How long does memory last? For shape memory alloys, the longer the better

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Known to many as muscle wire or memory metal, shape memory alloys are materials that can be bent or deformed, and then return to their original shape when heat is applied. While people are most familiar with the material in "unbreakable" eye-glass frames, these alloys are also used as vibration dampers, actuators, and sensors in high technology applications like the aerospace and automotive industries, medical

devices, and civil engineering.

Heat pumping systems are another potential use for shape memory alloys , taking advantage of their elastocaloric effect, which is a cooling effect that happens when the alloy is cyclically acted upon by mechanical forces. Scientists at Ames Laboratory think heat pumping systems designed in that way could lead to greener, more energy efficient HVAC and refrigeration systems than currently available gas compression models.

For that application, shape memory alloys need to "remember" their original shape more exactly, for longer periods of time, through many repeated cycles.

"The application of shape memory alloys (SMA) is dependent on what is called martensitic phase transition, which transfers heat back and forth many times, ideally without any degradation of the heat cycle, such as cracking," said Lin Zhou, a scientist at Ames Laboratory. "To understand why that degradation happens and find ways to improve SMAs for real-world applications, we must look at the microstructure of these materials."

The researchers compared two copper-based SMAs of the same composition but fabricated differently— after annealing, the samples were cooled at different rates. Then both samples were heated inside the transmission electron microscope (TEM), so that scientists could observe the martensitic phase transition in real time.

The rapidly cooled sample transformed at a lower temperature and with better "memory" than the more slowly cooled sample. Researchers attributed this to the formation of tiny nickel-rich dots that appeared in the slowly-cooled sample, which changed the phase transition pathway and negatively affected the alloy's performance.

"Those Ni-rich precipitates change the matrix alloy composition and make phase transition harder to reverse, thus the energy loop is less reliable," said Zhou. "It is this kind of insight that will help us fabricate better SMAs."

The research is further discussed in the paper, "In-situ TEM analysis of the phase transformation mechanism of a Cu–Al–Ni shape memory alloy," authored by Tae-Hoon Kim, Gaoyuan Ouyang, Jonathan D. Poplawsky, Matthew J. Kramer, Valery I. Levitas, Jun Cui, and Lin Zhou; and published in *The Journal of Alloys and Compounds*.

More information: Tae-Hoon Kim et al. In-situ TEM analysis of the phase transformation mechanism of a Cu–Al–Ni shape memory alloy, *Journal of Alloys and Compounds* (2019). DOI: 10.1016/j.jallcom.2019.151743

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