Nano-Energetic Material Decomposition Processes

Principal Investigator: Dr. Ronald K. Hanson

Research Associates: Dr. Jay Jeffries; Dr. David Davidson

Research Assistant: David Jackson

Motivation

It has been recognized by many within the energetic materials community that the use of nano-sized energetic particles can lead to substantial increases in overall performance and safety of energetic materials. Nano-sized energetic particles offer the potential of high heat release rates, increased combustion efficiencies, tailored burning rates, and reduced sensitivity. In order to successfully exploit these properties, however, a fundamental understanding of how nano-particles undergo chemical and physical changes at elevated temperatures and pressures is essential.

Overview

These phenomena, we believe, can be studied using a recently developed aerosol shock tube and an existing array of laser extinction and absorption diagnostics. A schematic representation of the operation of this aerosol shock tube is shown in Fig. 1.

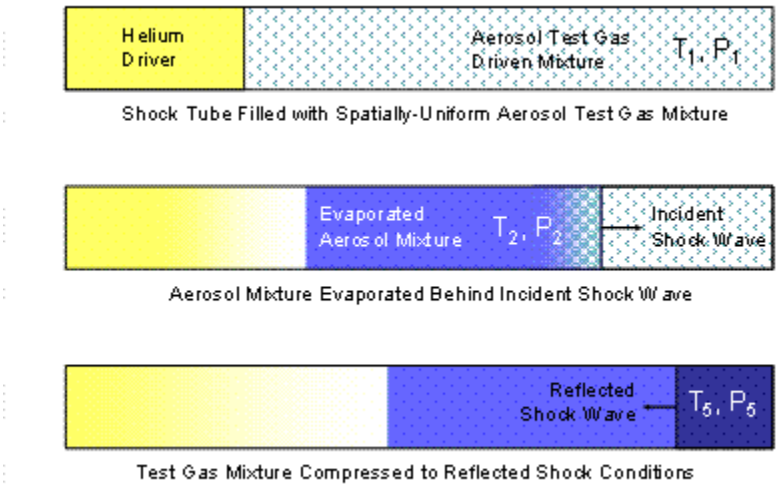

Figure 1: Schematic of aerosol shock tube technique

What is of direct and immediate interest to the study of solid explosives chemistry is the application of the aerosol shock tube technique to study the effect of nano-particles on fuel mixtures. Thixotropic propellants (i.e. gel propellants) consisting of a mixture of nano-aluminum suspended in a hydrocarbon fuel offer the potential of increased operational safety, improved energy density, and a reduction in ignition time compared to conventional hydrocarbon fuels. Only limited quantitative chemical kinetic data are available on the influence of nano-particles on kerosene-type fuels; most previous studies have been concerned with larger aluminum particles (micron to millimeter size). In this

study we have investigated the influence of aluminum nano-particles on the ignition delay times of a single component kerosene/jet fuel surrogate n-dodecane.

In order to produce aerosols with high loadings of suspended nano-particles, a Sono-Tek Ultrasonic spray nozzle was used. A photograph of the operating nozzle is shown in Fig. 2. This device can nebulize suspensions with up to 40 wt.% nano-particles. This nozzle operates at 120 kHz and produces an aerosol with number mean diameter of approximately 18 microns. A representative size distribution is shown in Fig. 3.

