"An irreverent, comprehensive romp, by an experienced science popularizer, through the many fascinating details of the nano-world."

—The Wall Street Journal

NANOTECHNOLOGY

The Future of Nanotechnology: Nanodream or Nano-Nightmare

Rishabh Anand

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Nanotechnology

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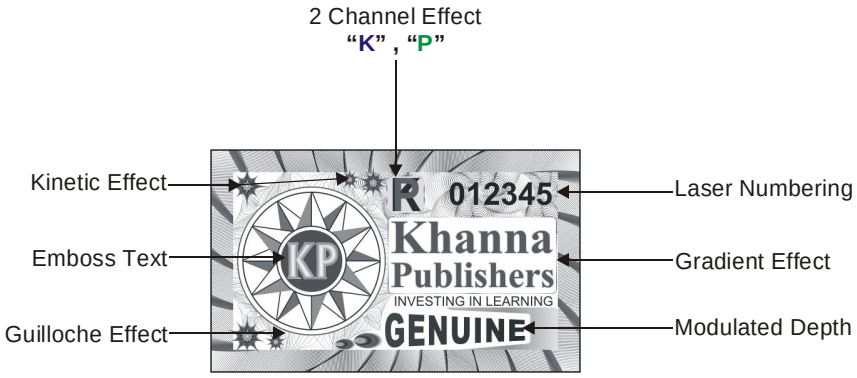

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Preface

"One cannot learn anything so well as by experiencing it oneself."

—Albert Einstein

Nanotechnology is a much talked about, and rapidly expanding area of science, which is sometimes little understood. It looks set to make a significant impact on human life and, with numerous commercial developments emerging, will become a major industry over the coming years.

The term "nanoworld" is understood differently by many experts. Do we have to restrict ourselves to the field of nanomaterials, which consists of building nanometric structures made up of a limited number of atoms? Should we include the miniaturized world which is largely dominated by microelectronics and in which the dimensions of its devices are smaller than a hundredth of a nanometer? How do we approach concepts which at first glance seem to be very different, i.e. the link between volume and surface of the different aggregates, the functionality of macromolecules and the complexity brought about by our electronic systems? In fact, all different scientific disciplines, including every single sector (such as nanomaterials, micro and nanomachines, micro and nanoelectronics), have their own paradigm . This is why innovations and industrial developments are profoundly different. However, these fields are strongly interlinked. It is therefore necessary to make our studies more interdisciplinary in order to enable us to understand the nanoworld.

Nanotechnology is the science and engineering of making materials, functional structures and devices in nanometer scale. One nanometer scale is equal to 10^{-9} meter. In Greek, Nanos means dwarf and technologia means systematic treatment of an art or craft. Nanostructured inorganic, organic, and biological materials may have existed in nature since the evolution of life started on Earth. Nanotechnology deals with materials or structures in nanometer scales, typically ranging from 1-100 nm. Size reduction can lead to a whole range of new physico-chemical properties and a wealth of potential applications. However, access to these nanostructured entities requires the development of suitable methods for their elaboration.

Taking this idea as a basis for our work, we would like to introduce nanosciences and nanotechnologies in the broadest scale possible by showing their common scientific basis as well as their multiple interconnections. We will cover different fields in the chapters to come. This is not a straight textbook; those are easily accessible in libraries or on the Internet. The following chapters will both provoke reflection and provide the reader with a better understanding of the subject. This is a guided tour of the discovery of the nanoworld which we hope will arouse the reader's curiosity so that they will engage more profoundly with the subject.

The concept of atomic precision was first suggested by Physics Nobel Laureate Richard Feynman in 1959, in his legendary speech at the California Institute of Technology. He stated: "The principles of physics, as far as I can see, do not speak

against the possibility of maneuvering things atom by atom....". Several major research and development programs on nanostructured materials and nanotechnology have been launched by governments worldwide. This field of research has become an area of great scientific and commercial interest because of its rapid expansion to academic institutes, laboratories and industries. The research on nanotechnology is evolving rapidly, and hence it is impossible to cover all the aspects of this field in one book. Thus, the aim of this book is to summarize briefly the fundamentals and established techniques of synthesis, processing, characterization, properties and potential applications of nanomaterials so as to provide important information on nanotechnology to the readers. All care has been taken to make students comfortable in understanding the basic concepts of the subject. The book will be very useful not only to the students but also to the subject teachers.

