Nano Science and Nano Technology

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Abstract- **Nanotechnology is the manipulation of matter on an atomic and molecular scale inclusive of all types of research and technologies that deal with the special properties of matter that occur below the given size thresold(1-100 nm).Nanotechnology is very board, including fields of science as diverse as surface science, organic-inorganic chemistry, molecular biology, semiconductor physics, micro fabrication, etc.**

The term nanotechnology was coined in 1974 by Prof. Norio L Anguichi at the Tokya Science University.Broadly,there are three main divisions in Nanotechnology: Nanometers,Nano electronics and Nano-biotechnology.

I. GENERAL INTRODUCTION TO NANOPARTICLES

Nanotechnology is the science that deals with matter at the scale of 1 billionth of a meter (i.e., 10^{-9} m = 1 nm), and is also the study of manipulating matter at the atomic and molecular scale. A nanoparticle is the most fundamental component in the fabrication of a nanostructure, and is far smaller than the world of everyday objects that are described by Newton's laws of motion, but bigger than an atom or a simple molecule that are governed by quantum mechanics.

In general, the size of a nanoparticle spans the range between 1 and 100 nm. Metallic nanoparticles have different physical and chemical properties from bulk metals (e.g., lower melting points, higher specific surface areas, specific optical properties, mechanical strengths, and specific magnetizations), properties that might prove attractive in various industrial applications. However, how a nanoparticle is viewed and is defined depends very much on the specific application.

II. DESCRIPTION

For example, nanoparticles of carbon black (tire soot) have been used in the fabrication of rubber tires of automobiles from the beginning of the twentieth century. Pigments such as SiO_2 and TiO_2 have been prepared by a high-temperature combustion method. Since the 1970s, the innovative development of nanoparticles is due to a combination of theory and experiments in the fields of physics, chemistry, materials science, and biosciences. Specific phenomena (chemical properties and physical properties), other than the optical property of a nanoparticle, have led to new possibilities in various fields. Applications of nanoparticles in various fields require an inexpensive and simple process of synthesizing high quality shaped nanoparticles. In this regard, recent years have witnessed significant research being done in the use of microwave radiation in nanoparticle syntheses.

Table 1.1 Chronological table of nanotechnology.

Year	Remarks	Country/people
1200–1300 BC	Discovery of soluble gold	Egypt and China
290–325 AD	Lycurgus cup	Alexandria or Rome
1618	First book on colloidal gold	F. Antonii
1676	Book published on drinkable gold that contains metallic gold in neutral media	J. von Löwenstern-Kunckel (Germany)
1718	Publication of a complete treatise on colloidal gold	Hans Heinrich Helcher
1857	Synthesis of colloidal gold	M. Faraday (The Royal Institution of Great Britain)
1902	Surface plasmon resonance (SPR)	R. W. Wood (Johns Hopkins University, USA)
1908	Scattering and absorption of	G. Mie (University of Göttingen, Germany)

	electromagnetic fields by a nanosphere	
1931	Transmission electron microscope (TEM)	M. Knoll and E. Ruska (Technical University of Berlin, Germany)
1937	Scanning electron microscope (SEM)	M. von Ardenne (Forschungslaboratorium für Elektronenphysik, Germany)
1959	Feynman's Lecture on "There's Plenty of Room at the Bottom"	R. P. Feynman (California Institute of Technology, Pasadena, CA,USA)
1960	Microelectromechanical systems (MEMS)	I. Igarashi (Toyota Central R&D Labs, Japan)
1960	Successful oscillation of a laser	T. H. Maiman (Hughes Research Laboratories, USA)
1962	The Kubo effect	R. Kubo (University of Tokyo, Japan)
1965	Moore's Law	G. Moore (Fairchild Semiconductor Inc., USA)
1969	The Honda–Fujishima effect	A. Fujishima and K. Honda (University of Tokyo, Japan)
1972	Amorphous heterostructure photodiode created with bottom-up process	E. Maruyama (Hitachi Co. Ltd., Japan)
1974	Concept of nanotechnology proposed	N. Taniguchi (Tokyo University of Science, Japan)
1976	Carbon nanofiber	M. Endo (Shinshu University, Japan)
1976	Amorphous silicon solar cells	D. E. Carlson and C. R. Wronski (RCA, USA)
1980	Quantum hall effect (Nobel Prize)	K. von Klitzing (University of Würzburg, Germany)
1982	Scanning tunneling microscope (STM) (Nobel Prize)	G. Binnig and H. Rohrer (IBM Zurich Research Lab., Switzerland)
1986	Atomic force microscope (AFM)	G. Binnig (IBM Zurich Research

		Lab., Switzerland)
1986	Three-dimensional space manipulation of atoms demonstrated (Nobel Prize)	S. Chu (Bell Lab., USA)
1987	Gold nanoparticle catalysis	M. Haruta (Industrial Research Institute of Osaka, Japan)
1990	Atoms controlled with scanning tunneling microscope (STM)	D. M. Eigler (IBM, USA)
1991	Carbon nanotubes discovered	S. Iijima (NEC Co., Japan)
1992	Japan's National Project on Ultimate Manipulation of Atoms and Molecules begins	
1995	Nano-imprinting	S. Y. Chou (University of Minnesota, USA)
1996	Nano sheets	T. Sasaki (National Institute for Research in Inorganic Materials, Japan)
2000	National Nanotechnology Initiative (NNI),	USA
2003	21st Century Nanotechnology Research and Development Act,	USA
2005	Nanosciences and Nanotechnologies: An action plan,	Europe

III. METHODS OF NANOPARTICLE SYNTHESIS

Two approaches have been known in the preparation of ultrafine particles from ancient times. The first is the breakdown (top-down) method by which an external force is applied to a solid that leads to its break-up into smaller particles. The second is the build-up (bottom-up) method that produces nanoparticles starting from atoms of gas or liquids based on atomic transformations or molecular condensations.

