Laser Induced Deflagration of Energetic Materials

Eric Collins
Jennifer Gottfried
U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

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1. Background

- **Large scale tests are conducted to characterize performance of explosives**
  - Expensive, time consuming, must be conducted in proper facility to protect personnel and equipment from blasts
- **Hypothesis: Characteristics from the deflagration of explosives such as temperature, energy generation and signatures, can be analyzed in a laboratory setting using small amounts of material**
  - Cheaper, faster, safer

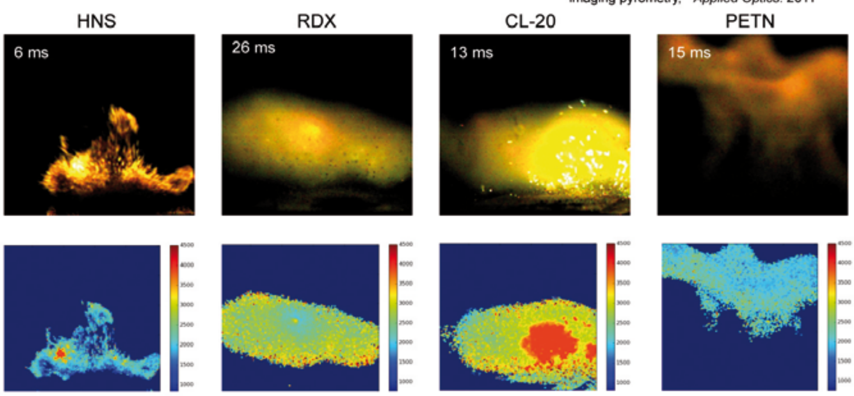
2. Diagnostics

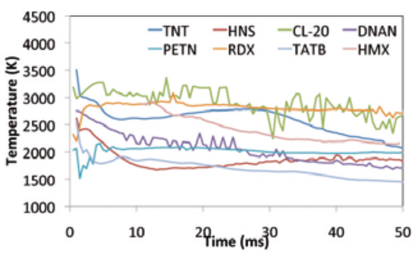
- **New techniques were developed with laboratory diagnostics to characterize the performance of energetic materials using only 15-20 mg of material**
  - Time resolved temperature from high speed color camera and photo receivers
  - Relative energy output
  - Emission signatures from spectrometer
  - Ignition source - Nd:YAG laser
    - Energy = 850 mJ, Pulse Width = 6 ns, Wavelength = 1064 nm

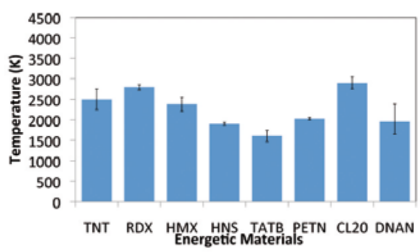
3. Temperature – High Speed Color Camera

- **Color high speed camera used as pyrometer**
  - Temperature of deflagration events was calculated from a calibrated high speed digital color camera
    - Demosaicing algorithm was used to create a full color image from the color filter array
    - Two color ratio analysis

Densmore, J, "High-speed digital color imaging pyrometry," *Applied Optics*. 2011



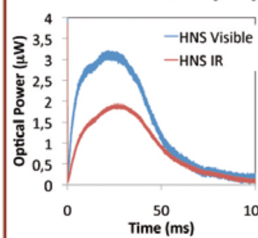




4. Temperature – Photo Receivers

- **Ratio pyrometry technique**
  - Band pass filters of 700nm and 1200nm were placed in front of photodiodes
  - Assumes gray body process where emissivity is same for all wavelengths
  - Equations derived from Planck's equations

Shah, K, Ross, H, "Measurement Techniques for Data Recording and high Temperature Measurement," 2010

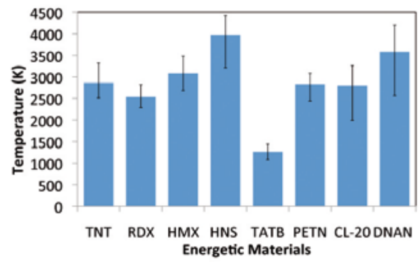


$$T_{Theoretical} = \frac{\frac{hc}{k}\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right]}{Ln\left(\frac{V_{\lambda_1}}{V_{\lambda_2}}\right) - 5\,Ln\left(\frac{\lambda_2}{\lambda_1}\right)}$$

$$T_{Actual} = \frac{C_2}{Ln\left(\frac{V_{\lambda_1}}{V_{\lambda_2}}\right) - C_1}$$

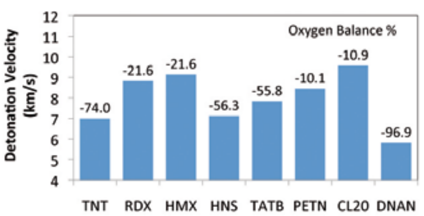
Adiabatic Flame Temperatures (K) (CHEETAH 6.0)

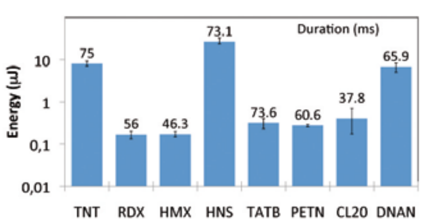
TNT	RDX	HMX	HNS	TATB	PETN	CL-20	DNAN
3244	3436	3251	3544	2462	4007	3828	2771



5. Optical Energy Output

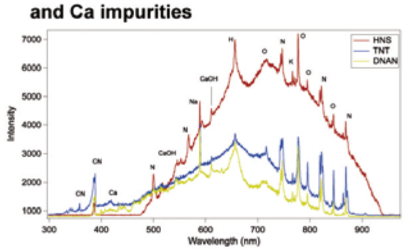
- **Time resolved light intensity**

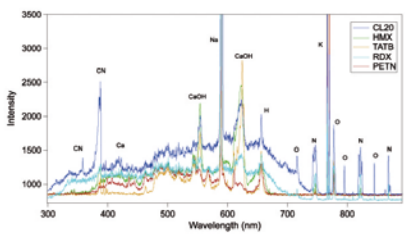




6. Signatures

- **Analyze emission features such as Na, K, and Ca impurities**





7. Summary

- **On average, the difference between the adiabatic flame temperatures and experimental temperatures was 22% with the high speed camera and 23% with the photo receivers**
- **Duration of the deflagration was shorter for compositions with an oxygen balance closer to zero**
- **Compositions with high detonation velocity resulted in low deflagration energy output**
  - Exception of CL-20 due to its high sensitivity and complete propagation throughout the sample

8. Acknowledgements

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