In Situ Nano-Aluminum Composites for Energetic Materials

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Chemistry-Focused
Nano-energetic Product Development
- Reactive & energetic materials
  - Solid & liquid fuels and propellants
  - Explosives
  - Catalysts
  - Structural reactive materials
  - Energetics additive manufacturing
- Patented nanocomposite production technology
- Grams to kilograms laboratory & scale-up
- Functional polymers
- Films and coatings

Photo credit: Helicon
Technology Introduction:
In Situ Reactive Aluminum Composites
Helicon’s reactive composites enable advanced aluminum performance in energetic materials

Aluminum nanocomposite solid fuel
- Produced using Helicon’s patented process
- *Molecular-level mixing* of nano-aluminum fuel and polymer binder
- Extremely rapid nanoparticle combustion
- Maximum energy release from aluminum fuel
- Safe to handle, store, use
- Replacement for conventional fuel ingredients that have unwanted behavior such as sensitivity, toxicity, aging, poor performance

Photo credit: Helicon
Solving the “Nanoparticle” Problem

Problems of conventional nanoparticles are eliminated:

- Handling and safety
- High mix viscosity
- Poor dispersion
- Particle agglomeration
- Lower than ideal performance

SEM cross-section of AP/HTPB propellant containing conventional nanopowder

Nanoparticle agglomerates

Photo credit: Helicon
Helicon’s Metallized HTPB R45M Binder

- HTPB R45M binder / nano-aluminum composite
- Drop-in replacement for conventional HTPB R45M

Cured binder cross-sections
@ 50,000X magnification:

Photo credit: Helicon

Photo credit: Helicon
How It Works

Conventional Al combustion:
- Large molten aluminum droplets (LMDs) form on the propellant surface

Helicon technology:
- Reduces LMDs and improves combustion efficiency

Photo credit: Helicon
**Plateau Propellant Development**

**SBIR Goal:** Develop a new composite propellant with equivalent performance to be a drop-in replacement for a current propellant used in CAD/PAD rocket motors and cartridges.

**Benefit:** Composite propellant will extend the service life of affected CAD/PAD items, lower procurement cost, reduce maintenance and impact to warfighting capability.

We modified a composite propellant to:

- Increase burning rate
- Reduce temperature sensitivity
- Create extended burning rate plateaus at the desired operating pressures
- Match specific impulse to target
- Maintain thermally stable aging of all ingredients

Example of minimized temperature sensitivity of propellant made with nAl-HPB binder:
Exploiting Melt Layer Effects for Plateau Burning Propellants

- Larger AP particles protrude through melt layer; smaller particles are smothered
- Melt layer becomes thinner as pressure increases
- Effects can be tuned to produce plateau burning over various pressure ranges
Ballistic Modeling of CAD/PAD Device

- Ballistic model was based on propellant strand data, thermochemical calculations, and CAD/PAD device design and original test data.

- Ballistic model with Helicon’s optimized propellant matched the target performance.

- Ballistic model confirmed the importance of the plateau region in stabilizing thrust over time.
Propellant Scale Up Issues Encountered

- Propellant mixes were too viscous due to the narrow AP size distribution used
- Plateau effects began to vary based on mix size and material lots used
Improving Plateau Consistency

• Plateau burning behavior is controlled by the binder melt layer properties

• Tighter control of HTPB cure chemistry was achieved through binder synthesis optimizations

• Propellant mix viscosity was improved by introducing micron Al powder to create a bimodal particle distribution (in combination with AP)
Solid Fuel Ramjet Technology Development
SBIR Goal: Develop high-performance solid ramjet fuel having a high regression rate with stable combustion in airbreathing rocket configurations, and high combustion efficiency over a wide range of operating conditions.

Benefit: Helicon's advanced, high-performance, insensitive fuels will meet the challenging performance goals for future Naval weapons platforms, providing the improved range and reduced time to target required to defeat evolving threats.

Helicon's revolutionary nanocomposite manufacturing process provides this performance advantage

- Scalable, cost-effective approach
- Compatible with current production methods
- High performance without hazardous or sensitive ingredients

Photo credit: Helicon

Test of Helicon fuel at Purdue University
DoD & Commercial Markets

**DoD focus areas in energetics**
- 3D printable propellants and warheads
- Airbreathing propulsion
- Liquid fuels & propellants
-Insensitive munitions
- Industrial base obsolescence
- Next-generation chemical propulsion systems

**Commercial applications**
- Fuel & propellant for commercial space launch
- Explosives and propellants for oil/gas/mining
- High-strength, lightweight composites
- Thin film technology for electronic systems
- Pulsed power, capacitors, and photovoltaics
- Fuel cells nanocomposite membranes & catalysts
- Multi-functional coatings

Photo courtesy of US Navy
Thank you

Questions?