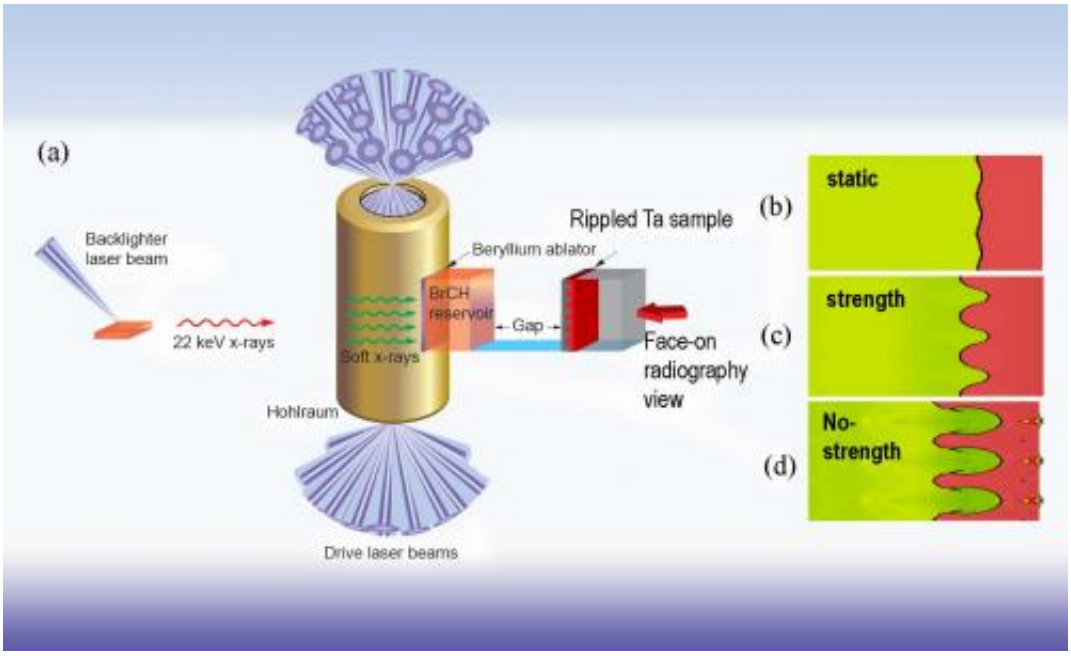
Determining structural evolution under pressure

March 9 2015, by Breanna Bishop



In this experimental setup at the Omega Laser Facility, the hohlraum drives the reservoir-gap configuration, creating a ramped plasma drive that compresses and accelerates the sample without shock melting. The team measured the Rayleigh-Taylor instability ripple growth amount to infer the dynamic flow stress of the sample.

The study of material properties under the conditions of extreme high pressures and strain rates is very important for understanding meteor, asteroid or comet impacts, as well as in hyper velocity impact engineering and inertial confinement fusion capsules. In a recent study

published by *Physical Review Letters*, (link is external) a team of Lawrence Livermore National Laboratory scientists report an important finding that can be used to determine the evolution of structures under high pressure and strain rates.

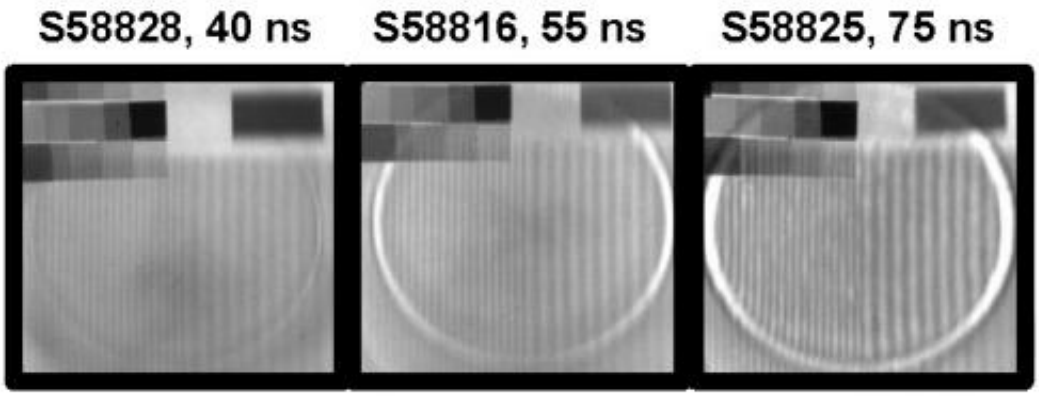
The paper details experimental results on the grain size dependence of plastic flow stress under high pressure (>100 gigapascals, or GPa, a measurement of pressure) and high strain rates. Higher flow stress means that the material is stronger against an applied force. Under static conditions, smaller grain sized materials are stronger. This is known as the Hall-Petch (H-P) relation and is used in industry to increase hardness, durability, survivability and ductility of structural materials. However, it was not known if the H-P relation holds under high pressure and high strain rate conditions such as in hyper velocity impacts of meteors or asteroids.

"Measuring material flow stress at high pressures and strain rates without melting is a formidable task," said lead author Hye-Sook Park. "We designed an experimental platform to drive samples to high pressures without melting using a laser-generated plasma piston drive."

The strength of a sample material is measured by radiographying the growth of ripples machined into the surface. The ripples grow because of instabilities formed at the interface boundary under the applied pressure. Low strength materials have little resistance to deformation and the ripples grow rapidly. In high strength materials ripple growth is suppressed. The team measured the amount of ripple growth to infer the strength.

The team completed a series of experiments at the University of Rochester's Omega Laser Facility with unexpected results. Measurements showed that flow stress is insensitive to grain size at the level of tens of microns, whereas the H-P theory predicted an increase in

strength of at least a factor of two on the tested samples.



These figures show face-on radiography of Rayleigh-Taylor induced ripple growth at different delay times. Higher contrast ripples mean that the ripples are grown more rapidly.

"There are many surprises to be found in nature under the extreme conditions that we call the high-energy-density regime, and exploring material properties under these conditions has been challenging," Park said. "Laser experiments provide a unique way for us to study this regime. No one expected that the common grain size vs. hardening rule would be overturned under extreme conditions."

The experiments studied materials at pressures of 100 GPa. Plans are now under way to extend the study to pressures of 500-1,000 GPa at LLNL's National Ignition Facility and to include nano-grain samples (