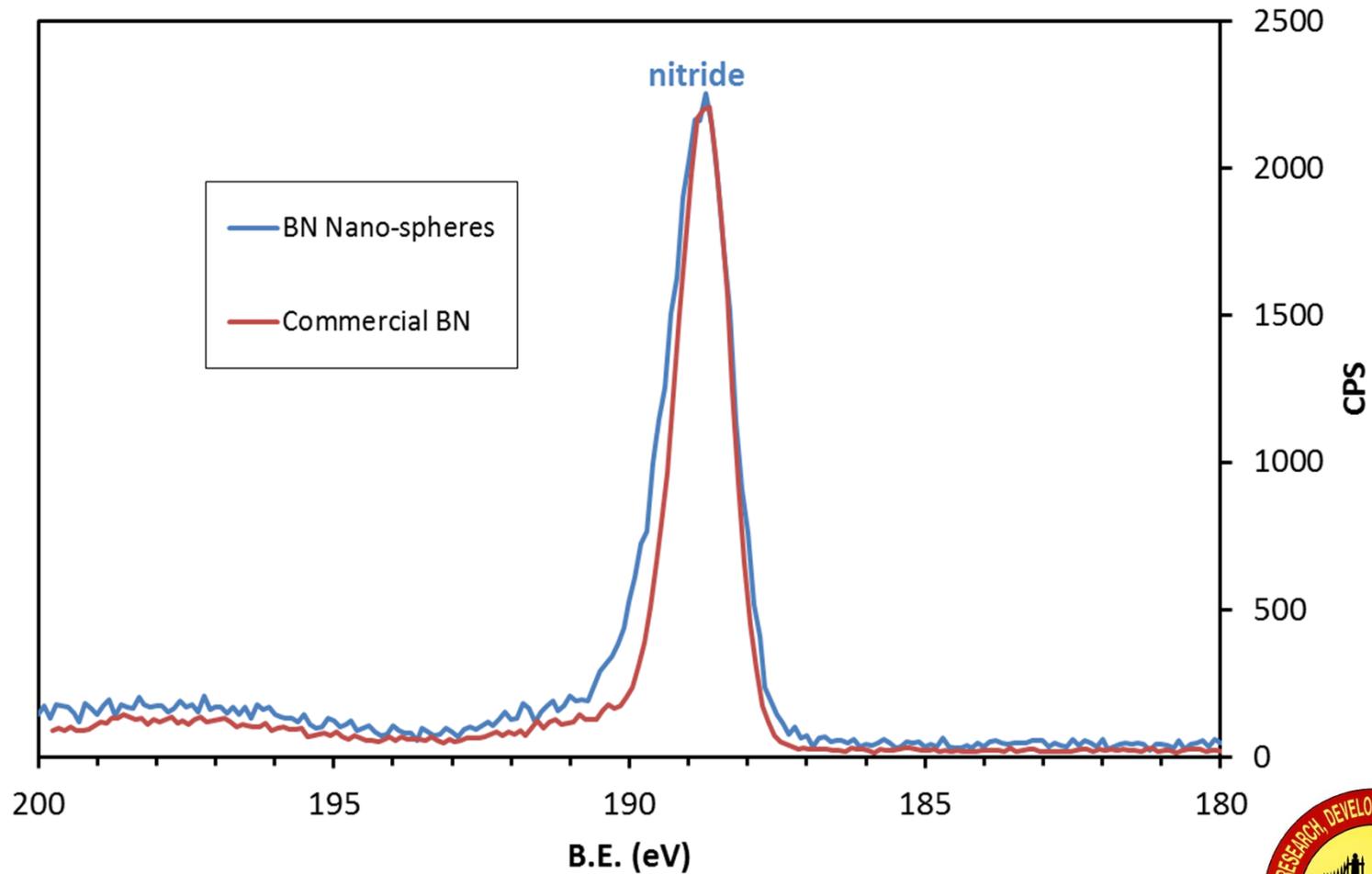
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## Procedure

