Processing and Characterization of Nano RDX

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Introduction

- **Common high explosives including RDX, HMX, and CL-20 are vulnerable to accidental initiation**
- **Accidental initiation may be caused by stimuli including:**
  - Bullet or fragment impact
  - Incident shock waves from adjacent detonation
- **Sensitivity of a HE to incident energy is associated with:**
  - Chemical structure
  - Physical properties (crystal size, shape, defects)
  - Formulation characteristics (binder material /processing)
- **Sensitivity generally increases with power**

Introduction

- **Experimental data and theoretical models indicate that reduction of the crystal size should generally lead to a lowered sensitivity**
- **Some effects of size reduction include:**
  - Smaller size of crystal defects
  - Smaller size of inter-crystal voids
  - Improved mechanical properties
    - Enhanced resistance to plastic deformation
  - Due to a larger number of heterogeneities with smaller dimensions a more homogeneous distribution of incident energy

Objectives

- Develop method for the bulk production of high quality and purity nanocrystalline RDX
- Prepare explosive formulations using nano-RDX
- Determine the effects of particle size reduction on the sensitivity and performance:
  - Shock and impact sensitivity
  - Detonation characteristics:
    - Critical diameter

RESS Process Background

Rapid expansion of supercritical solutions (RESS) using carbon dioxide as solvent was successfully demonstrated to recrystallize RDX with following product characteristics:

- Nano-scale dimensions
- Narrow size distribution
- High purity
  - No residual solvents
- Near-spherical crystal shape

