# Fine-grained microstructure could toughen protective coatings

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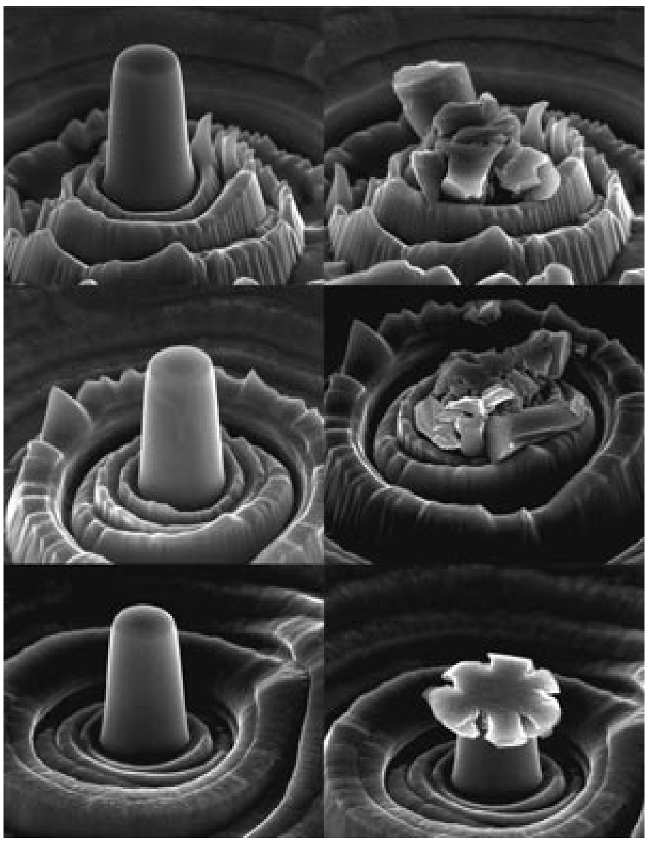

Scanning electron microscope images show pristine (left) and compressed (right) micropillars of (top) chromium nitride, (middle) chromium aluminum nitride, and (bottom) chromium aluminum nitride / silicon nitride nanocomposite. Credit: AIP Publishing

Hard materials like chromium nitride are used as wear and corrosion protection coatings in a wide range of applications, including metal cutting. Now, A*STAR researchers have discovered exactly how such materials behave when used in high-stress situations, paving the way to producing even better coatings.

One way to improve a material's resistance to wear is to increase its hardness. This depends mainly on the force it can withstand before it starts to permanently deform. In most crystalline materials, this deformation occurs when defects, known as dislocations, start to move through a material's crystal structure.

Currently used coating materials are very brittle, with a toughness only a little more than that of window glass. Also, previous research has shown that it is very difficult to break crystals that are extremely small. So Shiyu Liu of the A*STAR Singapore Institute of Manufacturing Technology and co-workers have used this effect to study how coatings based on chromium nitride might deform.

The researchers first made microscopic pillars of the material, roughly 380 nanometers across. Then they compressed them using a diamond flat punch in a scanning electron microscope at temperatures up to 500 degrees Celsius, and studied their responses (see image).

They found that if the chromium-nitride-based coatings are made with very fine grains, each roughly 10 nanometers across, with each grain separated by a thin grain boundary phase, the force required to deform such materials increased dramatically. Indeed, deformation began at stresses very much higher than expected, and close to the theoretical maximum value from calculations. Liu's team has shown that this increase happened when the grains became so small that they did not contain dislocations, so that the applied forces had to be sufficiently large to form new dislocations within the grains.

It had long been thought that the thin grain boundary phase would be the main factor in determining the material's properties. However, the researchers have shown this was not the case, providing a way to reliably make a hard material.

The results show that the formation of a fine-grained microstructure could provide a ceramic coating with enhanced hardness and fracture toughness. "This could be a viable approach for the development of super-hard and tough protective coatings for high-temperature and high-pressure applications," says Liu.

The team plans to use the results in advanced manufacturing and engineering applications, such as protective coatings in high-speed machining tools for titanium and nickel-based alloys.

**More information:** S. Liu et al. Plastic flow at the theoretical yield stress in ceramic films, *Scripta Materialia* (2016). DOI: 10.1016/j.scriptamat.2016.02.008

S. Liu et al. Compressive deformation and failure of CrAlN/Si3N4 nanocomposite coatings, *Applied Physics Letters* (2014). DOI: 10.1063/1.4867017

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