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Recent Trends in Nanotechnology and its Future Scope -A Review

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ABSTRACT: Nanotechnology has generated a great deal of excitement world-wide and is being cited as the key technology of the 21st century. Nanotechnology is an engineering of functional systems at the molecular level, covers a broad range of topics and is focused on controlling and exploiting the structure of matter on a large scale below 100 nanometers. Nanotechnology is the future of advanced development. It is everything today from clothes to foods there are every sector in its range we should promote it more for our future and for more developments in our current life. In this paper we have discussed the concept of Nanotechnology along with its history, applications, risks and development of nanotechnology in India.

Keywords: Nanotechnology, Nanomaterials, Nano-biotechnology, Meta-materials, Magneto rheological fluid.

I. WHAT IS NANOTECHNOLOGY?

Manipulation of matter on an atomic, molecular and supramolecular scale,with atleast one dimension sized from 1 to 100 nm.

II. HISTORY OF NANOTECHNOLOGY

The history of nanotechnology traces the development of the cocepts and expiremental work falling under the broad category of nanotechnology. The emergence of nanotechnology in 1980's was caused by the convergence of experimental advances such as the invention of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985 , In the early 2000's commercial application of nanotechnology were grown .

III. THE PRESENT NANOTECHNOLOGY

It seems that nanotechnology has begun to blossom in the last ten years, this is largely due to the development of new instruments that allow researchers to observe and manipulate matter at the nanolevel. Technologies such as scanning tunneling microscopy, magnetic force microscopy, and electron microscopy allow scientists to observe events at the atomic level. At the same time, economic pressures in the electronics industry have forced the development of new lithographic techniques that continue the steady reduction in feature size and cost. Just as Galileo's knowledge was limited by the technology of his day, until recently a lack of good instrumentation prevented scientists from gaining more knowledge of the nanoscale. As better instrumentation for observing, manipulating and measuring events at this scale are developed, further advances in our understanding and ability will occur.

Currently, scientists find two nano-size structures of particular interest: **nanowires** and **carbon nanotubes**. Nanowires are wires with a very small diameter, sometimes as small as 1 nanometer. Scientists hope to use them to build tiny transistors for computer chips and other electronic devices. In the last couple of years, carbon nanotubes have overshadowed nanowires. We're still learning about these structures, but what we've learned so far is very exciting.

A carbon nanotube is a nano-size cylinder of carbon atoms. Imagine a sheet of carbon atoms, which would look like a sheet of hexagons. If you roll that sheet into a tube, you'd have a carbon nanotube. Carbon nanotube properties depend on how you roll the sheet. In other words, even though all carbon nanotubes are made of carbon, they can be very different from one another based on how you align the individual atoms.

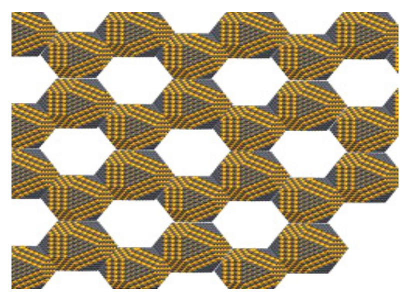

Fig. 1. Carbon nanotubes.

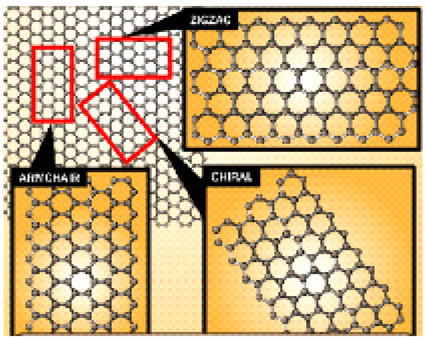

Fig. 2. Structure of graphene.

One leader in nanotechnology policy has identified four distinct generations in the development of nanotechnology products, to which we can add a possible fifth.

