A protective layer applied to gold nanoparticles can boost its resilience

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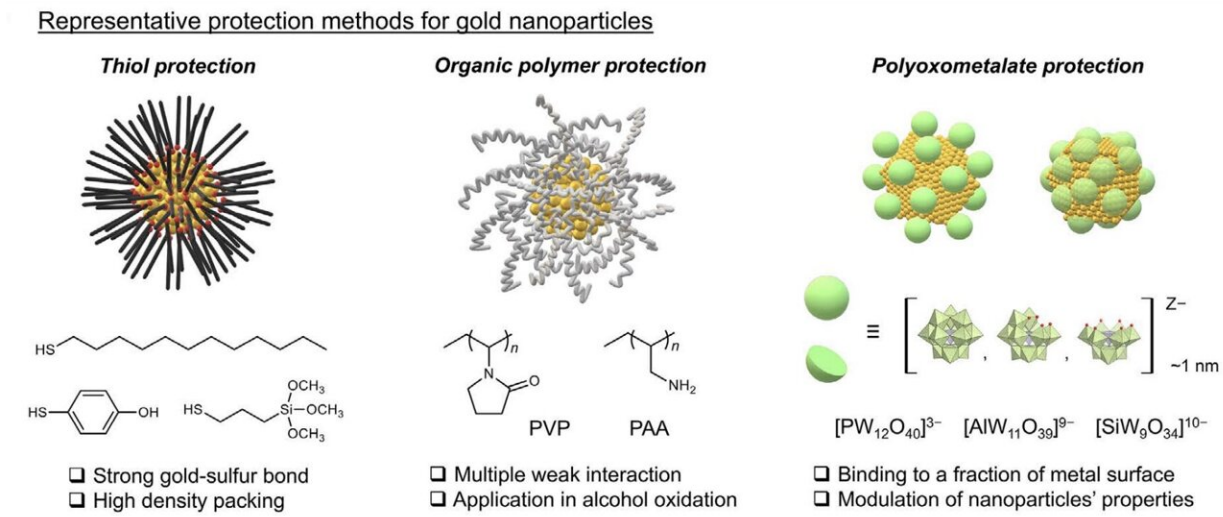


Thiol and organic polymer protection are two existing ways to add resilience to gold nanoparticles. On the right is a representation of the researchers' new method using polyoxometalate. Credit: 2024 Suzuki et al.

For the first time, researchers including those at the University of Tokyo have discovered a way to improve the durability of gold catalysts by creating a protective layer of metal oxide clusters. The enhanced gold catalysts can withstand a greater range of physical environments than unprotected equivalent materials can.

This advancement could increase the catalysts' range of possible applications, as well as reduce energy consumption and costs in some situations. These catalysts are widely used throughout industrial settings, including chemical synthesis and production of medicines, these industries could benefit from improved gold catalysts.

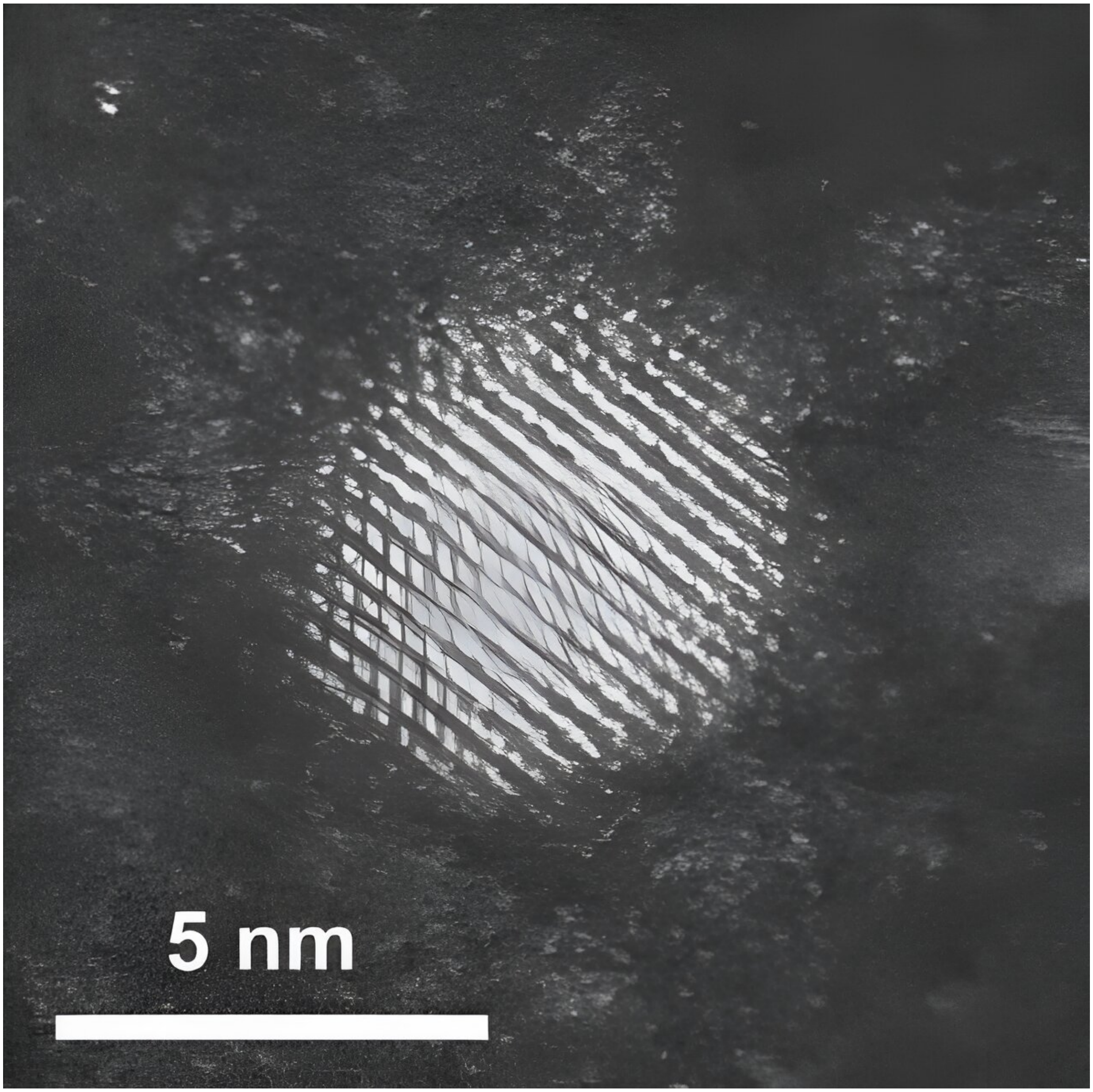
The research appears in *Nature Communications*.

