New Diamond-like Cubic Spinel Carbon: Low Density High Strength Solid

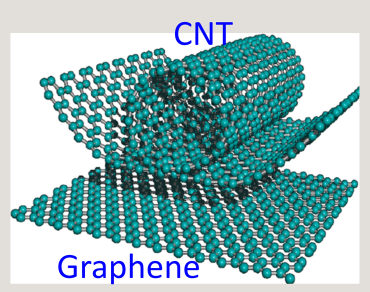
Minseob Kim, Jing-Yin Chen, Dane Tomasino, and Choong-Shik Yoo

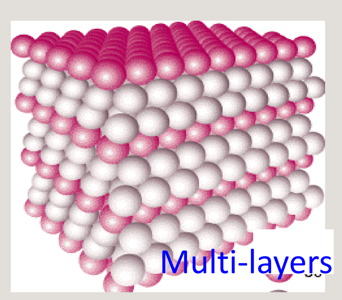
Department of Chemistry and Institute for Shock Physics, Washington State University, Pullman, Washington 99164 (csyoo@wsu.edu)

Abstract

This project is to investigate shock wave propagation in advanced materials and structures:

- Novel materials: high strength carbon nanotube (CNT) and Graphene with large anisotropy in shock impedance
- Advanced structures: mutilayers, amorphous solids, and energetic composites

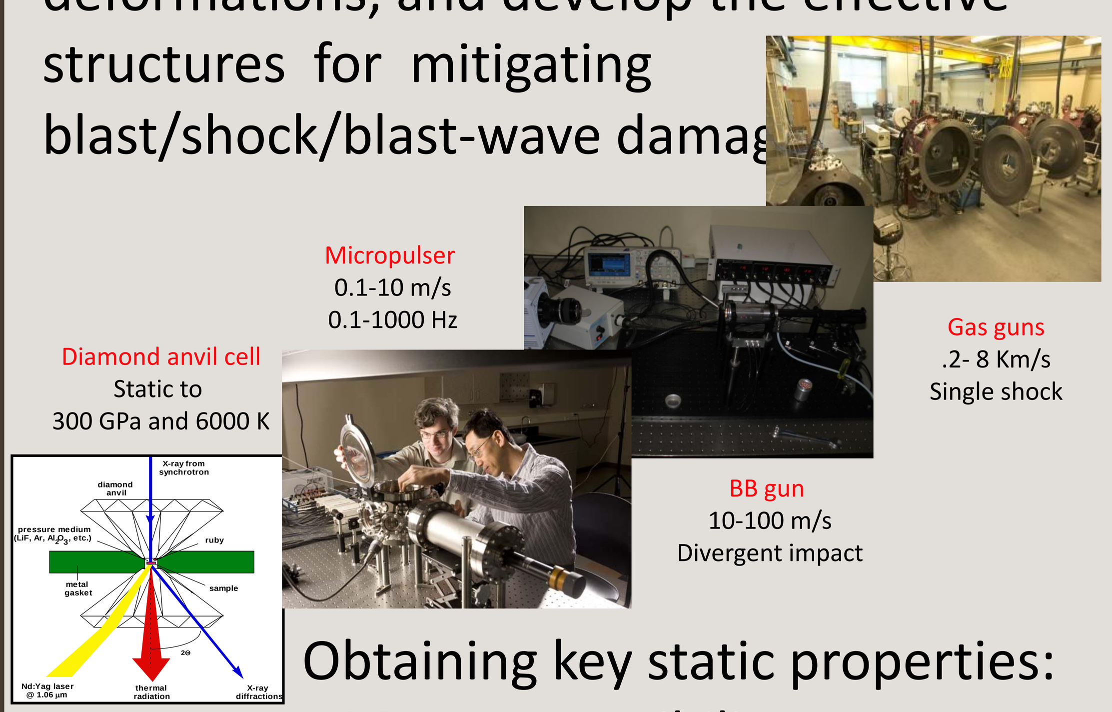




Atomistic materials structures can disperse, absorb and dissipate shock/blast waves

Approach

investigate dynamic responses of materials under large strains, strain rates, and deformations, and develop the effective structures for mitigating blast/shock/blast-wave damage



