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Role of Nanotechnology in Manufacturing Sector in the Field of Mechanical Engineering – A Review

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ABSTRACT

The purpose of this review paper is to look into the present aspects of "Nanotechnology". This paper gives a brief description of what Nanotechnology Is? Its application in various fields viz. manufacturing, mechanical, computing, medicine, food technology, Robotics, Solar cells etc. This paper also deals with the future perspectives of Nanotechnology. The world is presently witnessing the advancement and development of a new multidisciplinary technology i.e. "Nanotechnology". Nanotechnology is now became the key area of technology to create and manipulate materials at the nanometer scale i.e. (nm or 10-9 m) either by bottom up approach from single groups of atoms to bulk matter or by top down approach which is reducing bulk materials to a group of atom. This review also covers the manufacturing processes in the evolving field of nanotechnology describes the production of nanomaterials by the modification of various conventional production techniques and processes. Nanomaterials (NMs) have gained prominence in technological advancements due to their tunable physical, chemical, mechanical and biological properties with enhanced performance over their bulk various counterparts. Here the role of Nanostructured materials in mechanical engineering applications has also been discussed. In this study, the application in the field of Automobile Industry, Manufacturing Sector, Construction, and Energy are investigated briefly. This studiy is very important for understanding the Properties which are considered for various mechanical and manufacturing applications.

Keywords: Nanotechnology, Nanoparticles, Nanomaterials, Nan manufacturing.

INTRODUCTION

Nanotechnology

Nanotechnology is a multidisciplinary field, as it combines the knowledge from other different disciplines: Physics, Chemistry and Biology etc. Nanotechnology is an art and science of manipulating matter at the atomic or molecular scale which holds the promise of providing significant improvements in various technologies for protecting the environment at large scale. While many definitions for nanotechnology exist these days , the U.S. Environmental Protection Agency (EPA) uses the definition which is developed by the National Nanotechnology Initiative (NNI). According to The National Nanotechnology Initiative of the USA, Nanotechnology is defined as: Research and Technology development at the atomic, molecular, or macromolecular levels using a length scale of approximately one to one hundred nm in any dimension; the creation and use of structures, devices and systems that have novel properties and functions because of their small size; and the ability to control or manipulate matter on an atomic scale (USEPA, 2007). The technology has the excellent prospects for exploitation across the engineering, manufacturing, medical, , biotechnology, tele-communications and information technology markets, pharmaceutical sectors.[1]

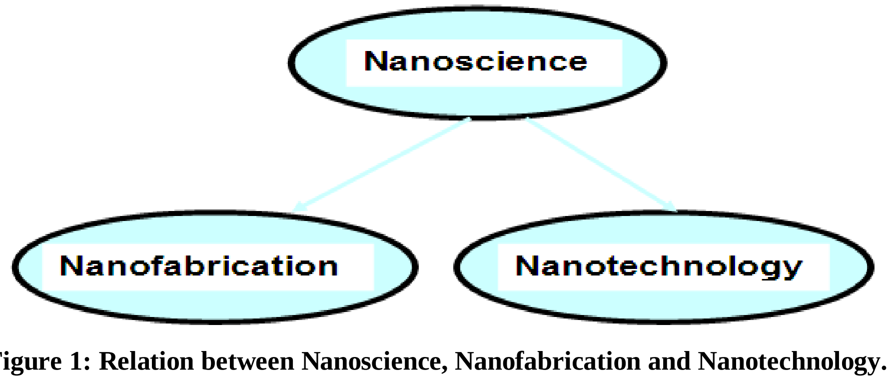

Figure 1: Relation between Nanoscience, Nanofabrication and Nanotechnology.

Historical Development of Nanotechnology

It is quite difficult to describe the history of nanotechnology which is , according to R. D Booker is due to two principal reasons which are: (1) Ambiguity of the term "nanotechnology" and (2) Uncertainty of the time span corresponding to the early stages of the nanotechnology development.

The word "nanotechnology" was firstly introduced by Norio Taniguchi at the International Conference on Industrial Production, Tokyo in year 1974 in order to describe the super thin processing of materials with the nanometer accuracy and creation of nano-sized mechanisms. The ideas of Nanotechnological strategy was put forward by Richard Feynman (who is known as "Father of Nanotechnology") in his own lecture which was delivered in 1959 at the session of the American Physical Society,which were developed by Eric Drexler in 1986.

