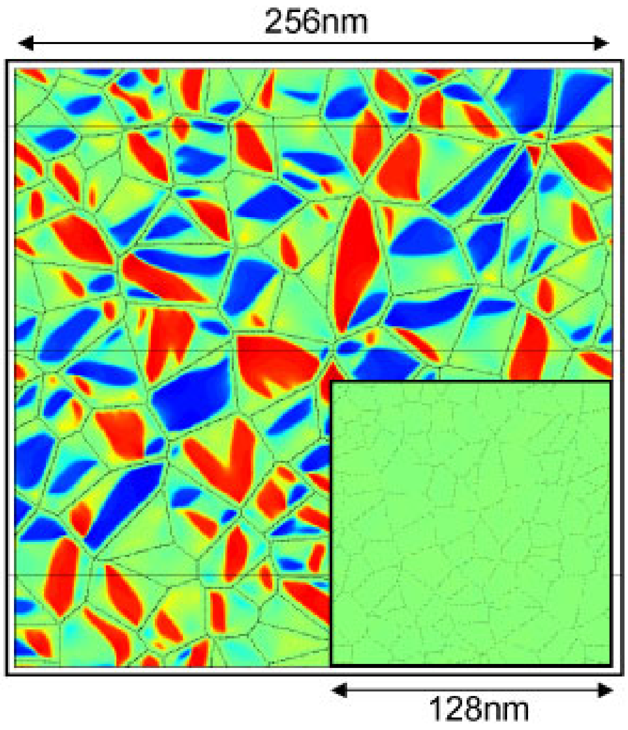
Nanocrystalline shape memory alloys lose their memory as the crystalline grains get smaller

February 24 2016



In nanocrystalline shape memory alloys, martensitic transformation (red and blue areas) is suppressed as the grain size decreases (inset) due to grain boundary effects. Credit: AIP Publishing LLC

The ability of shape memory alloys, used as materials for medical stents, to revert to their original shape after an increase in temperature is suppressed at nanometer grain sizes due to effects related to the larger proportion of grain boundaries, according to a mathematical model developed by A*STAR researchers. This finding helps explain shape memory loss in and increase our understanding of nanocrystalline shape memory materials, which will lead to improvements in the design of such devices.

"Shape memory alloys are commonly used as materials for medical stents because of their interesting shape memory and mechanical properties, and also in other biomedical and engineering applications," says lead researcher, Rajeev Ahluwalia, from the A*STAR Institute of High Performance Computing.

Shape memory refers to the ability of a material to return to its original form, usually by heating, after relatively large degrees of deformation. This shape recovery occurs because atoms in the crystalline structure of the material change their relative arrangements when there is a decrease in temperature, and return to their original sites upon reheating. This type of 'martensitic' transformation can be extremely useful in various applications, but experimentally it has been found that this transformation is suppressed as the constituent crystal grains approach nanoscale dimensions. This potentially reduces the applicability of shape memory alloys at small scales.

Ahluwalia and his team developed a mathematical model for martensitic transformation that successfully reproduces experimentally observed suppression of the transformation in these materials (see image).

"Our model shows that this suppression of the martensitic transformation can be attributed to grain boundary effects," explains Ahluwalia. "Grain boundaries can impose an energy penalty during transformation, suppressing the transformation locally at grain boundaries, and leading to complete suppression of transformation in small grains below a critical grain size."

While showing that the temperature induced transformation is suppressed in the nanograin regime, the team's findings also explained the reduction in 'mechanical hysteresis'—the difference in how a material deforms under a given force depending on whether it is loading or unloading—as the grain size decreases. This implies reduced energy loss and reduced mechanical fatigue — desirable properties that can be obtained by decreasing the grain size.

"Understanding the cause behind these interesting behaviors at small grain sizes gives us a means of designing material microstructures to have desirable properties," says Ahluwalia.

More information: Rajeev Ahluwalia et al. Simulation of grain size effects in nanocrystalline shape memory alloys, *Journal of Applied Physics* (2015). DOI: 10.1063/1.4923044

Provided by Agency for Science, Technology and Research (A*STAR), Singapore

Citation: Nanocrystalline shape memory alloys lose their memory as the crystalline grains get smaller (2016, February 24) retrieved 25 April 2024 from https://phys.org/news/2016-02-nanocrystalline-memory-alloys-crystalline-grains.html