V. Stepanov et al., Propellants, Explosives, Pyrotechnics, 3, 2005

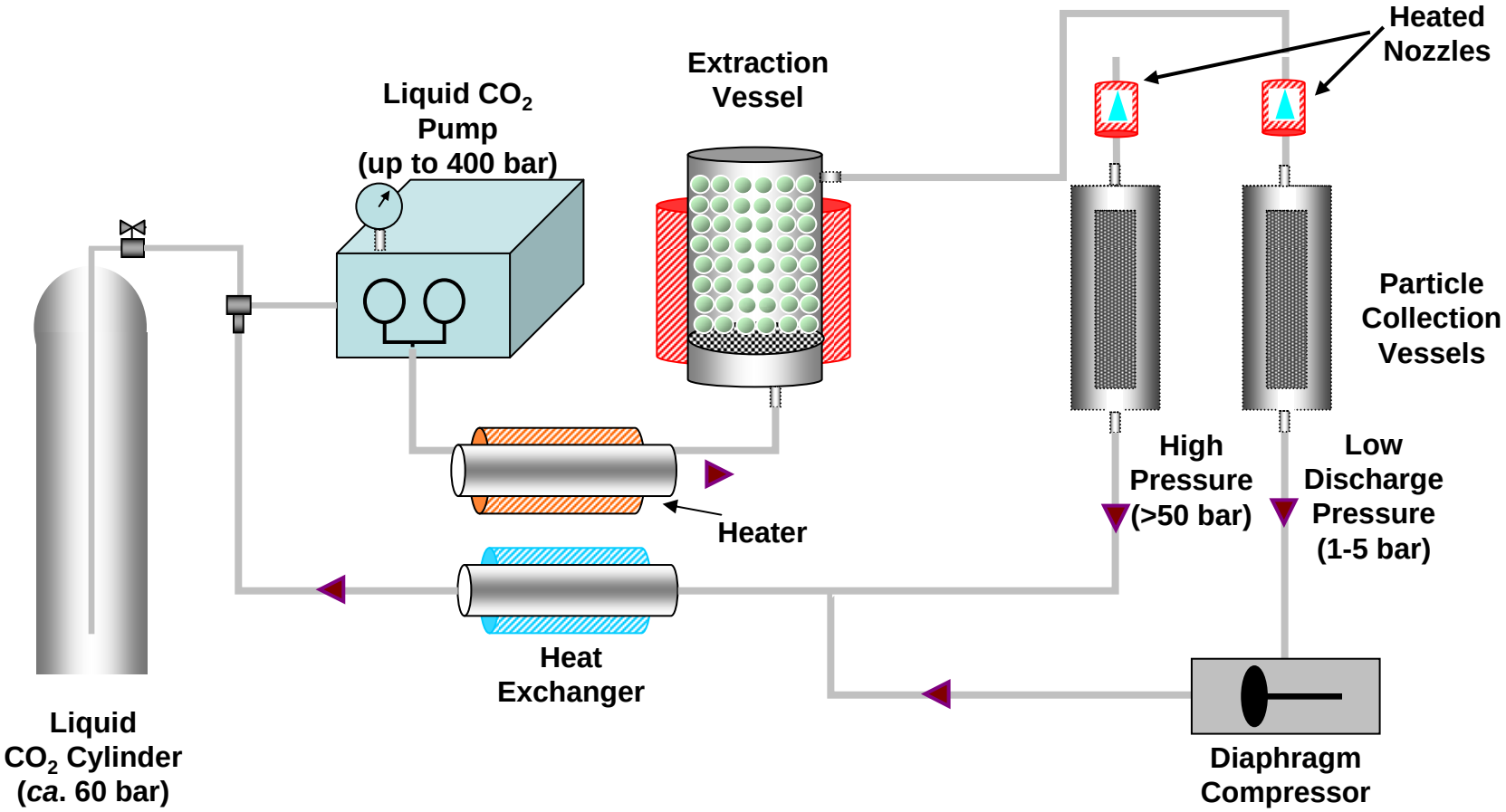
RESS Process

To generate bulk quantities of nano-RDX required for testing, a high throughput RESS process was developed with following characteristics

- Continuous processing
- Solvent (CO_2) Recycling
- Efficient product collection
- Variable discharge pressure operation

