

Opening Catalytic Powers of Nonprecious Nanomaterials

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Abstract

Although the valuable metal-based materials are broadly recognized as prevalent impetuses for clean energy applications, their enormous scope business use has been blocked by their costly and shortage nature. The improvement of high performance, ample and modest nonprecious materials based impetuses is in this way crucial for the business feasibility of clean energy future. Tragically, the majority of nonprecious materials in their perfect structures have practically zero reactant activity. Thusly, opening the reactant exercises of nonprecious materials has become a significant logical undertaking, however profoundly testing.

This show reports various comprehensively appropriate approaches to open the synergist exercises of nonprecious nano-organized materials. Various models from our new examinations will be utilized to show the viability and relevance of such methodologies.

Materials science is an intrinsically interdisciplinary examination field, which includes physical science, science, and science. The re-search of materials science underlines understanding a mama-terial's construction, and hence its properties and execution, through different abilities going from union, measure ing, and portrayal to hypothesis. As materials are the essential substances that make up every single ordinary item, materials science is so imperative to virtually every part of science and technolo-gy in human life and public activity.

Non-precious-metal single atom (NPM-SA) confined nanoma-terials with maximum metal atom utilization have recently at-tracted particular interest, providing opportunities for exploit- ing novel heterogeneous electrocatalysts with low cost and high efficiency. The applications of non-precious-metal single-atom catalysts (NPM-SACs) have been extensively developed in elec-trochemical energy technologies such as fuel cells, metal-air batteries, and hydrogen production via water splitting. NPM- SACs can be confined on substrates with various structures and dimensions from 1D to 3D. However, the role of the structural dimensions of substrates has not been critically summarized. In

this review, recent advances in NPM-SACs such as facile synthe-sis, characterization, performance in catalyzing oxygen redox reactions, and related applications are highlighted through a focus on different dimensional substrates (1D, 2D, and 3D). The general fabrication strategies and the catalytic mechanism of NPM-SACs in the oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) are extensively discussed. Moreover, the opportunities and challenges in this emerging field are pre-sented on the basis of its current development.

It remains elusive as to how exactly the site-specific atom in a catalyst can induce a chemical reaction mainly due to the ob-served catalytic performance from an ensemble average of all active atoms in the catalyst. In this work, we have reported the catalytic properties of four metal clusters (namely, Au8Pd, Au9, Au24Pd and Au25) for the oxidation of benzyl alcohol. It was found that the Pd atom in the Au8Pd cluster is likely to be a key to catalyze the oxidation reaction, in which the Pd atom can provide an active site to adsorb and activate O₂. Our calcula-tion study suggests that the high catalytic activity of the Au8Pd cluster is due to the unique ability of Au8Pd to mediate the elec-trons and holes of the adsorbates. This work provides a feasible strategy to enable highly efficient chemical processes via pre-cisely doping foreign atoms into catalysts with atomic precision.

CO₂ and sustainably produced hydrogen have the potential to serve as an ingredient for converting electrical power generat-ed by windmills or solar panels into a gas fuel. This 'power-to-gas' concept can solve two problems at once: it reduces CO₂ emissions while creating more flexible applications of sustain-able energy. However, profitable conversion of CO₂ would re-quire an extremely effective catalyst. Researchers from Utrecht University have found a way to study the conversion process in detail and to determine the perfect size for the catalytic nickel nanoparticles. The researchers will publish their results in Na-ture Catalysis on Monday, 29 January.

Lead author Charlotte Vogt explains: "When we make metal nanoparticles smaller and smaller, they start to show very dif-ferent properties to what we expect and understand from clas-sical physics and chemistry". Together with colleagues Florian Meirer and Bert Weckhuysen from Utrecht University and re-searchers from chemical company BASF, Vogt found that nickel

particles exhibit optimal catalytic activity at a size of 2.5 nanometres, about 40,000 times smaller than a human hair. The researchers also found that a specific architecture of these tiny nickel particles facilitates the activation of CO₂.

Catalysis, as a key and enabling technology, plays an increasingly important role in fields ranging from energy, environment and agriculture to health care. Rational design and synthesis of highly efficient catalysts has become the ultimate goal of catalysis research. Thanks to the rapid development of nanoscience and nanotechnology, and in particular a theoretical understanding of the tuning of electronic structure in nanoscale systems, this element of design is becoming possible via precise control of nanoparticles' composition, morphology, structure and electronic states. At the same time, it is important to develop tools for in situ characterization of nanocatalysts under realistic reaction conditions, and for monitoring the dynamics of catalysis with high spatial, temporal and energy resolution. In this review, we discuss confinement effects in nanocatalysis, a concept that our group has put forward and developed over several years. Taking the confined catalytic systems of carbon nanotubes, metal-confined nano-oxides and 2D layered nanocatalysts as examples, we summarize and analyze the fundamental concepts, the research methods and some of the key scientific issues involved in nanocatalysis.

Moreover, we present a perspective on the challenges and opportunities in future research on nanocatalysis from the aspects of: (1) controlled synthesis of nanocatalysts and rational design of catalytically active centers; (2) in situ characterization of nanocatalysts and dynamics of catalytic processes; (3) computational chemistry with a complexity approximating that of experiments; and (4) scale-up and commercialization of nanocatalysts.

Sulfur hexafluoride (SF₆) is a refractory greenhouse gas. Catalytic decomposition of SF₆ was seldom reported. In this work, we synthesized novel multi-metal containing catalysts from heavy-metal solid wastes, and applied them in green catalytic decomposition of SF₆ for the first time. As a result, the waste-derived catalysts, which mainly contained Cr, Cu and Fe oxides, remarkably removed SF₆ at a capacity of 1.10 mmol/g at 600°C. This active temperature was 100-200°C lower than that of phosphate catalyst, but much lower than 5000 K by electrical arc reported elsewhere. XRD analysis showed that the solid phase transformed from metal oxides (e.g. Fe₂O₃) to fluorides (e.g. FeF₃) with the consumption of SiO₂. At the same time, on-line FTIR analysis detected that the