The book will be very useful not only to the students but also to the subject teachers. It will serve as a general introduction to people just entering the field of nanotechnology, and also for experts seeking information on other subfields.

New Delhi **—Rishabh Anand**

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Basic Concepts of Nanotechnology and its Applications

1.1 INTRODUCTION

Grief may come as a cloudburst, but good news—especially that modern form of it called technology—has occured to date as a steady, all-day drizzle. Futurists and historians, and their fictive counterparts the historical novelists and science-fiction writers, see this more clearly than most. As they consider where the present started, the long view is forced upon them.

The prefix '*nano*' in the word nanotechnology means a billionth (1×10^{-9}). Nanotechnology deals with various structures of matter having dimensions of the order of a billionth of a meter. While the word nanotechnology is relatively new, the existence of functional devices and structures of nanometer dimensions is not new, and in fact such structures have existed on earth as long as life itself. As the subject is very wide, only few examples will be taken as an illustration of applications in those areas.

The word '*nanotechnology*' is an '*umbrella term*'. It has the ability of accommodating conventional Physics, Biology, Chemistry, Materials Science and all engineering disciplines. This new concept in manufacturing makes most products embossed with unique characteristics, such as cleaner, precise, lighter, stronger and cost effective. Such nanoscale objects of matter are referred to as nanoparticles, nanomaterials or nanostructures.

When **Neil Armstrong** stepped onto the moon, he called it a small step for man and a giant leap for mankind. Nano may explore another giant leap for mankind, yet with a step so small that it makes Neil Armstrong look the size of a solar system.

Nanotechnology will affect every aspect of our lives, from the food we eat to the clothes we wear, the medicines we use, the buildings we live in, the energy supplies we require, the computers and other electronic appliances we use, and all other spheres of life that we can think of. This will be realized sooner, than what most people would imagine. By 2020, we won't be able to count the number of products based on nanotechnology applications. What

we see today is the beginning of a revolution, caused by our ability to work on the same scale as nature does. We will discuss here some of the broad areas of nanotechnology applications of interest by presenting a brief overview. Nanotechnology mainly deals with materials at nanoscale materials and devices are usually composed of carbon nanotubes, but some other types of materials are used too.

Over the past few years, a little word with big potential has been rapidly insinuating itself into the world's consciousness. That word is "nano". It has conjured up speculation about a seismic shift in almost every aspect of science and engineering with implications of ethics, economics, international relations, day-to-day life, and even humanity's conception of its palce in the universe. Visionaries tout it as the panacea for our woes. Almaristsee it as the next step in biological and chemical welfare or, in extreme cases, as the opportunity for people to create the species that will ultimately replace humanity. While some of these views are farfetched, nano seems to stir up popular, political, and media debate in the same way that space travel and the internet did in their respective hey days. What are the historical milestones in the saga of nano? Many nano forms of matter exist around us.

Real nanotechnology is not about physical immortality, or killer nanbots, or waking up dear dead Auntie Flo from her long nap in the freezer. Real nanotechnology is more amazing than any pipe dream. It is closing in our structural materials stronger than anything we've known, on computers the size of molecules; on complete diagnostic laboratories smaller than your thumbnail, on ways to painlessly cook cancer cells to death; on buildings that stay up despite storms, earthquakes and attacks.

Set pulp fiction aside. The genuine nanocosm has sci-fi beat six ways to Sunday. Not much may seem to change in your day-to-day round of getting and spending, washing dishes, and going to school. But when you sit down and sum up all the tiny adjustments that an average modern decade brings, you realize just how far the leading edge of our planet's culture has gone and how quickly it got there. Now the speed of such transformation is about to take another leap.

The word **'nano'** is derived from the Greek word nanos or Latin word nanus, meaning **'dwarf'.** Nanotechnology is the engineering of functional systems at the molecular scale. This covers both current and work and concepts that are more advanced. In its original sense, nanotechnology refers to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make completes high performance products. A nanometer is one billionth (10^{-9}) of a metre, which is tiny, only the length of a few hydrogen atoms, or about one hundred thousandth of the width of a hair! Nanotechnology involves "research and technology development at the atomic, molecular or macromolecular levels in the length scale of approximately 1 to 100 nm range to provide a fundamental understanding of phenomena and materials at the nanoscale to form and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size." Nanotechnology is science, engineering and technology conducted at the nanoscale which is about 1 to 100 nanometers. The U.S. National Nanotechnology initiative definition includes

anything smaller than 100 nanometers with novel properties is termed 'Nanotechnology'; and has described four generations of nanotechnology *viz.,*

(*i*) Passive Nanostructures (~ 2000)

- Dispersed and contact nanostructure
  For *example,* aerosols, colloids
- Products incorporating nanostructures
  For *example;* coatings, nanoparticle reinforced composites; nanostructured metals, polymers, ceramics.

