Scientists turn dents into smart bumps

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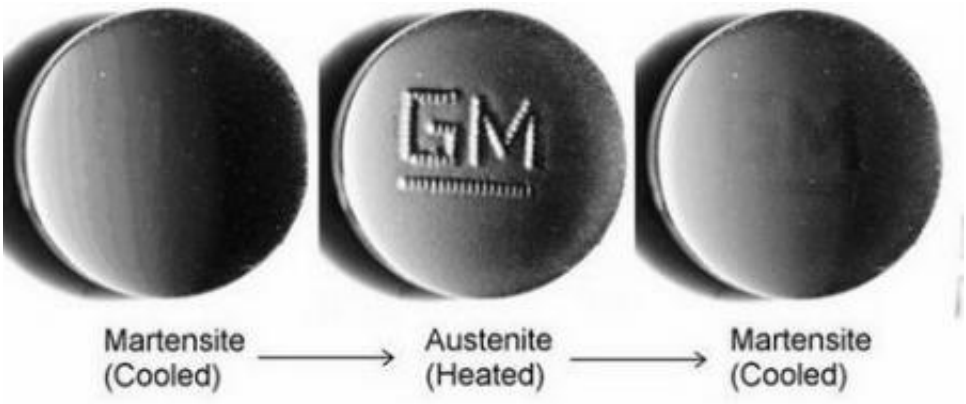

This temperature-controlled reversible sign shows how images can appear on a surface simply by heating or cooling. The shape memory effect occurs because a surface “remembers” different arrangements while in different phases. Image credit: Yang-Tse Cheng.

Due to a phenomenon called the shape memory effect (SME), certain "memory metals" can be distorted and then brought back to their original shape by a simple temperature change. While a one-way memory effect has inspired applications since the '60s, and a two-way memory effect can also make objects remember two different shapes, scientists have recently discovered that the effect can now be realized at micro or nano scale on surface – dents can be turned into "mirrored" bumps.

A team of researchers from Michigan State University and General Motors, Yijun Zhang, Yang-Tse Cheng, and David Grummon, is pioneering two-way, reversible shape memory surfaces where micro-

and nano-scale surface features can come and go as a result of phase transformations in the materials' structures.

While SME technology already surrounds us – from bendable eyeglass frames and surgical tools to anti-scald faucets and fire sprinklers – reversible SME will likely be exploited for an even wider range of optical, tribological (rubbing), and microelectromechanical applications. For instance, surfaces can become slippery or sticky by changing temperature, or signs can appear and disappear by heating and cooling (see figure).

In essence, the two-way shape memory effect describes the peculiar ability of certain materials to obtain different shapes depending on two of their structural phases, which can be switched by increasing or decreasing temperature (about a 100 degree K difference). Here, Zhang *et al.* used nickel titanium (NiTi) – one of the rare materials to exhibit the effect – to further investigate the two-way shape memory effect. After denting or scratching the metal at a low temperature (in its asymmetric, "martensite" phase) the object can be heated (to its symmetric, "austenite" phase) to retain its original, flat shape. Depending on how severely the metal is distorted, the object may keep some of its distorted shape when re-cooled to the austenite phase.

"Typically, SME is a one-way phenomenon," wrote Zhang, Cheng, and Grummon in a recent issue of *Applied Physics Letters*. "When a sample is cooled from the austenite to martensite phase again the shape memory alloy (SMA) does not change shape. Two-way shape memory effect refers to the reversible shape changing ability of SMAs during cyclic heating and cooling, which is usually achieved after certain thermal-mechanical training cycles under given stress or strain. … We show that this shape memory effect can [also] be accomplished by a single indentation in the martensite NiTi without additional thermal-mechanical training cycles."

The team trained NiTi objects to exhibit protruding bumps in the austenite phase by first making dents in the martensite phase, and then "planarizing" (a flattening technique using mechanical polishing) the NiTi to remove the dents before increasing the temperature.

"[M]icrostructure and stress distribution beneath the indents and scratches remain largely intact [after planarization]," wrote Zhang, *et al.* "As a result, the two-way shape memory effect gives rise to surface protrusion instead of indent depth recovery. ... These protruding structures disappear when the sample was cooled down to the martensite phase."

In a sense, the scientists tricked the austenite structure to believe that it had to "fix" a dent that had already been fixed, causing the surface to over-compensate and swell out. For the first time, the scientists show that memory metals can be given "false" memories, encouraged to take on a shape they have never experienced by a manipulative preparation process.

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