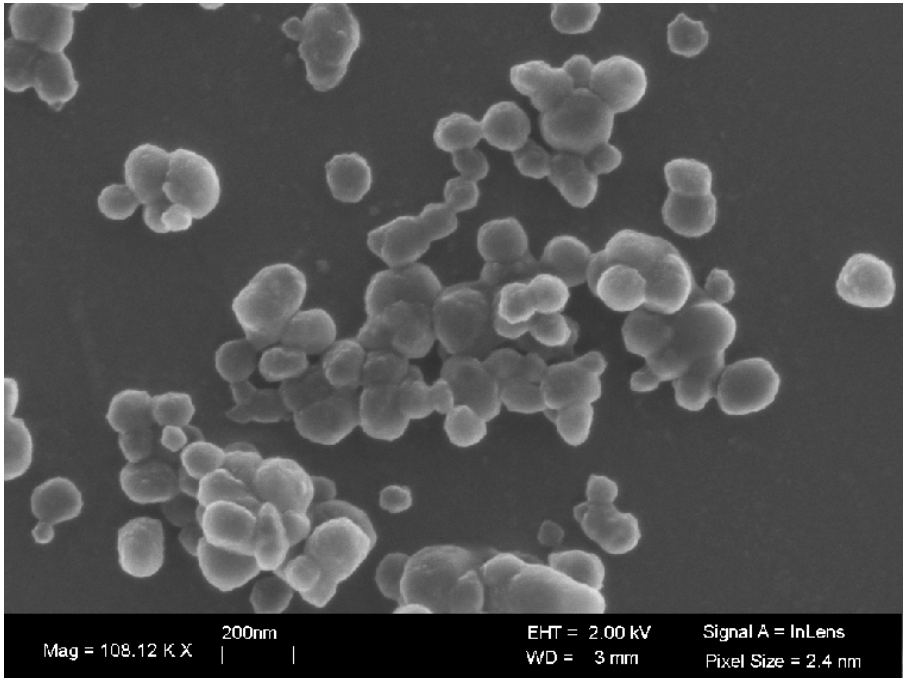
Experimental

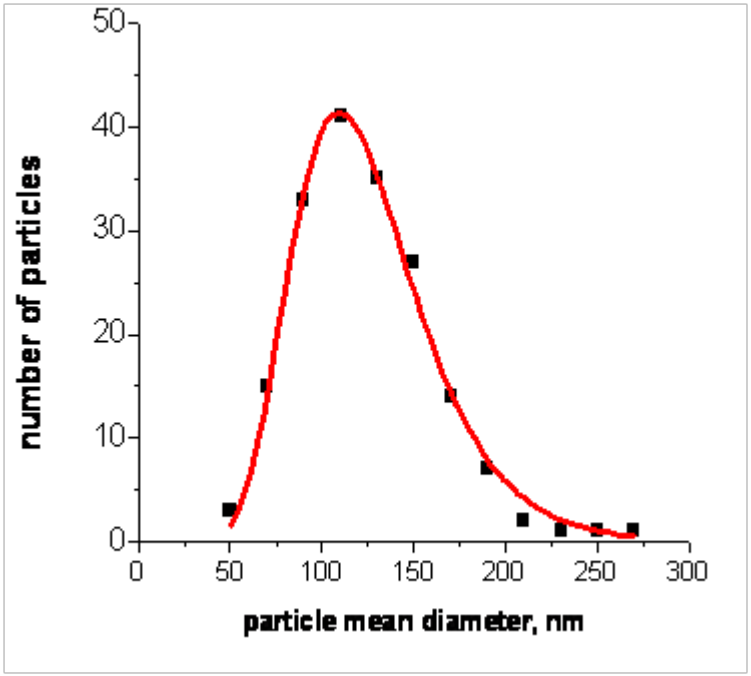
RESS Set-Up with CO_2 Recycling



Experimental

Expansion to Atmospheric Pressure (Type A Nano-RDX)



