Helium channels in nanocomposites could be game changers

November 13, 2017

Formerly problematic element could provide self-healing features in metals

In bulk, polycrystalline metals, helium forms nanometer-scale precipitates that maintain a roughly spherical shape as they grow, much like a helium balloon as it is being inflated. These precipitates can severely damage the material. New research from Los Alamos National Laboratory with collaboration from Texas A&M University shows, however, that the growth trajectory that He precipitates follow in nanocomposites is very different: rather than simply expanding uniformly in all directions, they link up with each other to form long, vein-like channels. This finding could have value in determining if such channels not only do not damage the material, but may even help it to "self-heal" by providing easy paths for the He to escape.

"It's well known that He precipitates that typically expand as spheres of ever-increasing size wreak havoc on the mechanical integrity of the material," said Yongqiang Wang, the principal investigator of the project that supported this research at Los Alamos and a lead author on a paper in the journal *Science Advances*. "By contrast, when He aggregates into channels, the outcome could be much different**.** Knowing the way He precipitates grow is crucial because that's what determines how—and even if—He ends up damaging the material."

So far, nanocrystalline or nanostructured metals have been explored in the nuclear energy industry context only to evaluate their potential for future use and to perform basic research studies. In fact, the technological uses of nanostructured metals in any field so far are still minimal. However, the Los Alamos work opens new avenues for engineering applications of these materials. If helium within a nanostructured metal can be continuously released through viable escape channels, the problematic helium build-up rates in the material can be significantly reduced or eliminated.

"Our work required us to innovate several new experimental and modeling methods," Wang said. "One of the most important challenges that we faced was finding a way to view layered composites from a new perspective. While all previous work looked at cross sections of these materials, we looked perpendicular to the layers. Looking at the material from this new angle allowed us to see something that hadn't been discovered before, the formation of channels instead of spheres."

The idea came in the course of research in the Energy Frontier Research Center – Center for Materials under Irradiation and Mechanical Extremes project, in which these nanolayered interfaces were designed to absorb defects produced by ion irradiation and mechanical deformation processes. “We had an ultimate goal that these materials could potentially self-heal damage under these extreme operating conditions,” Wang said.

Funding: LDRD-ER

The team: Di Chen and Yongqiang Wang in Los Alamos’s MST-8 group, Nan Li and Kevin Baldwin in the Center for Integrated Nanotechnologies at Los Alamos; and external collaborators Michael J. Demkowicz at TAMU-Materials Science and Engineering Dept. and his former student at Massachusetts Institute of Technology Materials Science and Engineering Dept., Dina Yuryev.

Nanolayer interface selection and helium evolution in the interfaces were modeled by the external collaborators; the designer nanolayer interface structures were fabricated at the Center for Integrated Nanotechnologies, application of helium into the nanointerfaces was carried out at the Ion Beam Materials Laboratory (IBML), and observation of helium nanochannels in the structure was performed at the Electron Microscopy Laboratory (EML) at the Materials Science Laboratory at Los Alamos. This research used resources of the Los Alamos Center for Integrated Nanotechnologies, which is a DOE Office of Science User Facility.