- 1:1 ethanol:acetone solvent

- Ultrasonication until even dispersion

- Mixed with softened propellant

Dispersion

Light Microscope

Improved dispersion

SEM Imaging

Acc.V Spot Magn Det WD 20 µm
10.0 kV 4.0 625x SE 5.0 4
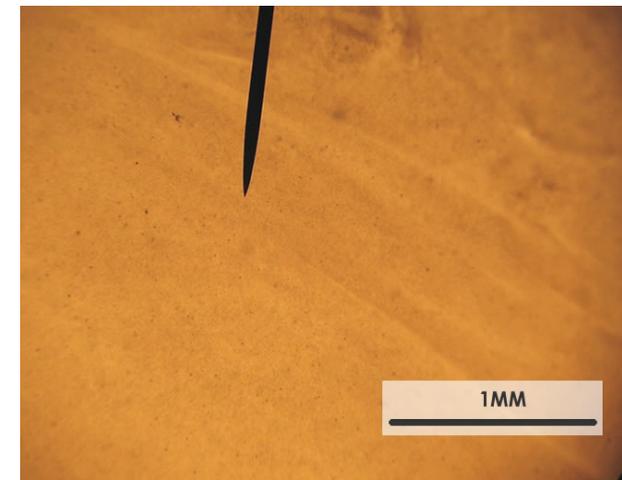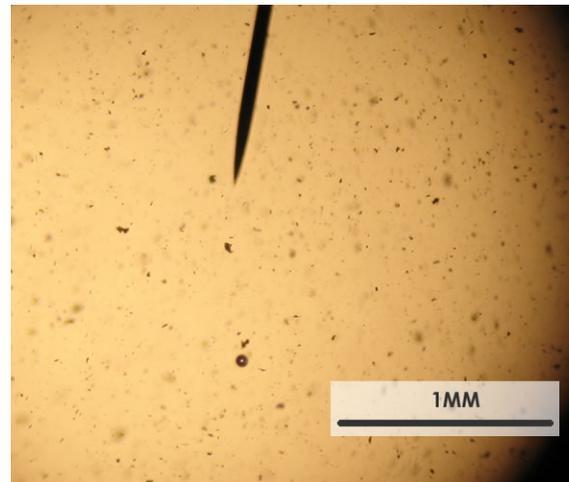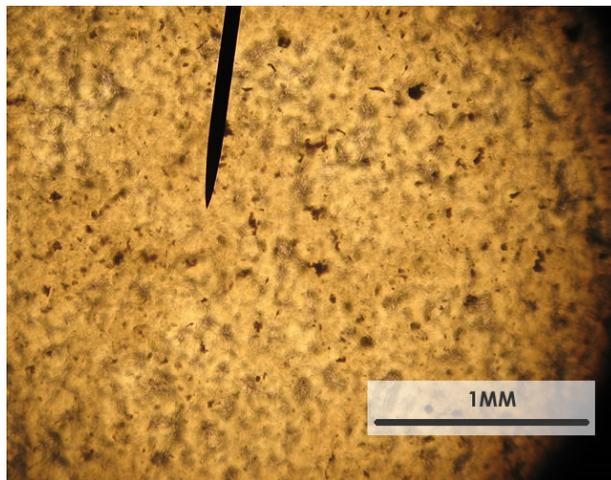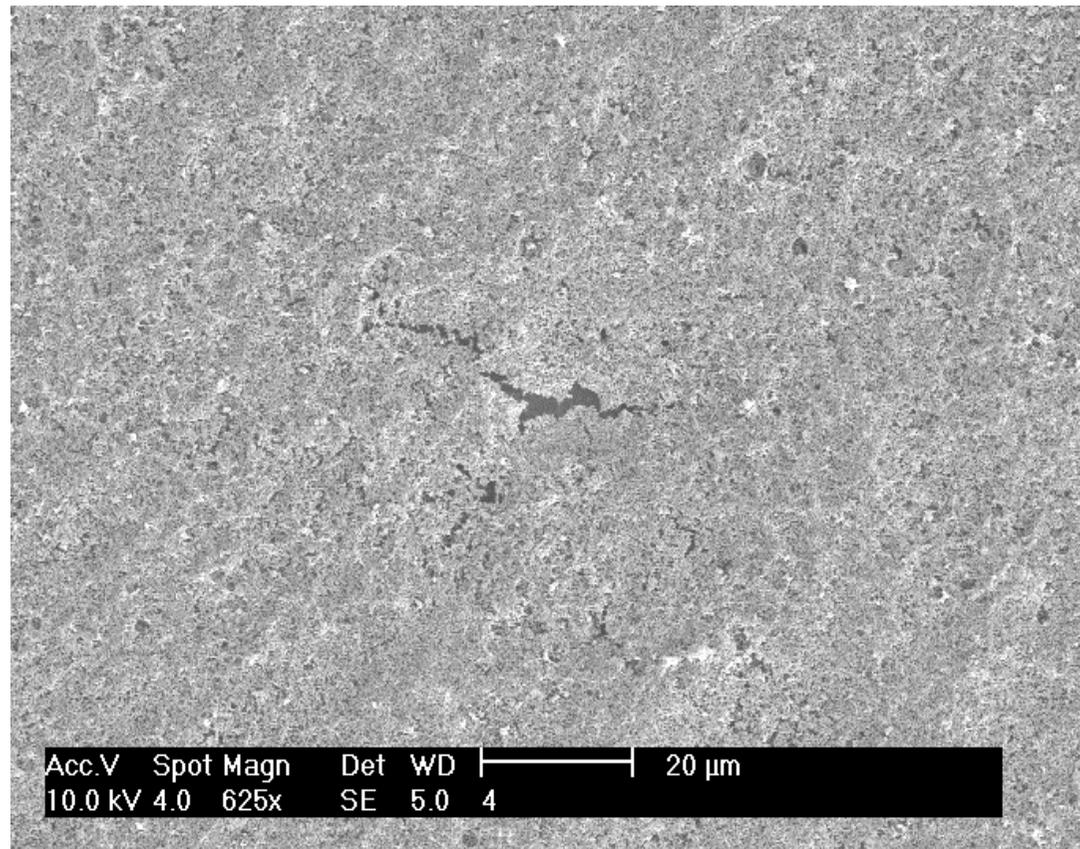
SEM Imaging
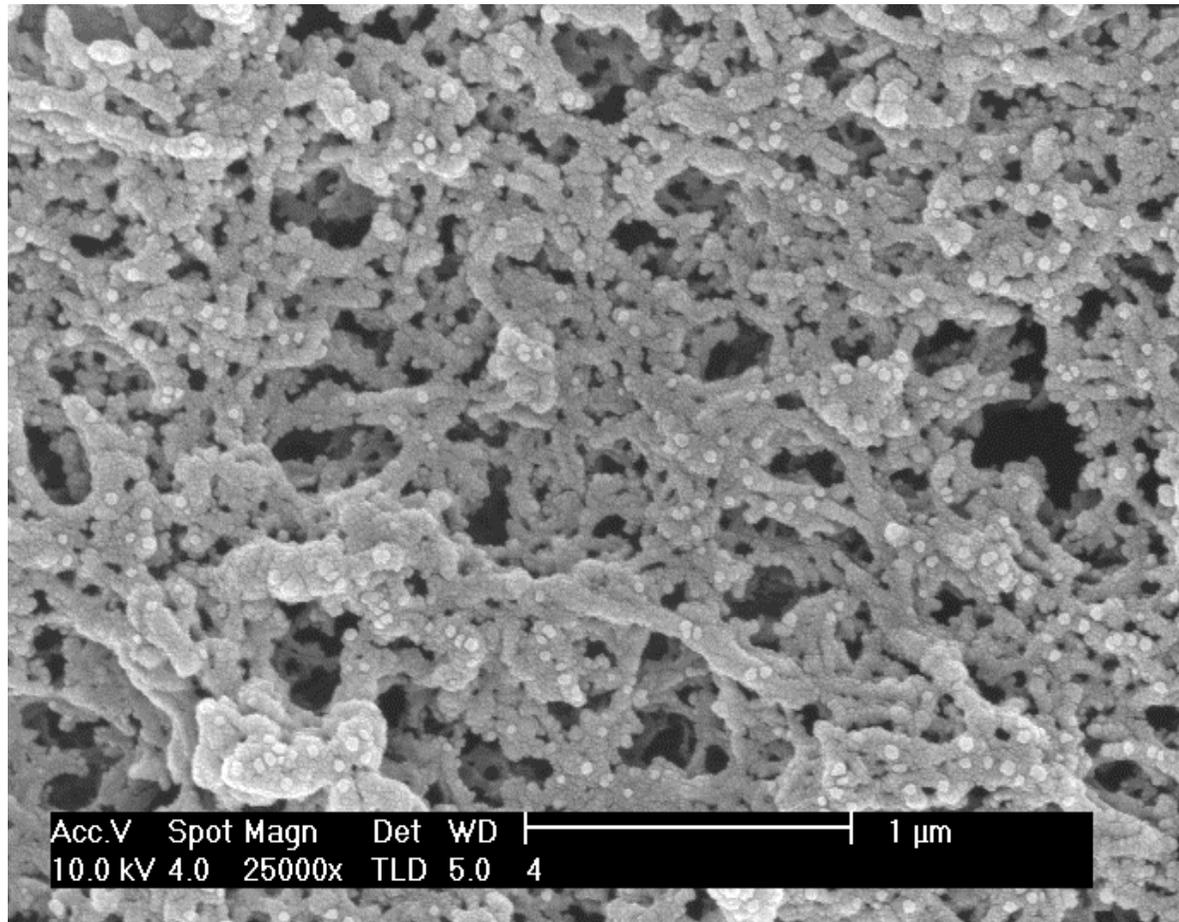
IMR-4198 Composition