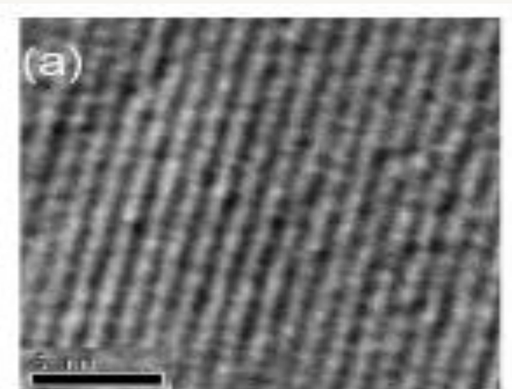
Obtaining key static properties: EOS, compressibility, structure, etc.

Relevance

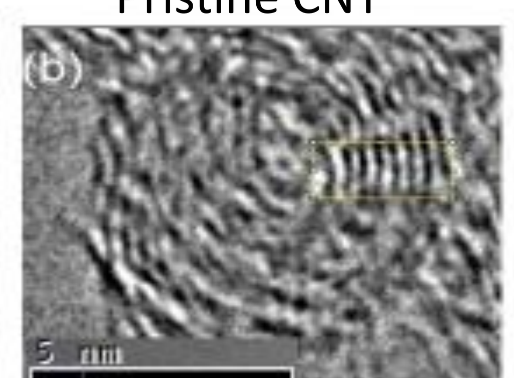
- Understanding shock-wave interactions with novel materials
- Developing advanced structures that can dissipate, absorb, or retard shock-wave propagation
- Mitigating blast damages of thermite mixtures and energetic composites

Technical Approach

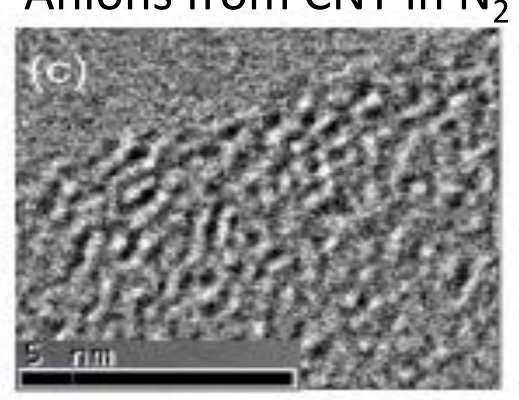
TEM of various carbons from high pressures



