Preface

One of the key frontiers in nanomaterial fabrication is the integration of different materials within the same structure as a means to increase functionality. After the remarkable success in synthesizing more conventional hybrid nanomaterials, for example, core-shell, alloy, and bimetallic heterostructures with controlled dimensions and intriguing morphologies, there has been increasing interest devoted toward the development of semiconductor/metal oxide-noble metal nanocomposites that consist of different classes of materials with solid-state interfaces. The lure of these nanostructured composites is that they combine materials with distinctly different physical and chemical properties to yield a unique hybrid system with tunable optical properties, enhanced photocatalytic activities, and ultrafast carrier dynamics. Furthermore, the interactions between the nanoscale metal and semiconductor components can greatly improve the overall application performance of the nanocomposites and can even generate new synergetic properties. For example, in the Ag_2S-noble metal nanostructures reported recently, the Pt-containing nanocomposites were found to exhibit superior catalytic activity toward methanol oxidation, the key reaction in direct methanol fuel cell, due to the electronic synergism of the ultrafine Pt crystallites and the semiconductor domains. In core-shell structured CdSe@Pt nanocomposites obtained by reducing platinum precursors with sodium citrate in the presence of previously formed CdSe nanocrystals, the compressive strain effect imposed from the CdSe core on the deposited Pt shell results in an appropriate downshift of the d band center of Pt catalysts, which leads to the enhancement of the core-shell structured nanocomposites for catalyzing the oxygen reduction and methanol oxidation in direct methanol fuel cells. The metal ingredients in semiconductor-metal nanocomposites can also enhance the photocatalytic and light-harvesting efficiencies of semiconductors by improving the charge separation and by increasing the light absorption. In addition, as presented by Talapin and coworkers, contrary to the n-type PbS semiconductor, core-shell structured Au-PbS nanocomposites demonstrated strong p-type gate effects due to the intraparticle charge transfer.

Within the last decade, the development of wet-chemistry methods leads to the blossoming of research in composite nanomaterials. Following the breakthrough

made by Banin and coworkers in 2004, who demonstrated a solution synthesis for nanohybrids via the selective growth of gold tips on the apexes of hexagonal-phase CdSe nanorods at room temperature, various approaches were developed for the synthesis of semiconductor or metal oxide-noble metal nanocomposites (e.g., ZnO–Ag, CdS–Au, InAs–Au, TiO_2–Co, Fe_3O_4–Au, $CoFe_2O_4$–Ag, PbS–Au, Ag_2S–Au, and semiconductor-Pt systems) by anisotropic growth of metals on semiconductors through reduction, physical deposition, or photochemistry. These novel nanostructures displayed modified physical/chemical properties due to strong coupling among the different domains in the nanocomposites. For example, in CdSe-Au nanocomposites, the gold tips show increased conductivity, as well as selective chemical affinity for forming self-assembled chains of rods. The architecture of these nanostructures is qualitatively similar to bifunctional molecules such as dithiols, which provide two-sided chemical connectivity for self-assembly and for electrical devices, and contacting points for colloidal nanorods and tetrapods.

The efforts of many leading research groups have led to a rich variety of composite nanomaterials. However, the design and synthesis of composite nanomaterials with controlled properties remain a significant challenge. We prefer to devote this book to summarize the solution-based methods for the preparation of noble metal-based nanocomposites, their characterization, and potential applications in a diversity of areas so as to provide the readers a systematic and coherent picture of the field. Most of these works have only been carried out in the last several years, particularly by the authors in different laboratories.

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