(*ii*) Active Nanostructures (~ 2005)

- Bio-active health effects
  For *example,* Targeted drugs, biodevices
- Physico-chemical active
  For *example,* 3D-transistors, amplifiers, actuators, adaptive structures.

(*iii*) Systems of Nanosystems (~ 2010)

For *example,* Guided assembling, 3D-networking and new hierarchical architectures robotics, evolutionary.

(*iv*) Molecular Nanosystems (~ 2015–2020)

e.g., Molecular devices by design; atomic design, emerging functions.

A nanometer is used to measure things that are very small. Atoms and molecules—the smallest pieces of everything around us are measured in nanometers.

Sometimes nanotechnology is referred to as a general purpose technology, due to its advanced form. It will have tremendous impact on almost all the industries and touched all the areas of society. It will offer better infrastructure, durability, cleaner, safety and smaller products for the house, communications, medicine, transportation, agriculture and industry in general. Academic interest in the unconventional characteristics of the nano-structured materials received a boost through the multifold application of new materials precisely generated at nano-dimensions. Realisation of the bottom-up approach of molecular nanotech further attracted the interests of scientists working for materials, IT, biotech, healthcare, environment protection, etc. While the research interest diversified from nanodevice to nanosciences, nanotechnology and design of nanomaterials, the number of design of nanomaterials, and the number of institutions investigating nano-phenomenon spurted.

Nanotechnology (or "nanotech") is manipulation of matter on an atomic, molecular, and supramolecular scale. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macroscale products, also now referred to as molecular nanotechnology. A more generalized description of nanotechnology was subsequently established by National Nonotechnology Initiative, which defines nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometer.

The definition reflects the fact that quantum mechnical effects are important at this quantum—realm scale, and so the definition shifted from a particular technological goal to a research category inclusive of all types of research and technologies that deal with the special properties of matter which occur below the given size threshold. It is therefore, common to see the plural form "nanotechnologies" as well as "nanoscale technologies" to refer to the broad range of research and applications whose common trait *i.e.*, size.

The nanotechnology is a very important field of science. But it is not entirely new science. Did you know that some nano materials were used centuries ago? And still, many people today do not know what the nanotechnogy is.

As well as reaching for the immense, SI delves in the opposite direction: down into the tiny. One thousandth of a gram is a *milligram;* one thousandth of that—a millionth of a gram-is a microgram. A thousandth of a micro-unit, one billionth of something, is expressed by the prefix *nano*-from *nanos*, classical Greek for *dwarf*. But whereas dwarf might be half the weight of an average adult, a nanometer is but one billionth of a meter. That's the diameter of a small molecular. Here's an image, a *la Hitch Hiker's Guide*. If a nanometer were scaled up to the width of your little finger nail, then you finger nail would be the size of Delware and your thumb would be the Size of Florida. Yet the smallest manipulable element inside that monstrous hand, an atom of hydrogen, would still scale up to only one twenty-fifth of an inch. The nanocosm is a serious kind of small.

Small it may be; unknown it is not. Higher, faster, better, boast the Olympics. This could also be the moeto of science, which constantly seeks to extend its understanding. But science adds other comparatives*; lower, slowest, smaller, less* obvious.

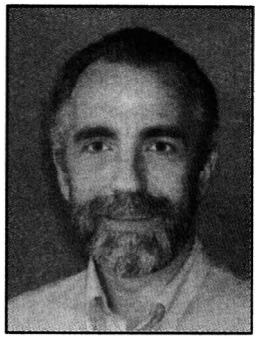
Nanotechnology is also sometimes called ***'Engineering at Molecular Level'*.** It is a multi-disciplinary area of applied science and engineering that deals with the design and manufacture of extremely small components and systems. They are built at the molecular level of matter, are characterised by large surface areas in comparison with their volumes, and have behaviours that are governed by the laws of quantum mechanics. In contrast, large-scale engineered objects are built with masses large enough they could be described, starting with uniform bulk properties, according to the classical laws of physics and chemistry.