A. Passive Nanostructures
During the first period products will take advantage of the passive properties of nanomaterials, including nanotubes and nanolayers. For example, titanium dioxide is often used in sunscreens because it absorbs and reflects ultraviolet light. When broken down into nanoparticles it becomes transparent to visible light, eliminating the white cream appearance associated with traditional sunscreens. Carbon nanotubes are much stronger than steel but only a fraction of the weight. Tennis rackets containing them promise to deliver greater stiffness without additional weight. As a third example, yarn that is coated with a nanolayer of material can be woven into stain-resistant clothing. Each of these products takes advantage of the unique property of a material when it is manufactured at a nanoscale. However, in each case the nanomaterial itself remains static once it is encapsulated into the product.

B. Active Nanostructures
Active nanostructures change their state during use, responding in predicable ways to the environment around them. Nanoparticles might seek out cancer cells and then release an attached drug. A nanoelectromechancial device embedded into construction material could sense when the material is under strain and release an epoxy that repairs any rupture. Or a layer of nanomaterial might respond to the presence of sunlight by emitting an electrical charge to power an appliance. Products in this phase require a greater understanding of how the structure of a nanomaterial determines its properties and a corresponding ability to design unique materials. They also raise more advanced manufacturing and deployment challenges.

C. Systems of Nanosystems
In this stage assemblies of nanotools work together to achieve a final goal. A key challenge is to get the main components to work together within a network, possibly exchanging information in the process. Proteins or viruses might assemble small batteries. Nanostructures could self-assemble into a lattice on which bone or other tissues could grow. Smart dust strewn over an area could sense the presence of human beings and communicate their location. Small nanoelectro mechancial devices could search out cancer cells and turn off their reproductive capacity. At this stage significant advancements in robotics, biotechnology, and new generation information technology will begin to appear in products.

IV. NANOMATERIALS

A. Nanoceramic Powders
– Nanoceramic powders constitute an important segment of the whole nanostructured materials.
– Constitute more than 50% of the total nanostructured materials.

B. Nanotubes
– Conductors or semiconductors
– Strong materials with good thermal conductivity

C. Nanocomposites
– Generally polymer based with nanosized fillers
• Nanoceramics are available commercially in the form of dry powders or liquid dispersions.
• The most commercially important nanoceramic materials are simple metal oxides, silica (SiO_2), titania (TiO_2), alumina (Al2O3), iron oxide (Fe_3O_4, Fe_2O_3), zinc oxide (ZnO), ceria (CeO_2) and zircona (ZrO_2).
• Silica and iron oxide nanoparticles have a commercial history spanning half a century or more
• Of increasing importance are the mixed oxides and titanates
– indium-tin oxide (In_2O_3-SnO_2 or ITO)
– antimony-tin oxide (ATO),
– barium titanate ($BaTiO_3$).
• Nanocrystalline titania, zinc oxide, ceria, ITO, and other oxides have more recently entered the marketplace.

V. APPLICATIONS

Nanotechnology, being an interdisciplinary field, has three main extensively overlapping areas: Nanoelectronics, nanomaterials and nanobiotechnology which find applications in materials, electronics, environment, metrology, energy, security, robotics, healthcare, information technology, biomimetics, pharmaceuticals, manufacturing, agriculture, construction, transport, and food processing and storage.

A. Nanobiotechnology

Drug delivery

New formulations for drug and gene therapies

Tissue engineering

Reproduction and repair of damaged tissues using nanomaterial based scaffolds.

B. Nanotechnology and medical applications

Development of newer drug delivery systems based on nanotechnology methods is being tried for conditions like cancer, diabetes, fungal infections, viral infections and in gene therapy. The main advantages of this modality of treatment are targeting of the drug and enhanced safety profile. Nanotechnology has also found its use in diagnostic medicine as contrast agents, fluorescent dyes and magnetic nanoparticles.

Carbon-based Nanomaterials such as Carbon Nanotubes. Carbon nanotubes are essentially elongated molecules, formed entirely from carbon atoms. The property currently under research is their ability to elongate or contract in suitable electrolytes under very low voltages which may render them very useful as actuators or sensors in a variety of medical devices. Other potentially valuable characteristics are their possible use as sensors, e.g. for CO_2 monitoring in anaesthesiology.

