1.1. Introduction:

In the heady days of any new, emerging technology, definitions tend to abound and are first documented in reports and journal publications, then slowly get into books and are finally taken up by dictionaries, which do not prescribe, however, but merely record usage. Ultimately the technology will attract the attention of the International Standards Organization (ISO), which may in due course issue a technical specification (TS) prescribing in an unambiguous manner the terminology of the field, which is clearly an essential prerequisite for the formulation of manufacturing standards.

In this regard, nanotechnology is no different, except that nanotechnology seems to be arriving rather faster than the technologies we might be familiar with from the past, such as steam engines and digital computers. As a reflection of the rapidity of this arrival, the ISO has already set up a Technical Committee (TC 229) devoted to nanotechnologies. Thus, unprecedentedly in the history of the ISO, we shall have technical specifications in advance of a significant industrial sector.

The work of TC 229 is not yet complete, however, hence we shall have to make our own attempt to find a consensus definition. As a start, let us look at the roots of the technology. They are widely attributed to Richard Feynman, who in a now famous lecture at Caltech in 1959 advocated manufacturing things at the smallest possible scale, namely atom by atom hence the prefix “nano”, atoms typically being a few tenths of a nanometre (10^{-9} m) in size.[(1)]

Nanotechnology is a field of applied science, focused on the design, synthesis, characterization and application of materials and devices on the nanoscale. This branch of knowledge is a sub-classification of technology in colloidal science, biology, physics, chemistry and other scientific fields and involves the study of phenomena and manipulation of materials in the nanoscale. This results in materials and systems that often exhibit novel and significantly changing physical, chemical and biological properties due to their size and structure. Also, a unique aspect of nanotechnology is the "vastly increased ratio of surface area to volume", present in many nanoscale materials, which opens new possibilities in surface-based sciences.(2)

Nanoscience and nanotechnology primarily deal with the synthesis, characterization, exploration, and exploitation of nanostructured materials. These materials are characterized by at least one dimension in the nanometer (1 nm =10^{-9} m) range. Nanostructures constitute a bridge between molecules and infinite bulk systems. Individual nanostructures include clusters, quantum dots, nanocrystals, nanowires, and nanotubes, while collections of nanostructures involve arrays, assemblies, and superlattices of the individual nanostructures.(3)

In the recent times, nanoparticles, or objects of size in the range of nanometer (1-100 nm) have become one of the most exciting objects ofinvestigation and have played important roles in the forefront areas of Physics, Chemistry, Engineering, Biology and Medical Science. Such materials show great promise in providing many breakthroughs in the near future that may change the direction of technological advances in a wide range of applications . Nanoscience or the science of nanoparticles refers to the control and manipulation of matter at nanometer dimension, which includes synthesis, characterization, exploration, and application of nanostructured and nanosized materials. While the word ‘nanoscience’ is relatively new, the applications of nanomaterials can be historically traced back to even before the generation of modern science and technology. Nature makes nanometer sized objects of varying kind. Several structures of nanometer dimensions have probably existed on earth ever since the inception of life on it.[(4)]

1.2. Synthesis Of Nanoparticles Are Further Broadly Classified Into Three Major Types:

1. Physical Method
2. Chemical Method
3. Biological Method

1.3. Synthesis Of Nanomaterials:

Fabrication of nanomaterials with strict control over size, shape, and crystalline structure has become very important for the applications of nanotechnology in numerous fields including catalysis, medicine, and electronics. Synthesis methods for nanoparticles are typically grouped into two categories: “top-down” and “bottom-up” approach. The first involves the division of a massive solid into smaller and smaller portions, successively reaching to nanometer size. This approach may involve milling or attrition. The second, “bottom-up”, method of nanoparticle fabrication involves the condensation of atoms or molecular entities in a gas phase or in solution to form the material in the nanometer range. The latter approach is far more popular in the synthesis of nanoparticles owing to several advantages associated with it.[5]

1.3.1. Hydrothermal method:

Hydrothermal synthesis is typically carried out in a pressurized vessel called an autoclave with the reaction in aqueous solution. The temperature in the autoclave can be raised above the boiling point of water, reaching the pressure of vapour saturation. Hydrothermal synthesis is widely used for the preparation of metal oxide nanoparticles which can easily be obtained through hydrothermal treatment of peptized precipitates of a metal precursor with water [6]. The hydrothermal method can be useful to control grain size, particle morphology, crystalline phase and surface chemistry through regulation of the solution composition, reaction temperature, pressure, solvent properties, additives and aging time.