Nanotechnology offers ample opportunities in creating new features and functions. It is already providing the long-term solutions to many long-standing medical, social and environmental problems, Due to its tremendous potential it has generated global interest. It attracts more public funding than any other areas of technology, estimated at 3.8 billion euros worldwide in 2005. The contribution of nanotechnology to new products and processes cannot be made in isolation and requires a concerted effort, which may include scientists, biologists and biochemists working with physicists, chemists and information technology experts. Consider the development of a new cochlear implant and what that might require—at least physiologists, an electronic engineer, a mechanical engineer and a biomaterials expert. This kind of teamwork is essential, not only for a cochlear implant, but also for any new nano-based product.

Nanotechnology is the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanoscale. By creating nanometer scale structure it is possible to control fundamental characteristics of a material including its melting point, magnetic properties, and colour without changing its chemical composition. The goal of nanotechnology is to direct atoms and molecules to form desired structures or patterns with ideal functionality. At the nanoscale, the physical, chemical and biological properties of materials vary in fundamental and valuable ways from the properties of individuals' atoms and molecules or bulk matter. Nanotechnology Research and Development is directed toward understanding and creating improved materials, devices and systems that exploit these new properties. Although nanotechnology is a relatively new research area, nanotechnologies are already emerging that will change our lives in unforeseeable ways in the coming decades, and the range of possible future applications is constantly growing.

Nanotechnology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, energy storage, micro fabrication, molecular engineering etc. The associated research and applications are equally diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale to direct control of matter on the atomic scale.

According to Physicist Richard Feyman, the father of Nanotechnology is nanoscience and nanotechnology are the study and application of extremely small things and can be used across all other science fields, such as chemistry, biology, physics, material science and engineering. The branch of science dealing with the systematic study of nature and behaviour of nanomaterials based on experimental observations and formulation of general laws describing their properties is called *nanoscience*.



The ideas and concepts behind nanoscience and nanotechnology started with a talked entitled **"*There is plenty of Room at the Bottom*"** by physicist Richard Feyman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term ***'Nanotechnology'*** was used. In his talk, Feyman described a process in which scientists would be able to manipulate and control individual atoms and molecules. Over a decade later, in his explorations of ultraprecision machining. Professor ***Norio Taniguchi*** coined the term ***'Nanotechnology'***. It was not until 1981, with the development of scanning tunnelling microscope that could see individual atoms that modern nanotechnology began. The term nanotechnology made its startling revelation in 1986 with the publication of **"*Engines of Creation: The Coming Era of Nanotechnology*"** by Eric Drexler. Dr. Eric Drexler, SB and SM (USA) and Ph.D. in Molecular Technology, is an author and theoretical researcher. He is a pioneer of Nanosystems, an advanced technical text nanomachines building products with atomic precision. He has also written three books on this topic, and is founder and Chairman of Foresight Institute, a non-profit educational organisation that aims to enable society prepare for emerging technological revolutions.

Researchers and technologies are approaching the field of nanotechnology from three directions, *viz.,*

(*i*) In Physics, the field of microelectronics is moving towards smaller feature sizes and is already at submicron line widths. Processors in computing systems will need nanometer line widths in the future as miniaturisation proceeds.

(*ii*) In Chemistry, improved knowledge of complex systems had led to new catalyst, membrane sensor and coating technologies, which rely on the ability to tailor structures at atomic and molecular levels.

(*iii*) In Biology, living systems have sub-units with sizes between micron and nanometer scales,· and these can be combined with non-living nanostructured materials to create new devices.

We are now at the threshold of a revolution in the ways in which materials and products are created. This has resulted from the convergence of the traditional fields of chemistry, physics and biology to form the new field of nanotechnology.

Scientists and technologists have always been fascinated and we are working tirelessly to make novel and improved devices as a symbol of the continuous progress of mankind, in terms of their size, performance and cost. To achieve this goal, they have laid major emphasis on the miniaturization of the devices and implements, which has been particularly useful in the field of electronics. In a quick succession to MEMS technologies, nanotechnology has opened new avenues for fabrication of devices and systems on the nanoscale with high sensitivity and frequency response in the range of gigahertz and beyond.

A Note on Measures

SI Units (abbreviation)	***Description***
Metre (m)	Approximately three feet or one yard
Centimeter (cm)	1/100 of a meter, around half an inch.
Millimeter (mm)	1/1000 of a meter
Micro meter (μm)	1/1000 of a meter, also called a micron, this is the scale of most integrated circuits and MEMS devices.
Nanometer (nm)	1/1,000,000,000 of a meter; the scale of single small molecules and nanotechnology.

