Versatile Fabrication of Complex Shaped Metal Oxide Nano-Microstructures and Their Interconnected Networks for Multifunctional Applications†

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Abstract

Metal oxide nano-microstructures are applied in photocatalytic surfaces, sensors or biomedical engineering, proving the versatile utilization of nanotechnology. However, more complex or interconnected nano-microstructures are still seldomly met in practical applications, although they are of higher interest, due to enhanced structural, electronic and piezoelectric properties, as well as several complex biomedical effects, like antiviral characteristics. Here we attempt to present an overview of the novel, facile and cost-efficient flame transport synthesis (FTS) which allows controlled growth of different nano-microstructures and their interconnected networks in a scalable process. Various morphologies of nano-microstructures synthesized by FTS and its variants are demonstrated. These nano-microstructures have shown potential applications in different fields and the most relevant are reviewed here. Fabrication, growth mechanisms and properties of such large and highly porous three-dimensional (3D) interconnected networks of metal oxides (ZnO, SnO_2, Fe_2O_3) nano-microstructures including carbon based aerographite material using FTS approaches are discussed along with their potential applications.

Key words: Flame transport synthesis, metal oxide, ZnO, SnO_2, Fe_2O_3, nano-microstructures, nanorods, nanowires, interconnected tetrapods networks, multifunctional applications, aerographite

1. Introduction

Metal oxide nano-microstructures such as nanorods, nanowires, nanobelts, nanotetrapods and others are being significantly investigated due to their new and extraordinary properties appropriate for versatile nanotechnological applications[1–3]. Fabrication of several nanostructures from various metal oxides like ZnO, SnO_2, TiO_2, and Fe_2O_3 has already been performed using several growth techniques and their properties have been reported[1–4]. Among them, ZnO is one of the most investigated materials in the last decades, because of its wide and direct bandgap of ~3.37 eV, large exciton binding energy ~60 meV and simplicity in growth[1–3, 5]. Due to its hexagonal-wurtzite crystal structure, Zn and O terminated polar surfaces, different growth rates of the diverse crystal planes, quasi-1-Dimensional (Q1D) nanostructures and complex morphologies from ZnO can be synthesized. The direct bandgap which lies in the near ultraviolet -(UV) spectral region and alternating Zn and O stacking layers enable ZnO nanostructures to exhibit exceptional optical, luminescent[6, 7] and electrical properties[5, 8–11]. Bendability is also a very important property required for different applications but bulk ceramics or metal oxides are brittle in nature[1–3]. However, their Q1D structures can bent elastically to larger curvatures once their thickness is in the nanoscopic range[1–3, 12]. Nanorods and nanowires from ZnO have already shown interesting piezoelectric properties for energy or mechanical applications[1–3, 13]. Illumination of ZnO nanostructures with UV light creates electron-hole pairs and thus changes their conductivity and enables its uses for photodetectors[14–19]. Additionally ZnO nano-microstructures are extensively investigated for light emitting diodes and gas sensing applications[14, 20–22]. By doping with different elements it is possible to enhance the sensing performances of ZnO nanostructures[23, 24]. ZnO nanostructures have also been considered as biocompatible material and

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