Nanowires. Nanowires differ from nanotubes in that they have no inner cavity. Semiconducting silicon-based nanowires are showing promise for the detection of viruses in solution and their capabilities in such applications may exceed those of other methods.

Nanoporous Materials. Nanoporous materials, e.g. of carbon-, silicon-, ceramic- or polymer-based materials, with holes in the region of 100nm have greatly increased surface area and can have extremely useful catalytic, adsorbent and absorbent properties. These may have valuable applications in implant technology or in drug delivery.

Nanocoated surgical blades. By means of nanoparticulate coatings onto specially prepared hard metal substrates,e.g. plasma polished diamond nanolayers, it is possible to manufacture surgical blades of extreme sharpness and low friction that are highly suited to optical- and neurosurgery.

Needles. Nanocoated needles are now available for very fine suturing in demanding applications .Such needles have good ductility, exceptional strength and corrosion resistance.

Catheters for minimally invasive surgery. Nanomaterials, e.g. carbon nanotubes, have been successfully added to catheters used in minimally invasive surgery to increase their strength and flexibility and reduce their thrombogenic effect.

In-vitro Diagnostics. The area of in-vitro diagnostic medical devices is one of great growth and potential for nanotechnology. The development of micro- and nano-fluidic systems allows for the use of tiny mounts of analyte and the degree of miniaturisation possible will allow for the development of true "lab-on-a-chip" devices capable of simultaneously carrying out dozens, or even hundreds, of analyses in virtually real time. Linked to other devices, this will allow for continuous monitoring of the patient's condition and variations in treatment, e.g. drug delivery, to take account of the patient's actual needs.

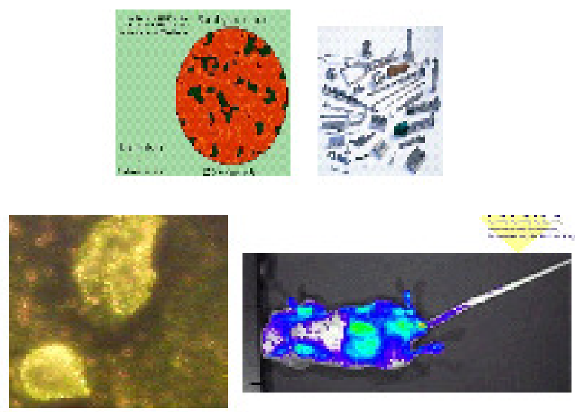

Fig. 3. Gold nanoparticle, coated with antibodies and which fluoresce and heat up, can track and destroy cancer cells.

Optical Nanosurgery. Nanotechnological tools such as "optical tweezers" and "nanoscissors" can be used at the cellular level for cell manipulation and immobilisation. Essentially these devices use the forces arising from the momentum of, for example, laser light at particular tuned wavelengths to precisely reposition minute objects by steering the laser beam. This opens up the possibility of medical or surgical procedures at the cellular level.

C. Applications in electronics

The semiconductor industry has been able to improve the performance of electronic systems for more than four decades by downscaling silicon-based devices but this approach will soon encounter its physical and technical limits.

This fact, together with increasing requirements for performance, functionality, cost, and portability have been driven the microelectronics industry towards the nano world and the search for alternative materials to replace silicon. Carbon nanomaterials such as one-dimensional (1D) carbon nanotubes and two-dimensional (2D) graphene have emerged as promising options due to their superior electrical properties which allow for fabrication of faster and more power-efficient electronics.

Graphene transistor. In 2004, it was shown for the first time that a single sheet of carbon atoms packed in a honeycomb crystal lattice can be isolated from graphite and is stable at room temperature. The new nanomaterial, which is called graphene, allows electrons to move at an extraordinarily high speed. This property, together with its intrinsic nature of being one-atom-thick, can be exploited to fabricate field-effect transistors that are faster and smaller.