Now it is widely accepted that nanotechnology is an emerging a major factor for commercial success in the 21st century era and is regarded as "the next Industrial Revolution".[1]

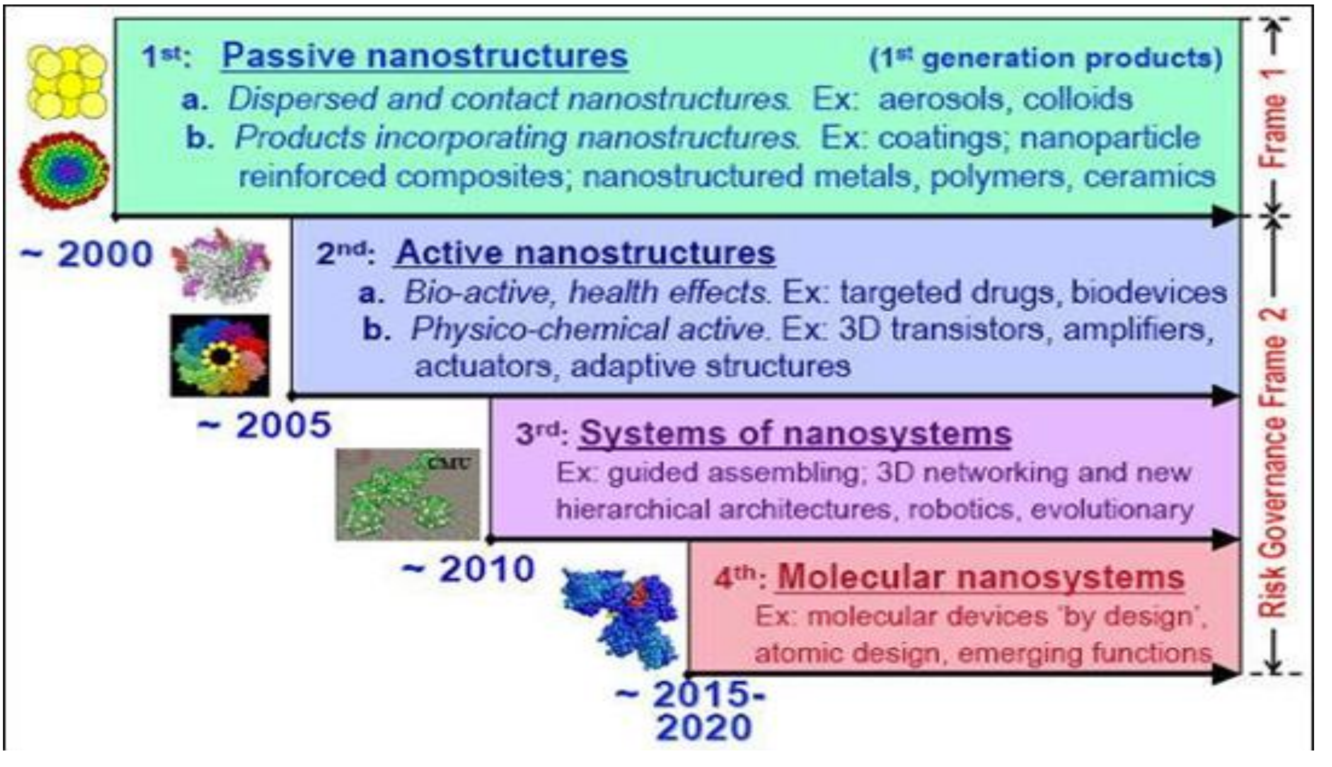

Figure 2: Generations of Nanotechnology Development Roco.[7]

Various Approaches to make Nanotechnology Products:

Nanotechnology brings out the idea that assembly can be hierarchical and controlled in a specific way. There are mainly two distinct approaches to make products with nanoscale features and various attributes:

Top-Down Approach

This approach, which leads physicists and engineers to manipulate progressively the smaller pieces of the matter by various Photolithography, Electron-beam lithography, X-ray lithography and related techniques, which has been operated in an outstanding way until now. It is now becoming increasingly apparent, for taking an example, that miniaturization in computer technology, which relies on silicon-based chips, is rapidly approaching the various Upper Limits of its capabilities. But it is on very large scale of atoms and molecules. Therefore, "there is a plenty of room at the bottom" for further miniaturization. [12]

Bottom-Up Approach

An alternative and most promising strategy to exploit the science and technology at the nanometer scale has been offered by the bottom-up approach, which starts from nano or subnano scale objects (i.e. atoms or molecules) to build up nanostructures. The bottom-up approach is largely the realm of the nanoscience and nanotechnology. This is the biggest reason why chemists, are being able to manipulate the atoms and molecules, which are in the ideal position to contribute to development of the nanoscience and nanotechnology.[12]

