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Preface

This issue of Topics in Catalysis is devoted to "Nanotechnology in Catalysis" and covers some of the presentations made at a symposium of the 19th North American Catalysis Society (NACS) Meeting, Philadelphia, May 22–27, 2005 dedicated to this topic.

Nanotechnology covers a wide range of scientific and technological endeavors at the nanometer scale, typically less than 100 nm. The term applies to processes, synthesis methods, and characterization techniques that help controlling matter at the nanometer scale. At this scale, typical of clusters of atoms and small molecules, unique phenomena take place generating exceptional properties and enabling novel applications. Among these unique phenomena, the changes in electronic and optical properties due to re-organization of energy levels, known as quantum confinement, are perhaps the most dramatic.

The field of Heterogeneous Catalysis is an obvious application of Nanotechnology. A well-known advantage of reducing particle size is the increase in surface area per unit volume of catalyst, which accelerates the chemical reaction and reduces the quantity of catalytic material necessary to reach a certain conversion. However, other more subtle advantages, such as unique crystal structures, electronic configurations, or surface compositions that can only be obtained with nanostructured materials may be even more important, as will be illustrated in some of the articles included in this issue.

A common goal in several of the works presented at this symposium was the production of well-controlled nanostructures, in some cases producing close to monodisperse entities (nanoparticles, nanotubes) of uniform size and shape. Novel synthesis methods of nanostructured materials with better control than standard methods used in the past are opening new opportunities for the catalytic scientist. Also, one of the advantages of today's scientist is the greater availability of sophisticated techniques that allow characterizing the materials at the nanoscale level.

For example, in several of the studies presented in this issue, electron beam lithography has been used to fabricate arrays of metal nanoparticles on oxide thin films in a controlled fashion. In those studies, the size, the spatial arrangement and the purity of the supported model catalysts were characterized by a combination of modern techniques (SEM, AFM, STM, XPS, AES, etc.) that allowed the scientist to draw fundamental structure–properties relationships. In another study, the sintering of catalyst nanoparticles at elevated temperatures have been investigated using grazing incidence small angle X-ray scattering technique (GISAXS) to obtain depth profiles and particle-to-particle distances, as well as the aspect ratio (height/diameter) of metal clusters.

Another technique that is being used in a number of interesting investigations is the atomic layer deposition (ALD). Several studies reported in this issue have used this technique to produce nanodispersed oxides supported on mesoporous silica, catalyst supports and catalytic membranes.

Nanosized hollow spheres (silica or carbon) have been investigated in a couple of studies and used as novel supports. This is a new type of structured materials that generates the possibility of creating controlled porosity and molecular sieving effects.

Gold nanoparticles, which have long been considered of little relevance to catalysis, have recently received special attention by many catalysis research groups because of their very high carbon monoxide oxidation catalytic activity at low temperatures. Most interestingly, the enhanced activity is a strong function of particle size at the nanoscale level. Some of the works presented at the Symposium have focused on the study of gold nanoparticles. For example, the Au/FeO_x interface has been investigated on Fe-dopped Au/SiO_2 systems, in which the size of Au nanoparticles was systematically varied by Ar^+ ion bombardment after electron beam evaporation. With this method Au islands of varying size were obtained. Ultraviolet and X-ray photoelectron spectroscopy (UPS, XPS) were used to characterize the unique electronic properties of these clusters and the effect of size on the catalytic CO oxidation. In another contribution, the thermal stability and growth of gold nanoparticles supported on silica or alumina layers on Si(111) single crystals were investigated as a function of initial cluster size, support material and level of surface coverage. In this case, synchrotron techniques were used to characterize the nanostructured materials at the atomic level.

Nanotechnology and Heterogeneous Catalysis share common goals such as the understanding and structural control at the molecular level. Nanotechnology is pushing the limits for development of improved synthesis techniques, coupled with in situ spectroscopies with chemical specificity, as well as high temporal and spatial resolution. The application of these techniques to Heterogeneous Catalysis is generating tangible benefits.

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