1.3.2. Gas phase methods:

Gas phase methods are ideal for the production of thin films. Gas phase synthesis can be carried out chemically or physically. Chemical vapour deposition (CVD) is a widely used industrial technique that can coat large areas in a short space of time [7].

During the procedure, metal oxide is formed from a chemical reaction or decomposition of a precursor in the gas phase. Physical vapour deposition (PVD) is another thin film deposition technique. The process is similar to chemical vapourdeposition (CVD) except that the raw materials/precursors, i.e. the material that is going to be deposited starts out in solid form, whereas in CVD, the precursors are introduced to the reaction chamber in the gaseous state. The process proceeds atomistically and mostly involves no chemical reactions. Various methods have been developed for the removal of growth species from the source or target. The thickness of the deposits can vary from angstroms to millimeters. In general, these methods can be divided into twogroups: evaporation and sputtering. In evaporation, the growth species are removed from the source by thermal means. In sputtering, atoms or molecules are dislodged from solid target through impact of gaseous ions (plasma) [7].

1.3.3. Sol-gel method:

The sol-gel process is a capable wet chemical process to make ceramic and glass materials. This synthesis technique involves the conversion of a system from a colloidal liquid, named sol, into a semi-solid gel phase. The sol-gel technology can be used to prepare ceramic or glass materials in a wide variety of forms: ultra-fine or spherical shaped powders, thin film coatings, ceramic fibres, microporous inorganic membranes, monolithics, or extremely porous aerogels. This technique offers many advantages including the low processing temperature, the ability to control the composition on molecular scale and the porosity to obtain high surface area materials, the homogeneity of the final product up to atomic scale. Moreover, it is possible to synthesize complex composition materials, to form higher purity products through the use of high purity reagents. The sol-gel process allows obtaining high quality films up to micron thickness, difficult to obtain using the physical deposition techniques. Moreover, it is possible to synthesize complex composition materials and to provide coatings over complex geometries [8].

Sol-gel is another purely chemical route for the formation of inorganic nanostructured materials. This method was known for many years, but was resurrected about 20 years ago.

The sol-gel method offers a unique opportunity for ceramic fabrication at relatively low temperatures, often at room temperature. Later the sol-gel method was successfully adopted for the processing of a wide variety of materials, from monolithic ceramic and glasses, to fine powders, thin films, ceramic fibers, microporous inorganic membranes, and extremely porous xerogel materials.[10]

The main idea of the sol-gel process is the spontaneous formation of a dual phase material (gel), containing a solid skeleton filled with solvent, from the solution (sol), containing either solid clusters or required chemical reagents (e.g., inorganic precursors and stabilizing agents). Further transformation of the gel phase is driven by the evaporation of the solvent, and the subsequent formation of the xerogel phase. The sol-xerogel transformation may take place in the bulk of the solution, but it works much more effectively when the solution is spread over the surface of solid substrate. Thin xerogel films (in the range of 100 nm) can be formed on the solid substrates by dip coating, spin coating, or spraying of the solution. Heating of the xerogel completely removes solvent molecules, and perhaps stabilizers, therefore leading to further aggregation of inorganic clusters and the formation of solid materials, either bulk or in the form of thin films. Subsequent repeating of the routine allows the formation of thicker multilayered films [(10)].