Pristine CNT

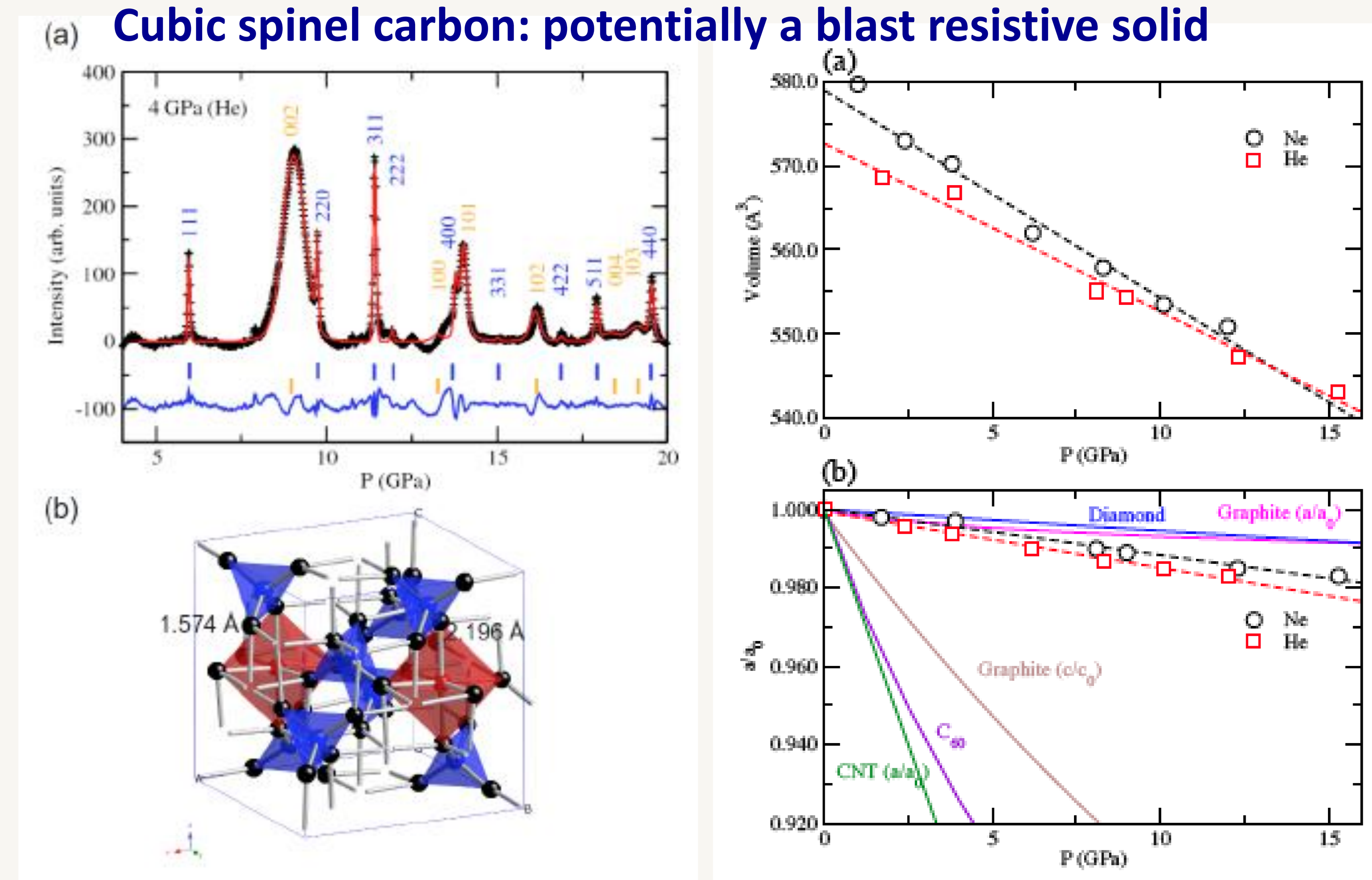


Anions from CNT in N_2



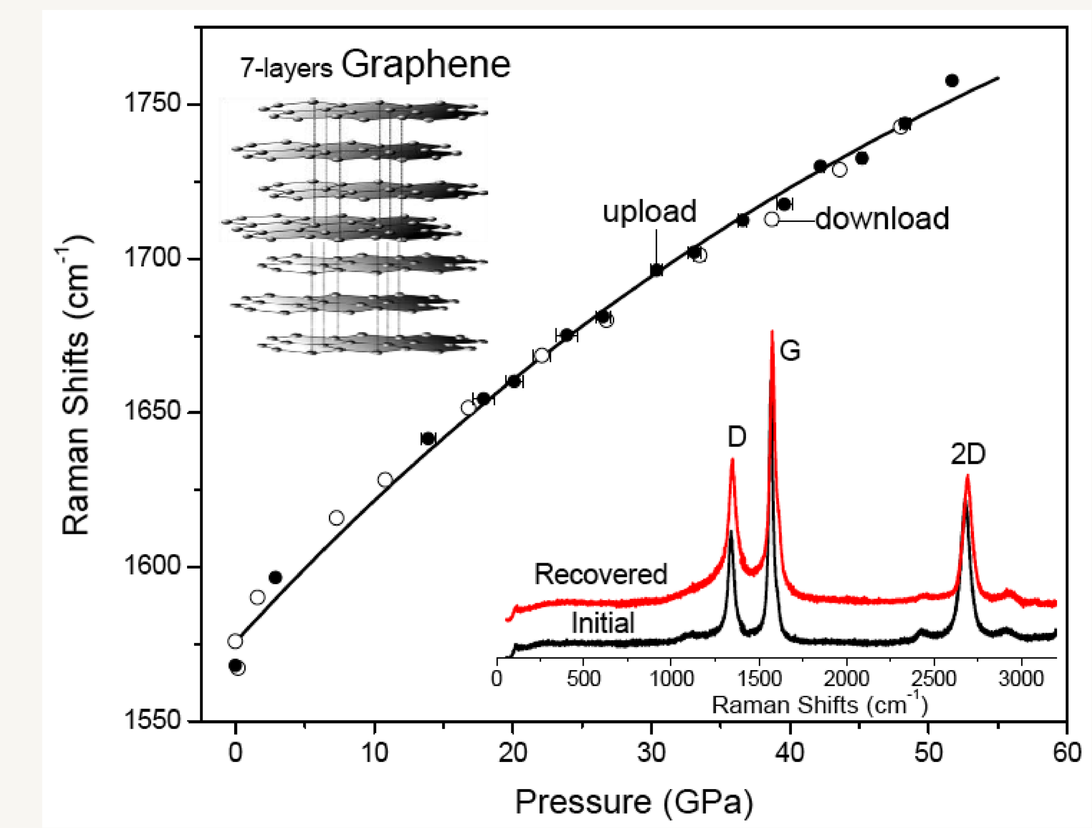
Diamond-like carbons from CNT in He, Ne

Cubic spinel carbon: potentially a blast resistive solid



- The present x-ray data indicates that new carbon recovered from CNT in He(or Ne) at 4 GPa is diamond-like in cubic spinel structure
- It consists of tetrahedrally bonded carbons (C-C at 1.5 Å) and octahedrally bonded carbon (C-C at 1.9 Å)
- Its three-dimensional network structure results in high bulk moduli (B=270 GPa) despite its relatively low density solid (ρ = 2.0 g/cc)

Graphene: potentially a shock absorbing solid



- Found high structural stability of 7-layered Graphene to 60 Gpa, greater than CNT (35 GPa)
- Found high compressibiiity on the c-axis, potentially a shock absorbing or self-healing material
- Characterized a new form of diamond-like extended carbon made from CNT in various stress conditions

Accomplishments Through Current Year

- Discovered new diamond-like cubic spinel carbon, which can be developed into novel blast-resistive low density high strength solids
- Found high structural stability of Graphene, which can be a shock-absorbing material
- Multilayer samples of various carbon species are in preparation for blast effect measurements

Future Work

- Synthesis of bulk amounts of new diamond-like carbon in large volume cells
- Investigate dynamic properties of Graphene and CNT
- Investigate in-contact blast mitigations of carbon species using reactive carbon multilayers

Opportunities for Transition to Customer