While the word *nonotechnology* has gained wide currency, its use to mean something already in existence was initially premature. Even today the nanocosm has not generated much solid technology. It's about to that is inevitable. But the basic of its a few years, and in some cases more than a decade, away. We have only begun to sail, chart, and record; are still have not undertaken systematic trade or colonization.

1.2 NANOMATERIALS—MATERIALS AND MANUFACTURING

The word nanoparticles, nanomaterials, or nanostructures, together, with the related concepts, came into frequent use in the early 1990s. However, the use of various such materials by humanity could go back to thousand of year in the past. Nanomaterials and their manufacture are distinct in comparison to the other useful emerging technology based on macromaterial manufacturing, nanoscience and technology are interdisciplinary in nature and include disciplines such as chemistry, physics, biology, mathematics, life science, biotechnology, information technology, etc.

Nanomaterials (nano crystalline materials) are materials possessing grain sizes on the order of a billionth of a meter. They manifest extremely fascinating and useful properties, which can be exploited for a variety of structural and non-structural applications. As per the new models of manufacturing industry, it is the materials that are becoming the first step in increasing the value of products and their performance, rather than the processing steps. New advanced materials with higher knowledge contents, new functionalities and improved performance are increasingly critical for industrial competitiveness and sustainable development. Research will focus on developing new knowledge-based materials with tailored properties. This requires an intelligent control of intrinsic properties, processing and production, and taking into account potential impacts on health and the environment throughout their entire life cycle. Emphasis is given on new advanced materials achieved using the potential of nanotechnologies and biotechnologies and/or ***'learning from nature'***, in particular higher performance nanomaterials, bio-materials and hybrid materials. A new approach is required for the manufacturing industry from a resource intensive to a knowledge-based industrial environment and will rely on the adoption of totally new attitudes towards the continued procurement, development, protection and funding of new knowledge and its use, including towards sustainable production and consumption patterns. Material characterisation, design and simulation are also necessary for better understanding of materials phenomena; improve materials assessment and reliability and extend the concept of virtual materials for material design.

1.3 NANOTECHNOLOGY IN DRUG DISCOVERY

The medical application of nanotechnology is known as ***nanomedicine.*** The approaches to nanomedicine start from the medical use of nanomaterials to nanoelectronic biosensors and for future applications of molecular nanotechnology. Nanomedical approaches to drug delivery include developing nanoscale particles or molecules to improve the bioavailability of a drug. Bioavailability refers to the presence of drug molecules where they are needed in the body and will do the most good. Drug delivery focuses on maximising bioavailability both at specific places in the body and over a period of time. This will be achieve by molecular targeting through nanoengineered devices. The new methods of nanoengineered materials that are being developed might be effective in the treatment of illnesses and diseases such as cancer. Drug delivery systems, lipid or polymer-based nanoparticles can be designed to improve the pharmaceutical and therapeutic properties of drugs. One of the major impacts of nanotechnology and nanoscience is leading the development of completely new drugs with

useful behaviour and less side effects. The strength of drug delivery systems is their ability to alter the pharmacokinetics and biodistribution of drug. Nanoparticles have unusual properties which can be used to improve drug delivery system. Potential nanodrugs work by very specific and understood mechanisms.

To describe what nanotechnology can do to manufacture nano/micro drug delivery systems, one can use manufacturing of nano/micro particles or capsules as an example. The current methods of preparing nano/micro particles are mainly based on double emulsion methods or solvent exchange technique. Bioavailability refers to the presence of drug molecules where they are needed in the body and where they will do the most good.

In the conventional treatment of diseases, drugs or medicines are administered to the patient orally or through intravenous injections of the dose into the complete blood circulation system of the body. In this manner, only a very small fraction of the medicine reaches the diseased part. Alternatively, if an excessive dose is administered to ensure that the appropriate dose reaches the affected part, it would simultaneously subject the rest of the body to unintended adverse side effects.

In terms of drug discovery and development, the role of nanotechnology currently lies in improving diagonistic methods, developing improved drug formulations and drug delivery for disease therapy.

Although the benefits of nanotechnology are huge, there are certainly many hurdles ahead. Nanotechnology based solutions in drug delivery are beginning to generate substantial new insights into how biological systems function, and likewise will lead to the design of entirely new classes of micro- and nano-fabricated devices and systems. The use of microfabrication as a method of miniaturising multidisciplinary devices is just beginning to reach the life science industrial community.

