Chapter 1
Nanomaterials, Novel Preparation Routes, and Characterizations

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ABSTRACT

The important aspect of nanotechnology is the remarkable size dependant physico-chemical properties of nanomaterials that have led to the development of synthesis protocols for synthesizing nanomaterials over a range of sizes, shapes, and chemical compositions. This chapter describes the various aspects of nanotechnology: its dimensions and manipulation of matter with primary focus on inorganic materials. Detailed accounts of various methods lying within top-down and bottom-up synthesis approaches are discussed, like Chemical Vapour Condensation (CVC), arc discharge, hydrogen plasma-metal reaction, and laser pyrolysis in the vapour phase, microemulsion, hydrothermal, sol-gel, sonochemical taking place in the liquid phase, and ball milling carried out in the solid phase. The chapter also presents a brief account of the various characterization techniques used for the identification of the nanomaterials: X-ray diffraction, UV-visible spectroscopy, and electron microscopy (e.g. Transmission Electron Microscopy [TEM], Scanning Electron Microscopy [SEM], Atomic Force Microscopy [AFM]).

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INTRODUCTION

"Nanotechnology" broadly defined as the creation of objects and surfaces whose unique functions are the direct result of the nanoscale dimensions and / or organization. These unique properties may be mechanical, electrical, or photochemical and are not seen in the bulk materials. The prefix comes from the ancient Greek word *νᾶνος* through the Latin *nanus* meaning literally *dwarf* and, by extension, *very small*. Within the convention of International System of Units (SI) it is used to indicate the reduction factor of 10^{-9} times. Nanotechnology manipulates matter at the scale of one billionth of a meter. It is more of an approach to engineering than a science, although it draws on the scientific knowledge of biology, physics, chemistry, and materials science and is expected to change these sciences dramatically.

"Nanoscale" generally refers to objects 1-100 nm in one or more dimensions. At its lower limit this definition intentionally excludes individual molecules which generally define the lower end of the nanotechnology, i.e. nano derived features are as much a function of larger bulk materials approaching a molecular scale as they are a selective change in molecules' properties as they aggregate (Ratner, 2003).

Nanocrystals/Nanoparticles are crystalline clusters of a few hundred to a few thousand atoms with sizes of a few nanometres. Although more complex than individual atoms, their properties are different from bulk crystals. Due to their small size, much of their chemical and physical properties are dominated by their surfaces and not by their bulk volume. Nanocrystals can be synthesized from metallic materials such as gold (Brust, 1995; Brown 1999; Ahmad, 2013), silver (Rivas, 2001; Wani, 2010;Wani, 2011; Wani, 2013) or cobalt (Ershov, 2000; Puntes, 2001), from semiconductor materials such as cadmium sulphide (Murray, 1993; Merkoci, 2006), cadmium selenide (Steigerwald, 1990; Colvin, 1992), cadmium telluride (Eychmuller,2000; Talapin, 2001), gallium arsenide (Olshavsky, 1990) or indium phosphide (Guzelian, 1996; Micic, 1997), and from insulators such as iron oxide (Rockenberger, 1999; Santra, 2001) or titanium oxide (Trentler, 1999) and many others.

Inorganic nanosystems are defined as the chemical objects whose composition is merely inorganic, which exhibit new phenomenon due to quantum size effects due to the occurrence of large amounts of surfaces and interfaces because of their reduced size in the nanometre scale (1-100 nm). Infact, isolated molecules exhibit properties that follow quantum mechanical rules, while the chemical and physical properties of bulk materials obey the laws of quantum mechanics. In the middle, nanosystems display electronic, photochemical, electrochemical, optical, magnetic, mechanical or catalytic properties that differ significantly not only from those of molecular units, but also from those of macroscopic systems.