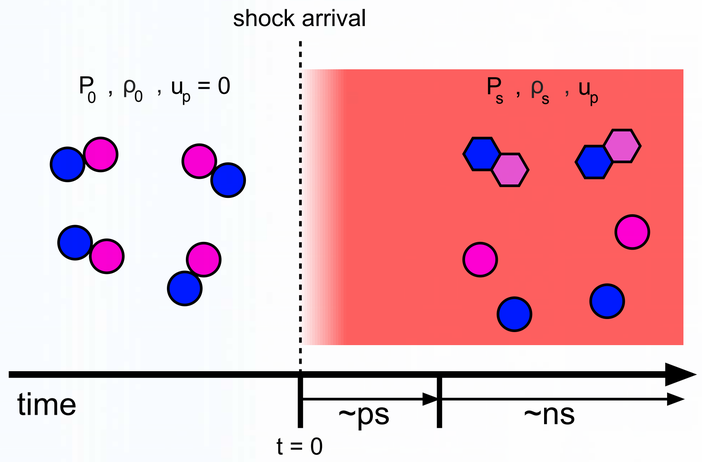
SAND2017-3219C

Ultrafast Shock Interrogation (USI) of Energetic Materials

Samuel D. Park

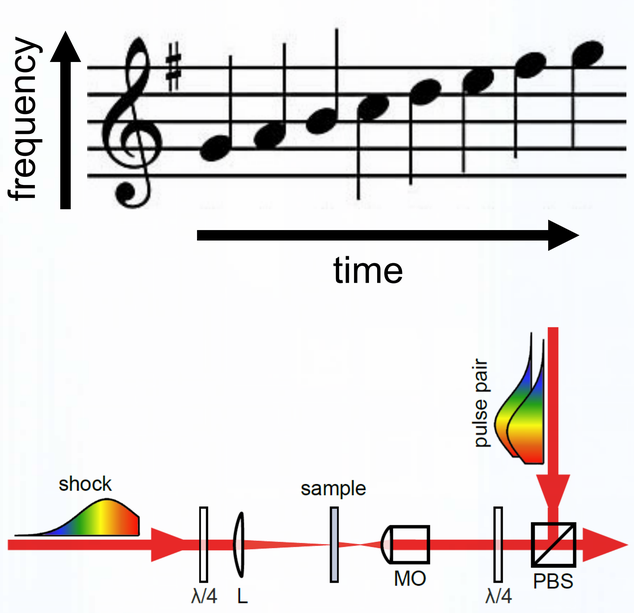
Introduction

- Shock waves can change the thermodynamic state of a material over the picosecond time scale.[1]
- Understanding shock initiation of energetic materials requires the ability to diagnose the state of materials on the picosecond time scale of shock compression.[2]

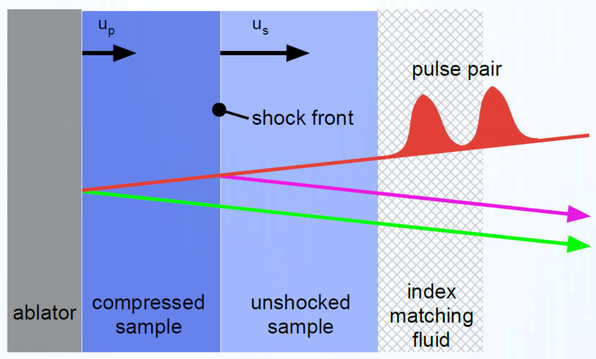


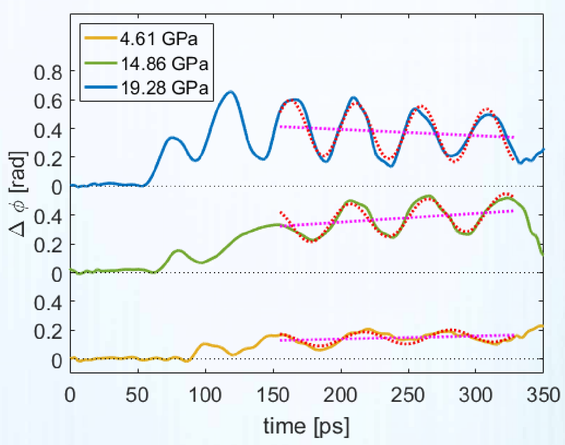
Experimental Methods

- Detonation chemistry is an irreversible process.
- Measure in time-frequency domain to probe the material during the initial stages of shock compression with high time resolution (~10 ps).
- Ultrafast pulses are linearly chirped to ~400 ps, which governs the temporal range and resolution of our measurements.



