Development of energy resource conversion, Fuel cells, Optical functional materials, etc.

Next-generation alloy nanoparticle catalyst with high activity, high temperature resistance, and high durability

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Abstract

High-entropy alloys (HEAs) represent a new class of metallic materials in which more than five near-equimolar components are mixed to form single-phase solid solutions with high mixing entropy values, rather than intermetallic phases. Various unique synergistic effects result from such mixtures, including high configuration entropy, lattice distortion, sluggish diffusion and cocktail effects, which endow HEAs with high mechanical strength, good thermal stability, and superior corrosion resistance. However, a simple nanoparticle synthesis method has not been established, and it is completely unexplored as a catalyst material. We have established a method for making high-entropy alloys into nanoparticles with the aim of exhibiting catalytic functions, and have found that they exhibit unique catalytic activity and high durability in the CO_2 hydrogenation reaction.

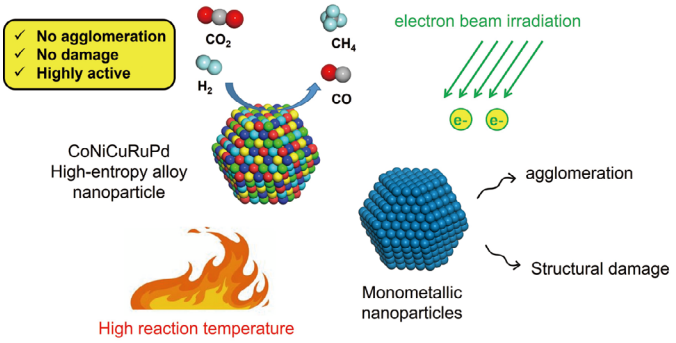
Background & Results

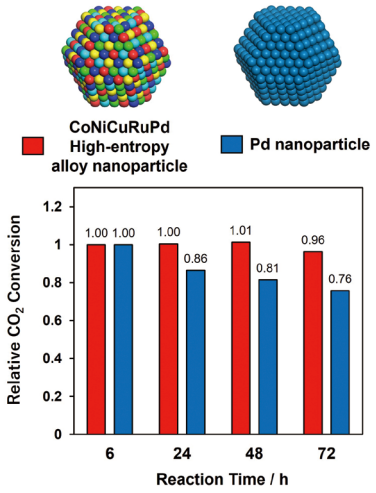
Metal nanoparticles are used in various catalytic reactions, but due to their high surface energy, they are deactivated and changes in the surface structure under harsh environments. In order to overcome this problem, we focused on high entropy alloy (HEA), which exhibits high specific strength, high-temperature strength, and corrosion resistance. However, the development of HEA nanoparticles (NPs) with a mean diameter of less than 10 nm lags significantly behind, despite the potential practical applications of these NPs in catalysis.

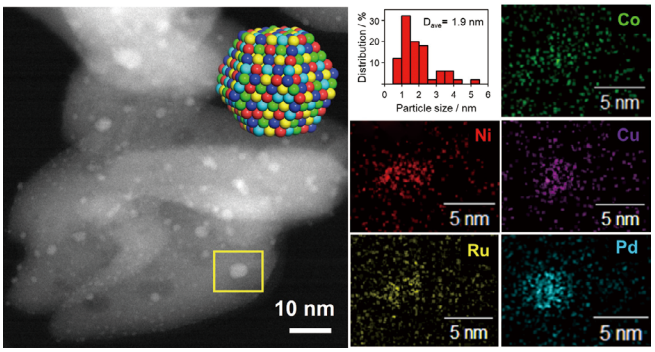
We have previously demonstrated that TiO_2 is a promising platform for the synthesis of non-equilibrium binary alloy NPs, such as RuNi and RhCu, which are essentially immiscible at equilibrium due to the positive enthalpies of formation of their solid solution alloys. This process is driven by the pronounced hydrogen spillover effect on TiO_2 in conjunction with coupled proton/electron transfer. In the present work, we developed and demonstrated that this facile strategy can be applied to the synthesis of TiO_2-supported HEA NPs. Specifically, CoNiCuRuPd HEA NPs on TiO_2 displayed high activity and outstanding stability during the CO_2 hydrogenation reaction.

Significance of the research and Future perspective

The high-entropy alloy nanoparticle-supported catalysts are in powder form, which is highly stable even in harsh environments and easy to separate and recover. Furthermore, theoretical calculations have been used to prove that unique catalytic activity and the structural stability of the nanoparticles are caused by the cocktail effect and sluggish diffusion effect, which is of extremely high academic significance. The results of this research are expected to have a significant ripple effect not only in the field of catalysis, which aims at the effective use of energy resources, but also in the field of advanced material science based on nanotechnology.







Patent

Treatise Mori, Kohsuke; Hashimoto, Naoki; Yamashita, Hiromi et al. Hydrogen Spillover-driven Synthesis of High Entropy Alloy Nanoparticles as a Robust Catalyst for CO_2 Hydrogenation, Nature Communications, 2021, 12, p.3884–3893, doi: 10.1038/s41467-021-24228-z

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