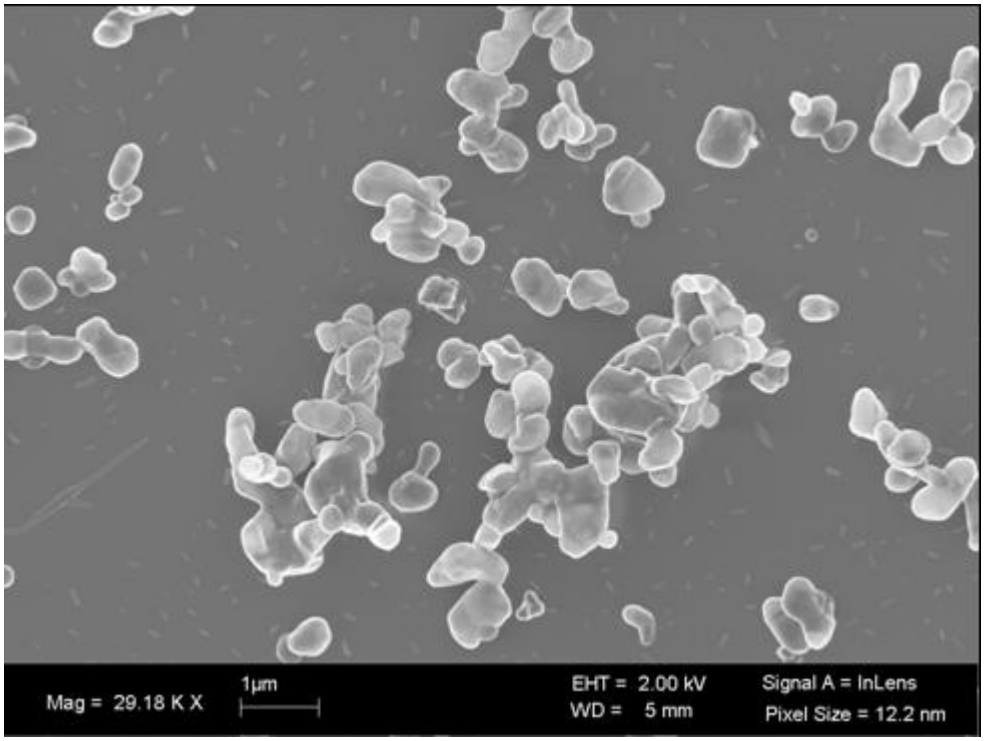


Mean Particle Size: 125 nm

Specific Surface Area (SSA): ~15-20 m^2/g

Experimental

Expansion to 55 bar (Type B Nano-RDX)



Mean Particle Size: ~ 500 nm

SSA: 5-6 m^2/g

Experimental

Bulk image of class-5 and nano-RDX

Sensitivity Testing

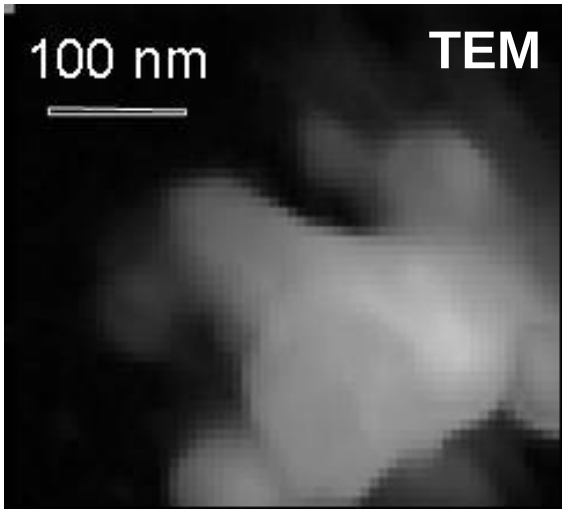
- Sensitivity testing was performed on pure and formulated nano-RDX samples. 4 μm RDX was used as the reference material.

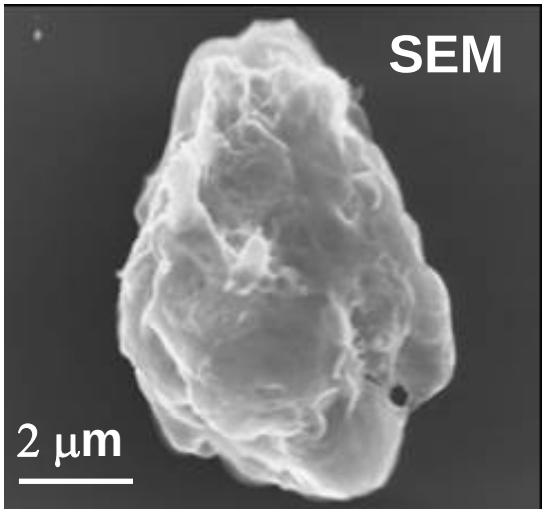
- Formulations consisted of 88 wt. % RDX and 12 wt. % wax
  - Wax applied by slurry coating in H_2O/MEK (90/10)
  - Lecithin used as surfactant to aid dispersion and stabilization

- Sensitivity tests performed:
  - Electrostatic discharge sensitivity
  - ERL type 12 impact test (impact sensitivity)
  - NOL small-scale gap test (shock sensitivity)

