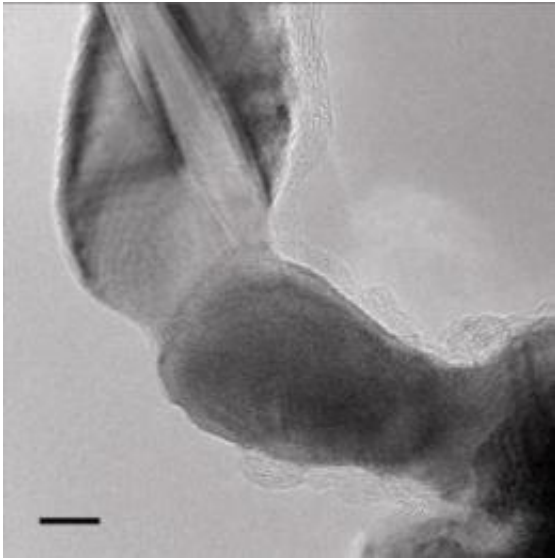


Gold and silver nanowires bond naturally, stay strong

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Two gold nanowires weld when their tips touch. Credit: Jun Lou/Rice University

(PhysOrg.com) -- Welding uses heat to join pieces of metal in everything from circuits to skyscrapers. But Rice University researchers have found a way to beat the heat on the nanoscale.

Jun Lou, an assistant professor in mechanical engineering and materials science, and his group have discovered that [gold](#) wires between three-billionths and 10-billionths of a meter wide weld themselves together quite nicely - without heat.

They report in today's online edition of the journal *Nature Nanotechnology* that clean gold [nanowires](#) with identical atomic structures will merge into a single wire that loses none of its electrical and mechanical properties. The process works just as well with [silver](#) nanowires, which bond with each other or with gold.

This cold-welding process has been observed on the macro scale for decades, Lou said. Clean, flat pieces of similar metals can be made to bond under high pressure and in a vacuum. But only Lou and his colleagues have seen the process happen on the nanoscale, under an electron microscope.

As so often happens in basic research, that's not what they were looking for at all. Lou and Rice graduate student Yang Lu, with collaborators at Sandia National Laboratories and Brown University, were trying to determine the tensile strength of gold nanowires by attaching one end of a wire to a probe in a [transmission electron microscope](#) (TEM) and the other to a tiny [cantilever](#) spring called an [atomic force microscopy](#) (AFM) probe.

Pulling the wire apart gave the team a measurement of its strength. What they didn't expect to see was the broken wire mending itself when its ends or sides touched. Measurements showed the reconnected wire was as strong as before.

"Before you can actually stretch something, you need to clamp it well," said Lou, who received a Young Investigators Research Program grant from the Air Force Office of Sponsored Research last year. "During the manipulation process, we observed this type of welding behavior all the time.

"Initially, we didn't pay attention to it because it didn't seem significant. But after doing a little research on the field, I realized we discovered

something that may be useful."

In testing, Lou found the nanowires could be snapped and welded many times. Mended wires never broke again at the same spot; this attests to the strength of the new bond.

The wire's electrical properties also seemed unaffected by repeated breaking and welding. "We'd break a wire and reweld it 11 times and check the electrical properties every time. All the numbers were very close," he said.

The keys to a successful weld are the nanowire's single crystalline structure and matching orientation. "There are a lot of surface atoms, very active, that participate in the diffusion at the nanoscale," Lou said. "We tried gold and silver, and they weld in the same way as long as you satisfy the crystalline-orientation requirement."

Lou sees the discovery opening new paths for researchers looking at molecular-scale electronics. He said teams at Harvard and Northwestern are working on ways to pattern arrays of nanowires, and incorporating cold welding could simplify their processes. "If you're building high-density electronic devices, these kinds of phenomena will be very useful," he said, noting that heat-induced welds on the [nanoscale](#) run the risk of damaging the materials' strength or conductivity.

Lou said the discovery has caused a stir among the few he's told. "Different people see different aspects: Electrical engineers see the application side. Theory people see some interesting physics behind this behavior. We hope this paper will encourage more fundamental study."

The paper's co-authors include Jian Yu Huang, a scientist at the Center for Integrated Nanotechnologies at Sandia National Laboratories; and Professor Shouheng Sun and former graduate student Chao Wang of

Brown University.

Provided by Rice University

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