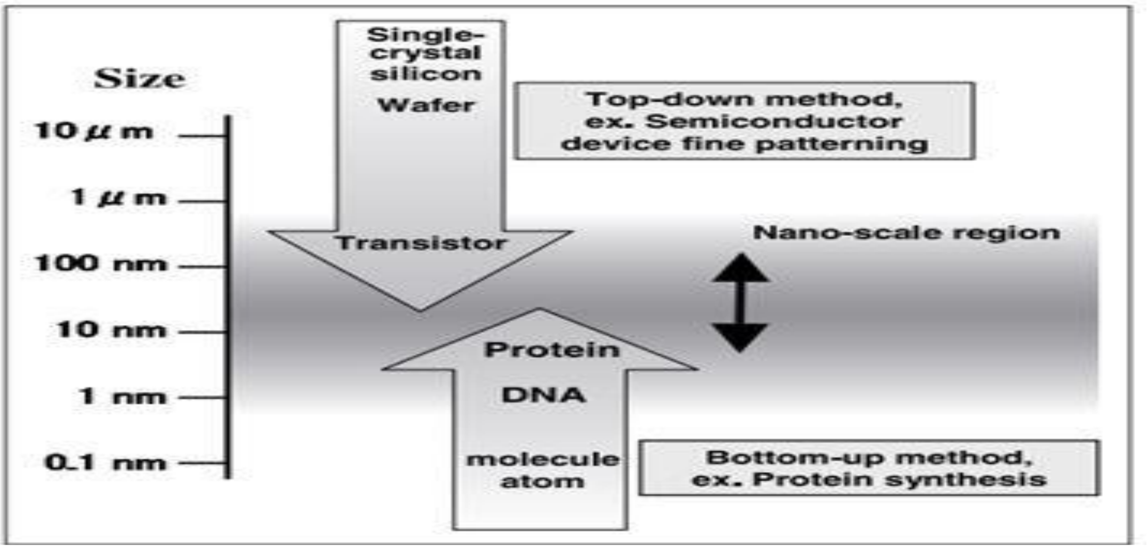

Figure 3: Two methods of approach to Nano-scale.[12]

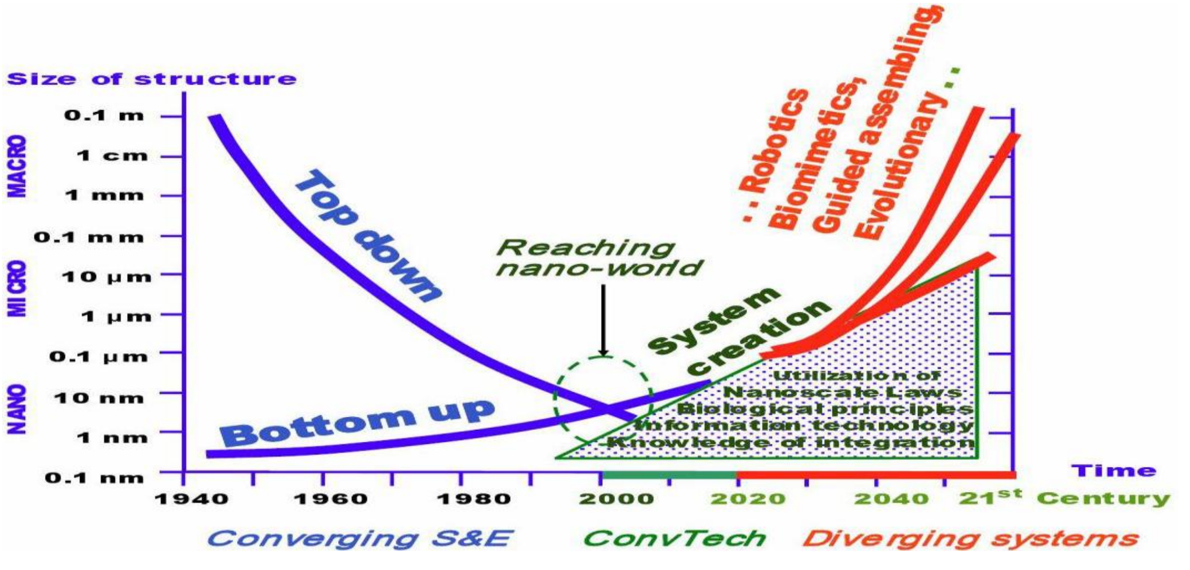

Figure 4: Reaching at the Nanoworld (about 2000) and "Converging Technologies" approach for system creation from the Nanoscale (2000-2020) towards the new paradigms for Nanosystem architectures in applications (after 2020).[6]

Nanomanufacturing

Nano-scale manufacturing is refers to the Production of structures, materials and components with at least one lateral dimension between 1 nm to 100 nm including the surface and subsurface patterns, nano-wires, nanotubes, 3D nano structures, and nano-particles.