Carbon nanotube electronics. When a layer of graphene is rolled into a tube, a single-walled carbon nanotube (SWNT) is formed. Consequently, SWNTs inherit the attractive electronic properties of graphene but their cylindrical structure makes them a more readily available option for forming the channel in field-effect transistors. Such transistors possess an electron mobility superior to their silicon-based counterpart and allow for larger current densities while dissipating the heat generated from their operation more efficiently. During the last decade, carbon nanotube-based devices have advanced beyond single transistors to include more complex systems such as logic gates and radio-frequency components.

Carbon-based nanosensors. In addition to the exceptional electrical properties of graphene and carbon nanotubes, their excellent thermal conductivity, high mechanical robustness, and very large surface to volume ratio make them superior materials for fabrication of electromechanical and electrochemical sensors with higher sensitivities, lower limits of detection, and faster response time. A good example is the carbon nanotube-based mass sensor that can detect changes in mass caused by a single gold atom adsorbing on its surface.

Nano-Electro-Mechanical Systems (NEMS). All electronic tools have one thing in common: an integrated circuit (IC) acting as their "brain". Nano-electro-mechanical systems have evolved during the last 10 years to make this dream come true by creating sensors and actuators at the same scale as the accompanying nanoelectronics. Recent developments in synthesis of nanomaterials with excellent electrical and mechanical properties have extended the boundaries of NEMS applications to include more advanced devices such as the non-volatile nano-electro-mechanical memory, where information is transferred and stored through a series of electrical and mechanical actions at the nanoscale.

Spintronics. Similar to electrical charge, spin is another fundamental property of matter. While conventional electronic devices rely on the transport of electrical charge carriers, the emerging technology of spintronics employs the spin of electrons to encode and transfer information. Spintronics has the potential to deliver nanoscale memory and logic devices which process information faster, consume less power, and store more data in less space. The extension of the hard disk capacities to the gigabyte and the terabyte ranges was the main achievement of spintronics by taking advantage of Giant Magneto-Resistance (GMR) and Tunnel Magneto-Resistance (TMR) effects which are effective only at the nano scale.

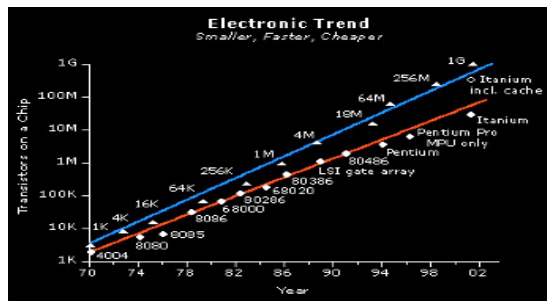

Fig. 4. Trend of nanotechnology in electronic field.

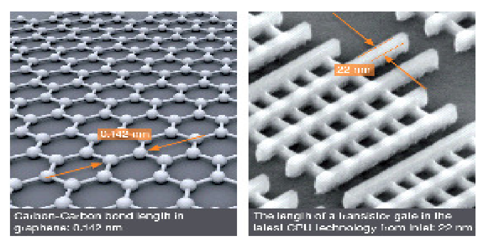

Fig. 5. Bond length of carbon in graphene.

D. Nanotechnology in Paints and Coatings

Paints & coating industry is growing day by day around the globe. Nanotechnology in paint and coatings promises to fulfill all desire properties. New paint technology fights bacterial and fungal growth with Nano scale silver. Silver Nanoparticles in wall paint prevent the formation of mould inside buildings and the growth of algae on outside walls. Silver interferes with various stages of cell metabolism; it can destroy a wide range of germs and make it difficult for microbes to develop resistance. Nanoparticles are so small that they can 'organize themselves' closely enough and bond together to form a 'molecularly' sealed surface.

The appearance and usefulness of nanoparticles brings many advantages like better surface appearance, good chemical resistance, easy to clean, anti-fogging, anti-fouling, anti-reflective, anti-fingerprints, scratch resistance, UV resistance, hydrophobic & oil repellent in nature, fire resistant, high performance coating, self-cleaning etc.

