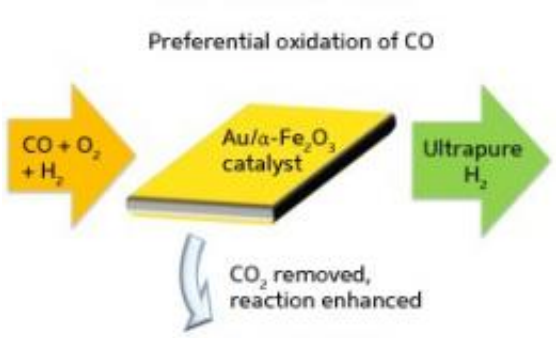
Making manufacturing ultrapure hydrogen gas easier than ever

September 29 2011, By Lee Swee Heng



A combined catalyst/carbon dioxide (CO2)-sorbent system (middle) that removes carbon monoxide (CO) contaminants from hydrogen gas (H2) may soon be part of on-board fuel cells. Credit: A*STAR

Pure hydrogen (H2) is an important chemical widely used in the chemical industry, many semiconductor fabrication processes, as well as in Polymer Electrolyte Membrane (PEM) fuel cells. Almost all of the hydrogen (H2) gas generated today comes from the steam reforming of natural gas at oil refineries. However, this process also produces trace amounts of carbon monoxide (CO) byproduct, which limits the application of H2 and can 'poison' or destroy the delicate catalysts used in the manufacture of semiconductor and state-of-the-art fuel cells. Researchers led by Ziyi Zhong and Jizhong Luo from the A*STAR Institute of Chemical and Engineering Sciences in Singapore have now developed a material that purifies H2 gas by catalytically converting CO

to carbon dioxide (CO2) while simultaneously removing excess CO2—an approach that enables CO removal down to the parts-per-million (ppm) level.

Although several methods exist for H2 purification, the preferential oxidation (PROX) reaction is often favored by fuel cell designers because it can be adapted for use in small, on-board reactors. In the PROX system, a mixture of H2, CO and oxygen gases passes over a metal catalyst located on a ceramic support. This sets off a complex series of oxidation reactions that consume CO, which generates various by-products including CO2.

Currently, gold nanoparticles are garnering attention as PROX catalysts because they are active below 100°C; lower temperatures enable more selective CO oxidation and are safer for vehicle applications. One problem with these catalysts, however, is their inability to lower CO concentrations below 100 ppm. Previous studies have suggested that the reason CO2 gradually deactivates these catalysts is because CO2 binds to the catalyst surface as carbonate.

Removing CO2 from the gas mixture with a solid-state sorbent material is one way to enhance PROX reactions and lower CO concentrations to the single ppm levels needed for H2 fuel cells. However, the challenge faced by Zhong and co-workers was that most common inorganic CO2 sorbents are incompatible with gold nanoparticles—their high working temperatures decrease the effectiveness of CO oxidation and destabilize the tiny metallic particles.

The team chose a novel porous material known as APTES/SBA-15 for their sorbent because it has a robust silica structure and contains amine groups that readily react with free CO2 at low temperatures. Further experiments revealed that APTES/SBA-15 sorbents boosted CO removal by an average 10% over unprotected gold PROX nanocatalysts.

Optimizing the layered arrangement of catalysts and sorbents in the reactor lowered the CO levels in H_2 gas from 2000 ppm to 25 ppm. Zhong says that he expects even better performance in the future. “There is still plenty of room for development of better CO_2 sorbents and catalysts for this process,” he notes.

More information: Ng, J. W., et al. Enhancing preferential oxidation of CO in H_2 on Au/α-Fe_2O_3 catalyst via combination with APTES/SBA-15 CO_2-sorbent. *International Journal of Hydrogen Energy* 35, 12724–12732 (2010).

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