Propellant Name	Nitrocelulose Composition (wt%)	Dinitrotolulene Composition (wt%)	Other Components (wt%)
M1	86%	9.9%	3% Dibutylphtalate 1% Diphenylamine
M14	90%	8%	2% Dibutylphtalate 1% Diphenylamine 0.7% Residual solvent 0.6% Moisture 0.2% Graphite
IMR 4198 (Hodgdon)	>85%	<10%	<10% Non-hazardous additives

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Propellant Testing

DSC Testing

Propellant Material Tested	Heating Rate (°C/min)	Sample Amount (mg)	Exotherm		
			Onset (°C)	Peak (°C)	End (°C)
IMR4198 w/o BN	10	0.36	162	206	265
	10	0.15	162	207	265
	10	0.58	159	207	265
Average			161	207	265
IMR4198 w/ 2% BN	10	0.22	163	207	265
	10	0.40	158	207	265
	10	0.45	161	207	265
Average			161	207	265

Heat of Combustion

Material Tested	Heat of Combustion; ASTM D240 (J/g)
IMR-4198 w/o BN	10038
IMR-4198 w/ 2% BN	10036

Closed Bomb Testing

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Propellant Testing

<u>Closed Bomb Testing</u>

Material Tested	Amount (gram)	Chamber pressure (psig)	Observations
IMR-4198 w/o BN	5.0	10k*	Oxidation (rust color)
	7.5	15k*	Deep oxidation (rust)
Mix 50/50 of pure and composite (1% BN)	5.0	10,250	Black residue on the surface, no visible oxidation
IMR-4198 w/ 2-wt% BN	5.0	10k*	Black residue on the surface, no visible oxidation
	7.5	15k*	Possible slight oxidation (green color)
IMR 4198 as received	5.0	9,170	Reference sample, used high speed DAQ system.
	7.5	15,470	Reference sample, used high speed DAQ system.

