# Nanophysicists find unexpected magnetic effect: Kondo effect noted in single-atom contacts of pure ferromagnets

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Spanish and U.S. physicists studying nanoelectronics have found that size really does matter when it comes to predicting the behavior of electrical contacts that are just one atom wide.

In new research appearing this week in the journal *Nature*, physicists at Spain's University of Alicante and at Rice University in Houston have found that single-atom contacts made of ferromagnetic metals like iron, cobalt and nickel behave very differently than do slightly larger versions that are on the order of the devices used in today's electronic gadgets.

"We've found that the last atom in the line, the one out there on the very end, doesn't want to align itself and behave like we expect it to," said study co-author Doug Natelson, associate professor of physics and astronomy at Rice. "What this shows is that you can really alter what you think of as a defining property of these metals just by reducing their size."

The findings center on the "Kondo effect," one of the most studied and well documented phenomena in magnetic materials. Scientists learned early in the study of electromagnetism that normal metals, like copper, conduct electricity better as they became colder. But in the 1930s, scientists found that adding even trace amounts of ferromagnetic metals like iron would throw off this effect.

In the 1960s, Japanese physicist Jun Kondo explained the effect: while cooling normal metals results in fewer vibrations among atoms, and thus less electrical resistance, mobile electrons in the metals tend to align their spins in the opposite direction of the spins of electrons in a magnetic atom. Thus, at low temperatures, an electron moving past a magnetic impurity will tend to flip its spin and therefore get deflected from its path. This explains why even tiny magnetic impurities can cause electrical resistance to rise, in spite of further cooling.

Based on decades of experimental evidence, physicists would not ordinarily expect the Kondo effect to play a role in wires and contacts made entirely of ferromagnetic metals like iron, cobalt and nickel. Yet that is precisely what co-authors Maria Reyes Calvo and Carlos Untiedt found occurring in experiments in Untiedt's laboratory in Alicante, Spain, in 2008. Calvo, a graduate student, was working with single-atom ferromagnetic contacts that were created by lowering and raising the tip of a scanning tunneling microscope onto a surface.

Untiedt knew that Natelson worked on similar-sized systems that were created in a wholly different way, by laying down metals on a flat surface. So Untiedt arranged for a travel grant from the Spanish government and Natelson agreed to oversee Calvo's recreation of the study at Rice.

"Reyes was a very quick study, and within just a few weeks she had mastered our technique for making single-atom junctions," Natelson said. "She conducted dozens of experiments on junctions made of cobalt and nickel, and we saw the characteristic Kondo effect in the conductance, just as she had seen in Spain."

Co-authors Joaquín Fernández-Rossier and Juan José Palacios, both of the University of Alicante, and David Jacob of Rutgers University. provided a theoretical framework to help explain the unexpected effect.

Natelson said the team's discovery is yet another example of the unique types of effects that characterize nanotechnology.

"The fact that this atom is all by itself at the surface is what makes it behave so differently, and it shows that engineers need to be mindful of surface effects in anything they design at this level," Natelson said.

Source: Rice University (news : web)