A High Energy Green Composite Propellant

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Introduction

In the latter half of the 20th century, composite propellants have evolved rapidly: polybutadiene binders, high enthalpy fuels, and ammonium perchlorate have all contributed to dramatic increases in stability, safety, and performance of solid-fuel combustion devices. Despite the excellent performance and low cost of such systems, they still possess several drawbacks – perchlorate toxicity, corrosive HCl exhaust, and limited ranges of burning rate characteristics among them. The continued desire for improved performance, along with the desire to avoid these issues, has led to an exhaustive search for novel oxidizers to improve existing formulations.

One of the most exciting recent developments in this vein was the publication of the synthesis of a novel nitrate ester by Chavez, *et al.*[1] in 2008. This nitrate ester (2,3-(hydroxymethyl)-2,3-dinitro-1-4-butane-diol tetranitrate, $C_6H_8N_6O_{16}$, colloquially SMX, Fig. 1) is a CO_2-balanced molecule with a high density ($\rho = 1.917$ g-cm^{-3}) and low melting point (~ 85 °C). In thermochemical calculations, SMX fares quite well as a direct replacement for ammonium perchlorate (Fig. 2). Because it is a nitrate ester, SMX can be used in green, perchlorate-free applications. Additionally, the lack of chlorine prevents the formation of toxic exhaust products.

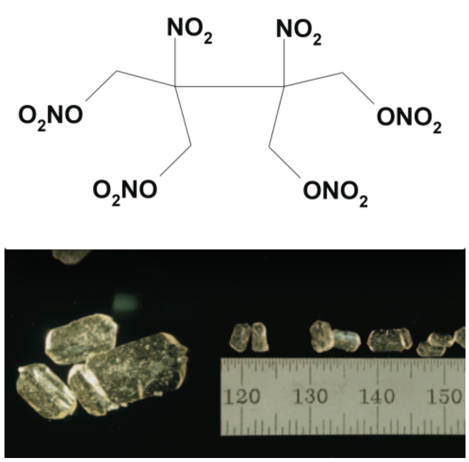

Figure 1: SMX molecular structure (top) and crystalline appearance (bottom)[1].

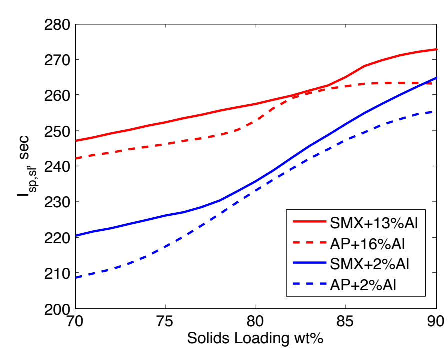

Figure 2: Performance comparison of SMX-HTPB and AP-HTPB propellants.

[1]D. E. Chavez, M. A. Hiskey, D. L. Naud, D. Parrish, Synthesis of an energetic nitrate ester, Angew. Chem., Int. Ed. 47 (2008) 8307-8309.

Experimental

In our current work, we examine the behavior of an 85% solids SMX-HTPB-Al formulation. Safety characteristics of the propellant to drop weight impact, electrostatic discharge, and friction stimuli were assessed using methods laid out in MIL STD 1751A. Additionally, a zero-gap shock initiation test was conducted to evaluate detonability of the propellant. Mechanical properties were evaluated by hardness testing in accordance with ASTM D2240.

Propellant strands were burned in a window bomb over a range of pressures amenable to rocket operation (3.45-10.35 MPa) and filmed with a high speed camera to determine the coefficient and exponent for the burning rate, as given in Saint Robert's law

$$r = aP^n \ , \tag{1}$$

where r is the burning rate, P is the operating pressure, and a and n are the burning rate constant and pressure exponent, respectively.

Results & Future Work

Early results from this work are promising; burning rates and safety characteristics are similar to AP-HTPB propellants. A typical sample undergoing combustion at 8.3 MPa is shown in Fig. 3. An evaluation of the combustion properties of neat SMX is simultaneously underway to assist in interpreting the propellant's characteristics.

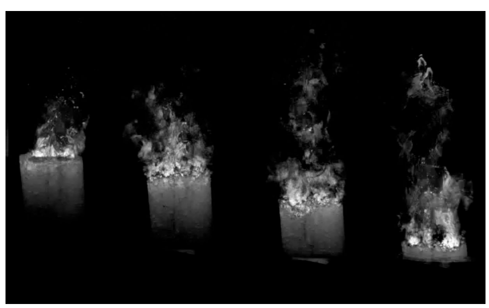

Figure 3: SMX-HTPB-Al propellant burning at 8.3 MPa.

After the safety characteristics of the material are determined, we plan to fire a small rocket motor combustor with SMX-HTPB-Al propellant to evaluate combustion efficiency and stability. Additional surface imaging and combustion diagnostics experiments are also planned to aid in further understanding of the combustion process of this unique propellant.