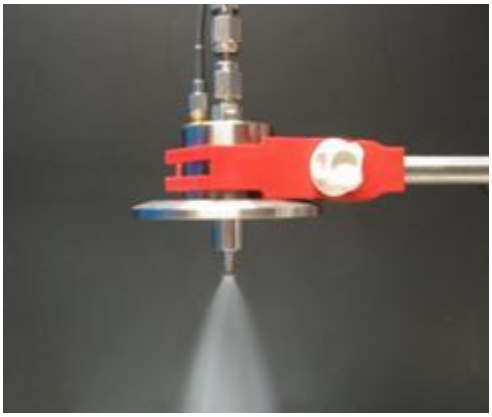

Figure 2: Sonotek ultrasonic spray nozzle in operation in our laboratory

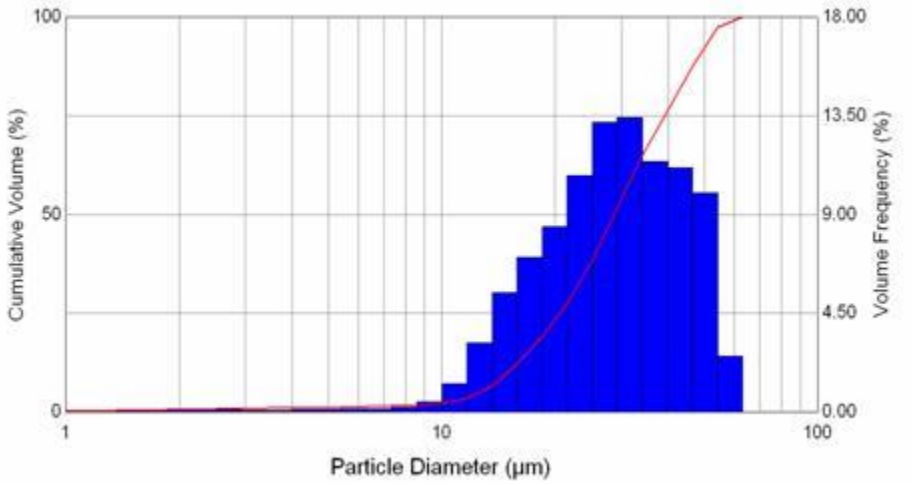

Figure 3: Volume size distribution plot for a n-dodecane aerosol produced using the 120 kHz Sonotek spray nozzle at a mass flow rate of 200 ml/hr and a power of 1.0 watt

Figure 4 shows the laser diagnostic systems used in the shock wave experiments. Three laser systems are used. Two diode lasers at 660 and 670 nm (referred to as the non-resonant laser systems) are used to measure droplet evaporation and particle loading. One HeNe gas laser at 3.39 microns (referred to as the resonant laser system) is used to measure hydrocarbon (n-dodecane in the current experiments) absorption. The 3.39 micron absorption measurement is also used to measure fuel loading after droplet evaporation behind the incident shock waves.

