Chapter 20
Fabrication of Metal@SnO_2 Core-Shell Nanocomposites for Gas Sensing Applications

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ABSTRACT

Metal/SnO_2 is one of the most popular composite systems because of its application in gas sensors, where the metal in contact with the SnO_2 (semiconductor) enhances sensor performance in terms of sensitivity, response, and recovery time. This is because the metal acts as an electron reservoir, improving the depletion layer formation by interfacial charge-transfer process and delaying the electrons-holes recombination process in SnO_2. Conventionally, the metal nanoparticles are anchored on the surface of SnO_2 to produce hetero-interfaces. Despite effective catalytic activity, this structural drawback exposes metals to other chemical species. Therefore, it is necessary to design new strategies to improve the chemical and thermal stability of metal/SnO_2. Recently, nanocomposites with metal core and SnO_2 shell became potential candidates due to their chemical and thermal stability and superior material property. In this chapter, fabrication of metal@SnO_2 core-shell nanocomposites are discussed as a potential gas sensing material.

INTRODUCTION

Nanocomposites (NCs) have always received considerable attention for their potential applications in gas sensors, photocatalysis, energy conversion, coatings, and other solid-state devices (Thostenson et al. 2005). A major goal of designing NCs is to tailor the physical and/or chemical properties of the resultant hybrid structure by manipulating their chemical composition and/or morphologies. Noble metal/metal oxide based hybrid system is one of the most popular NCs because of its well studied application in solid-state gas sensors, where the metal in contact with the semiconductor greatly enhances the sensor performance in terms of sensitivity and selectivity due to the catalytic

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role of metal nanoparticles (NPs) (Yamazoe et al. 2003). The metal NPs in contact with the metal oxide can store and shuttle charge carriers from the semiconductor surface to an acceptor such as target analyte (such as test gas), thus greatly enhances the overall sensing efficiency (Franke et al. 2006). In most cases, the metal NPs are impregnated on the surfaces of the metal oxides as isolated ''islands'' to produce hetero-interfaces during a surface doping process (Yamazoe 1991, Korotcenkov 2007, Tiemann 2007). The resultant NCs although have shown enhanced sensitivity, unprotected and reactive metal NPs become vulnerable to perturbation in surrounding chemical environment such as high temperature, reactive chemical species, and reaction byproducts etc (Tiemann 2007). This structural disadvantage results in catalyst poisoning by other reacting species and in turn will reduce the life time of the sensing device. Additionally, the deposition of noble metal NPs on the surface of metal oxide is expected to reduce the effective surface area available for redox reaction. Therefore, researchers are trying to design NCs which can protect the nano-catalysts in harsh environment. Of the wide range of NCs currently under investigation, particles with core–shell morphology (Figure 1) have shown potential results. Core-shell NPs usually consist of a metallic core and metal oxide molecular shell (Chaudhuri et al. 2012). The major benefits of materials with core–shell morphology can be summarized as (Tripathy et al. 2010):

1. Metal NPs can be protected against aggregation and can be transferred from a liquid phase to a solid phase while retaining the size dependent properties.
2. Very small metal oxide NPs can be formed on a metal NP surface.
3. Crystal size and structure of the metal oxide shell can be retained at high temperature.

Thus, researchers have used various metal oxides such as SiO_2, TiO_2, and Fe_2O_3 as the shell materials since they offer a range of refractive indices and dielectric constants. Recently, metal@ SnO_2 core–shell NC has received considerable attention. The wet chemical synthesis offers the most economic route for the preparation of core–shell NCs.

Figure 1. Structure of metal@semiconductor core-shell structure