When bonding noble metals to 2-D materials, interfaces matter

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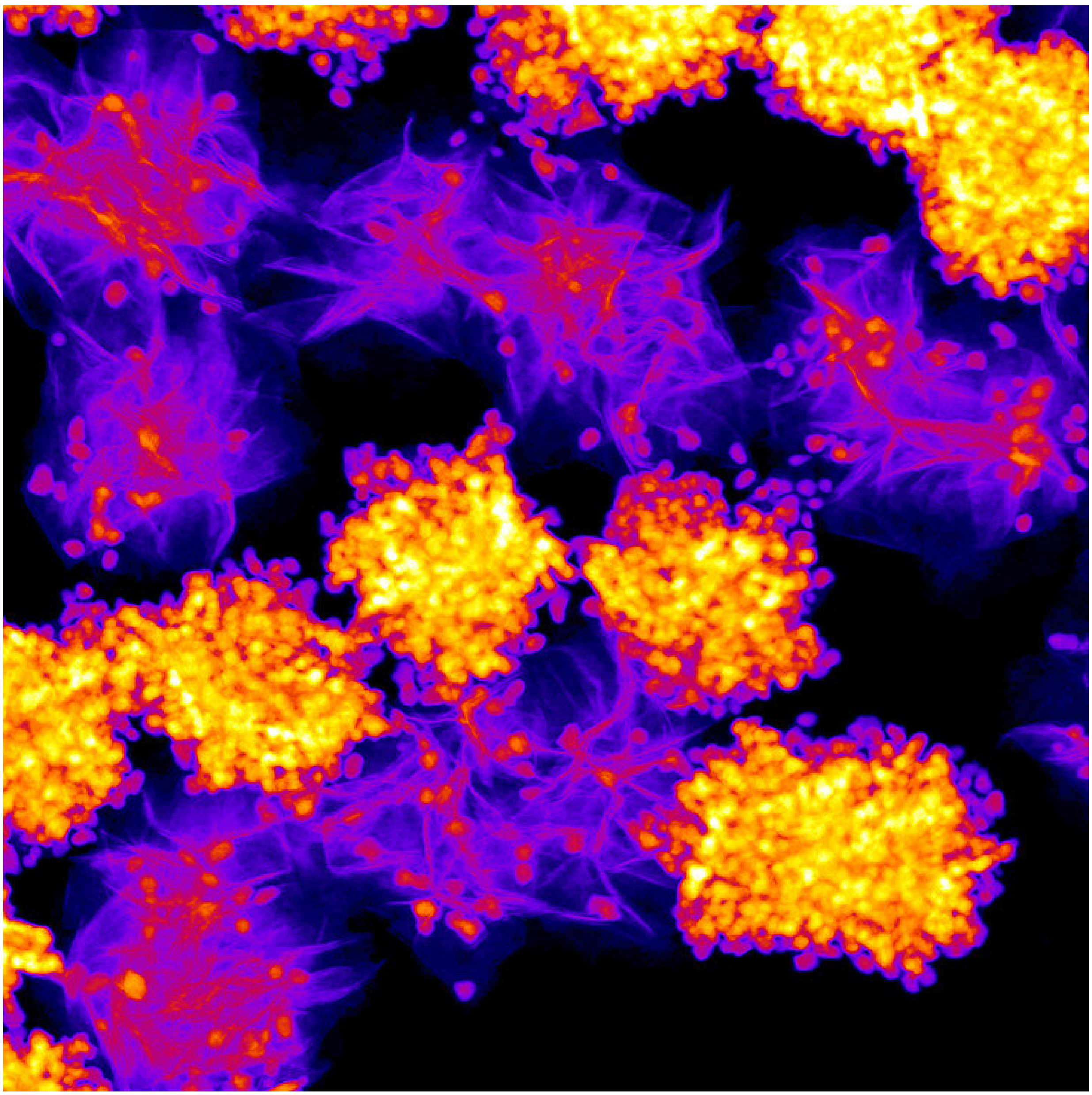

Electron microscope image showing preferential deposition of gold nanoparticles onto transition metal ditellurides relative to the disulfide counterparts. Credit: Yifan Sun, Penn State

Researchers at Penn State and Purdue University have developed new materials for improved single-atom catalysis and future electronics.

The materials, based on two-dimensional transition metal dichalcogenides (TMDs) that include disulfides, diselenides and tellurides, have a variety of interesting properties that scientists would like to exploit, especially for next-generation electronics and catalysis.

The team deposited the noble metals gold and silver on the two-dimensional TMD substrates and studied how the metals formed and grew on the TMD surfaces. In every case but one, the metals formed zero-dimensional nanoparticles, as theory predicted. But in the case of silver deposited on ditellurides, the silver formed a single atom layer coating the entire substrate.

"We tried the experiments again and again, but did not see any evidence of silver nanoparticle formation on the transition metal ditellurides, yet we knew the silver was there," said Yifan Sun, former Penn State doctoral student and lead author on a paper published this week in the journal *Nature Chemistry*.

The team found that the interfaces between the TMDs and the noble metals were important in determining the growth and final structure of the metals.

"That was really interesting to us and provides new insights into how to probe the interfaces between 2-D and 3-D nanostructures," Sun added.

The team believes this knowledge will be useful in an important field of chemistry called single-atom catalysis. The problem that single-atom catalysis currently faces is that as the density of the catalytic atoms increases they tend to form aggregates that cluster into nanoparticles, which lowers the catalytic activity. As more than 85 percent of chemicals are produced by catalysis, a single-atom process that didn't aggregate could have huge benefits.

"The process allows us to think in the future of how you could design single-atom catalysts that had minimal amounts of these expensive noble metals and have enhanced properties because of that," said Ray Schaak, Dupont Professor of Chemistry, and corresponding author on the Nature Chemistry paper.

Another place where people would like to use this type of material is in electronics. They often need to make a contact with a metallic wire and this kind of growth on TMDs gives that anchoring point.

"2-D metals is an emerging area and it was very hard to convince people we had a 2-D silver layer," said Mauricio Terrones, Verne M. Willaman Professor of Physics, and distinguished professor of physics, chemistry and materials science and engineering, Penn State. "It doesn't happen with other materials."

In the future, the researchers intend to try other metals that have more interesting catalytic properties than silver.

More information: Yifan Sun et al. Interface-mediated noble metal deposition on transition metal dichalcogenide nanostructures, *Nature Chemistry* (2020). DOI: 10.1038/s41557-020-0418-3

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