Nanoglues Stabilize Metal Atoms for Catalysis

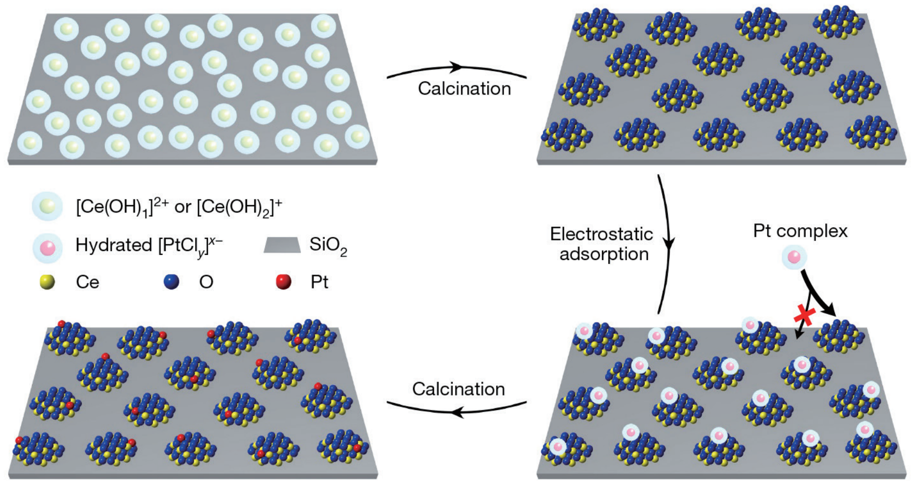
In a study published in *Nature*, Prof. ZENG Jie from the University of Science and Technology of China (USTC) and his collaborators Prof. WANG Yong, Prof. Bruce C. Gates, and Prof. LIU Jingyue from the United States developed a novel "nanoglue" strategy to stabilize atomically dispersed metal catalysts.

In heterogeneous catalysis, atomically dispersed metal catalyst has attracted tremendous attention due to their unique geometric and electronic properties, the highest atom efficiency, and uniform active sites. However, the atomically dispersed metal atoms either move and agglomerate easily on weak-interaction supports because of their high surface energy, resulting in low stability, or interact with some supports too strong to become catalytically passivated. Therefore, how to obtain "moving but not agglomerating" metal sites that can enhance both catalytic activity and stability has always been a tough spot in catalysis.

Given this, the research team designed a new type of "nanoisland" catalyst (also called nanoglue), in which active metal atoms are isolated on "islands" where they can move within their respective "islands", but the migration to neighboring "islands" is suppressed, consequently obtaining "moving but not agglomerating" atom sites.

It is important and very tricky to choose appropriate materials for "nanoislands" and their supports. The affinity between metal atoms and "nanoislands" should be much stronger than that between metal atoms and support. Otherwise, the metal atoms can easily leave their own "nanoislands". Therefore, the researchers chose oxides with high affinity to metal atoms as "islands" (such as ceria) in the designed model catalyst and weak-interaction oxides (such as silica) as support to stabilize "islands".

To efficiently isolate metal atoms, the "islands"



The fabrication processes of functional ceria nanoglue and atomically dispersed platinum catalysts. (Image by Prof. ZENG Jie's team) should be of small enough size and high enough number density on support. The conventional synthesis methods (such as the impregnation method) tend to obtain large and non-uniform particles which are not suitable as "islands". So the team developed a strong electrostatic adsorption method in an aqueous solution. The high-density cerium atoms were firstly coated to a silica surface, then they agglomerated into isolated "islands" with a size of less than 2 nanometers through calcination, as shown in the figure below.

The next challenge is accurately placing the metal atoms onto the "nanoislands" rather than the support. To this end, the researchers again used the strong electrostatic adsorption method to make the ceria island and silica surface oppositely charged, accompanied by adjusting the solution pH value between the point of zero charges of ceria and silica. The negatively charged platinum precursor could only be adsorbed on the positively charged ceria "nanoislands" rather than on the negatively charged silica support, so platinum atoms were exclusively grown on ceria island. Owing to the limited area of ultra-small "nanoislands" and low-concentration of platinum precursor, less than one platinum atom was deposited on each "island" on average.

The study showed that the platinum atoms on the ceria "nanoislands" can resist sintering during calcination in the air up to 600℃. Particularly, platinum atoms were proved to move within their own "island" in a hydrogen-reducing condition at elevated temperatures instead of diffusing to neighbor "island". Moreover, compared to the untreated catalyst, the hydrogen-activated catalyst showed an enhanced activity by two orders of magnitude toward carbon monoxide oxidation and outstanding stability.

This work provides a new strategy to boost both catalytic activity and stability. In the future, it is expected to apply this "nanoglues" concept to more catalytic reactions by choosing appropriate supports, "nanoislands" and active metal atoms.

(USTC News Center)

Reference

Li, X., Pereira-Hernández, X. I., Chen, Y., *et al*. (2022). Functional CeO_x nanoglues for robust atomically dispersed catalysts. *Nature, 611*(7935), 284–288. doi:10.1038/s41586-022-05251-6