Method for Preparation of Nanometer Cerium-based Oxide Particles

Technology

The production of nanometer-scale CeO_2 particles of varying size, size distribution, and state of agglomeration through the varying of mixing conditions for use in a wide array of applications.

Benefits

- Large oxygen vacancies
- Uniform size of particles
- Uniform shape of particles

Commercial Applications

Cerium dioxide based materials have been studied for use in applications such as the following:

- Purification of exhaust gases
- Production of better sunscreens
- Production of polishing materials
- Usage as a low temperature electrolyte
- Usage as an anode component in solid oxide fuel cells

Technology Description

This invention consists of the production of new doped and undoped cerium-based oxide particles and a new semi-batch reactor method for directly synthesizing the new particles at room temperature. Control over the particle size, size distribution, and state of agglomeration can be achieved through variation of the mixing conditions. While this invention is described with respect to cerium, it can also be produced with iron, chromium, manganese, niobium, copper, nickel, and titanium either in place of or in combination with the cerium.

The base process involves mixing a cerium salt with an alkali metal or ammonium hydroxide to form a reactant solution. While the reactant solution is being stirred under turbulent flow conditions, oxygen is passed through the solution. CeO_2 particles having particle sizes ranging predominantly from 3 – 100 nm are precipitated from the reactant solution.

There are several variables involved during the mixing step that can be controlled in order to produce ceria particles of uniform shape at the desired size.

First, passing oxygen gas through the reactants decreases the particle size. Using the oxygen can produce particles as small as 3 nm, as opposed to 12 nm when the oxygen is omitted.

Second, adjusting the temperature at which the reaction takes place will also affect the particle size. Using 20ºC will produce ceria particles of 15 nm and using 70ºC will produce particles of 50 nm. Also, heating the produced particles for one hour while result in their coarsening to larger sizes depending on the temperature used.

Finally, varying the order in which the reactants are mixed will affect the pH value at which crystallization takes place. Adding the precipitate into the salt (PIS) starts the pH out low due to the slightly acidic nature of the cerium salt. The result being primary particle sizes of approximately 10 nm with the agglomerates being large and non-uniform in shape. In the case of mixing the salt into the precipitate (SIP), the pH remains higher than 9 during the entire reaction resulting in particle sizes approximate to the results of the PIS reaction. However, there is significantly less agglomeration and the particles consist of uniform size and shape due to homogenous nucleation.

Consequently, using this process, it is possible to produce ceria particles having a uniform shape and size where the size is controllable within the range of 3 nm to 100 nm.

Pure and doped CeO_2 (cerium dioxide) exhibits a structure similar to ZrO_2 (zirconia or zirconium oxide), which is currently used in oxygen sensors and solid oxide fuel cells. Doping CeO_2 with lanthanide series elements results in the formation of oxygen vacancies and a high ionic conductivity. Some variations of this process can produce results with as much as five times more oxygen vacancies than ZrO_2 based materials. These results make CeO_2 an excellent choice for use as a low temperature electrolyte and as an anode component in solid oxide fuel cells. These ceria particles with large oxygen storage capabilities can also be used as three-way catalysts to purify gases like those from automobiles.

When CeO_2 is mixed into an organic thin film, the cerium dioxide particles have a higher transparency and greater UV blocking ability than the currently used titanium dioxide or zinc oxide. According to reports, this improved sunscreen reduces sunburns, skin aging, and the potential causes of skin cancer (http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/740400.pdf).

Options for Commercialization

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References

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Key Words

Cerium dioxide
Ceria particles
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Solid oxide fuel cells (SOFC)
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Ion conductors
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