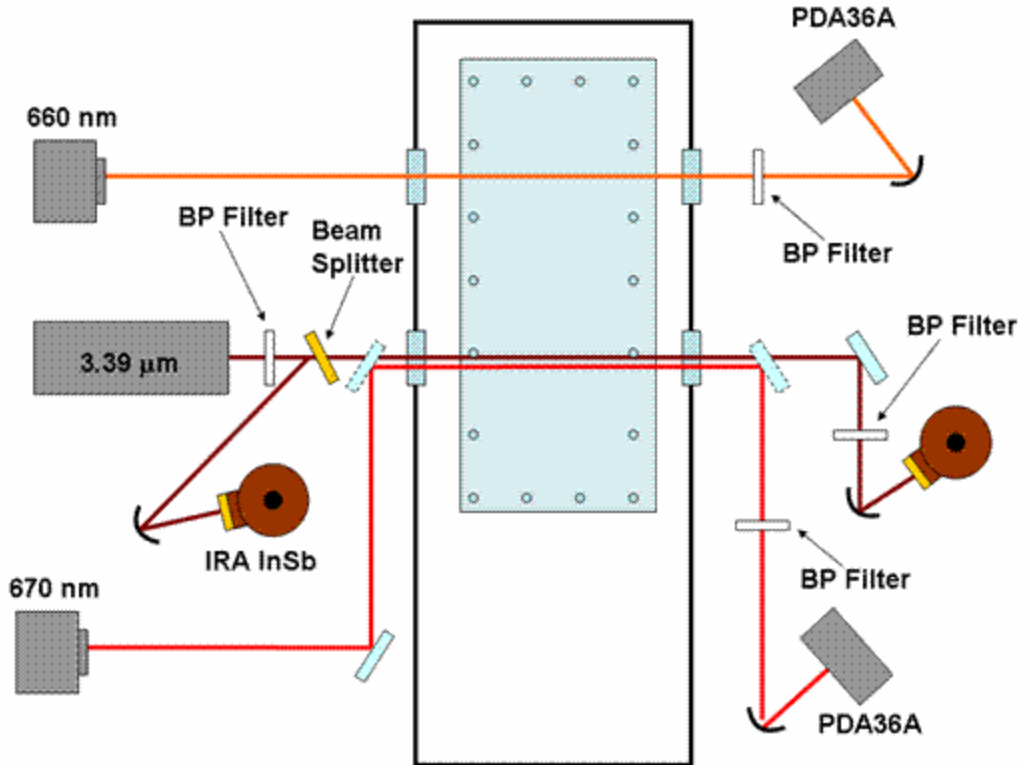

Figure 4: Schematic of laser diagnostic setup for aerosol shock tube

Representative data traces from baseline ignition measurements with neat n-dodecane using the new jet nebulizer are shown in Fig. 4. The ignition delay time (t = 793 ms) can be readily identified in the CH* emission, PZT pressure and 3.39 mm laser absorption signals. Figure 5 shows similar data traces for a shock tube ignition experiment with 20% by weight nano-aluminum particles added to the n-dodecane aerosol. Several significant differences are seen between this set of measurements and the neat n-dodecane measurements. First, the pressure trace (red) in Fig. 5 shows a much larger step and much more sudden rise in pressure at ignition. Second, both non-resonant laser signals (660 and 670 nm) show continued constant extinction behind the incident shock wave after the complete evaporation of the liquid aerosol carrier, confirming the presence of nano-aluminum particles. Finally, rapid decay in the 660 nm signal at the 2 cm location is coincident with the strong rise seen in the 431 nm emission signal (green). This emission extends through the ignition event with a FWHM of approximately 80 ms. No emission peak is seen in the experiment with no aluminum nano-particles.

The present experiments extends significantly the range of combustion conditions for which mixtures of aluminum and kerosene-like fuels have been studied. Furthermore, this present exploratory research program has successfully demonstrated that these shock tube methods can be used to obtain critically needed information about rapidly thermalized nano-energetic materials.