E. Nanotechnology in Textiles and Clothing

The wave of nanotechnology has shown a huge potential in the textile and clothing industry which is normally very traditional. The first work on nanotechnology in textiles was undertaken by Nano-Tex, a subsidiary of the US-based Burlington Industries. Coating is a common technique used to apply Nano-particles onto textiles. Nanoparticles have a large surface area-to-volume ratio and high surface energy due to which nanotechnology can provide high durability for fabrics. The future success of nanotechnology in textile applications lies in areas where new functionalities are combined into durable, multifunctional textile systems without compromising the inherent favorable textile properties, including process ability, flexibility, wash ability and softness. The use of nanotechnology allows textiles to become multifunctional and produce fabrics with special functions, including antibacterial, UV-protection, easy clean, water & stain repellent and anti-odor.

F. Nanotechnology in Food Science

Complex set of engineering and scientific challenges in the food and bioprocessing industry for manufacturing high quality and safe food through efficient and sustainable means can be solved through nanotechnology. Nanotechnology may be used in agriculture and food production in the form of Nano sensors for monitoring crop growth and pest control by early identification of plant diseases. These Nano sensors can help enhance production and improve food safety. Bacteria identification and food quality monitoring using biosensors; intelligent, active and smart food packaging systems; Nano capsulation of bioactive food compounds are few examples. A Nano composite coating process could improve food packaging by placing anti-microbial agents directly on the surface of the coated film. They can also improve the mechanical and heat-resistance properties and lower the oxygen transmission rate.

G. Nanotechnology in Catalysis

Catalysis is the essential application of metal nanoparticles. As catalysts, nanomaterials show a great potential because of the large surface area of the particles. Many chemists suggest that metal colloids are very efficient catalysts because of a great ratio of atoms remaining at the surface, and so available to chemical transformation of substrates. There are different types of nanomaterial's which are used as a catalysts e.g. metals or metal oxide & sulfides or silicates. The activity of catalyst can also be described by the turn over number (TON) and the catalytic efficiency by the turn over frequency (TOF). The TON is the number of reactant molecules that 1 g of catalyst can convert into products. There are two types of catalyst: heterogeneous catalysis & homogeneous catalysis. Heterogeneous catalysts act in a different phase than the reactants whereas homogeneous catalysts function acts in the same phase as the reactants.

H. Military applications

Nanotechnology research in the following areas can help the military:

• Fabrics/Materials
-Armor
• Robotics
• Security
• Weapons
-Detection
-Defense
• Vehicles
-Fuel economy
-Soldier protection
• Military personnel health
-Medicine
-Diagnosis

Waterproof and Bullet-proof Vests. One of the first advancements that came out of the center was developed by Prof. Karen Gleason. She and her researchers were able to create ultrahydrophobic surfaces (waterproof) using a technique called chemical vapor deposition (CVD). With CVD they could deposit nanolayers of Teflon (yes, the same stuff that's on your frying pan) on Kevlar panels, the material used to make bullet-proof vests.

Fig. 6. Water proof vest.

Magneto rheological Fluid (MR Fluid). Magneto rheological fluid is a fluid where colloidal ferrofluids experience a body force on the entire material that is portion to the magnetic field strength (*Ashour, Rogers & Kordonsky,* 1996). This allows the status of the fluid to change reversibly from liquid to solid state.

Thus, the fluid becomes intelligently controllable using the magnetic field. MR fluid consists of a basic fluid, ferro magnetic particle and stabilizing additives .The ferro magnetic particles are typically 20 to 50 micro meter in diameter where as in the presence of magnetic field , the particles align and form linear chains parallel to the field . Response times 21 that requires impressively low voltages are being developed. Recently, as shown the ability of MR fluids to handle impulse loads and an adaptable fixing for blast resistant and structural membranes. For military applications, the strength of the armor will depend on the composition of the fluid. Researchers propose wiring the armor with tiny circuits. While current is applied through the wires, the armor would stiffen, and while the current is turned off, the armor would revert to its liquid, flexible state. Depending on the type of particles used, a variety of armor technology can be developed to adapt for soldiers in different types of battle condition. Nanotechnology could increase the agility of soldiers. This could be accomplished by increasing the mechanical properties as well as the flexibility for battle suit technology.

