Air Force SBIR/STTR Innovation

Air Force SBIR/STTR Innovation Story

Topic Number:
OSD05-T001

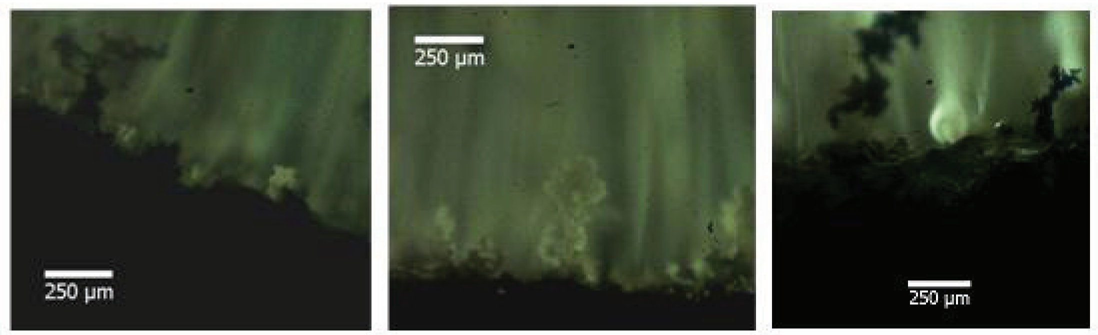
Title:
New Energetic Solid Propellant Ingredients

Contract Number:
A9300-06-C-2001

Company Name:
MACH I, Inc.,
King of Prussia, PA

Technical Project Office:
AFRL Propulsion Directorate West,
Edwards AFB, CA

This Air Force SBIR/STTR Innovation Story is an example of Air Force supported SBIR/STTR technology that met topic requirements and has outstanding potential for Air Force and DoD.



Combustion surface @ 20 bar: MgB90 (left), MgB95 (middle), and Al_30μm (right)

Magnesium-Boron Composites Developed as a New Fuel for Propulsion and Combustion

- The Department of Defense needs higher performing solid propellants for use on space access and strategic and tactical missile systems
- MACH I improved the ignition and combustion characteristics of boron by employing the company's proprietary magnesium-boron composites (MgB)
- The research results show that adding magnesium to boron to form a MgxBy composite (via MACH I's proprietary process) improves ignition by reducing ignition temperature from ~2000 to ~1100 K, improves combustion rate (by 46%), and maintains ultimate delivered energy
- MgB is ideally suited for use as a fuel in thermobaric explosives

Air Force Requirement

The Department of Defense needs higher performing solid propellants for use on space access and strategic and tactical missile systems. Simultaneously attaining higher energy and density, while maintaining acceptable physical properties, are extremely challenging but desirable goals.

SBIR Technology

In this Phase II STTR project, MACH I improved the ignition and combustion characteristics of boron by employing the company's proprietary magnesium-boron composites (MgB). In addition to MACH I (small business program leader), program participants were the New Jersey Institute of Technology (NJIT, academic partner), and Talley Defense Systems (TDS, thermobaric munitions manufacturer). MACH I produced multi-kg quantities of magnesium-coated boron composites on both 90-92% active boron and 95-97% boron. The magnesium weight percentage varies form 10% to 60%.

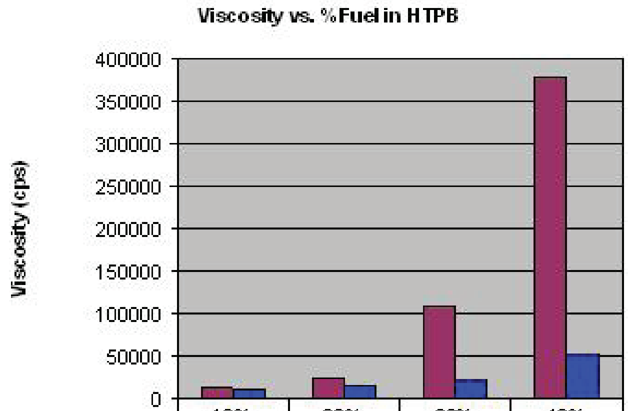
Boron has the highest theoretical energy density (~59 kJ /g) of the relatively easy to handle metal or metalloid fuels (fuels with no toxicity or reactivity issues such as lithium or beryllium). It is difficult to realize this potential due to ignition and combustion issues, including:

- The ignition temperature is about 2000 K.
- A molten oxide surface layer forms on the burning surface inhibiting combustion (until temperature gets high enough to vaporize it).
- About one-third of the theoretical energy is lost if gaseous boron oxides and hydroxide are not condensed in the combustion product. This requires impractically low temperatures (<1000 K) for condensed phase product formation.

The research results show that adding magnesium to boron to form a MgxBy composite (via MACH I's proprietary process) improves ignition by reducing ignition temperature from ~2000 to ~1100 K, improves combustion rate (by 46%), and maintains ultimate delivered energy as measured in the NJIT constant volume explosion (CVE) experiments.

Potential Air Force Application

MACH I found that addition of magnesium to form MgB composites can reduce the viscosity of hydroxyl terminated polybutadiene (HTPB) blends with 30% solids by a factor of six. Beyond that, the recent discovery of a new synthetic process reduces that viscosity by another factor of two. Much higher concentrations of MgB (than with boron) can thus be blended with formulations requiring HTPB.



	10%	20%	30%	40%
(% B in HTPB)	12500	24825	108620	378750
(% (20% Mg/B) in HTPB)	12049	15754	22553	52404

MgB is ideally suited for use as a fuel in thermobaric explosives. This was demonstrated at TDS where MgB was substituted for aluminum in a standard thermobaric formulation.

Company Impact

"This STTR project provided our company the opportunity to develop a highly promising propellant technology," said Bernard Kosowski, President of MACH I. "Extensive testing of boron as a fuel for solid rocket propellant alternative to aluminum in the 1980s and 1990s concluded that boron required a great deal more oxidant such as ammonium perchlorate per unit mass or volume due to boron's lower equivalent weight. However, work done parallel to MACH I – namely, research by Professor Luigi DeLuca at the Space Propulsion Lab Politecnico di Milano – proved that the combustion of MACH I's magnesium-boron composites was 'cleaner' and more efficient than that of aluminum and did not produce the agglomerates which reduce aluminum specific impulse."

MACH I strives to be a leader in the commercialization of advanced nanostructured materials for the aerospace, catalytic, and bio-tech markets.

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