One-Dimensional Nanostructures: Synthesis, Characterization, and Applications**

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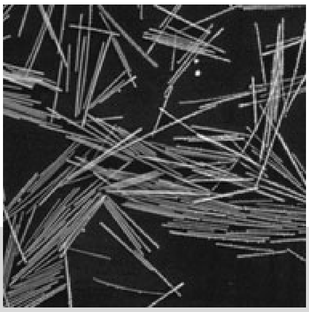

This article provides a comprehensive review of current research activities that concentrate on one-dimensional (1D) nanostructures—wires, rods, belts, and tubes—whose lateral dimensions fall anywhere in the range of 1 to 100 nm. We devote the most attention to 1D nanostructures that have been synthesized in relatively copious quantities using chemical methods. We begin this article with an overview of synthetic strategies that have been exploited to achieve 1D growth. We then elaborate on these approaches in the following four sections: i) anisotropic growth dictated by the crystallographic structure of a solid material; ii) anisotropic growth confined and directed by various templates; iii) anisotropic growth kinetically controlled by supersaturation or through the use of an appropriate capping reagent; and iv) new concepts not yet fully demonstrated, but with long-term potential in generating 1D nanostructures. Following is a discussion of techniques for generating various types of important heterostructured nanowires. By the end of this article, we highlight a range of unique properties (e.g., thermal, mechanical, electronic, optoelectronic, optical, nonlinear optical, and field emission) associated with different types of 1D nanostructures. We also briefly discuss a number of methods potentially useful for assembling 1D nanostructures into functional devices based on crossbar junctions, and complex architectures such as 2D and 3D periodic lattices. We conclude this review with personal perspectives on the directions towards which future research on this new class of nanostructured materials might be directed.

1. Introduction

Nanostructures—structures that are defined as having at least one dimension between 1 and 100 nm—have received steadily growing interests as a result of their peculiar and fascinating properties, and applications superior to their bulk counterparts.[1–3] The ability to generate such minuscule structures is essential to much of modern science and technology. There are a large number of opportunities that might be realized by making new types of nanostructures, or simply by down-sizing existing microstructures into the 1–100 nm regime. The most successful example is provided by microelectronics, where “smaller” has meant greater performance ever since the invention of integrated circuits: more components per chip, faster operation, lower cost, and less power consumption.[4] Miniaturization may also represent the trend in a range of other technologies. In information storage, for example, there are many active efforts to develop magnetic and optical storage components with critical dimensions as small as tens of nanometers.[5] It is also clear that a wealth of interesting and new phenomena are associated with nanometer-sized structures, with the best established examples including size-dependent excitation or emission,[6] quantized (or ballistic) conductance,[7] Coulomb blockade (or single-electron tunneling, SET),[8] and metal–insulator transition.[9] It is generally accepted that quantum confinement of electrons by the potential wells of nanometer-sized structures may provide one of the most powerful (and yet versatile) means to control the electrical, optical, magnetic, and thermoelectric properties of a solid-state functional material.

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