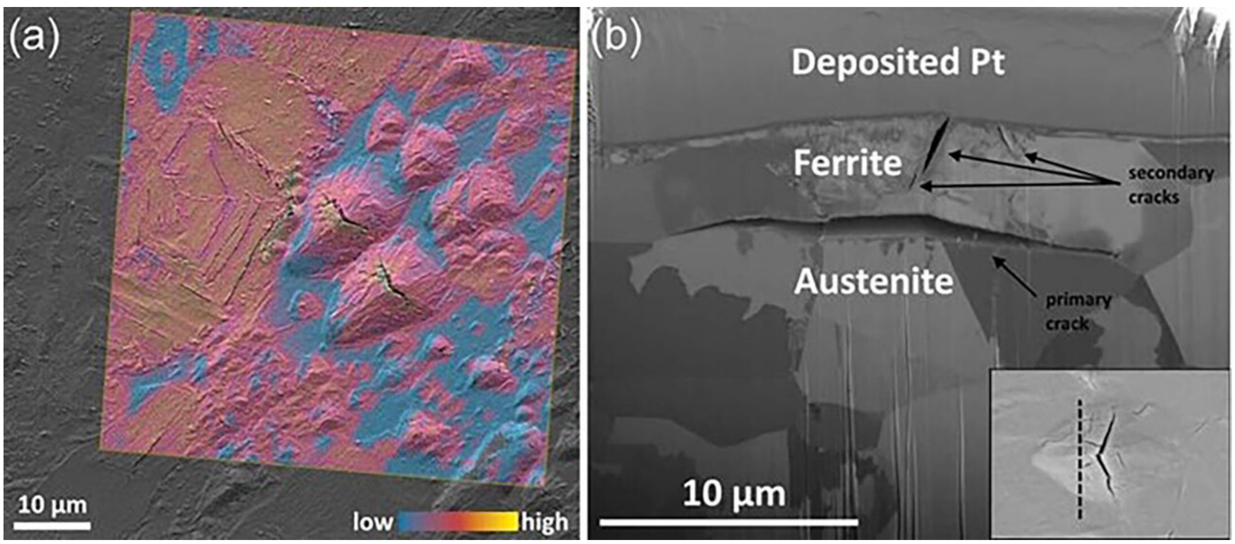
Hydrogen embrittlement creates complications for clean energy storage, transportation

October 6 2020



Hydrogen can cause brittleness in several metals including ferritic steel, but recent advancements provide insight into the embrittlement process.a) The arrowhead-shaped delaminations in stainless steel reveal cracks with significantly higher deuterium concentrations b) Secondary ion cross-sectional profile for one such delamination. Credit: O. Sobol, G. Holzlechner, G. Nolze, T. Wirth, D. Eliezer, T. Boellinghaus, and W.E.S. Unger

As the global energy market shifts from coal, petroleum fuel, and natural gas to more environmentally friendly primary energy sources, hydrogen is becoming a crucial pillar in the clean energy movement. Developing safe and cost-effective storage and transportation methods for hydrogen is essential but complicated given the interaction of hydrogen with structural materials.

Hydrogen can cause brittleness in several metals including ferritic steel —a type of steel used in structural components of buildings, automobile gears and axles, and industrial equipment. Recent advancements in experimental tools and multiscale modeling are starting to provide insight into the embrittlement process.

A review of various methods, published in *Applied Physics Reviews*, has improved the understanding of the structure, property, and performance of ferritic steels that are subjected to mechanical loading in a hydrogen environment. While there are many studies of stainless steel, the researchers concentrated on ferritic steel, a cheaper steel that is used in the construction of pipelines and other large structures.

"Determining the location of the hydrogen in the host metal is the million-dollar question," said May Martin, one of the authors.

Specifically, understanding where the hydrogen goes under strain in a bulk material is critical to understanding embrittlement.

"We haven't answered this question but by combining techniques, we are getting closer to that answer," said Martin.

The researchers highlighted several combinations of techniques and methods, including atom probe tomography. APT is a measurement tool that combines a field ion microscope with a mass spectrometer to enable 3-D imaging and chemical composition measurements at the atomic scale, even for light elements like hydrogen.

Other techniques that show promise are 2-D mapping by secondary ion mass spectrometry to answer the question of where hydrogen lies in a material. Ion mass spectrometry is a technique used to analyze the composition of solid surfaces and thin films by sputtering the surface of the specimen with a focused primary ion beam and collecting and analyzing the ejected secondary ions.

The researchers said it is particularly in the last decade that large advances have been made in hydrogen embrittlement, thanks to the development of new experimental capabilities. As new experimental techniques are refined it is expected the field will continue to develop at a remarkable pace.

"As the field expands, we hope our paper is a good resource for those getting into the field," said Martin.

More information: "Hydrogen embrittlement in ferritic steels," *Applied Physics Reviews* (2020). aip.scitation.org/doi/10.1063/5.0012851

Provided by American Institute of Physics