The top-down method is the method of breaking up a solid substance; it can be sub-divided into dry and wet grinding. A characteristic of particles in grain refining

processes is that their surface energy increases, which causes the aggregation of particles to increase also. In the dry grinding method the solid substance is ground as a result of a shock, a compression, or by friction, using such popular methods as a jet mill, a hammer mill, a shearing mill, a roller mill, a shock shearing mill, a ball mill, and a tumbling mill. Since condensation of small particles also takes place simultaneously with pulverization, it is difficult to obtain particle size of less than 3μm by grain refining. On the other hand, wet grinding of a solid substrate is carried out by using a tumbling ball mill, or a vibratory ball mill, a planetary ball mill, a centrifugal fluid mill, an agitating beads mill, a flow conduit beads mill, an annular gap beads mill, or a wet jet mill. Compared with the dry method, the wet process is suitable for preventing the condensation of the nanoparticles so formed, and thus it is possible to obtain highly dispersed nanoparticles other than the above, the mechanochemical method and the mechanical alloying are also known as top down methods. That is, the synthesis of nanoparticles requires the use of a device or process that fulfills the following conditions:

- ❖ control of particle size, size distribution, shape, crystal structure and composition distribution
- ❖ improvement of the purity of nanoparticles (lower impurities)
- ❖ control of aggregation
- ❖ stabilization of physical properties, structures and reactants
- ❖ higher reproducibility
- ❖ higher mass production, scale-up and lower costs

The plasmon resonance phenomenon, but also found that it changed with the composition of the liquid in touch with the metal surface. Although he speculated on how the light, grating and the metal interacted with each other, a clear rationalization of the phenomenon was not provided. He observed a pattern of "anomalous" dark and light bands in the refracted light when he shone polarized light on a mirror with a diffraction grating on its surface.

The first theoretical treatment of these anomalies was put forward by Rayleigh in 1907 [1] . Rayleigh's "dynamical theory of the grating" was based on an expansion of the scattered electromagnetic field in terms of outgoing waves only. With this assumption, he found that the scattered field was singular at wavelengths for which one of the spectral orders emerged from the grating at the grazing angle. He then observed that these wavelengths, which have come to be called the Rayleigh wavelengths, λ_R, correspond to the Wood anomalies. Further refinements were made by Fano [2] , but a complete explanation of the

phenomenon was not possible until 1968 when Otto [3] , and in the same year Kretschmann and Raether [4] , reported the excitation of the surface plasmon band. Surface plasmon resonance has also been similarly researched in solid state physics in recent years in application studies, especially in such applied research as biosensing, solar cells, and super high-density recording.

Since electrons are also particles with an electric charge, when they vibrate they also generate an electric field, and when the electric field from the vibration of free electrons and the applied external electric field (e.g., electromagnetic waves) resonate the resulting phenomenon is referred to as a surface plasmon resonance that takes place at the surface of the metal. However, if light irradiates a solution that contains dispersed metal nanoparticles smaller than the wavelength of light, then depending on the electric field of light, the deviation produces a free electron at the surface of the metal. As a result, the weak or thick portions of the electric field appear on the nanoparticle surface and can be considered as a kind of polarization.

IV. CONTROL OF SIZE, SHAPE, AND STRUCTURE

a. Size Control Of Nanoparticles

The physical and chemical properties of nanomaterials depend not only on their composition but also on the particle size [5] and shape [6]. Accordingly, a high quality synthesis protocol must first of all provide control over particle size and shape . For example, if the diameter of an Au nanosphere is made to increase, the surface plasmon resonance will be gradually shifted from 530 nm to the longer wavelength side [7]. Thus, if nanoparticles differ in size, their optical characteristics will also change significantly.

In optical applications of nanoparticles, simplification of the size distribution of the particles becomes a very important factor. Therefore, it is important to fabricate nanoparticles with a single target size in mind. Generally, in order to prepare monodispersed nanoparticles, it is imperative that the nanoparticles grow very slowly after the rapid generation of the seed particles [8]. If the size of the nanoparticles decreases (i.e., increase in specific surface area), then the increase in the surface energy of such nanoparticles will facilitate their aggregation. Consequently, after their growth to the desired optimal size, it will be necessary to stabilize the particulate surface by addition of a dispersing agent.

b. Structure Control of nanoparticles:

Nanoparticles that are composed of two or more metals differ in their catalytic, magnetic, and optical

characteristics from nanoparticles that consist of a single metal. Such nanoparticles can be sub-divided into three kinds of structures:

(i) the alloy structure that exists randomly in a crystal;
(ii) the core–shell structure in which the metal at the center differs from the peripheral metal; and
(iii) the twinned hemisphere structure wherein two sorts of hemispheres are joined. The latter heterojunction structure facilitates phase separation. Nanostructures consisting of complex metal nanoparticles tend to hide the various new features.

The spherical, semi – conductor nanoscrystal atoms, ranging in size from 2 to 50 mm (nanometers), also called quantum boxes or quantum dots, have intermediary properties between those of a molecule and a solid. The electron's energy is no longer spread out in bands of energy as in an ordinary semi-conductor, but in discrete, quantified levels as in an atom or in a molecule. The distribution of energy on these levels is relative to the size of the crystal.

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