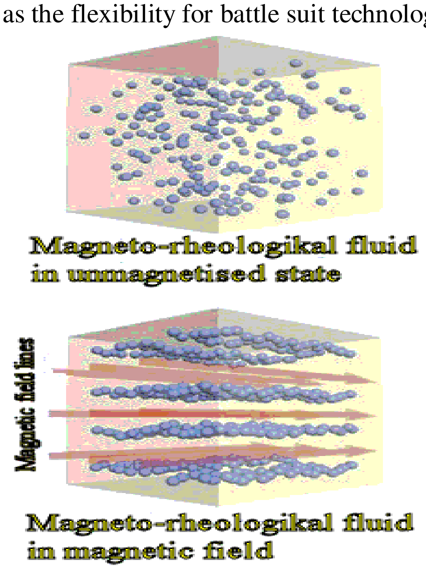

Fig. 7. Allignement of rheological fluid under magnetic field.

VI. PRODUCTS OF NANOTECHNOLOGY

A. Smart drugs—cancer treatments

A good deal of research, involving a variety of different nanotechnologies, is being devoted to cancer detection and cure. One of the main goals of using nanotechnology for medical purposes is to create devices that can function inside the body and serve as drug delivery systems with specific targets. Current treatments for cancer using radiation and chemotherapy are invasive and produce debilitating side effects. These treatments kill both cancerous and healthy cells. Nanotechnology has the potential to treat various forms of cancer by targeting only the cancer cells.

B. Complex materials—a super-adhesive

The gecko's ability to stick to surfaces and walk up walls with ease has led researchers to design materials that can mimic the microscopic elastic hairs that line this animal's feet. Using carbon nanotubes, Liangti Qu and colleagues at the University of Dayton (Ohio) have created a material that has an adhesive force about 10 times stronger than that of a gecko's foot. These carbon nanotube materials have a much stronger adhesion force parallel to the surface they are on than that perpendicular to the surface. The result is a material that can be used to attach a heavy weight to a vertical surface, and yet be peeled off with ease. And just as a gecko is able to walk up vertical surfaces with ease, the material opens up the possibility of creating clothing that will enable humans to achieve the same feat.

C. Metamaterials - controlling the flow of light

A whole new field of scientific research, called transformation optics, has been made possible by the ability of nanotechnology to create new materials that bend light "in an almost arbitrary way," making possible "applications that had been previously considered impossible". These applications include an "electromagnetic cloak" that bends light around itself, thereby making invisible both the cloak and an object hidden inside; and a "hyperlens" that could be added to conventional microscopes allowing them to be used to see down to the nanoscale and thus to see viruses and possibly DNA molecules.

D. Energy generation and use

New generations of nano-based sensors, catalysts and materials have already resulted in major reductions in energy use, and further progress is certain. The ConocoPhillips oil company recently awarded a three-year, $1.2 million grant to the University of Kansas to research the use of nanotechnology to enhance oil recovery catalyst. Nanoscales and nanoporous membranes are, under some circumstances, being used to facilitate production of biomass fuel. Energy transmission could potentially be made much more efficient by using engineered nanomaterials. Throughout the renewable-energy sector, nanotechnology has the potential to increase process efficiencies and process yields, decrease costs and enable energy processes that would not be attainable any other way. Nanotechnology is transforming photovoltaic cells through the development of new and less expensive manufacturing techniques and new methods of generating high-surface-area structures, optimizing sensitivity and increasing the spectral absorbency of the cells.

Other applications in the renewable-energy sector include using nanoscale surface properties and novel nanofabrication techniques to increase production of electricity in hydrogen fuel cells. Most renewable-energy technologies can be made more efficient using various forms of nanotechnology, at least at the laboratory scale.