The drug discovery industry has become such a competitive market that it continually faces a challenge to find better drug discovery technologies. This industry has to discover and develop innovative medicines for a wide range of diseases in a marketplace that is likely to experience growing regulatory challanges, pricing pressures and various other bottlenecks.

There are so many areas where nano-enhanced drugs could make a big difference in increasing oral bioavailability and reducing undesirable side effects. By increasing bioavailability, nanoparticles can increase the yield in drug development and most importantly may help treat previously unbeatable conditions. A new wave of technology and medicine is being created, and its impact on the world is going to be monumental.

1.4 NANOTECHNOLOGY IN TISSUE ENGINEERING

Currently, nanostructures in tissue engineering are gathering immense importance. In fact, tissue engineering can be viewed as a special category of drug delivery where the objective is to achieve controlled delivery and release of mammalian cells. Both, the drug delivery carriers (nanoparticles/nanorobots) and the tissue engineering scaffolds, need to be

biocompatible and biodegradable. Tissue engineering is connecting discipline between engineering materials science, medicine and biology.

There are various kinds of materials that can be electrospun into nanofibrous structures which have promising application in tissue engineering. The research of nanobiosystem is a priority to develop medical devices that once implanted will replace or enhance tissue function to impair diseases, injuries or age with special reference to tissue engineering. Tissue engineering scaffold with unique functional properties in a wide variety of applications especially focused on the collagen-based electrospun nanomaterials with variable applications. Fabrication of biodegradable polyster nanocomposites by electrospinning for tissue engineering reviewed several biodegradable polyster-based nanocomposites for tissue engineering applications. Depending on the type of tissue, the design process can involve a variety of disciplines including mechanical engineering, molecular biology, physiology, medicine, polymer chemistry and nanotechnology. Tissue engineering involves engineering and life sciences towards fundamental understanding and development of biological substitutes to restore, maintain and improve tissue functions. Biomaterial devices are created by seeding scaffold with cells at the nanoscale, which have certain properties to solve medical challenge and cater need in the area of nanomedical research. Nanomaterials compensate for limitations of scaffold. It can also increase cell viability, promote adhesion, control the growth factors and cytokines and even physically shape biomaterials and cells to create a desired tissue structure.

1.5 NANOTECHNOLOGY IN FOOD INDUSTRY AND AGRICULTURE

Nanotechnology has numerous potential applications in a wide range of consumer goods that include food and agriculture and other products of daily needs.

Basically, nanotechnology provides means to create novel structures with unique properties and wide applications. Encapsulation and delivery of nutrients directly to the targeted tissues in the body, improvement of flavour and taste, introduction antibacterial nanostructures in the food, and other affiliated benefits such as good packaging and processing are few examples of its application in the food industry. In addition, the understanding of their interactions with biological systems and the development of methods to optimize the related benefits and minimize the plausible risks to human health are also necessary. Nanotechnology has a great potential to revolutionize agriculture and the food industry by providing smart sensors and delivery systems to combat viruses and other pathgones, fast detection and molecular treatment of diseases, enhancement of the ability of the plants to absorb nutrients, and the improvement of efficiency and reduction of the cost of pesticides to control insects and also protect the environment.

In agriculture, nanotechnology is employed to increase food production, with equivalent or even higher nutritional value, quality and safety. Efficient use of fertilizers, pesticides, herbicides and plant growth factors/regulators are the most important ways to improve crop production.

Nanotechnology is applied in food processing to deliver nutrients, increase bioavailability and potency, effect timed and targeted release of nutrients, mask undesirable taste and odours, protect sensitive nutrients, increase solubility and improve rheological and anti-caking properties.

The significant interests of using nanotechnology in agriculture includes specific applications like nanofertilizers and nanoplesticdes to trail products and nutrients levels to increase the productivity without decontamination of soils, water and protection against several insect pest and microbial diseases.

With more than 60% of the population solely depend on agriculture for their livelihood as well as developing innovative systems for monitoring environmental conditions and delivering nutrients or pesticides as appropriate, so agriculture is the backbone of most developing countries. Nanotechnology can improve our understanding of the biology of different crops and thus potentially increase productions or nutritional values. In addition, it can offer routes to added value crops. Particle forming is one such example, which yields nanoparticles for industrial use by growing plants in specifically defined soils. For example, research has shown that 'alfalfa plants' grown in gold-rich soil, absorb gold nanoparticles, through their roots and accumulate these in their tissues. The gold particles can be mechanically separated from the plant tissue with the help of nanotechnology.