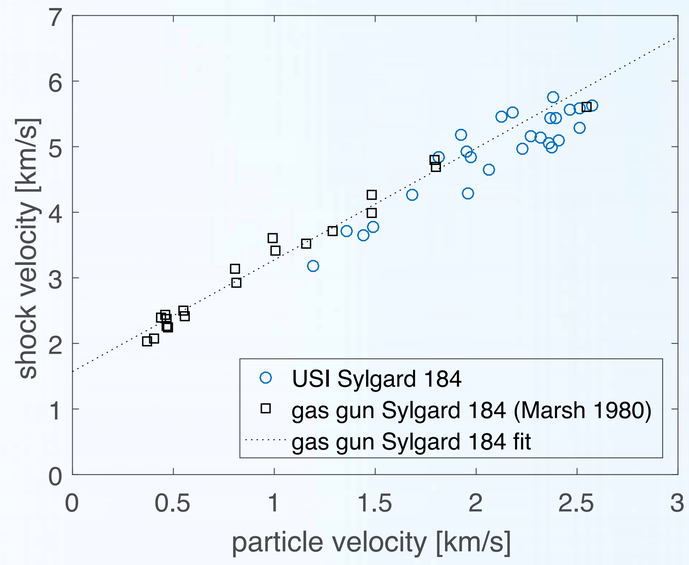
- Simultaneous spectral interferometry is used to retrieve phase information, which is where the particle and shock velocities are encrypted.
- Traveling shock wave compresses the material, which changes the thermodynamic and physical properties of the material (such as refractive index).
- The shock front and metallic ablator surface (typically Aluminum) act as a scanning optical etalon, with a total reflectance varying as the thickness of the shocked region.





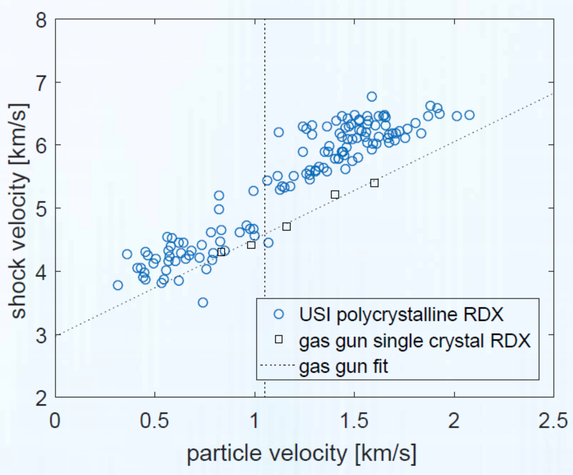
Results: Sylgard 184 (polymer)

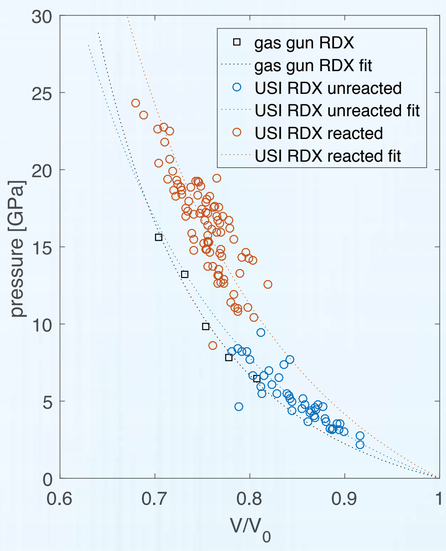
- Good agreement with previously reported gas gun results on polymer, Sylgard 184.[3]
- USI results are expected to lie on gas gun results because there are no expected chemical or physical changes in the material under shock compression.



Results: Polycrystalline RDX

- Good agreement with previously reported (unreacted) single crystal RDX gas gun data at lower pressures.[4] (Small discrepancies are attributed to a lower initial density in prepared RDX films.)
- Observation of volume expansion at ~9 GPa – signature of exothermic chemical reaction.
- Ultrafast shock induced chemical reactions have been previously observed in smaller molecules.[5,6]





Conclusions

- USI has the temporal and spatial capabilities relevant for measuring shock initiation.
- First USI measurements on polycrystalline RDX.
- Measurements that can resolve chemical reactions can lead to capabilities of measuring performance of energetic materials.
- Theoretical calculations are in progress to validate experimental results.
- Simultaneous measurement of electronic absorption can help elucidate the mechanism of initiation of energetic materials

References

1. Nellis, W. J. Dynamic Compression of Materials: Metallization of Fluid Hydrogen at High Pressures. Rep. Prog. Phys. 2006, 69, 1479-1580.
2. Zeldovich, I. B. Theory of Detonation; Academic Press: New York and London, 1960.
3. Marsh, S. P. LASL SHOCK HUGONIOT DATA (University of California Press, Berkeley, 1980).
4. Ilyukin V. S.; Pokhil P. F.; Rozanov O. K; Shvedova N. S. Soviet Phys. Doklady 1960, 5, pg. 337
5. Armstrong, M. R.; Zaug, J. M.; Goldman, N.; Kuo, I. F. W.; Crowhurst, J. C.; Howard, W. M.; Carter, J. A.; Kashgarian, M.; Chesser, J.M.; Barbee, T. W.; Bastea, S. Ultrafast Shock Initiation of Exothermic Chemistry in Hydrogen Peroxide. J. Phys. Chem. A 2013, 117 (49), 13051-13058
6. Brown, K. E.; McGrane, S. D.; Bolme, C. A.; Moore D. S. Ultrafast Chemical Reactions in Shocked Nitromethane Probed with Dynamic Ellipsometry and Transient Absorption Spectroscopy. J. Phys. Chem. A 2014, 118, 2559-2567
7. Park, S. D.; Armstrong, M. R.; Kohl, I. T.; Zaug, J. M.; Knepper, R.; Tappan, A. S.; Bastea, S.; Kay, J. J. (paper in preparation)

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND2XXXXXXX Sandia Creative Group 284-5637 SL-03-17

Sandia National Laboratories