There are the two characteristics to manipulate objects at the atomic or molecular level that lends a distinct advantage from manufacturing perspective and enable a set of production techniques which often collectively referred to as Nanomanufacturing.[1]

These two characteristics of the Nanotechnology effect the manufacturing through development of new materials and new fabrication processes which are described as below.

Material Synthesis – By Using the Nanomanufacturing techniques, new materials are loosely defined to include the compounds and devices,which can be synthesized with desirable properties. These new materials can be of nanoscale in 1 dimension (i.e. very thin films, layers and surfaces) or nanoscale in 2 dimensions (i.e. nanowires and nanotubes) or nanoscale in 3 dimensions (i.e. nanoparticles).[2]

Fabrication – The Ability to manipulate matter at nanoscale level gives a rise to new capabilities for the traditional fabrication processes which are used in manufacturing - like deposition and lithography.[2]

Nanomaterials

Nanoscale materials are defined as the set of substances in which at least one dimension is of less than 100 nanometers approx. A nanometer is the one millionth of a millimeter approx. 100,000 times smaller than the diameter of a human hair. Nanomaterials are of interest because at this scale unique, electrical, optical, magnetic and other properties emerges. These emergent properties have the potential for great impacts in medicine,electronics, and various other fields.

Types and Classification of Nanomaterials

Mostly the current NPs and NSMs can be organized into four material- based categories.

(1) Carbon-based nanomaterials: These NMs contain carbon, and are found in morphologies such as, ellipsoids, hollow tubes or spheres. Carbon nanotubes (CNTs), Fullerenes (C60), Carbon nanofibers, carbon black, graphene (Gr), and carbon onions are included under the carbon-based NMs category. Laser ablation, Arc discharge, and Chemical Vapour Deposition (CVD) are the important production methods for these carbon- based materials fabrication (except carbon black).

(2) Inorganic-based Nanomaterials: These NMs include metal and the metal oxide NPs and NSMs. These NMs can be synthesized into metals such as Ag or Au and NPs, metal oxides such as ZnO and TiO2 NPs, and semiconductors such as silicon and ceramics.

(3) Organic-based nanomaterials: These include NMs made mostly from the organic matter, excluding the carbon-based or inorganic- based NMs. The utilization of noncovalent (weak) interactions for their self-assembly and the design of molecules helps to transform the organic NMs into the desired structures such as, liposomes, dendrimers, micelles and polymer NPs.

(4) Composite-based nanomaterials: Composite NMs are multiphase NPs and NSMs with one phase on the nanoscale dimension that can either be combined NPs with other NPs or NPs combined with larger or with the bulk-type materials (e.g. Hybrid Nanofibers) or more complicated structures, such as a metal organic frameworks. These composites may be of any combinations which are of metal-based, carbon-based or organic-based NMs with any form of ceramic, metal or polymer bulk materials. [4]

Classification of Nanomaterials based on their origin

Apart from dimensions and the material-based classifications, NPs and NSMs can also be classified as the natural or synthetic based on their origin.

Natural Nanomaterials are produced in the nature either by biological species or through the anthropogenic activities.
Synthetic (Engineered) Nanomaterials are produced by engine exhaust and smoke, mechanical grinding or synthesized by chemical, biological, physical, or hybrid methods.[4]

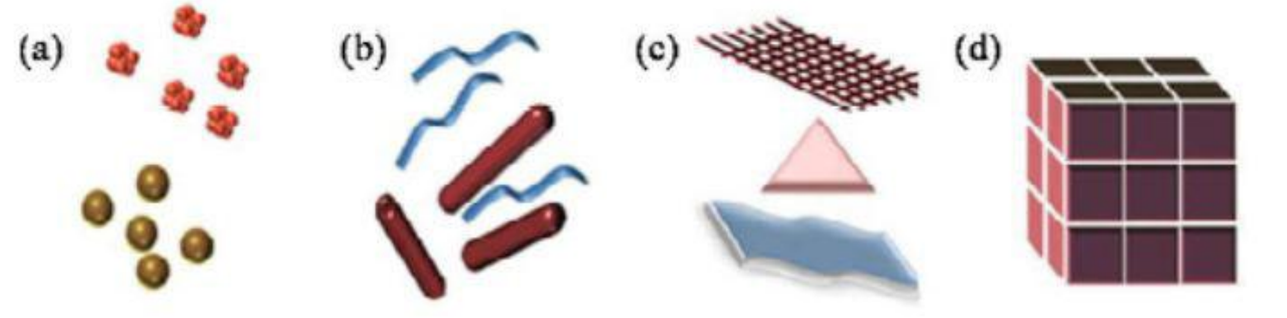

Figure 5: Classification of Nanomaterials (a) 0D spheres and clusters, (b) 1D nanofibers, wires, and rods, (c) 2D films, plates, and networks, (d) 3D nanomaterials.[12]

Nanoparticals

Nanoparticles are less than a few of 100 nm scale.

