Characterization of Air Particulate Matter from Radiological Dispersal Devices

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Introduction

In 2004, Defence Research and Development Canada (DRDC) launched an initiative to provide insight into possible Radiological Dispersal Device (RDD) terrorist attacks. These types of attacks are of growing concern for Canada.

Sandia National Laboratory (USA) has been performing explosive tests on the behaviour of metal sources in RDDs. However, there is a lack of knowledge concerning the behaviour of ceramic materials.

The information gained by this project will provide insight into the processes that occur during the explosion as well as an understanding of the dispersal patterns of the particles. Understanding how these explosives behave will in turn be used to develop a protocol for first responders who may be the first on scene following this kind of attack.

Research Objectives

The **objective** of this research was to characterize the morphology and chemical composition of particulate matter collected from explosive tests of non-radioactive analogues of $SrTiO_3$, $CaTiO_3$, and CeO_2.

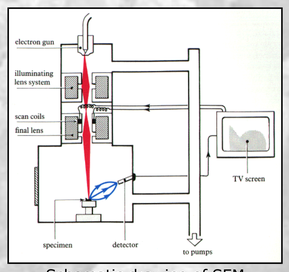
- $SrTiO_3$ was used to simulate the radioactive Sr-90.
- $CaTiO_3$ was used to simulate $SrTiO_3$ (outdoor).
- CeO_2 was used as a mechanical surrogate for PuO_2, UO_2 and AmO_2.

Experimental Methods

1. Explosive tests of ceramic samples were conducted inside a specialized silo.
2. Air particulate filters samples were mounted on aluminum stubs and coated with Au/Pd.

Fireball during explosion inside the silo.

Typical filter when it is first received and filters coated with Au/Pd.



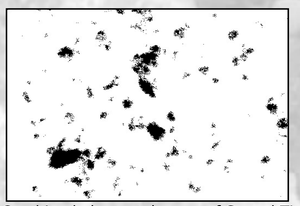
Schematic drawing of SEM

3. Characterize morphology and composition
   - JEOL JSM-5900LV SEM
   - Princeton Gamma-Tech IMIX-PC EDS system
     - secondary electrons
     - backscatter electrons
     - x-rays

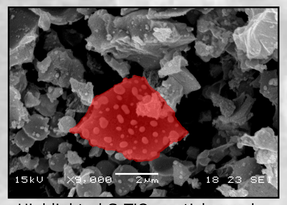
SEM/EDS system that was used

4. Global measurements: percent area fraction.

   Feature measurements: particle area, diameter, fractal dimension, roundness, aspect ratio.



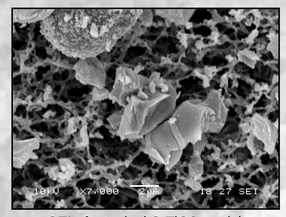
Combined elemental maps of Sr and Ti used to calculate % area fraction.



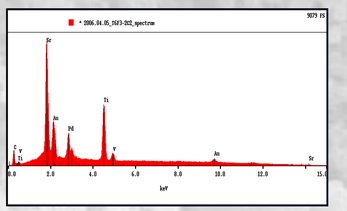
Highlighted $SrTiO_3$ particle used Calculate feature measurements.

Results and Discussion

- Both $SrTiO_3$ and CeO_2 particles generally had similar morphologies
- The physical measurements of each particle spanned a broad range.
- The particles were generally smooth, with relatively angular edges.
- Many particles also exhibited rounded bumps that were probably smaller particles melted to the surface.



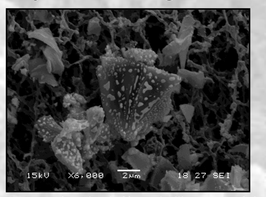
SEI of a typical SrTiO3 particle
Accelerating voltage: 10kV, magnification: 7,000X, spot size: 27, working distance: 18, aperture 2



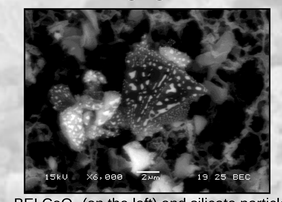
EDS spot analysis spectrum showing particle contains Sr and Ti.
Accelerating voltage: 10kV, magnification: 7,000X, spot size: 50, working distance: 18, aperture 3

- $SrTiO_3$ and CeO_2 particles appeared brighter when observed by the backscatter detector their large atomic number.

Secondary electron imagine vs. backscatter electron imaging;

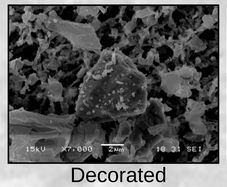


SEI CeO_2 (on the left) and silicate particle
Accelerating voltage: 15kV, magnification: 6,000X, spot size: 27, working distance: 18, aperture 2

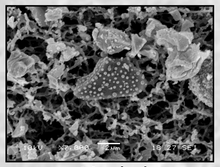


BEI CeO_2 (on the left) and silicate particle
Accelerating voltage: 15kV, magnification: 6,000X, spot size: 25, working distance: 19, aperture 3

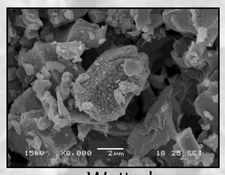
- Four different types of surface features that were observed consistently in all samples: decorate, mottled, wetted, partially melted.
- These four different types of surface features can be categorized into different stages of melting.
- The degree of melting is probably related to the location of the particle within the fireball during the explosion.



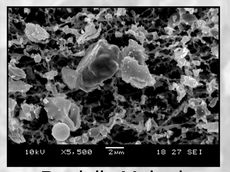
Decorated



Mottled



Wetted



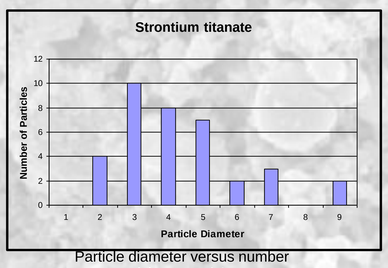
Partially Melted

The feature particle analysis preformed in Adobe Photoshop gave the following results for $SrTiO_3$ and CeO_2;

	$SrTiO_3$	CeO_2
Particle Area ***(range)***	$3 \pm 2 – 40 \pm 2 \mu m^2$	$10 \pm 2 – 51 \pm 2 \mu m^2$
Equivalent Diameter ***(avg)***	$4.3 \pm 0.1 \mu m$	$5.4 \pm 0.2 \mu m$
Roundness* ***(avg)***	0.6 ± 0.1	0.6 ± 0.1
Fractal Dimension ***(avg)***	1.01 ± 0.02	1.01 ± 0.09

*Perfect circle having value of 1.00

- Most of the particles were found to range from 3-5 µm in size.
- Particles with a diameter around 2.5 µm can have serious health implications if they are inhaled.



Particle diameter versus number of those particles

- No trends were observed between particle diameter and the filter height.
- No trends were observed between percent area fraction and filter height.

Acknowledgements