Size-specific cracking shakes out at the nanoscale

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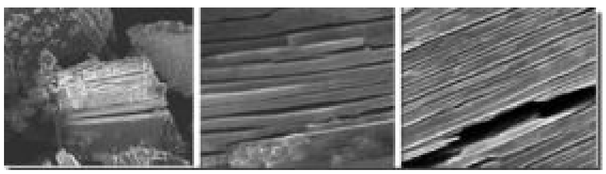

Scanning electron microscope images of a cerium hydride stacked-plate nanostructure. a Typical stacked-plate cluster. b Close-up view of the edges of the plates in a. c Close-up view of another particle showing a finer fracture scale.

(PhysOrg.com) -- Certain sizes of nanostructures may be more susceptible to failure by fracture than others. That is the result of new research by LLNL's Michael Manley and colleagues from Los Alamos National Laboratory that appears as a Rapid Communication in the journal *Physical Review B*.

As the size of a structure gets to the nanoscale, atomic vibrations (also known as phonons) begin to feel its size and shape in an effect called phonon confinement.

While these effects play an important role in thermal transport, electronic processes and thermodynamic stability, not much is known about their role in fracture.

However, in the new research, the scientists found that at a certain thickness, excess entropy of the confined vibrations reduces the fracture energy and results in a size-specific fracture.

Manley and the Los Alamos team found that particles formed during the reaction of cerium with hydrogen (cerium hydride) fractured into stacked plates. The plates exhibited two thickness scales, one at 100 nanometers, and an additional scale at 30-nanometer scale.

"When the fracture results in nanoplates, it leads to a low level of fracture energy at a certain size, resulting in a size-specific fracture," Manley said. "This has important implications for the design of nanostructures."

"It also may prove useful in the deliberate creation of large quantities of stable nanostructures," he said.

Manley said the time scale for phonon excitations typically occurs in picoseconds, while crack growth is a slower process involving the simultaneous displacement of many planes of atoms over a relatively large distance compared to atomic vibrations. "Thus, the phonon confinement should occur instantaneously as the crack propagates," he said.

Unlike with thermodynamic stability, fracture is a weak-link process, meaning that even a local weakening could be important in dictating the fracture process.

"This could have important consequences, not only for small materials, but also for the way cracks propagate in nanostructured bulk materials," Manley said.

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