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Closed Bomb Inserts

(a) No BN, 10K psi

(c) 1% BN, 10K psi

(d) 2% BN, 10K psi

Closed Bomb Inserts



(b) No BN,
15K psi

(d) 2% BN,
15K psi

Insert Characterization

XPS Analysis
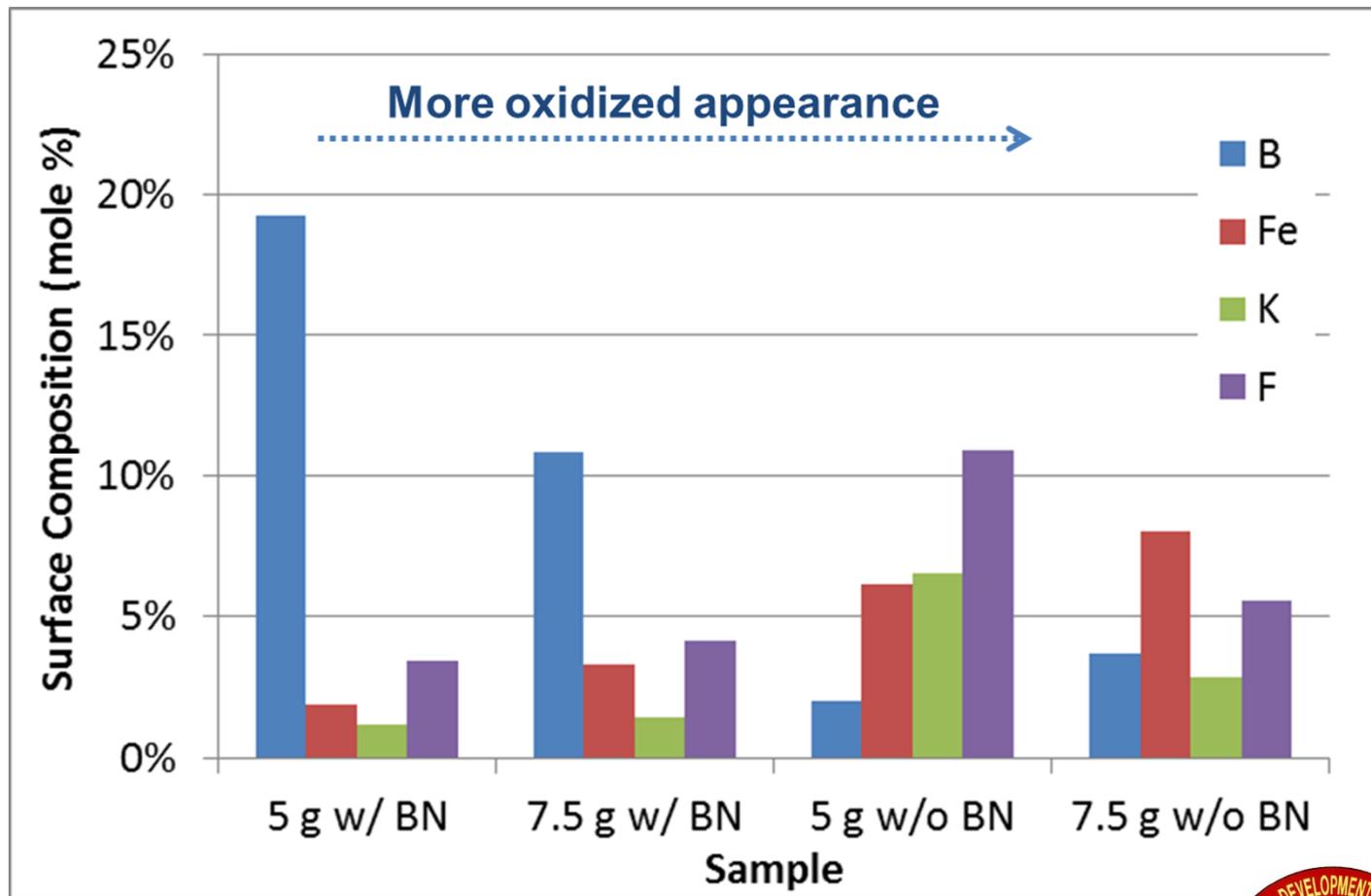
SEM – Fresh Insert

SEM – Insert Fired w/o BN

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Insert Characterization

## SEM – Insert Fired w/o BN


SE   03-Jul-13   WD 9.7mm 15.0kV x10k   5um

SEM – Insert Fired w 2-wt% BN
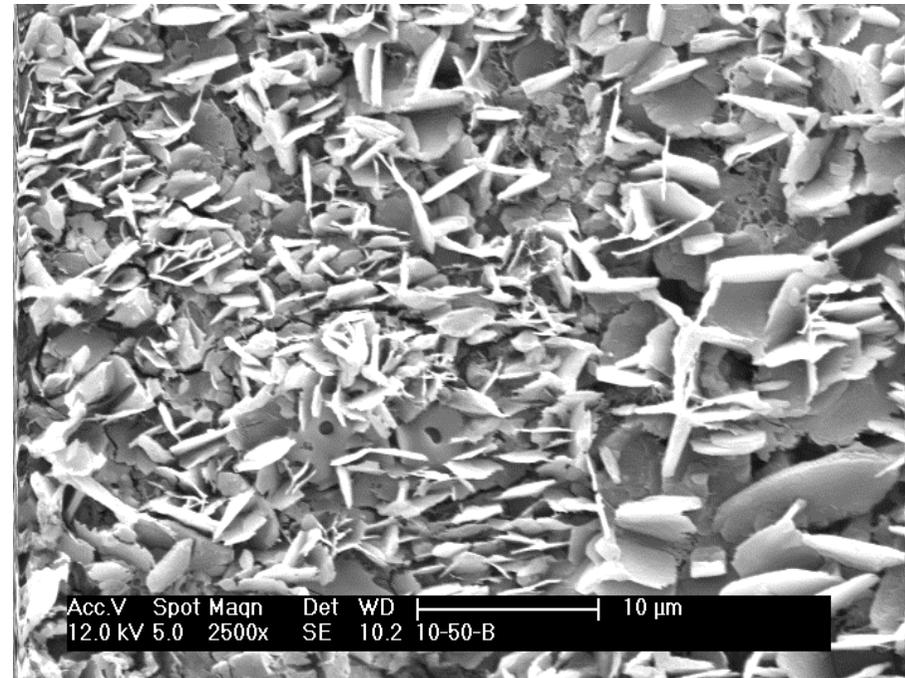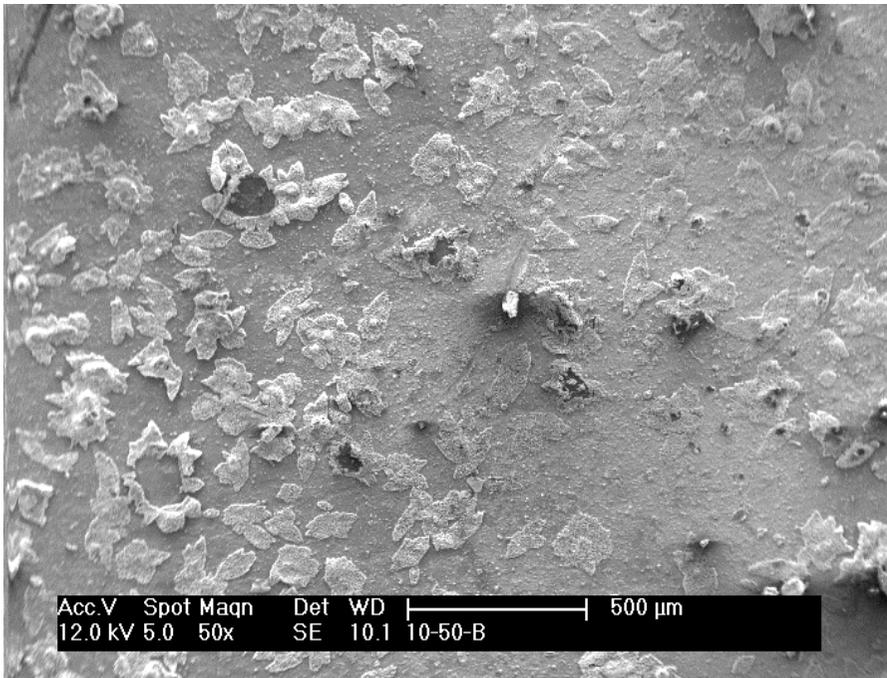
Conclusions/Future Work

- Scalable/economical process for BN nano-particle synthesis demonstrated.

- Dispersion in propellant demonstrated.

- No destabilizing effects on propellant.

- Evidence for reduced corrosion observed.

- Boron-based coating was observed.

- Next Step: wear and erosion testing in projectile test stand.

- Future work: examine additional additive applications.

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Acknowledgements

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