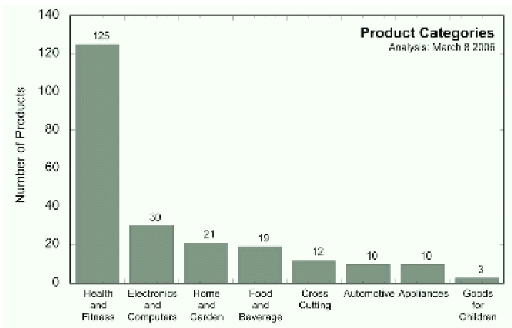

Fig. 8. Products of nanotechnology

VII. FUTURE SCOPE OF NANOTECHNOLOGY

Predicting the future of any major technology is difficult. On the one hand, there often is a tendency to underestimate the impact of a technology and the pace of its development. Nanotechnology development already is outpacing the predictions made when the NNI (National Nanotechnology Initiative) was created in 2000. At that time, the focus was on the impact nano might have in 20–30 years . Now, the analysis firm Lux Research predicts that by 2015 nano will be incorporated in $3.1 trillion of manufactured goods worldwide and will account for 11 percent of manufacturing jobs globally.

A. Molecular Nanosystems (2015-2020)

This stage involves the intelligent design of molecular and atomic devices, leading to “unprecedented understanding and control over the basic building blocks of all natural and man-made things.” Although the line between this stage and the last blurs, what seems to distinguish products introduced here is that matter is crafted at the molecular and even atomic level to take advantage of the specific nanoscale properties of different elements. Research will occur on the interaction between light and matter, the machine-human interface, and atomic manipulation to design molecules. Among the examples that *Dr. Roco* foresees are “multifunctional molecules, catalysts for synthesis and controlling of engineered nanostructures, subcellular interventions, and biomimetics for complex system dynamics and control.” Since the path from initial discovery to product application takes 10-12 years,the initial scientific foundations for these technologies are already starting to emerge from laboratories. At this stage a single product will integrate a wide variety of capacities including independent power generation, information processing and communication, and mechanical operation. Its manufacture implies the ability to rearrange the basic building blocks of matter and life to accomplish specific purposes. Nanoproducts regularly applied to a field might search out and transform hazardous materials and mix a specified amount of oxygen into the soil. Nanodevices could roam the body, fixing the DNA of damaged cells, monitoring vital conditions and displaying data in a readable form on skin cells in a form similar to a tattoo. Computers might operate by reading the brain waves of the operator.

B. The Singularity (2020 and beyond)

Every exponential curve eventually reaches a point where the growth rate becomes almost infinite. This point is often called the Singularity. If technology continues to advance at exponential rates, what happens after 2020? Technology is likely to continue, but at this stage some observers forecast a period at which scientific advances aggressively assume their own momentum and accelerate at unprecedented levels, enabling products that today seem like science fiction. Beyond the Singularity, human society is incomparably different from what it is today. Several assumptions seem to drive predictions of a Singularity. The first is that continued material demands and competitive pressures will continue to drive technology forward. Second, at some point artificial intelligence advances to a point where computers enhance and accelerate scientific discovery and technological change. In other words, intelligent machines start to produce discoveries that are too complex for humans. Finally, there is an assumption that solutions to most of today’s problems including material scarcity, human health, and environmental degradation can be solved by technology, if not by us, then by the computers we eventually develop.

Whether or not one believes in the Singularity, it is difficult to overestimate nanotechnology’s likely implications for society. For one thing, advances in just the last five years have proceeded much faster than even the best experts had predicted. Looking forward, science is likely to continue outrunning expectations, at least in the mediumterm. Although science may advance rapidly, technology and daily life are likely to change at a much slower pace for several reasons. First, it takes time for scientific discoveries to become embedded into new products, especially when the market for those products is uncertain. Second, both individuals and institutions can exhibit a great deal of resistance to change.

