PROJECT FACTS

UNIVERSITY OF KENTUCKY
CENTER FOR APPLIED ENERGY RESEARCH

Nanowires and Nanotubes for Catalyst Applications

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Nanotechnology is focused on the 0.1-100 nm (atomic) length scale and is rapidly advancing our understanding and ability to manipulate and control matter. The use of gallium catalysts for example can facilitate the high-volume production of SiO_2-nanowires and greatly improve the vapor-liquid-solid (VLS) process previously used to make these structures.

The gallium catalysts also produce Ga_2O_3 nanowires that appear to be branched structures. Moreover, 2D networks of nanowires and nanotubes of beta-Ga_2O_3, are obtained by exposing a gallium droplet covered substrate to hydrogen/oxygen plasma. Multiple nucleation from the gallium droplets and growth of 1D structures (wires) after coalescencing together parallel to the substrate yield the crystalline network shown in Figure 1 below. Because of the unique regular arrangement of nanowires in a polygonal fashion, these crystalline networks are described as "nanowebs". We postulate that the nucleation and growth of nanowebs occurs in six consecutive steps: (1) reduction of limited amount of polycrystalline gallium oxide particles with reactive hydrogen; (2) formation of thin film with nm-sized liquid gallium droplets; (3) decrease of surface tension of gallium droplets in a mixed hydrogen/oxygen plasma, which allows the metal to wet the substrate surface forming nm-sized flat gallium discs; (4) re-oxidation of the metal in the mixed plasma with preferential growth of nanowires from the gallium discs parallel to the substrate surface; (5) molecular assembly into nanotubular/wire structures; (6) spatial guidance of nanowires to grow toward each other. The formation mechanism and evolution of Ga_2O_3 nanowebs suggests that this process could be extended to other low melting metal oxides such as SnO_2, ZnO and In_2O_3 etc., all of which are considered important catalysts for our research group.

Nanowebs are of great technological interest since they contain nanowire densities on the order of $10^9/cm^2$. The molecular arrangement of the Ga_2O_3 nanowires and the large surface to volume ratios and crystalline nature of the individual web components, including tubes and wires (see Figure 2a, 2b) provide novel applications for catalysis and sensing distinctive from zero-dimensional nanoparticles, two-dimensional films. Individual nanotubes/wires contribute to a nanoweb's properties, and devices based on nanowebs are expected to follow. Therefore, as part of our future studies, it will be important to correlate the relationship between nanostructure, interconnectivity of nanotubes/wires and catalytic; electronic or optical performance.

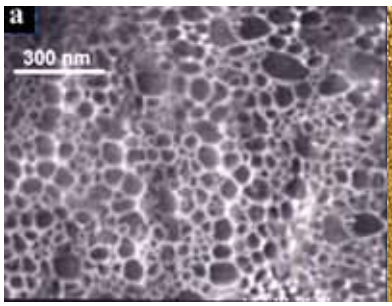

Figure 1: Ga_2O_3 "Nanoweb"

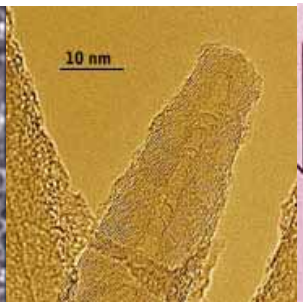

Figure 2a: "Nanotube"

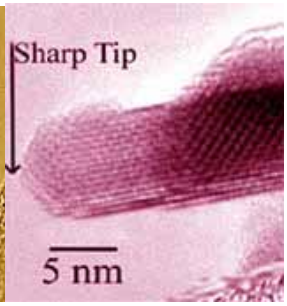

Figure 2b: "Nanowire"