Applications of Nanopareticals

The nanotechnology market can be broadly divided into 3 segments, viz. Materials, Tools and Devices:

Nanomaterials – These are used to describe the materials with one or more components that have at least one dimension in the range of 1 to 100 nm and it includes and Nanotubes, Composite materials and Nano-structured surfaces, Nanoparticles and Nanofibres.

Nanotools – The various tools and techniques for synthesizing nanomaterials, fabricating device structures and manipulating atoms and very importantly for measuring and characterizing materials and devices at the nanoscale;

Nanodevices – For making the devices at the nanoscale, important in the microelectronics, optoelectronics at the present time and at the interface with biotechnology where there is an aim to mimic the action of biological systems such as the cellular motors.

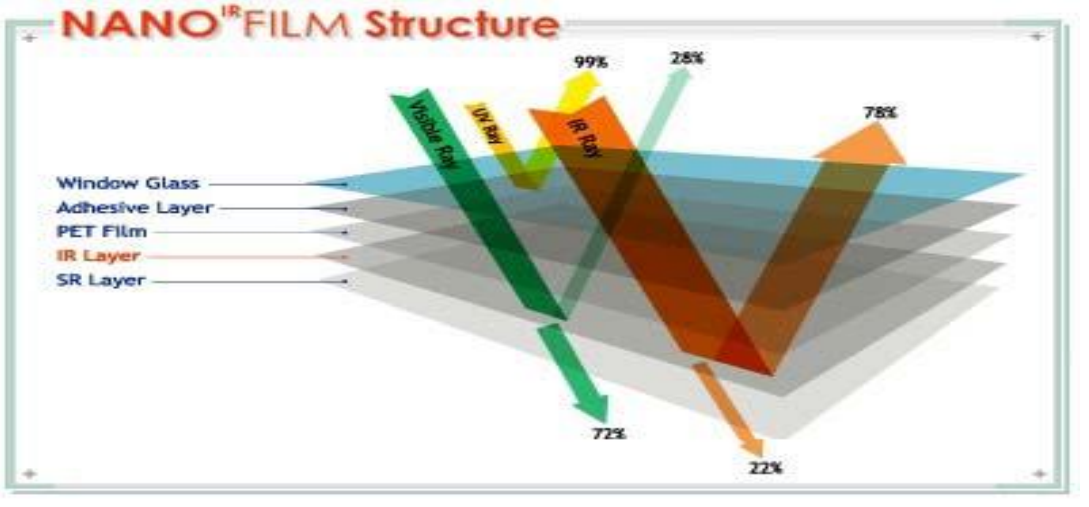

Figure 6: Nano Films.[6]

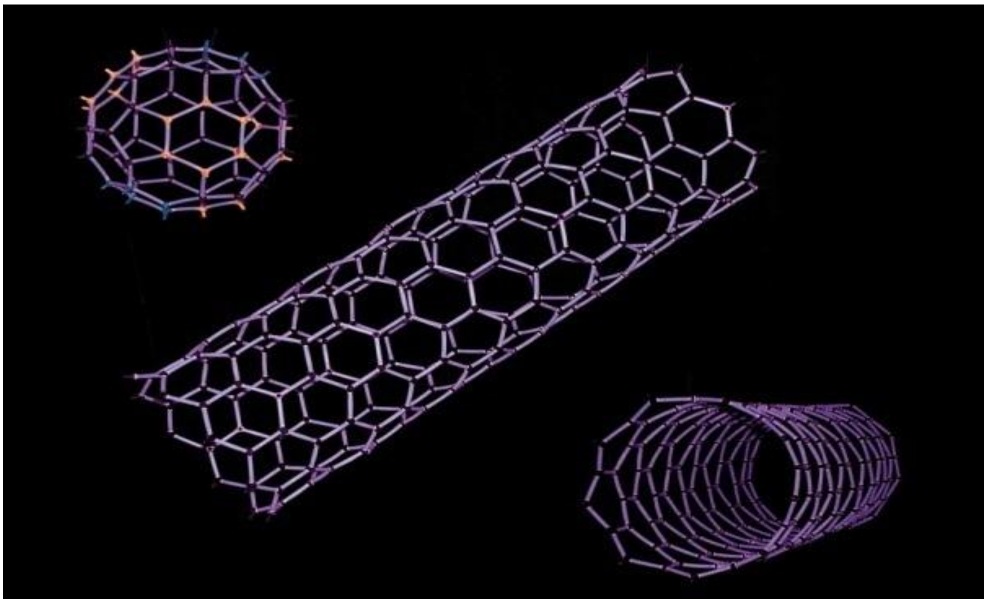

Figure 7: Nano Tubes.