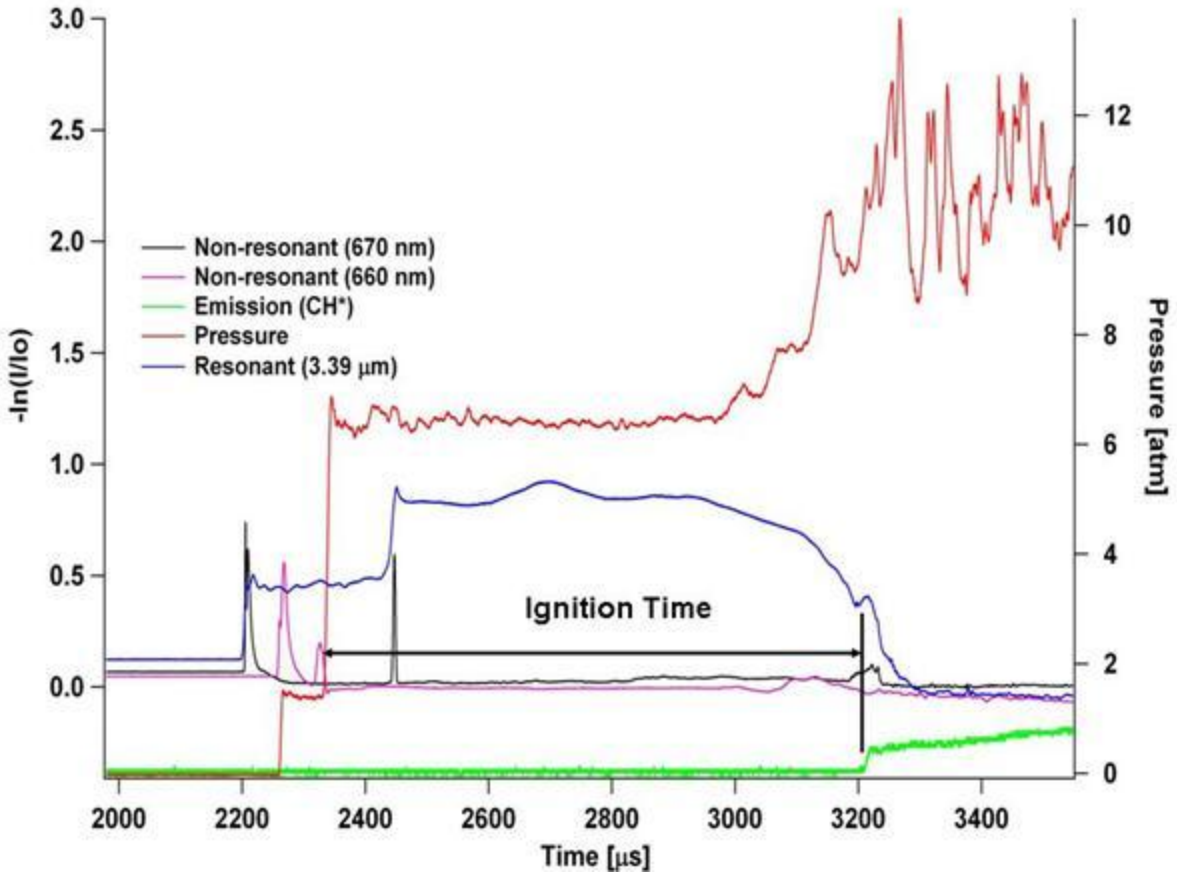

Figure 5: Representative data traces for n-dodecane ignition. Pre-shock conditions: T1 = 295 K, P1 = 201 torr; incident shock speed: Vs = 757.93 m/s, fuel loading Xfuel = 0.0021 in 21% O2 in argon; reflected shock conditions:T5 = 1187 K, P5 = 7.1 atm, ignition time = 793 ms

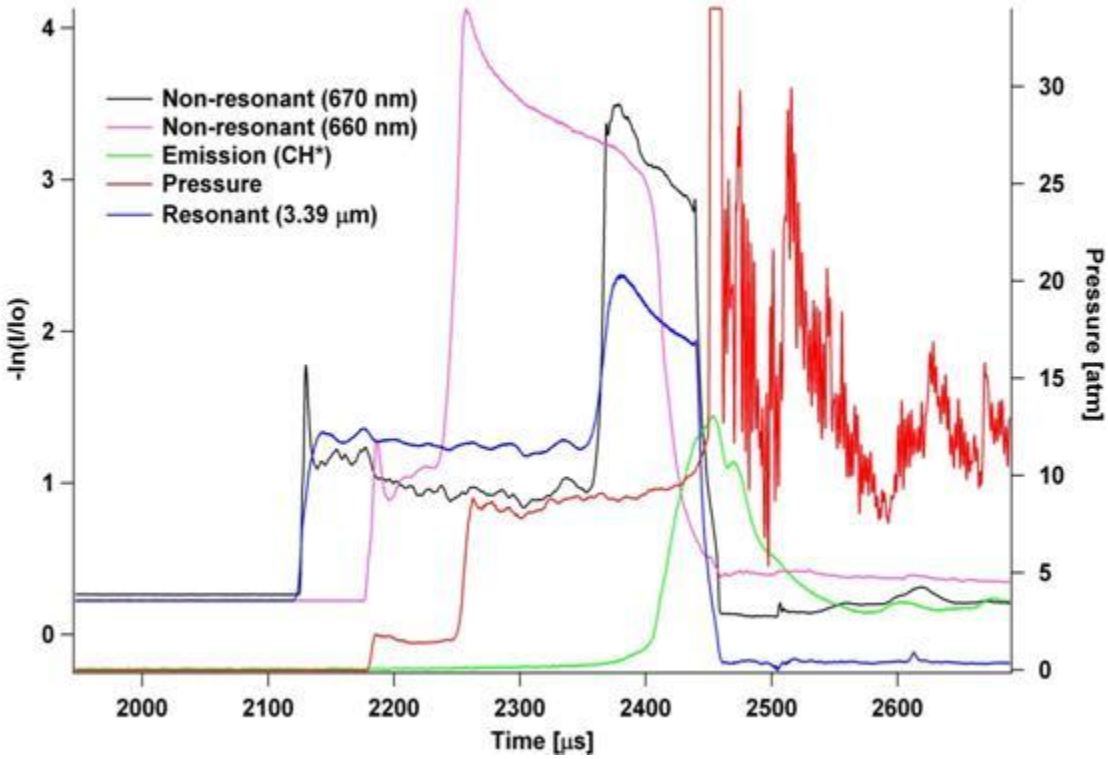

Figure 6: Representative data traces for n-dodecane ignition. Pre-shock conditions: T1 = 295 K, P1 = 201 torr; incident shock speed: Vs = 757.93 m/s, fuel loading Xfuel = 0.0021 in 21% O2 in argon; reflected shock conditions:T5 = 1187 K, P5 = 7.1 atm, ignition time = 793 ms.