Nanotripods of Zinc Oxide

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Abstract **We report the discovery of two-dimensional (2-D) nanotripods of ZnO, a new member of the ZnO nanostructure family. These planar nanotripods are synthesized via a novel approach known as catalyst-free combust-oxidized mesh (CFCOM) process that we developed using a ZnO factory furnace. At about 1200ºC, high velocity zinc vapor is instantly oxidized and captured in a steel mesh for 20s and then air-quenched. From this *subminute* synthesis process, three types of polycrystalline 2-D tripodal nanostructures are discovered. The ZnO tripods are composed of three planar arms that appear as rectangular nanoplates. We propose two growth routes for these planar tripods, namely *base-arm* and *tripodal-core* routes. For the former route, growth begins with the base arm in $[\bar{1}\bar{1}20]$ direction. During quenching, the other two arms grow from newly formed tapered facets, $(\bar{2}110)$ and $(1\bar{2}10)$. The *tripodal-core* growth route involves the formation of a hexagonal disc with $\pm(0002)$ larger surfaces. From this core, three arms grow simultaneously in $[11\bar{2}0]$, $[\bar{2}110]$ and $[1\bar{2}10]$ directions, while the core transforms into a Y-shaped configuration with $\pm(10\bar{1}0)$, $\pm(01\bar{1}0)$ and $\pm(\bar{1}100)$ planes. Morphological analyses are performed using FESEM, EDS, TEM and XRD. Photoluminescence test detects the presence of structural defects associated with green and red peak emissions.**

I. INTRODUCTION

The capability to crystallize into many crystallographic configurations could be the most striking characteristics of zinc oxide (ZnO). ZnO has been reported to crystallize in nanoscale structures that resemble the shapes of rods, wires, tubes, belts, bows, rings, helixes, spirals, propellers, combs, tetrapods, discs, polyhedrons, cages, drums, discs [1], flowers, stars [2], plates, boxes and mallets [3]. ZnO displays great versatility in its current and potential applications in micro- and nanoelectronics, healthcare, rubber and building materials. Novel nanoelectronic applications of ZnO include field-effect transistors [4], surface acoustic wave devices [5] and gas nanosensors [6]. ZnO structures have been fabricated via several growth techniques which include molecular beam epitaxy, metal organic chemical vapor deposition, vapor-liquid-solid method, cyclic feeding chemical vapor deposition and physical vapor deposition [1,2,7].

In this work, we report a novel two-dimensional (2-D) nanotripod of ZnO that is synthesized via a new approach known as catalyst-free combust-oxidized mesh (CFCOM) process that we developed using a factory ZnO furnace. Fig. 1a illustrates a schematic of the ZnO furnace while Fig. 1b shows the furnace in operation. Zinc melts at 419.5ºC with heat of fusion 7.39kJ/mol and boils at 907ºC with heat of vaporization 114.8kJ/mol [8]. Pressurized zinc vapor is contained inside a graphite crucible heated to 1000-1300ºC temperature range that results in an estimated vapor pressure of 0.2-1.1MPa [9]. Once the lid of the crucible orifice is removed, the pressure difference causes the zinc vapor to purge out through the orifice at high velocity. Zinc vapor is instantly oxidized by ambient atmospheric air and crystal growth takes place as temperature rapidly drops to below 800ºC in less than 5 seconds, after which the ZnO particles are transported into a 120m-long ducting for further cooling [3]. In this *subminute* growth technique, commonly known as French process, many micro- and nanostructures are produced which include rods, plates, boxes, mallets, drums and irregularly-shaped particles, that can coexist (and codiffuse) even in a minute region of 1μm^3 giving rise to the state of *nanoscopic inhomogeneity* [10,11]. In CFCOM process, we place a steel mesh sieve 10mm above the crucible orifice where the sieve captures freshly oxidized ZnO. After a preset capturing time of 10-30s, the sieve (Fig. 1c) is removed from the furnace area and it is air-quenched during which rapid crystal growth takes place with a relatively higher partial pressure of oxygen. Due to high growth temperatures and highly nonuniform growth parameters, the as-grown ZnO structures are mostly polycrystalline with small traces of single-crystallinity.

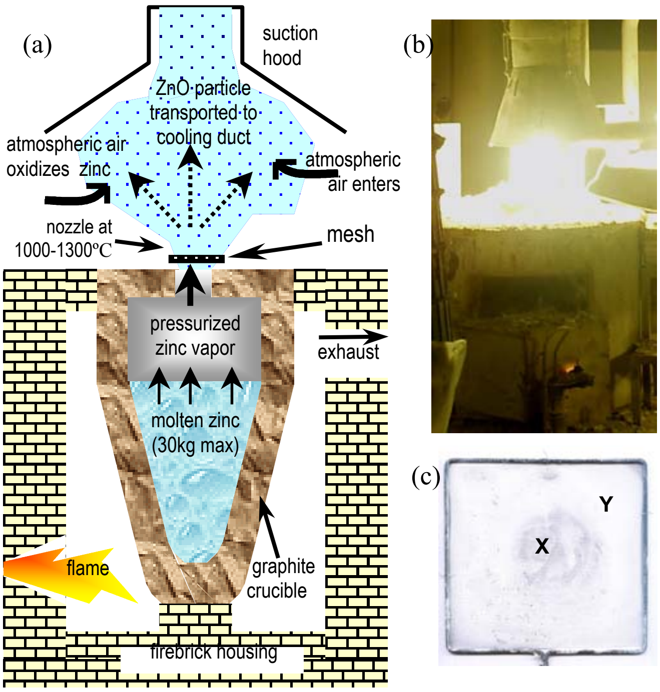

Fig. 1. French ZnO furnace showing (a) its schematic, (b) furnace in operation, and (c) mesh sieve after *subminute* capturing process.