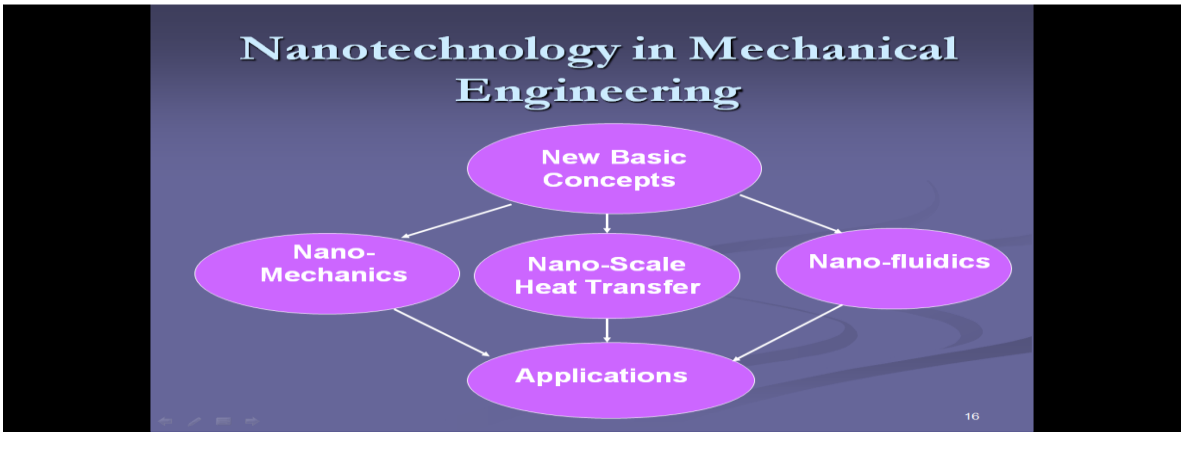

Figure 8:

Quantum Mechanics: Deals with atoms - Molecular Mechanics: Molecular Networks - Nanomechanics: Nano-Materials - Micromechanics: Macro-mechanic: Continuum substance

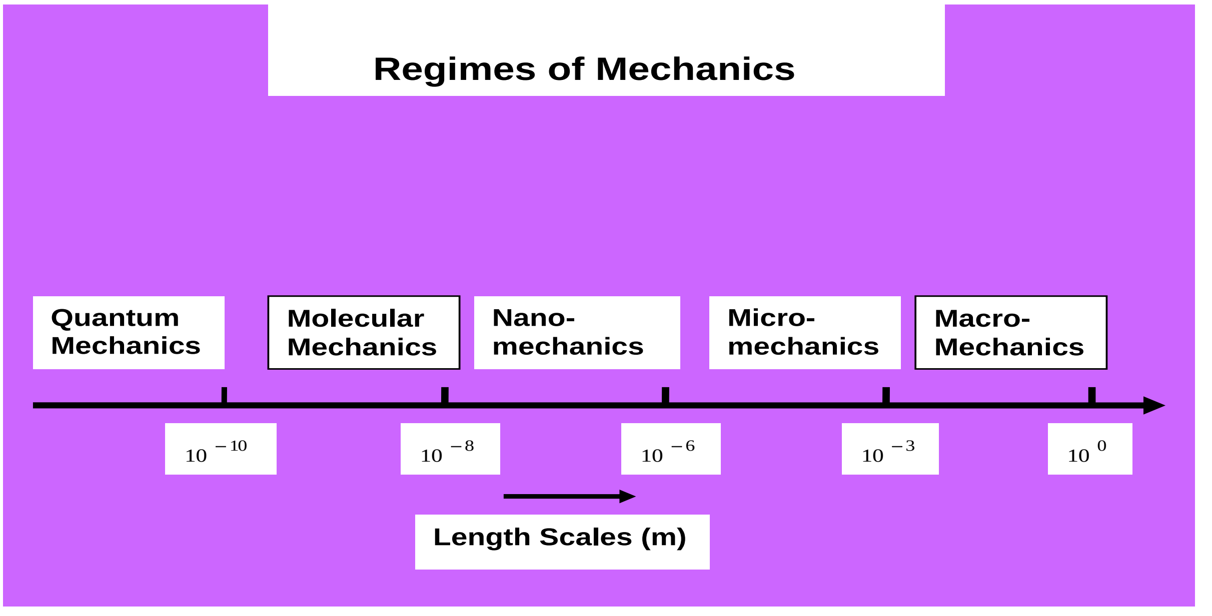

Figure 9: The Length Scales in Sciences and Mechanics

Nano-sensor and Nano-generator

The Role of Nanotechnology in the Field of Mechanical Engineering:

1. **Nano-Sensor and Nano-Generator**

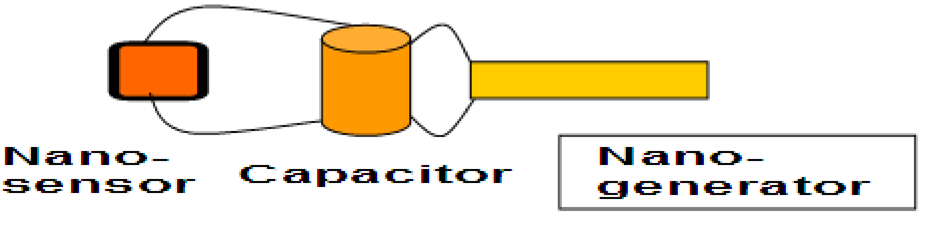

Figure 10: Nano-Sensor and Nano-Generator

1. **Piezoelectric Effect**

Some crystalline materials are generates electrical voltage when mechanically compressed.

2. **Typical Vibration-based Piezoelectric Transducer**

It uses a Two-layered beam with one end fixed and other end mounted with a mass, under the action of the gravity force beam is bent with upper-layer subjected to tension and lower-layer subjected to tension.

3. **Conversion of Mechanical Energy to Electricity in a Nanosystem.**

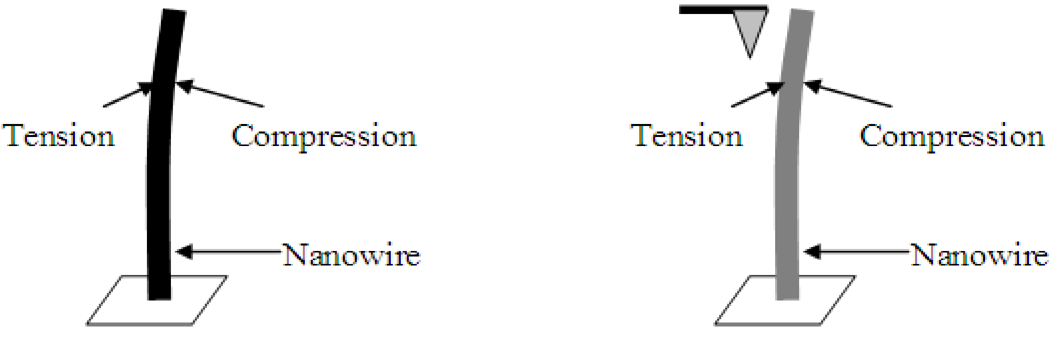

Figure 11: Conversion of Mechanical Energy to Electricity in a Nanosystem.

Figure 12:

Selected Applications of Nanotechnologgy and Nanomaterials:
Nanotechnology and Nanomaterials having a very wide range of applications in the field of various energy sectors. It is proved that Nanomaterials split their conventional counterparts because of their superior physical, chemical and mechanical properties and their exceptional formability.

1. Energy Sector
The most advanced nanotechnology which is related to conversion, energy storage, manufacturing improvements is by reducing materials and their process rate, energy saving and enhanced renewable energy sources. A reduction in the field of energy consumption can be reached by better insulation systems by the use of more efficient lighting or combustion systems by usage of lighter and stronger materials in the transportation sector. Various Nanotechnological approaches like light-emitting diodes [LED] or quantum caged atoms [QCA's] leads to strong reduction of energy consumption for lighting purpose.

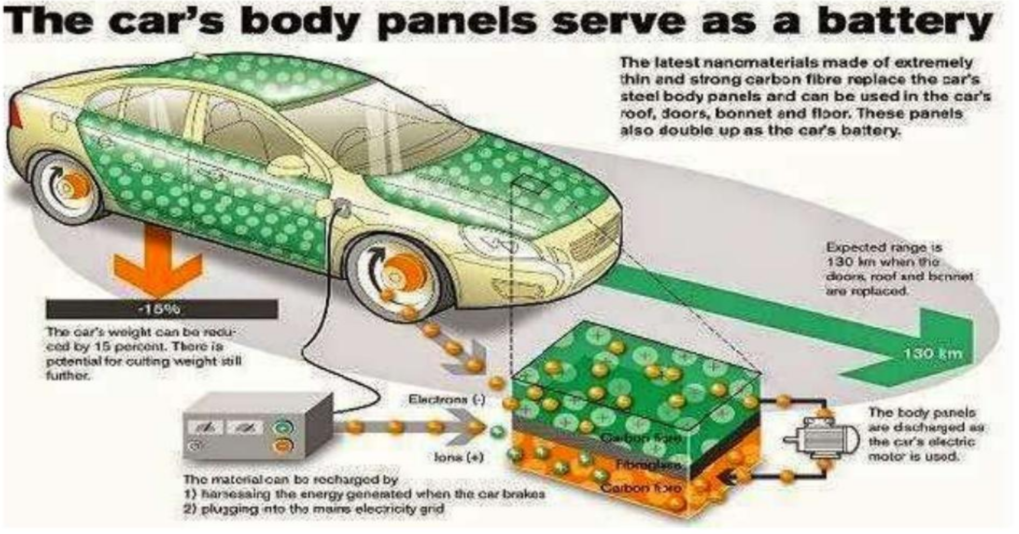

Figure 13:

