Assessing the latest findings regarding room temperature plasticity in ceramics

October 27 2022

Credit: Pixabay/CC0 Public Domain

Making ductile ceramics is a hard task. Plasticity in ceramics is rarely observed and typically requires special conditions such as extreme temperatures to be feasible. Therefore, instead of denting, a typical ceramic coffee mug will fracture into pieces when dropped on a hard floor.

In his commentary, Dr. Erkka J. Frankberg, an expert on plasticity of ceramics, assesses some of the latest findings regarding room temperature plasticity in ceramics, reported by J. Zhang et al. in *Science*. In his commentary, Frankberg paints a broader view on the potential benefits of such ductile ceramics, were they to be made possible and scaled for commercial use, possibly ushering in a new stone age.

Why would it be important to develop ceramics that are ductile at room temperature? It is due to the atoms themselves and the bonding between them. Ceramics have ionic and covalent bonding between the atoms that significantly differ from (for example) bonds in metal alloys. One major difference is that the ionic and covalent atom bonds are among the strongest we know. As a result, in theory, ceramics should be among the strongest engineering materials that exist.

"The catch is this: while the bonds are strong, they also prevent atoms from easily moving around in the material, and this movement is needed to create plasticity, or in other words, a permanent change in the perceived shape of the material. Without plasticity, unfortunately, ceramics fracture well below their theoretical strength, and in practice, often have lower ultimate strength than many metal alloys commonly used in engineering," Frankberg says.

As a demonstration of the potential of ductile ceramics, Zhang et al. show that if silicon nitride (Si_3N_4), a ceramic material, is engineered to exhibit plasticity, it can exhibit a whopping ultimate strength of ~11 GPa prior to fracture. This is around 10 times stronger than some common grades of high strength steel.

What could ultra-strong ductile ceramics give us?

"Higher strength means less material needed to build moving machines such as vehicles and robots. Less material means lower inertia, meaning lower energy consumption and higher efficiency for all moving machinery. Higher wear and corrosion resistance of ceramics would allow higher up-time in these applications, which enables economic benefits," Frankberg points out.

Humanity has a constant need for ever stronger engineering materials, because of the large cross-cutting impact it would have, improving the energy efficiency of society.

"Because of the softer bonding, there is a hard limit to how strong materials we can create from metals. To reach the next level in strength, ceramics are a good candidate," Frankberg states.

While the results of Zhang et al. are spectacular demonstration of the potential of ductile ceramics, the results are demonstrated at the nanoscale, such as most similar results in the field. Therefore, a long and winding road is still ahead to realize the dream of flexible ceramics, which essentially requires that these results be repeated in a bulkier material.

"But every discovery of a new room temperature plasticity mechanism, such as that presented by Zhang et al., keeps us holding on to the dream of flexible ceramics," Frankberg concludes.

More information: Erkka J. Frankberg, A ceramic that bends instead of shattering, *Science* (2022). DOI: 10.1126/science.ade7637. www.science.org/doi/10.1126/science.ade7637

Jie Zhang et al, Plastic deformation in silicon nitride ceramics via bond switching at coherent interfaces, *Science* (2022). DOI: 10.1126/science.abq7490

Provided by Tampere University