Coating Characterization

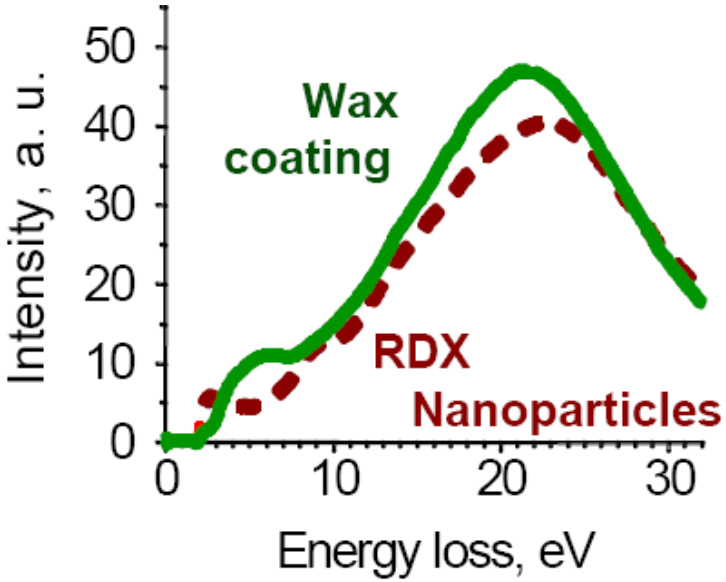
- Conventional TEM and SEM imaging of wax coated RDX nanoparticles





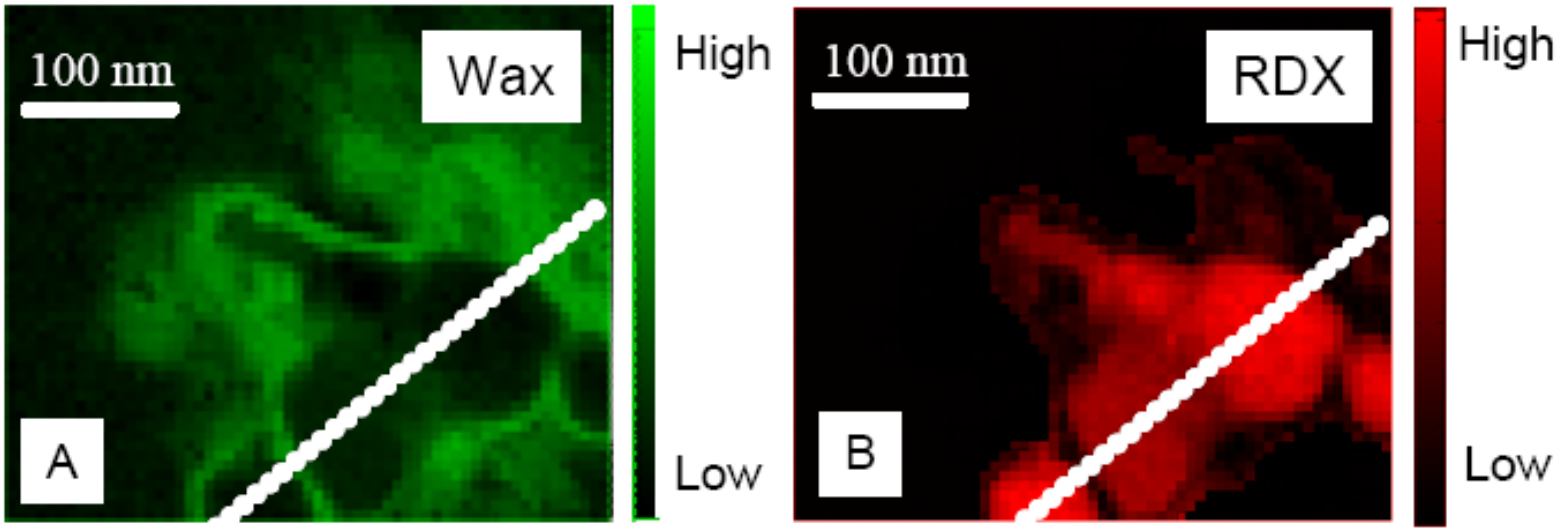
Coating Characterization

- STEM-EELS analysis used to analyze the distribution of wax on RDX. *(Prof. Matt Libera, Stevens Inst. of Tech.)*



