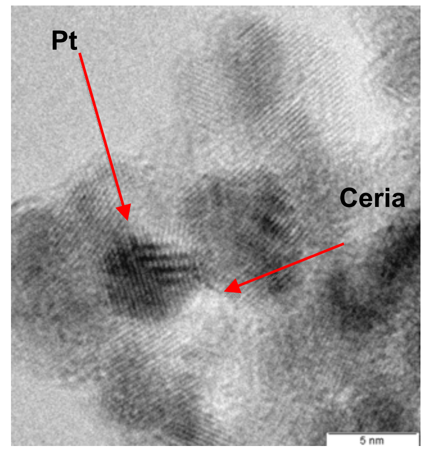
NREL Advances Spillover Materials for Hydrogen Storage

Project: Hydrogen Sorption Center of Excellence – Hydrogen Sorption via Spillover

Team: Hydrogen Storage Materials Development

Accomplishment 1: NREL developed a platinum-ceria catalyst to improve hydrogen spillover and storage (first reported in August 2009). Spillover is the result of dissociating hydrogen with metal catalyst to form hydrogen atoms that consequently "spill" onto the surface of a receptor material, where they are stored at ambient temperature. The viability of this technology relies on reproducible synthesis, long-term stability, and improved material costs.



Using a core-shell material such as platinum-ceria for catalysis improves hydrogen spillover for storage

NREL achieved reproducible spillover results using a platinum-ceria catalyst on activated carbon with no loss of hydrogen storage capacity after multiple cycles at both high and low pressures. Initial tests indicated that a 20% platinum-ceria-loaded activated carbon material provides ~1 wt% hydrogen storage at ~120 bar and room temperature. This is comparable with platinum-activated carbon despite the substantial decrease in specific surface area due to incorporating ceria and the reduction in total platinum content by a factor of eight.

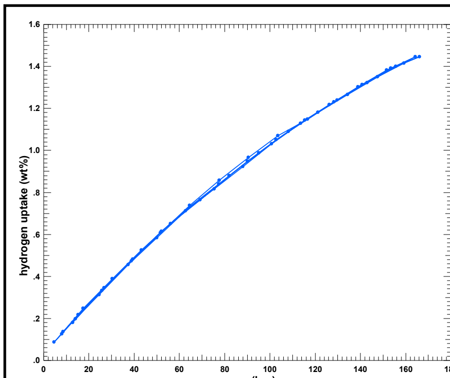
In the platinum-ceria catalyst, ceria helps stabilize the ~2-nm platinum particles on the carbon matrix, inhibiting their agglomeration during repeated cycles, which otherwise would reduce the spillover capacities. The ceria also allows the spillover hydrogen to travel easily to the carbon receptor. NREL is optimizing the platinum-ceria catalyst to improve the hydrogen storage rate and capacity.

Accomplishment 2: NREL demonstrated ~1.6% w/w reversible hydrogen adsorption using a ruthenium-activated carbon system (with specific surface area less than 2,500 m^2/g) at 160 bar and room temperature (first reported in August 2009). On a 3,000 m^2/g material, the rates of desorption of this activated carbon system meet U.S. Department of Energy (DOE) targets. NREL is currently working to optimize the loading/synthetic conditions for this set of materials. To do so, NREL developed new processing that directly pyrolyzes ruthenium acetylacetonate in the presence of activated carbon. The resulting ruthenium metal particles are ~2-3 nm in diameter but are heterogeneously distributed throughout the matrix. NREL is working to distribute the catalyst particles uniformly.

Applicable DOE Technical Targets: 0.055 kg H_2/kg system, 0.04 kg H_2/L system, \$133/kg H_2, 1500 cycles

Significance of Accomplishments:

Improved Reproducible Synthesis: To ensure reproducible, high-capacity hydrogen storage through spillover, NREL improved the processing to integrate the catalysts and demonstrated that core-shell materials such as platinum-ceria can be used as spillover catalysts. By encasing with ceria, platinum or other metal catalysts are stabilized, which improves the reproducibility of the materials and enables direct integration with less-stable materials.



Hydrogen spillover capacity of a ruthenium-activated carbon material made with NREL's advanced synthesis process

Improved Long-Term Durability: Because the metal materials are partially coordinated with the oxides, core-shell catalyst materials prevent the metal particles from agglomerating, which reduces performance. Furthermore, core-shell materials are less mobile on the receptor surfaces compared with pure metals; thus, again the performance will not degrade. Both of these factors will lead to substantially improving the durability and enhancing the lifetime of the spillover material for reversible hydrogen storage.

Improved Material Costs: The stability offered by these core-shell materials enables the use of fewer metals and potentially enables the use of inexpensive catalysts such as nickel. Both accomplishments reduce catalyst material costs.

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