Nanotechnology has great potential to revolutionise the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection, improving the ability of plants to absorb nutrients, etc. Smart sensors and smart delivery systems will help the agricultural industry to combat viruses and other crop pathogens. In the near future, nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. An agricultural methodology widely used in USA, Europe and Japan, which resourcefully utilises modern technology for crop management, is called ***Controlled Environment Agriculture*.**

'Nanofood' is in which nanotechnology techniques or tools are used during cultivation, production, processing or packaging of the food. The impact of nanotechnology in the food industry is growing significantly over the last few years with the organisation of various conferences dedicated to the topic, invitation of consortia for better and safe food. The concept isthat thousands of nanocapsules containing flavour or colour enhances, or added nutritional components (such as vitamins), would remain dormant in the food and only be released at the time of synthesising food after consume.

Nanotechnologists are more boyant about the potential to change the existing system of food processing and to ensure the safety of food products, creating a healthy food culture. They are also sanguine of enhancing the nutritional quality of food through selected additives and improvements to the way the body digests and absorb food. Although some of these goals are farther away, the food packaging industry already integrates nanotechnology in different products.

Nanotechnology

About the Book

"A fascinating look at the art and science of nanotechnology". Hold on to your hats, the world is about to change big time. . . . A comprehensive look at nanotechnology from the perspective of science, investment, IP, and business development with a healthy dose of vision for good measure.

Taken from the Greek, Nano means 'one billionth part of' a whole; or very very small. Nanotechnology is the next step after miniaturization. Nanotechnology: Basic Science and Emerging Technologies bridge the gap between detailed technical publications that are beyond the grasp of non-specialists and popular science books, which may be more science fiction than fact. It provides a fascinating scientifically sound treatment, accessible to engineers and scientists outside the field and even to students at the undergraduate level. After the basic introduction to the field, the author explore topics that include molecular nanotechnology, nanomaterials and nanopowders,nanoelectronics,optics, photonics, and nanobiometrics.

Since the beginning of the industrial age, many machines have grown steadily smaller even as they have grown more powerful and complex. Nanotechnology, based on the science of the infinitesimally small, takes technology beyond most popular definitions of reality, to a realm of molecular machines, cell-sized computers and other astounding possibilities. Nanotechnology reveals a spectacular view of the immediate future of nanotechnology and its applications in medicine, computing, manufacturing, engineering and countless other arenas that affect our world, redefining how we work, play and live.

As with any phenomenon, nanotechnology has both its naysayers and its zealots by turns clouding scientific truth with dismissals, prophecies, and pipe dreams. Nanotechnology distinguishes fact from fantasy, possibility from hype, and perspective from fear-mongering to present an emerging reality far more thrilling than any fiction.

This book scrutinizes the cutting edge of a new technology that will find usage in almost every single aspect of modern society. This book is useful for undergraduate and postgraduate students, teachers and researchers, scientists and industrial personnel working in the field of nanoscience and nanotechnology.

About the Author

Rishabh Anand received his Bachelor 's degree B.E (Hons) in Electronics and Communication Engineering from Maharishi Dayanand university, Rohtak in 2006. The author is M.Tech. in Electronics and Communication Engineering from Veer Bahadur Singh Purvanchal University, Jaunpur in 2014 and MBA from Indian Institute of Management, Kozhikode in 2016. The Author is Program Diploma in Innovation Management from International Business Management Institute, Germany (Berlin) in 2020.The author has contributed to research publications in refereed, cited International Conferences and Journals and attended many conferences, workshops, FDPs and seminars. He is a prolific author with 34 Text and Reference books to his credit, for B. Tech. (ECE/CSE/IT), M.Tech. (ECE/CSE/IT), BCA, MCA and other courses of different Universities of India and overseas. His areas of interest includes Nanotechnology, Software Project Management, Cloud Computing, Deep Learning and Machine Learning. He is currently working in ITES industry as a Global Service Delivery Manager. He is PMP,ITIL4, PRINCE2,CSM, LSSWBC,CSSWB and CSSGB.The author delivers lectures as Visiting Faculty (Assistant Professor) in Global Institute of Technology and Management, Farrukh Nagar, Gurgaon.

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