Nanotechnology has shaped the research and development in various disciplines of science and technology by redefining the interdisciplinary research. It has put materials science at the forefront of technology by allowing the researchers to engineer materials with properties ranging from electronics to biomedical by using materials as diverse as ceramics to just plain carbon. Nanoparticles demonstrate a greater tendency to interact with the environment in which they are present. In order to control the physico-chemical properties of nanoparticles, it is important to control the surface characteristics of nanoparticles. The current thesis demonstrates the interaction between nanoparticles and the environment by changing the surface characteristics of nanomaterials through the use of oxide nanoparticles, specifically cerium oxide nanoparticles (CNPs) and mixed cerium and titanium oxide nanoparticles as an example. It is depicted that a simple solvent, such as, water that can influence the optical properties of nanoparticles. It is shown that the strong polarizing effect of water on the non bonding f electrons can cause a blue shift in the optical properties of CNPs as a function of increase in trivalent oxidation state (contradictory to literature) of cerium. The concept is extended further by increasing the colloidal stability of nanoparticles through surface and/or medium modification by changing the medium from water to solutions of polyhydroxy compounds such as glucose and dextran. Complex forming ability of cerium with polysaccharides and the difference in the complexing ability of the monomer - glucose and its anhydro gluco polymer - dextran was employed to synthesize the CNPs in a one step process and the pH stability of NPs was shown between 2.0 to 9.5. Passive polymeric coatings are shown to play an active role in tuning the properties of nanomaterials in solution. It is demonstrated that the antioxidant activity of CNPs can be increased as a function of polyethylene glycol (PEG) while the biocompatibility is unaltered due to the biocompatible nature of PEG. It is demonstrated that in this PEGyltaed CNPs system, the PEG forms a complex with CNPs in the presence of hydrogen peroxide to facilitate scavenging of peroxide species. The superoxide dismutase (SOD) and catalase mimetic ability of CNPs is described and special emphasis is given to its biocompatibility.

The current thesis also emphasizes the role of synthesis and surface modification in influencing the catalytic performance of cerium oxide modified titanium dioxide catalysts for decomposition of methanol. It is demonstrated that the modification of surface of the oxide nanoparticles by noble metals is a function of the synthesis process. By keeping the size of the nanoparticles constant, it is demonstrated that the differences in the oxidation state of noble metals can lead to change in the activity of noble metals. The core level shifts in the binding energy of the 4f electrons of platinum is used to gauge the oxidation state. Results from in-house built catalytic reactor and in-situ diffuse reflectance infra-red spectroscopy are used to quantify the catalytic performance and identify the mechanism of reaction as well as products of methanol decomposition.

Major: Materials Science and Engineering

Educational Career:
Bachelor's of Chemistry, BS, 1999, University of Delhi, India
Master's of Chemistry and Corrosion Science and Engineering, MS, 2001, University of Delhi and Indian Institute of Technology, Bombay, India

Committee in Charge:
Prof. Sudipta Seal, Chair, Advanced Materials Processing and Analysis Center
Jiyu Fang, Advanced Materials Processing and Analysis Center
Helge Heinrich, Advanced Materials Processing and Analysis Center
Hyoung-Jin Cho, Electrical Engineering
Diego Diaz, Chemistry
Clovis Linkous, Chemistry, Youngstown University, Ohio

Approved for distribution by Prof. Sudipta Seal, Committee Chair, on May 3, 2010.

The public is welcome to attend.