Chapter 2
Properties of Nanomaterials and Environment

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ABSTRACT

The chapter provides a timely review of the various properties of nonmaterial and their applications into environmental compartments. An extensive variety of poisonous chemicals is discharged into the environment because of globalization and industrialization. The dimensional, compositional, geometric, and structural properties are fundamental to convey usefulness of the nanomaterials. The controlled sizes and shapes of nanoparticles are anticipated to yield unique catalytic, electrochemical, and photochemical properties. The electrochemical properties of monolayer-functional metal nanoparticles are expected to be controlled by the particle sizes. Metal nanomaterials have interesting optical properties due to strong surface plasmon absorption and field enhancement effects; metal oxides lack visible absorption due to very large bandgap. Nanocomposites have complex optical properties. Nanomaterials present gigantic advantages on diverse applications, catalysis, imaging, biotechnological, and sensor applications due to their improved properties.

INTRODUCTION

Nanotechnology is based on materials that fall in size range of 1-100nm.This exceptionally small size makes their surface to volume ratio very high which in turn is responsible for nanomaterial properties that are different from their bulk counterparts. By manipulating their size and shape these properties can be tailored and hence can be utilized for various commercial and domestic applications in different areas like; medical, energy resource research, agricultural and food, electronics, environmental applications etc. At this nano-scale the bonding is different from that of the bulk materials and so is the atom that is available on the surface to that of the one available inside the bulk. Further the differential behavior is shown by atoms that is present on a smooth surface to the ones available on rough surface; the ones present on cluster to the ones occurring on support and the atoms present in doped and pure form (Roduner, 2006).

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NANOMATERIALS' SIZE MATTERS

Nanomaterials have large surface to volume ratio and that ratio changes dramatically as the size reduces. For example, when the size of iron cube reduces from 1cm^3 to 10 nm^3 the 10% increase in surface atoms is noticed; with further decrease in size to 1nm^3 all the atoms present will be surface atoms only. Similarly, the total surface energy hypes from 7.2×10^{-5} J/g to 560 J/g with decrease in particle side from 0.77cm (total surface area 3.6 cm^2) to 1nm (total surface area 2.8×10^7 cm^2).This kind of pronounced impact of surface to volume ratio is held responsible for changes in physical and chemical properties of the nanomaterials (Cao, 2004).

These size based effects can be divided into two types:

1. Surface effects
2. Quantum effects

In the first case atoms at the surface have less neighboring atoms and hence less coordination number and consequently the bond energy per atom (cohesive energy). This is the reason of high stability of atoms preset in the bulk which increases with increase in coordination number and cohesive energy. The order of atom' stability for a cube follows the order: corner> edge > in-plane surface > interior atoms. Thus, owing to highest instability of the corner atom and maximum stability of the interior atoms reverse order of is followed for affinity for bond formation and absorption of atoms. Same factor goes for less well defined phase transitions in nanomaterials having lower number of atoms in a cluster. This surface driven effect is responsible for variations in material's properties like melting point, catalytic reactivity, adsorption capacity etc. (Roduner, 2006).

The second type of effect, quantum confinement, is based on delocalization of electron states. The density of states (DOS) refers to the band formed by contribution of a number of atoms and width of DOS is directly proportional to the number of atoms. This number amounts to the Avogadro's number in case of bulk and very low in case of nanomaterials thereby reducing the DOS. All this contributes to modification in distance between the highest and lowest occupied levels in case of nanomaterials resulting in size-induced metal-insulator transitions leading to conversion of insulator to semiconductor to metal. This phenomenon is also responsible for change in magnetic and optical properties in case of nano-size materials (Roduner, 2006).

The DOS unequivocally impacts the electronic and optical properties of semiconductors and metals. The adjustments in DOS, alongside changes in electronic and vibrational levels, modify the properties of the nanomaterials. This in turn brings changes in both their dynamic and harmony properties; for example changes in the DOS of the electrons and phonons influence the electron–phonon coupling and along these lines the electronic unwinding due to electron–phonon communication.

The density of state of a diminished measurement framework additionally changes significantly with diminishing size. For instance, for a three-dimensional mass material, the DOS is relative to the square foundation of vitality E. For a system with control in one measurement (a two-dimensional material or quantum well), the DOS is a stage work. For frameworks with imprisonment in two measurements (a one-dimensional material or quantum wire), the DOS has an idiosyncrasy. For frameworks with repression in three measurements (zero-dimensional material or supposed quantum dabs, QDs), the DOS has the state of a δ-work (Yang et al., 2009). The adjustment in DOS in decreased measurement frameworks is delineated in Figure 1.