1.4. A Very Brief Guide To The Science Behind Nanotech: Why 100 Nanometers?

The range of 1 to 100 nanometers mentioned in the National Nanotechnology Initiative NNI definition pops upcontinually in the nanotechnology literature. For example, one of the most popular introductions to nanotechnology defines nanoscience as “the study of the fundamental principles of molecules and structures with at least one dimensionroughly between 1 and 100 nm.

But just what is so special about 100 nm? Why not 10 nm? Or 1,000 nm? The answer is that under the 100 nm level, engineers begin to deal with properties of materials that ordinary engineers can quietly forget about. In particular these include: Quantum Mechanical Effects , Surface Science Effects.[(9)]

1.5. NanomaterialsAnd Nanodevices:

One of the virtues of the “three sectors to rule them all,” scenario is that it goes some way to pinning down what nanotechnologyisby stuffing it into a few reasonably well-defined categories. Another approach with a similar kind of reasoning behind it is to categorize nanoproducts into nanomaterials, nanodevices, and nanosystems:

• Nanomaterialsare the simplest type of nanoproduct. They include nanopowders, nanotubes, nanowires, nanocoatings, and so on. They are typically seen as the low-hanging fruit of nanotechnology. They are the first nanoproducts to hit the market and they are probably the area where the first nanotech fortunes are going to be made. However, like all pure materials plays, nanomaterials will ultimately become commoditized and money will be made through economies of scale, just like it is today in the specialty chemicals and materials sector. Examples of nanomaterials include carbon nanotubes and nanometallic inks used for printing certain kinds of electronic circuitry.

• Nanodevicesor nanostructures are more complex products, such as sensors or memory devices, built with nanotools and are likely to be using nanomaterials to some degree.

• Nanosystemsornano-enabled systems are macro-level products that are enabled in some significant way by nanomaterials or nanodevices in some significant way. This may be a pair of spill-resistant pants or it may be a new diagnostic system that employs a specially sensitive nanomaterial. It is probably stretching a point to include a missile just because it includes an MRAM chip somewhere or a car because it uses nanoengineered specialty glass for the windshield (9).

1.6. Carbon Nanotubes:

Carbon nanotubes are well described by their name. They are nanoscale cylinders of carbon, with a specific atomic structure. This structure consists of a lattice of carbon atoms in which each atom is covalently bonded to three other atoms.

Like buckyballs, carbon nanotubes (CNTs) are a quintessential nanomaterials and as much of the rest of this book records, they are being commercialized by a wide variety of companies in an even wider variety of applications. This enthusiasm for carbon nanotubes comes from the fact that thecapabilities of carbon nanotubes are quite remarkable. Indeed, if carbon nanotubes did not exist and some science fiction writer invented them, it is likely that such a writer would seem less a science fiction writer and more a writer of fantasies. Carbon nanotubes are an excellent exemplar of Arthur C [9].

Actually, carbon nanotubes have quite a long history. They were first described in the technical literature in the late 1950s and a patent was applied for in the 1980s. However, the history of carbon nanotubes is usually measured from 1991, when SumioIijima, a researcher at NEC, created and photographed carbon nanotubes, explained what they were, and also provided them with a name.[9]

1.7. Nanocomposites:

In general, a composite is an engineered material made up of two or more materials. Composite materials are lighter, stronger and sometimes cheaper than noncomposite materials. There is nothing especially “nano” about the composites per se. Particle board used as a building material is a very good example of a composite, as is fiberglass.[9]

Nanocomposites are already quite established in certain industries. General Motors has been using running boards constructed from nancomposites since 2001, as for instance, those found on the Safari and Astro minivans. The use of nanocomposites in this case adds strength to the machine, but also reduce weight and while a lighter running board is not going to make much difference to fuel consumption, once nanocomposites are more widely deployed in the materials used for both automobiles and for aircraft bodies and part, significant reductions in fuel use can be expected. This is, by the way, also an illustration of how the impact of nanotechology flows down to industry sectors, from one of the big three areas. In this case, the use of nanomaterials could well be classified under the nanonergy label.[9]