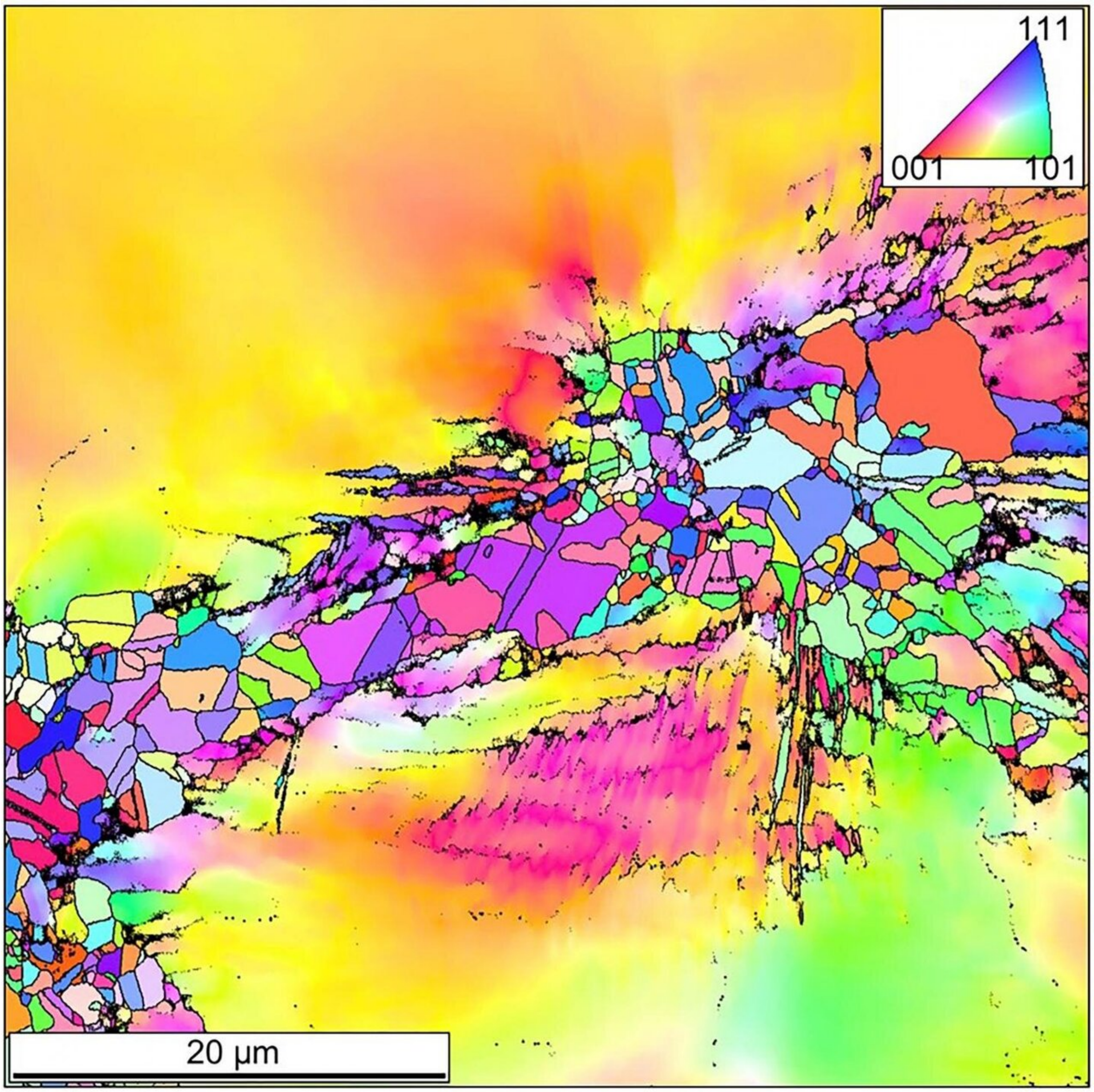
Lack of damage after secondary impacts surprises researchers

June 23 2020



A map showing crystallographic orientation of a region that originally contained a void, which was then subjected to a second shock loading (the shock wave passed from the bottom to the top of the image). The void has been recompacted with enough energy to not only reach a fully dense state, but drive recrystallization at the interface, as demonstrated by the thin band of very small grains. Credit: David Jones

When a material is subjected to an extreme load in the form of a shock or blast wave, damage often forms internally through a process called spall fracture.

Since these types of intense events are rarely isolated, research is needed to know how damaged materials respond to subsequent shock waves—a piece of armor isn't much use if it disintegrates after one impact.

To the surprise of researchers, recent experimentation on spall fracture in metals found that, in certain cases, there was an almost complete lack of damage with only a thin band of altered microstructure observed. Usually, under these sorts of conditions, the material would contain hundreds of small voids and cracks.

In an article for the *Journal of Applied Physics*, researchers from Los Alamos National Laboratory narrowed down exactly why the expected damage was missing.

"Conflicting hypotheses were suggested for the lack of damage. Was there some sort of strengthening occurring, so that damage never nucleated, or was the damage recompacted to a fully dense state by some other loading?" said author David Jones. "By splitting the experiment into two phases—damage formation and recompaction—we could determine which hypothesis was correct."

Materials experiencing shock damage at high strain rates from a sudden impact will exhibit significantly different behavior compared to their response under standard, low-rate mechanical testing.

The researchers used gas-gun flyer-plate impact experiments to first damage samples, and then impact these samples a second time to see how the shock wave interacts with the damage field, which had not been done before. They found a shock stress of just 2 to 3 gigapascal actually recompacted a damaged copper target and created a new bond where the once broken surfaces were brought back together.

"This research, where careful experiments are used to isolate the strength and damage response of a material under shock loading, helps to reveal how microstructure plays a key role in dynamic response," said Jones.

The authors hope the future of shock physics research will involve next-generation free electron X-ray lasers, a game-changing tool.

"Being able to image in real time these micrometer-scale, microsecond-duration damage events in metals will be a paradigm shift in shock physics diagnostics," said Jones.

More information: D. R. Jones et al, Shock recompaction of spall damage, *Journal of Applied Physics* (2020). DOI: 10.1063/5.0011337

Provided by American Institute of Physics