Materials Science and Engineering Doctoral Defense

Synthesis and functionalization of zinc oxide nanowires

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abstract

Zinc oxide nanowires (NWs) have broad applications in various fields such as nanoelectronics, optoelectronics, piezoelectric nanogenerators, chemical/biological sensors, and heterogeneous catalysis. To meet the requirements for broader applications, growth of high-quality ZnO NWs and functionalization of ZnO NWs are critical. In this work, specific types of functionalized ZnO NWs have been synthesized and correlations between specific structures and properties have been investigated.

Deposition of δ-Bi2O3 (narrow band gap) epilayers onto ZnO (wide band gap) NWs improves the absorption efficiency of the visible light spectrum by 70%. Furthermore, the deposited δ-Bi2O3 grows selectively and epitaxially on the {11-20} but not on the {10-10} facets of the ZnO NWs. The selective epitaxial deposition and the interfacial structure were thoroughly investigated. The morphology and structure of the Bi2O3/ZnO nanocomposites can be tuned by controlling the deposition conditions.

Various deposition methods, both physical and chemical, were used to functionalize the ZnO NWs with metal or alloy nanoparticles (NPs) for catalytic transformations of important molecules which are relevant to energy and environment. Cu and PdZn NPs were epitaxially grown on ZnO NWs to make them resistant to sintering at elevated temperatures and thus improved the stability of such catalytic systems for methanol steam reforming (MSR) to produce hydrogen. A series of Pd/ZnO catalysts with different Pd loadings were synthesized and tested for MSR reaction. The CO selectivity was found to be strongly dependent on the size of the Pd: Both PdZn alloy and single Pd atoms yield low CO selectivity while Pd clusters give the highest CO selectivity.

By dispersing single Pd atoms onto ZnO NWs, Pd1/ZnO single-atom catalysts (SACs) was synthesized and their catalytic performance was evaluated for selected catalytic reactions. The experimental results show that the Pd1/ZnO SAC is active for CO oxidation and MSR but is not desirable other reactions. We further synthesized ZnO NWs supported noble metal (M1/ZnO; M=Rh, Pd, Pt, Ir) SACs and studied their catalytic performances for CO oxidation. The catalytic test data shows that all the fabricated noble metal SACs are active for CO oxidation but their activity are significantly different. Structure-performance relationships were investigated.

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