Energy loss spectra of pure wax and pure RDX

Coating Characterization



Spatially resolved maps of the wax (A) and RDX (B) by EELS analysis

Sensitivity Testing

Pure and formulated samples tested included

- RDX recrystallized by RESS
  - Type A nano-RDX; SSA ~ 15-20 m^2/g
  - Type B nano-RDX; SSA ~ 5-6 m^2/g
- Commercially available RDX
  - 4 micron RDX; SSA ~ 1 m^2/g (Reference)
  - Class-5 RDX, ~20 μm mean size (Reference)
  - Class-1 RDX, >100 μm mean size (Reference)

Sensitivity Testing

Electrostatic discharge sensitivity test results

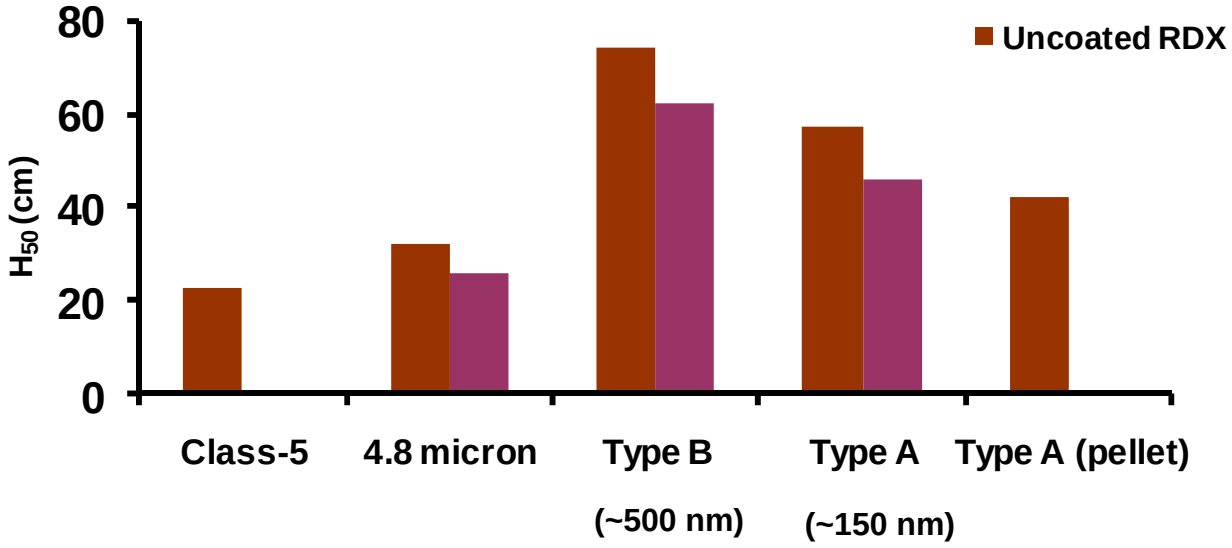
- Method 1032, MIL STD 1751A
- Maximum energy loading 0.25 J

Material	ESD Sensitivity to 0.25 J
4.8 Micron RDX	No fire
Type A nano RDX	No fire
Type B nano RDX	No fire

Sensitivity Testing

Impact sensitivity test results

- ERL/Bruceton method 1012, MIL STD 1751A
- Drop height corresponding to 50 % probability of initiation (H_{50}) determined



