

Research Interests

Professor Varma's research group investigates topics in hydrogen and other energy sources, and chemical

and catalytic reaction engineering. The projects typically involve combined experimental and modeling

studies.

A major current emphasis involves new methods to generate hydrogen for fuel cells, for both portable

applications such as notebook computers and mobile phones, and vehicle transportation. For portable

applications, combustion of novel chemical mixtures is used to obtain high hydrogen yield and safe solid

reaction products. For vehicle transportation applications, new methods (Ammonia Borane

hydrothermolysis and thermolysis, with additives and under effective reaction heat management) have

been developed in our laboratory. Regeneration of spent boron products to efficiently yield ammonia

borane is also being investigated. The new methods to generate hydrogen for PEM fuel cell vehicle

applications developed in our laboratory provide the highest hydrogen yield among all methods reported in

the literature.

Other current energy-related directions involve feasibility studies for underground coal gasification in the

state of Indiana, catalytic conversion of glycerol (byproduct of biodiesel production) to valuable chemicals,

and development of new catalysts for oxidative coupling of methane to ethylene and higher

hydrocarbons. A universal method for crude glycerol purification from different feedstock in biodiesel

production has also been developed recently.

Another recent direction is carbon sequestration, which involves capture and storage of CO2. Specifically,

we are developing new oxygen carriers for chemical looping combustion, a new technology with inherent

separation of CO2 in power plants using fossil fuels, either natural gas or gas from coal and/or biomass

gasifiers.

A major emphasis in recent years has been combustion synthesis, a process for the production of

advanced materials. We have focused on understanding the mechanisms involved in the synthesis and

structure formation of materials such as ceramics, intermetallics and composites. This understanding can

be used to control the microstructure, and hence the properties, of advanced materials such as nanoscale

oxide powders for adsorption and catalysis, intermetallic-ceramic composites for aerospace applications

and alloys for orthopedic implants. Our current efforts in this area are focused on developing solution

combustion synthesis, a one-step method for the preparation of nanostructured complex metal oxides

with tailored composition, phase, oxidation state, and surface areas by variation of tunable synthesis

parameters, for a variety of catalytic and other applications.

Other recent investigations in chemical and catalytic reaction engineering have included novel synthesis

of metal-composite and ceramic membranes, inorganic membrane reactors, and multiphase reactors.

Current research projects in multiphase reactors include two directions: hydrodynamics studies of tricklebed

reactors with a particle size distribution of catalyst support which has a significant effect on reactor

performance, makes reactor modeling difficult and leads to failure of scale-up; and experimental

hydrogenation studies for pharmaceutical applications.