The present results are high values to:

- Understanding how shock wave propagates through solids in atomistic scales
- Developing new low density high strength materials that can be resistive to shock/blastic waves.
- Enabling effective collaborations with DOE national laboratories (APS/Argonne, LANL) on DHS research interests

Patent Submissions

Via this and other related projects, we have developed several key technologies for investigation of dynamic response of solid, including time-resolved synchrotron x-ray diffraction and high-speed micro-photography

Publications Acknowledging DHS Support

- Jing-Yin Chen, Minseob Kim, and Choong-Shik Yoo, Chem. Phys. Lett. 479, 91 (2009).
- Minseob Kim, Jing-Yin Chen, and Choong-Shik Yoo, J. Appl. Phys. (2011) submitted
- Simon Clark, Jing-Yin Chen, and Choong-Shik Yoo, (2011) in preparation
- Choong-Shik Yoo, Novel Solids at Extreme Conditions, Pacifichem-2010, Dec. 15-19 (2010) (invited)

Other References

- Minseob Kim, Jing-Yin Chen, Choong-Shik Yoo, APS March Meeting, Portland, OR, March 2010
- Choong-Shik Yoo, Advanced Multi-Functional Shock-Resistive Materials and Materials Structures, an abstract submitted to DHS_Summit (2011)
- We are organizing the **2011 MRS_Fall** Symposium on ***Advances on Energetic Materials Research***, Nov. 28 – Dec. 2, 2011, Boston, MA

This material is based upon work supported by the U.S. Department of Homeland Security under Award Number 2008-ST-061-ED0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied of the U.S. Department of Homeland Security.