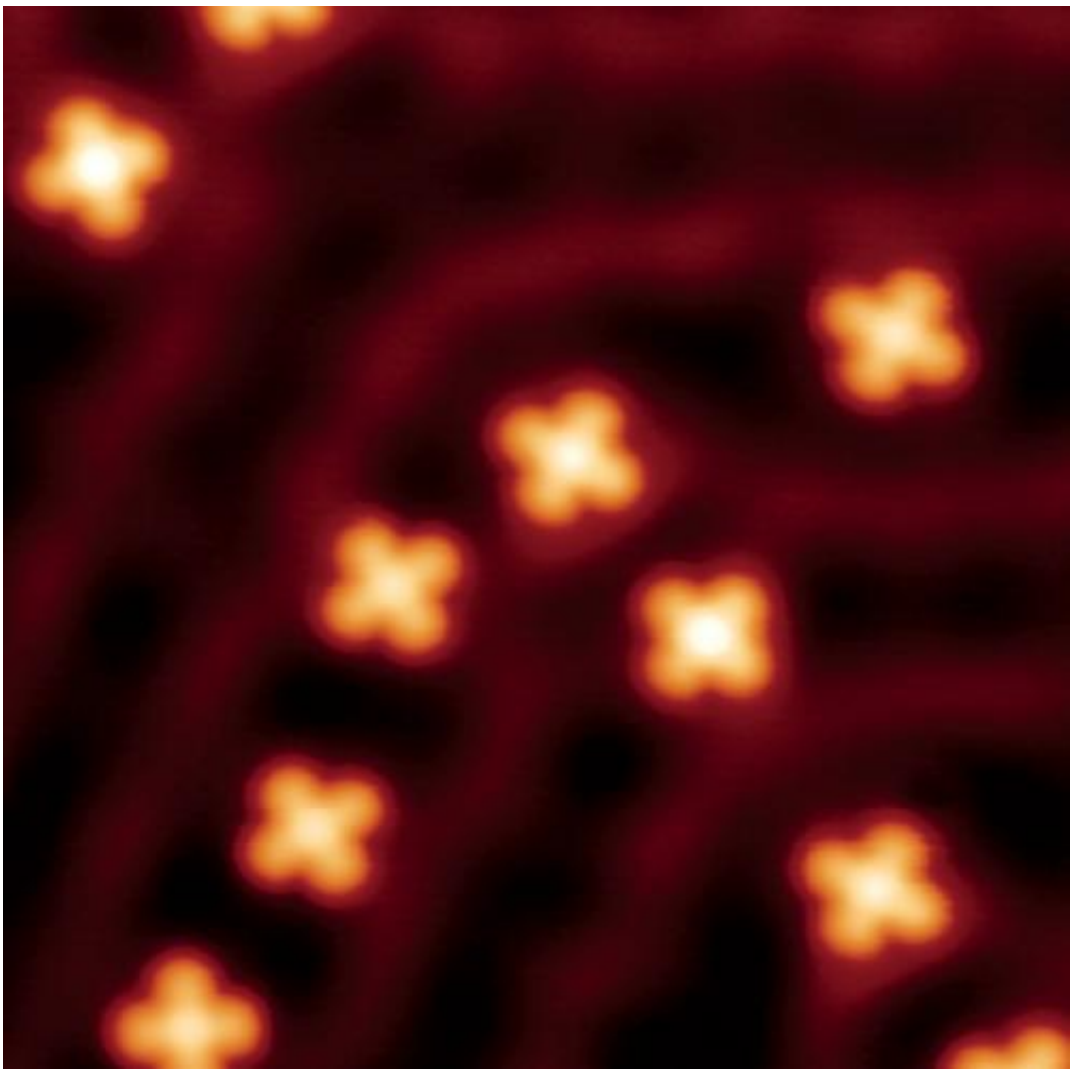
Novel form of electron–molecule interaction on metal surfaces provides fresh prospects for molecular electronics

January 25 2013



A scanning-electron micrograph of iron-phthalocyanine molecules (seen as bright crosses) adsorbed on a gold surface. The image size is 15 x 15

nanometers. Credit: Noriyuki Tsukahara, Department of Advanced Materials Science, The University of Tokyo

When a piece of metal is cooled down, it becomes easier for electrons to move through the material. Therefore, the electrical resistance of a metal normally decreases with lower temperatures. However, in the presence of magnetic impurities—tiny imperfections in the material—the resistance increases again below a certain temperature. This phenomenon has to do with how electrons scatter from the impurity and is generally known as 'the Kondo effect'. It can come in many forms—one of which has now been discovered by Emi Minamitani of the RIKEN Surface and Interface Science Laboratory, Wako and co-workers at the University of Tokyo and Osaka University. They have shown that in the case of magnetic molecules deposited on a metal surface, a Kondo effect appears that reflects the local symmetry of the molecule at the adsorption site.

The team studied the molecule iron phthalocyanine, which they deposited on a gold surface. The Kondo effect had been reported before in this system but a mystery remained—the effect depended on where exactly on the surface the molecules were located. When the iron atom of the molecule was on top of a single gold atom, the Kondo effect was much stronger than when the iron built a bridge between two gold atoms. Minamitani and her co-workers have shown that this unexpected adsorption–site specificity is due to the interplay between the geometry and symmetry of both the molecule and the surface. Only in the 'on top' case, the symmetry of the molecule is preserved, leading to a more pronounced Kondo effect.

So far, the researchers have shown the new manifestation of the Kondo effect for one specific type of molecule–surface combination, but the

phenomenon should also be present in other systems where magnetic molecules are deposited on metallic surfaces. "There are many candidate systems in which the Kondo effect and variants of it should appear," says Minamitani. Moreover, the geometry of the molecule-on-surface system allows researchers to tune the Kondo effect by chemical or mechanical manipulation.

"Our next step is to find ways of controlling and tailoring such novel types of Kondo systems," says Minamitani. And while the Kondo effect is a low-temperature phenomenon that may not affect devices operating at room temperature, Minamitani expects that their work will provide a route to exploring fundamental phenomena in the field of molecular electronics. "Our findings suggest that the electronic states of molecules exhibit a richer variety of behaviors than we expected," she says.

More information: Minamitani, E., Tsukahara, N., Matsunaka, D., Kim, Y., Takagi, N. & Kawai, M. Symmetry-driven novel Kondo effect in a molecule. *Physical Review Letters* 109, 086602 (2012). prl.aps.org/abstract/PRL/v109/i8/e086602

Provided by RIKEN