Sensitivity Testing

Shock sensitivity testing

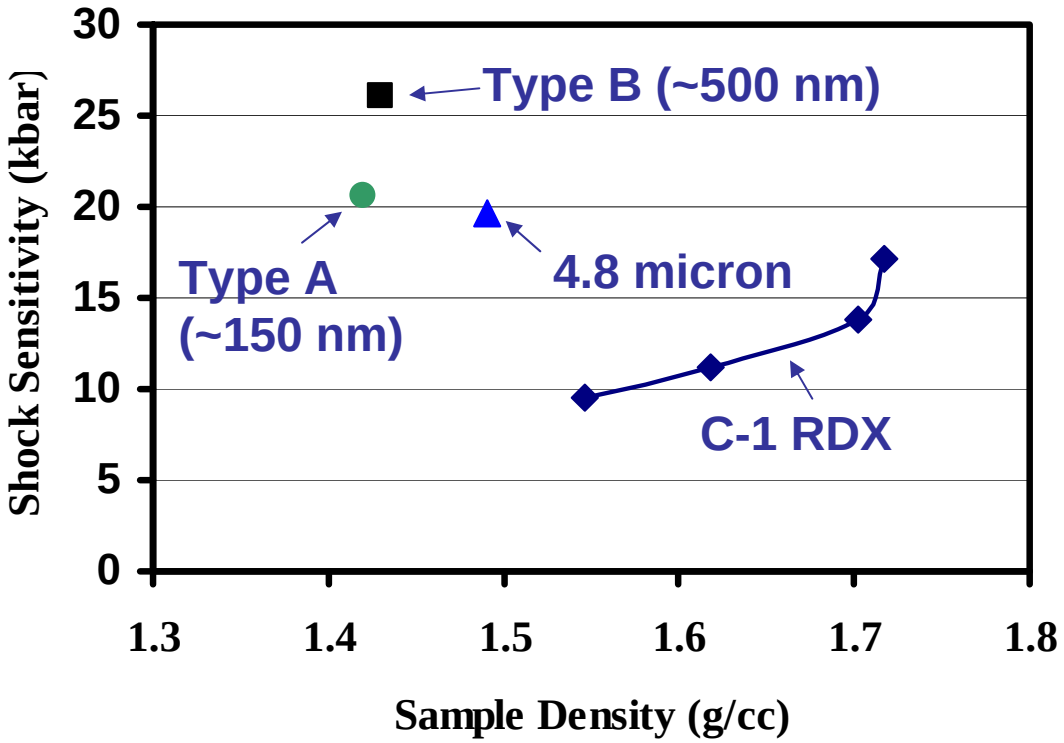
Test description

- Small-scale gap test, method 1042, MIL STD 1751A
- Samples pressed at 16,000 psig
- Shock pressure corresponding to 50 % probability of initiation determined

