Shocking results from diamond anvil cell experiments (w/ Video)

July 6 2010

The diamond anvil cell is small enough to fit in the palm of one’s hand, but it can compress a sample to extreme pressures up to about 3.6 million atmospheres at room temperature and 1.7 million atmospheres at 3,000 C.

(PhysOrg.com) -- At first, nanoshocks may seem like something to describe the millions of aftershocks of a large earthquake.

But Lawrence Livermore National Laboratory physicists are using an ultra-fast laser-based technique they dubbed "nanoshocks" for something entirely different. In fact, the "nanoshocks" have such a small spatial scale that scientists can use them to study shock behavior in tiny samples such as thin films or other systems with microscopic dimensions (a few tens of micrometers). In particular they have used the technique to shock materials under high static pressure in a diamond anvil cell (DAC).

Using a DAC, which probes the behavior of materials under ultra-high pressures (and which requires small samples), the team statically compressed a sample of argon up to 78,000 atmospheres of pressure and then further shock compressed it up to a total of 280,000 atmospheres. They analyzed the propagating shock waves using an ultra-fast interferometric technique. They achieved combinations of pressures, temperatures and time scales that are otherwise inaccessible.

In some experiments they observed a metastable argon state that may have been superheated -- a state at a pressure and temperature at which argon would normally be liquid but because of the ultra-short time scale does not have enough time to melt.

"It can be used to study fundamental physical and chemical processes as well as improve our understanding of a wide range of real-world problems ranging from detonation phenomena to the interiors of planets," said LLNL physicist Jonathan Crowhurst, a co-author of a paper, which will appear in the July 15 edition of the Journal of Applied Physics.

The time scale is short enough to permit direct comparison with molecular dynamics simulations, which usually run for less than a nanosecond (one billionth of a second).

Shocked behavior in microscopic samples can consist of the behavior of shocked explosives before chemistry begins or the high density, low temperature states of light materials such as those that are found in giant gas planets, according to LLNL lead author Michael Armstrong.

"Essentially, this allows us to examine a very broad range of thermodynamic states, including states corresponding to planetary interiors and high density, low-temperature states that have been predicted to exhibit unobserved exotic behavior," Armstrong said.

For decades, compression experiments have been used to determine the thermodynamic states of materials at high pressures and temperatures. The results are necessary to correctly interpret seismic data, understand planetary composition and the evolution of the early solar system, shock-wave induced chemistry and fundamental issues in condensed matter physics.

Armstrong said their technique for launching and analyzing nanoshocks was so fast they were able to see behavior in microscopic samples that is inaccessible in experiments using static or single-shock wave compression.

Provided by Lawrence Livermore National Laboratory