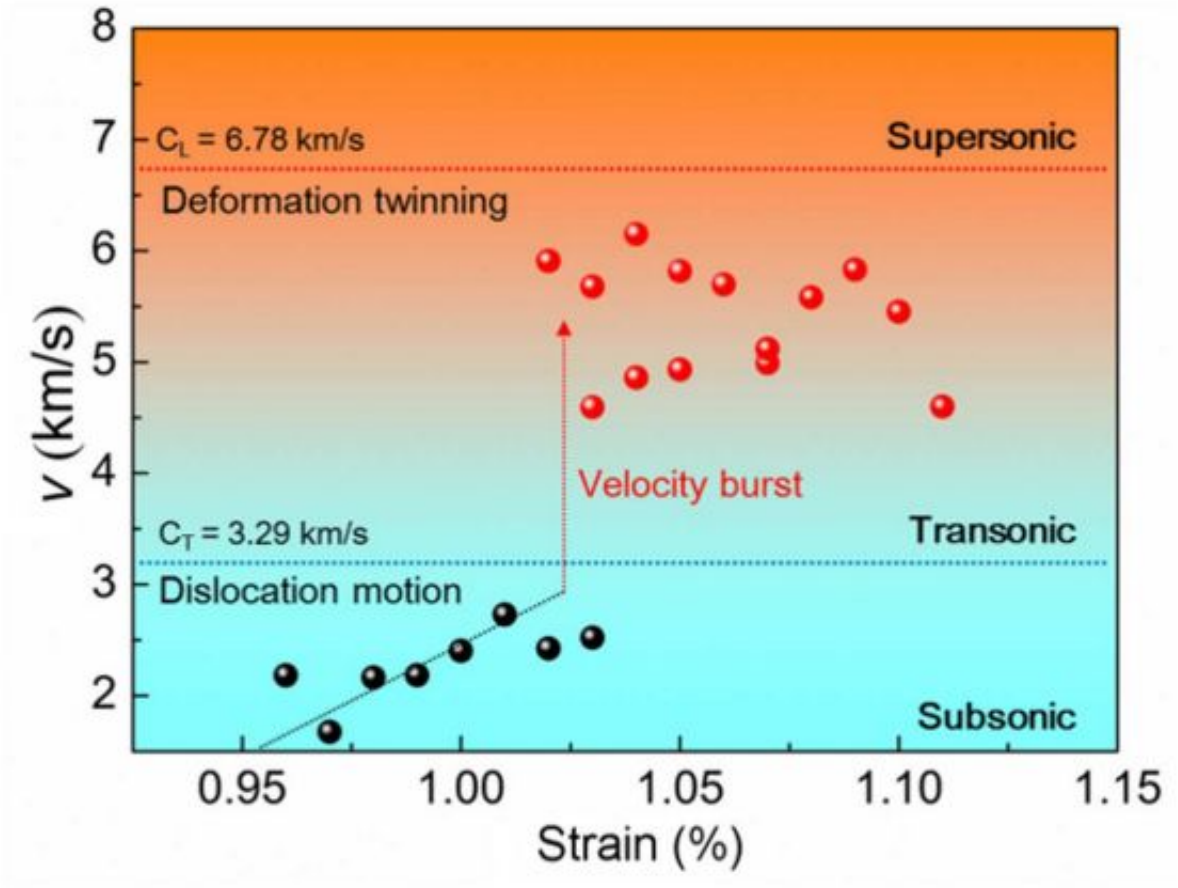
Experiments show that notions of twinning and slip in metals may not be as simple as thought

February 19 2016, by Bob Yirka



Propagation speed of dislocations and deformation twins during D-ECAP obtained from MD simulations. Credit: arXiv:1510.04404 [cond-mat.mtrl-sci]

(Phys.org)—A team of researchers from multiple institutions in China has cast doubts on the simple approach that has until now been taken regarding twinning and slip as metals deform. In their paper published in the journal *Physical Review Letters,* the team outlines experiments they conducted with aluminum, explain their results and suggest that new ways of categorizing the ways metal responds to stress must be defined.

To the eye, when metal is abused, it either bends or dents, which typically seem to be two aspects of the same end result—but at the atomic level, metals behave quite differently when force is applied. Two main categories of change have been identified—twinning, where the atoms that make up a crystal shift in their position relative to one another, and slip, where crystal planes slide along one another causing bonds between atoms to be broken and reestablished with other atoms. Over the years, various research efforts have led to general findings that some metals twin, and some slip, and rarely do they vary from expectations. But now, research by the team in China is contesting that view, suggesting that a material such as aluminum, which has traditionally been classified as one that exhibits slipping when stressed, can also exhibit twinning—when stressed in different ways. This finding suggests that expectations of other metals may be in error as well, which means the whole idea of categorizing metals in such ways may have to be rethought.

In their experiments, the researchers bent a bar made of aluminum until it formed a T shape. To explain what occurred in the metal as it was exposed to the large forces that caused such bending, the researchers built a computer model that sought to show what happened at the atomic level. The model wound up showing, via animated "movies" that the metal underwent both twinning and slipping, which contradicted what should have occurred. To test their model, the researchers looked at the bent metal under an electron microscope, which revealed the true nature of the metal—it did indeed both twin and slip. Their research results

suggest other metals will have to be tested and new ways of categorizing the ways that metals react to force will have to be found.

More information: F. Zhao et al. Macrodeformation Twins in Single-Crystal Aluminum, *Physical Review Letters* (2016). DOI: 10.1103/PhysRevLett.116.075501 . On *Arxiv*: arxiv.org/abs/1510.04404v1

ABSTRACT

Deformation twinning in pure aluminum has been considered to be a unique property of nanostructured aluminum. A lingering mystery is whether deformation twinning occurs in coarse-grained or single-crystal aluminum at scales beyond nanotwins. Here, we present the first experimental demonstration of macrodeformation twins in single-crystal aluminum formed under an ultrahigh strain rate (~106 s−1) and large shear strain (200%) via dynamic equal channel angular pressing. Large-scale molecular dynamics simulations suggest that the frustration of subsonic dislocation motion leads to transonic deformation twinning. Deformation twinning is rooted in the rate dependences of dislocation motion and twinning, which are coupled, complementary processes during severe plastic deformation under ultrahigh strain rates.

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