Sensitivity Testing

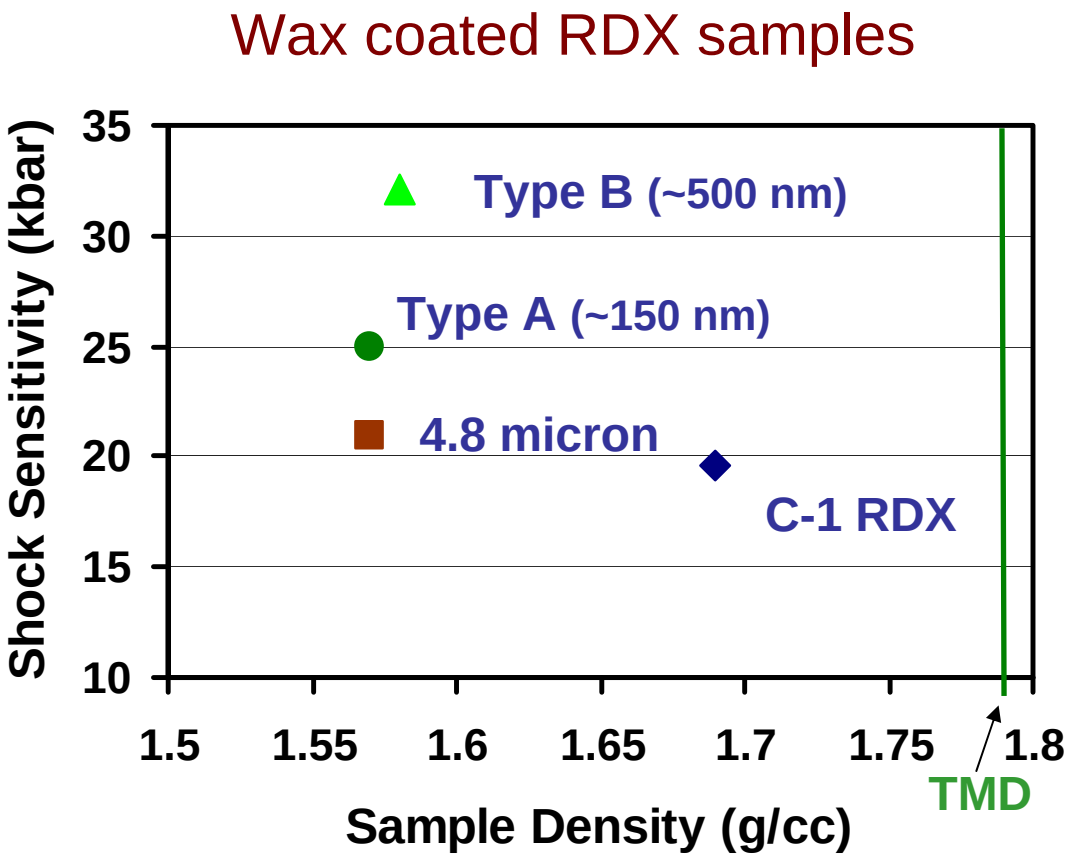
SSGT shock sensitivity test results

Uncoated RDX samples



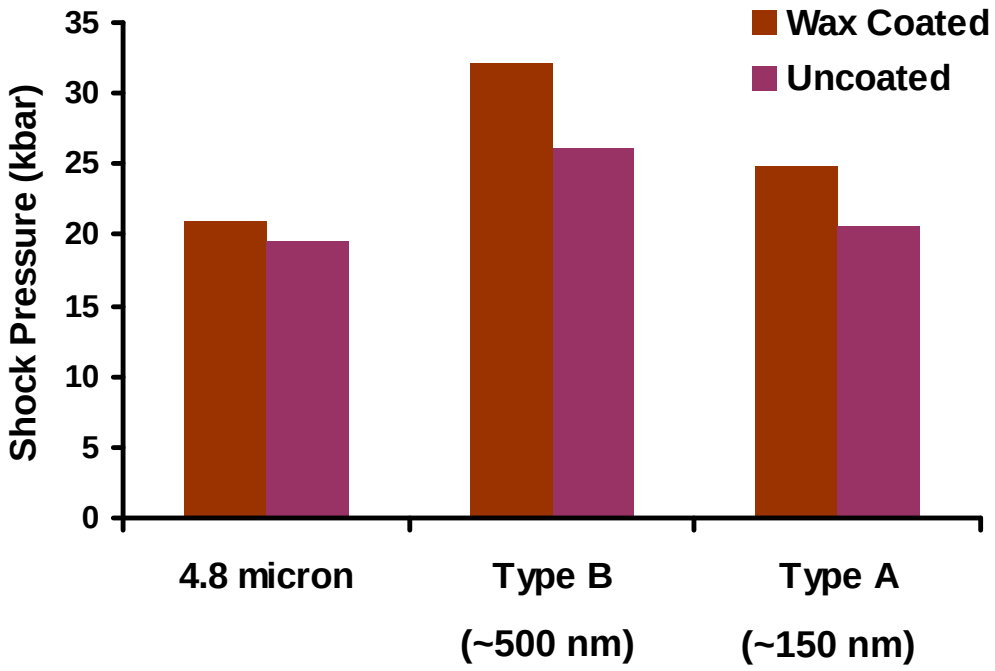
Sensitivity Testing

SSGT shock sensitivity test results



Sensitivity Testing

Shock sensitivity test results summary



Summary

- Capability to generate bulk quantities of nanocrystalline RDX developed
- Initial testing reveals a substantial reduction in sensitivity towards both shock and impact stimuli of coated as well as uncoated samples

Acknowledgements

ARDEC Contributors

Steven Nicolich, Ted Dolch, Robert Lateer, and Amy Wilson

Thank you!