

A low-cost catalyst prepares to take on power-plant emissions

4 October 2010, by Carol Kiely

(PhysOrg.com) -- Materials scientists develop clean nanoparticle-based catalysts that convert nitrogen oxides to nitrogen and water vapor.

A research group led by Charles Lyman, professor of materials science and engineering, has developed catalysts that convert the harmful [nitrogen oxides](#) emitted from coal- and gas-fired [power plants](#) to nitrogen and water vapor.

Unlike other methods of converting nitrogen oxides (NO_x), the low-cost nanoparticle-based catalysts developed by Lyman's group do not use ammonia.

NO_x is a generic term for nitrogen oxide (NO) and nitrogen dioxide (NO_2). The oxides, which are responsible for smog and acid rain, are produced when nitrogen and oxygen react in the air during combustion, especially at high temperatures.

The use of catalysts for pollution control in power plants is not new. A technique called selective catalytic reduction (SCR) can convert 95 percent of NO_x to nitrogen and water-but with a catch.

"Conventional SCR requires another toxic gas, ammonia, to carry out the reduction," says Rick Herman, a senior research scientist who works with Lyman. "In addition, these catalysts only perform well at high temperatures."

Finding the best preparation technique

Lyman and Herman sought first to improve the performance of a platinum-rhodium nanoparticle-based catalyst that uses hydrogen, rather than ammonia, as a reducing agent. This catalyst works at much lower temperatures.

"Choosing the correct catalyst preparation procedure was critical to ensuring that all these criteria were met," says Paul Dimick, a Ph.D. candidate in chemical engineering working with Lyman.

To obtain the desired microstructure, researchers sequentially impregnated an alumina support with aqueous solutions of platinum and rhodium chlorides. Then they applied a series of thermal treatments to convert the metal chlorides into active bimetallic nanoparticles.

"This procedure was chosen so that the desired microstructure would be achieved under reaction conditions," says Dimick.

When the researchers examined the prepared catalysts with Lehigh's high-resolution aberration-corrected scanning transmission electron microscope, they found nanoparticles with an average diameter of 2 nanometers (nm) well-dispersed on the alumina support. One nm is one billionth of a meter.

In-situ Fourier transform infrared (FTIR) spectroscopy revealed that the N-O chemical bond in a catalyst containing 5-percent rhodium was broken as soon as the molecule made contact with the nanoparticle. In a catalyst of 10-percent rhodium, however, the NO molecules tended to adhere to clusters of rhodium atoms present on the surface, which could potentially inhibit the desired reaction. Catalyst performance data also showed that the catalyst containing only 5-percent rhodium exhibited a much higher activity.

Cobalt's low-cost advantage

Rhodium, however, is rare and expensive. It now trades at around \$2,400 per troy ounce after exceeding \$10,000 in 2008. To reduce NO_x emissions more cheaply, the researchers turned to cobalt, which is 900 times less expensive than rhodium.

"Cobalt is also capable of breaking the N-O bond," says Lyman. "It forms a solid solution with platinum at low concentrations and finds its way to the surface of a nanoparticle under reaction

conditions."

The preparation of cobalt-platinum catalysts is almost identical to that of rhodium-platinum. The researchers merely substituted metal nitrates for chlorides.

While all catalysts containing less than 5-percent cobalt were found to be capable of reducing NO_x to nitrogen and [water vapor](#), the 2-percent cobalt catalyst performed best. "In-situ FTIR spectroscopy revealed that the 2-percent catalyst was the only one capable of immediately breaking the N-O bond," says Dimick.

The same methodology has now been applied to a nickel-platinum [catalyst](#) system with equally promising results.

Provided by Lehigh University

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