Functional Nanoglues for Robust Atomically Dispersed Catalysts

The strategy of using functional nanoglues to confine atomically dispersed metal catalysts and simultaneously enhance the activity is general. The single-atom catalysts could be used for practical applications.

The chemical industry relies on catalysts for 90% of its processes. Catalysts are widely used in environmental protection facilities, such as flue gas denitrification in industrial plants, catalytic converters in exhaust systems of cars, and petroleum refining. In recent years, extensive research on catalysts has been carried out in the field of green energy, including water splitting, nitrate reduction, carbon dioxide reduction, *etc*. These studies have provided mechanistic insights into the rational design of catalysts for environmental sustainability and net-zero emissions.

Several catalysts contain precious metals, which act as "active sites" in catalytic reactions. Single-atom catalysts make exceptionally efficient use of expensive noble metals, which can yield unique properties. However, their applications are often compromised, owing to the limited stability of the catalysts, which is due to sintering. In addition, strong metal–oxygen interactions often leave few metal sites available for reactant binding and catalysis, and when oxide-anchored single-atom catalysts are exposed to reducing conditions at sufficiently high temperatures, they even undergo sintering eventually. This study shows that the beneficial effects of anchoring can be enhanced by confining the atomically dispersed metal atoms on oxide nanoclusters or "nanoglues", which themselves are dispersed and immobilized on a robust, high-surface-area support. The isolated and defective CeOx nanoglue islands are prepared on high-surface-area SiO_2. Then, the nanoglue islands host on average one Pt atom. Although each atom can move, it remains confined to its respective nanoglue island. The Pt atoms remain dispersed under oxidizing and reducing environments at high temperatures, and the activated catalyst exhibits a markedly increased activity for CO oxidation. This strategy not only makes every metal atom an individual active site but also enhances reactivity. The catalytic efficiency for the oxidation of carbon monoxide is improved nearly 100 times, and its cost is therefore lowered. The strategy of using functional nanoglues to confine atomically dispersed metals and simultaneously enhance the reactivity is general, thus taking single-atom catalysts one step closer to practical applications.

The research team consisted of Jing-Yue Liu (Arizona State University, USA), Chih-Wen Pao (NSRRC), and scientists from Stanford Synchrotron Radiation Lightsource (USA).

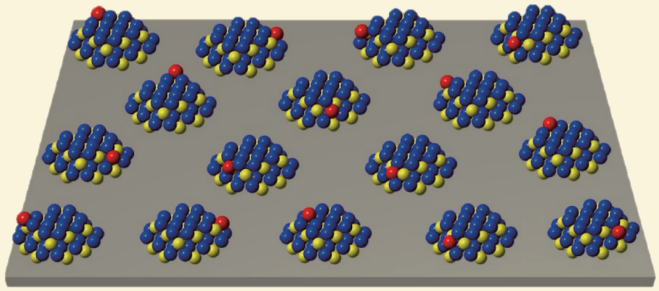

Fig. 1: Schematic of a single-atom catalyst (red represents a Pt atom, blue and yellow represent an island, and gray represents a substrate). [Reproduced from Ref. 1]

They used XAFS at the **TPS 44A** beamline to conduct a coordination environment analysis of the three components integrated into the catalyst in their proposed strategy: single metal atoms, nanoglues, and high-surface-area supports. The experimental technique of **TPS 44A** allows accurate measurement of structures with a very small amount of atoms and molecules because of its ultrahigh sensitivity at the atomic level and super-low detection limit. The Quick-EXAFS beamline at the TPS is very suitable for examining the dynamics of fine structures at the atomic (10^{-10}) level within milliseconds (10^{-6}). This technique is certainly a beneficial tool for studying catalytic reactions, such as charge/discharge dynamics of lithium batteries as well as the absorption process. (Reported by Heng-Liang Wu, National Taiwan University)

This report features the work of Jing-Yue Liu and his collaborators published in Nature ***611****, 284 (2022).*

TPS 44A Quick-scanning X-ray Absorption Spectroscopy

- XANES, EXAFS, XAFS
- Materials Science, Physics, Energy Storage Devices, Battery Materials, Chemistry, Condensed Matters, Functional Materials

Reference

1. X. Li, X. I. Pereira-Hernández, Y. Chen, J. Xu, J. Zhao, C.-W. Pao, C.-Y. Fang, J. Zeng, Y. Wang, B. C. Gates, J. Liu, Nature **611**, 284 (2022).