**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: multilayers, amorphous solids, and energetic composites

**Approach**

Investigate dynamic responses of materials under large strains, strain rates, and deformations, and develop the effective structures for mitigating blast/shock/blast damages.

**Accomplishments Through Current Year**

- Discovered new diamond-like cubic spinel carbon, which can be developed into novel blast-resistant 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

**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**

- **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 compressibility 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

**Publications Acknowledging DHS Support**

- Simon Clark, Jing-Yin Chen, and Choong-Shik Yoo, (2011) in preparation  

**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.