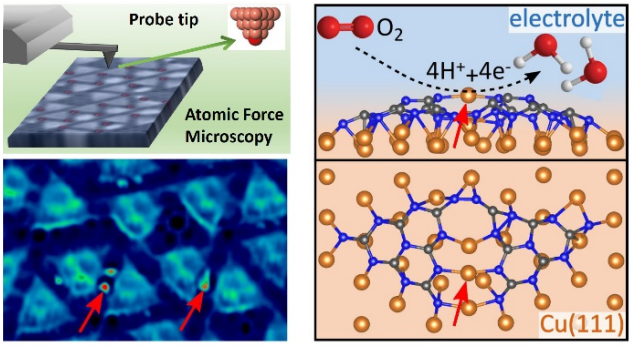
Study correlates high-resolution atomic force microscopy with the performance of copper single-atom catalysts

CeNTech scientists combine atomic-scale characterization of a single atom catalyst with a direct proof of the electrochemical performance in an oxygen reduction reaction, which is an important process in fuel cells. In collaboration with the Max Planck Institute for Colloids and Interfaces in Potsdam and the University of Paderborn, the researchers used organic supramolecular networks to stabilize single copper atoms as catalytically active sites.

Background: Conventional catalysts often use expensive nanoparticles of gold or platinum. Because such noble metals are so expensive, attempts are being made to replace them with more inexpensive materials and use them in the form of ever smaller particles. For this reason, the research area of so-called single-atom catalysts has developed rapidly over the past few years. Here, the metal is not present in the form of particles but as single atoms which are held in place on a surface. As a result, they display very high catalytic efficiencies, which basically means a higher gain and selectivity for a specific chemical reaction. One significant problem in the development of such single-atom catalysts is the tendency of the single atoms to aggregate and form particles, which leads a loss of their catalytic efficiency.



Left: Atomic force microscopy with atomically defined probe tip (top) and an experimental image of the copper-nitride network (below), with the red arrows marking the catalytically active copper atoms. Right: Theoretical model with a schematic representation of the catalytic reduction of oxygen. © American Chemical Society

In a study by a team of CeNTech scientists around PD Dr. Harry Mönig and Prof. Harald Fuchs, in collaboration with chemists from the Max Planck Institute for Colloids and Interfaces in Potsdam and the University of Paderborn, an approach was developed where singly dispersed copper atoms are embedded in highly ordered two-dimensional supramolecular networks. Allowing an atomic-scale characterization of these networks, the researchers used advanced atomic force microscopy techniques with functionalized probe tips at temperatures as low as 5 Kelvin. In combination with theoretical simulations and photoelectron spectroscopy experiments, they found that the interaction of these networks with a copper substrate was so strong that single Cu atoms are pulled up above the level of the 2D supramolecular network. Promising a pronounced chemical activity, the Cu atoms were found to be flexibly suspended within these networks.

Based on the atomic-scale characterization combined with electrochemical experiments and accompanying simulations, the researchers could demonstrate a robust catalytic activity of the single copper atoms in an oxygen reduction reaction, which is an important process for example in fuel cells. Using inexpensive copper instead of gold or platinum as catalytic material could lead to significant cost benefits in technological applications. The results of this study have been now published in the journal ACS Nano.

Original publication

Schulze Lammers, B., López-Salas N., Stein Siena, J., Mirhosseini, H., Yesilpinar, D., Heske, J., Kühne T.D., Fuchs, H., Antonietti, M. and Mönig, H. (2022). Real-Space Identification of Non-Noble Single Atomic Catalytic Sites within Metal-Coordinated Supramolecular Networks. ACS Nano. DOI: 10.1021/acsnano.2c04439

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Links

Original WWU press release:

https://www.uni-muenster.de/news/view.php?cmdid=12803

Original publication in ACS Nano:

https://pubs.acs.org/doi/full/10.1021/acsnano.2c04439

Nanoscale Interface Analytics group (PD Dr. Harry Mönig):

https://www.uni-muenster.de/Physik.PI/Fuchs/nanoscale_interface_analytics/nanoscale_interface_analytics.html