2. Aerospace
The Lighter and very stronger materials will be of an immense use for the aircraft manufactures, which are leading to increased their performance and weight.

3. Heavy Industries
An the inevitable usage of nanotechnology will be in the heavy industries.

4. Automobile Industry

The Nanotechnology and Nanomaterials are likely to play a very significant role in making sparkplugs which are strongest, harder and resist in their wear and erosion.

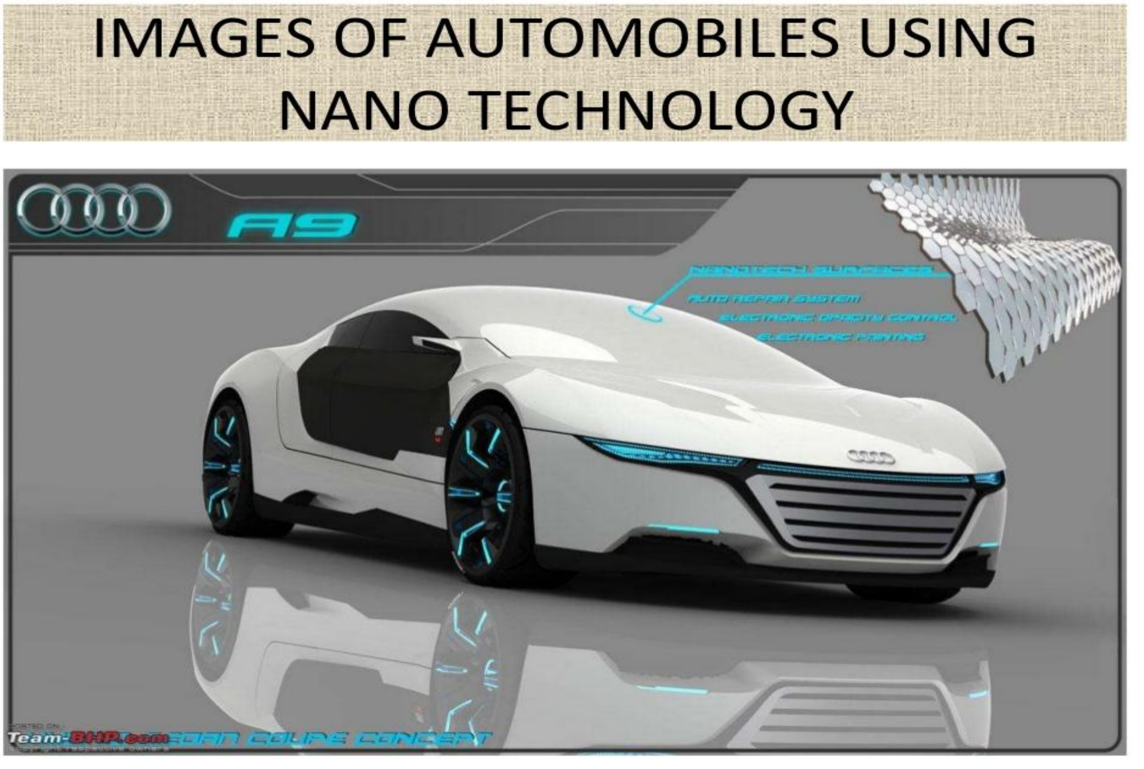

Figure 14:

5. Fuel Tanks

The ability of the nanoclay incorporation to reduce the solvent transmission through the polymers such as polyamides has been demonstrated successfully. The available data reveals the significant reductions in the fuel transmission through polyamide–6/66 polymers by incorporation of the nanoclay filler, which results in the reduced fuel transmission characteristics and their material cost reductions.

6. Corrosion Protection

The PNCs have improved the scratch and abrasion resistance because of their higher hardness combined with improved elastic properties.[9] [10]

CONCLUSION

Various advances in the nanoscale science in the last few decades have opened up the doors of possibility for using many new materials and new processes in manufacturing sectors for improving their production efficiency.There should be need of more research in the field of Nanotechnology, so that it can be used as an alternate source of manufacturing as well as new materials for more efficient and economic processes of production and manufacturing for almost every industry.

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