Synthesis of one-dimensional titanium dioxide nanostructures

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ABSTRACT

Finely structured titanium dioxide is a technological material of long-standing importance for many applications including pigments and catalysis. There is growing interest in smaller, truly nano-sized titanium dioxide particles with well-defined crystallinity and a range of geometries from spheres to rods and tubes, that are relevant to applications in composites, photovoltaics, sensors, and catalysis. High aspect ratios, in particular, introduce high surface to volume ratios, network forming abilities, and opportunities to control anisotropic properties. Here we report a number of different synthetic strategies for producing high aspect ratio titanium dioxide nanostructures.

Keywords: titanium dioxide, nanorods, microfluidics, templating, sol-gel synthesis

1 SOL-GEL ROUTES

Titanium dioxide is commonly obtained via hydrolysis of metal alkoxides or halides; however, enhanced control over the reaction can be achieved in non-hydrous conditions. In the absence of water, the surface does not become hydroxylated, leaving the organic ligands bound tightly to the surface. In addition, the reaction temperature can be raised to improve the crystallinity of the products without leading to ripening or sintering.

A comparison will be made between nanorods synthesised via hydrolytic and non-hydrolytic routes, using different structure directing agents. Typical products are small, single crystal nanorods of anatase (~ 3 × 25 nm), although aging reactions under suitable conditions yield single crystal rutile nanorods (15 x 135 nm). The hydrolytic synthesis can be dramatically accelerated when performed on a microfluidic chip, as compared to a conventional bulk reaction. The acceleration is attributed to improved contact between the immiscible reagent phases [1].

2 TEMPLATING

A second strategy is based on high temperature templating reactions on carbon nanotubes. In this case, titanium iodide is used as a reagent to convert aligned arrays of carbon nanotubes into titanium carbide. Subsequent oxidation reactions yield aligned arrays of anatase or rutile nanorods, depending on the reaction temperature. This route allows the versatility of carbon nanotube synthesis to be leveraged to create titania structures of different dimensions [2].

3 HYDROTHERMAL

Hydrothermal treatment in strongly basic conditions has been used to convert titanium containing starting materials into ‘nanotubes’ or ‘nanoribbons’. Early work identified these structures as anatase, but more recently it has become clear that layered titanate phases are more likely. The influence of changing the synthesis starting material, and washing conditions, on the nature of the product, casts light on the growth mechanisms involved. [3]

4 CONCLUSIONS

A variety of routes to titania nanorods have been explored, yielding products with different dimensions, orientation, crystallinity, and phase. These materials are relevant to a range of applications, particularly in phototvoltaics [4] and composite materials; preliminary application data will be provided, time permitting.

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