Everybody loves gold: athletes, pirates, bankers—everybody. It's historically been an attractive metal from which to craft things like medals, jewelry, coins and so on. The reason gold appears so shiny and alluring to us is that it's chemically resilient to physical conditions that might otherwise tarnish other materials: for example, heat, pressure, oxidation and other detriments.

Paradoxically, however, at nanoscopic scales, tiny particles of gold reverse this trend and become very reactive, so much so that for a long time now they have been essential to realizing different kinds of catalysts, intermediary substances that accelerate or in some way enable a chemical reaction to take place. In other words, they're useful or necessary to turn one substance into another, hence their widespread use in synthesis and manufacture.

"Gold is a wonderful metal and is rightly praised in society, and especially in science," said Associate Professor Kosuke Suzuki from the Department of Applied Chemistry at the University of Tokyo. "It's great for catalysts and can help us synthesize a range of things, including medicines.

"The reasons for this are that gold has a low affinity for absorbing molecules and is also highly selective about what it binds with, so it allows for very precise control of chemical synthesis processes. Gold catalysts often operate at lower temperatures and pressures compared to traditional catalysts, requiring less energy and reducing environmental impact."



Atomic resolution image of the researchers' novel nanoparticle made using a technique called annular dark-field scanning transmission electron microscopy. Credit: 2024 Suzuki et al.

As good as gold is, though, it does have some drawbacks. It becomes more reactive as smaller particles are made of it, and there is a point at which a catalyst made with gold can begin to suffer negatively from heat, pressure, corrosion, oxidation and other conditions. Suzuki and his team believed they could improve upon this situation and devised a novel protective agent that could allow a gold catalyst to maintain its useful functions, but across a greater range of physical conditions that usually hinder or destroy a typical gold catalyst.

"Current gold nanoparticles used in catalysts have some level of protection, thanks to agents such as dodecanethiols and organic polymers. But our new one is based on a cluster of metal oxides called polyoxometalates and it offers far superior results, especially in regard to oxidative stress," said Suzuki.

"We are currently investigating the novel structures and applications of polyoxometalates. This time we applied the polyoxometalates to gold nanoparticles and ascertained the polyoxometalates improve the nanoparticles' durability. The real challenge was applying a wide range of analytical techniques to test and verify all this."

The team used a variety of techniques collectively known as spectroscopy. It employed no less than six spectroscopic methods varying in the kinds of information they reveal about a material and its behavior. But generally speaking, they work by casting some kind of light onto a substance and measuring with specialized sensors how that light changes in some way. Suzuki and his team spent months running various tests and different configurations of their experimental material until they found what they were seeking.

"We're not just driven by trying to improve some methods of chemical synthesis. There are many applications of our enhanced gold nanoparticles that could be used to benefit society," said Suzuki.

"Catalysts to break down pollution (many gasoline cars already have a familiar catalytic converter), less impactful pesticides, green chemistry for renewable energy, medical interventions, sensors for foodborne pathogens, the list goes on.

"But we also want to go further. Our next steps will be to improve the range of physical conditions we can make gold nanoparticles more resilient to, and also see how we can add some durability to other useful catalytic metals like ruthenium, rhodium, rhenium, and of course, something people prize even more highly than gold: platinum."

More information: Ultra-stable and highly reactive colloidal gold nanoparticle catalysts protected using multi-dentate metal oxide nanoclusters, *Nature Communications* (2024). DOI: 10.1038/s41467-024-45066-9

Provided by University of Tokyo

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