Because new technology often requires significant organizational change and cost in order to have its full effect, this can delay the social impact of new discoveries. For example, computer technology did not have a noticeable effect on economic productivity until it became widely integrated into business offices and, ultimately, business processes. It took firms over a decade to go from replacing the typewriters in their office pools to rearranging their entire supply chains to take advantage of the Internet. Although some firms adopted new technologies rapidly, others, lagged far behind.

VIII. RISKS IN NANOTECHNOLOGY

Nanoparticles are believed to present the greater risk because:
-They are relatively cheap and can be manufactured in large quantities
-They are already used in consumer products
-Their properties can be very different to the larger forms of the material they are made from
-They can be highly reactive
-The particles often have unknown toxicity
-Their toxicity can be difficult to quantify
-They can disperse easily in air or water
The importance of nanoparticles being considered as the most potentially hazardous type may change in the future as other forms of nanotechnology become more common and nanoparticles become better understood.
Initial investigations carried out how some nanoparticles are acutely toxic when compared to larger particles composed of the same material, such as ultra-fine carbon and diesel exhaust particles respectively. Certain organs in mice have been shown to be adversely affected by some nanoparticles as well as significantly reduced offspring production in some aquatic life. If these effects are caused in other animals they may be possible in humans, though there have been no human studies to confirm this. There are several ways that nanoparticles can enter the body. These include inhalation, ingestion, absorption through the skin and direct injection for medicinal purposes. Once the particles are in the body they may be transported throughout the body before they are ejected, if at all. The blood brain barrier, which protects the brain from harmful chemicals in the blood, can be no barrier at all to certain nanoparticles.

IX. NANOTECHNOLOGY IN INDIA

In India, the nanoscience and technology undertaking has primarily been a government led initiative. Promoting nanotechnology and capacity building initiatives including investments, establishment of infrastructure and facilitation of public private partnerships are largely being directed by national policy making agencies.
Several government departments and agencies, such as the DST, DBT, DIT, CSIR, ICMR, DAE, DRDO and MNRE, have been supporting nanoscience and technology in different spheres and capacities. These initiatives have been growing not only at a central level but state levels as well, with states like Karnataka, Tamilnadu, Haryana adopting a very proactive approach. Overall, the support provided by the government for nanoscience and nanotechnology has been characterized by emphasis on fundamental research, some support for development of applications, multidisciplinary and interdisciplinary research, scant emphasis on risk related research of nanotechnology, in certain instances of multiplicity and overlapping R&D focus.
One of the biggest challenges has been in terms of the interdisciplinary nature of nanotechnology per se and the scope of its applications. These characteristics and the optimism regarding potential application of nanotechnology in a whole range of spheres, has to an extent lead to significant overlaps in the areas for R&D support identified by different agencies. For instance in health, a strong engagement of agencies like DST, DBT, and ICMR as well as the involvement of others like CSIR and even DRDO has been present. This may result in duplicative R&D efforts and a waste of financial and human resources in this already cost intensive domain. Other related challenges are in the form of lack of coordination, information flow, overlapping mandates and jurisdictions. An inadequate flow of information between policy makers and the scientific population as well as amongst policy makers acts as a barrier in developing real capacity due to inability to leverage existing capacity, expertise and initiatives.
Recently launched Nanoscience and technology mission specifies that one of its aims is to develop applications that serve sectors like health, water and agriculture. Indeed public funded projects have been instrumental in developing nanomaterial based water filters (IIT Chennai, ARCI) as well as diagnostic kits for tuberculosis (CSIO) and typhoid (DRDO and IISc). Moreover IIT Bombay that has been developed as a Centre of Excellence in nanotechnology has developed the iSens biochip that can allow the early detection of heart attack. The Agharkar institute is also developing a therapeutic nano-silver product that has antimicrobial activity and for which clinical trials are being considered. Also at the University of Delhi, the Department of Chemistry has focused on developing nanoparticle encapsulation for steroidal drugs delivery for ocular applications.

This technology is being transferred to the industry for commercialization. DST, the nodal department for organizing, coordinating and promoting S&T activities in India is the chief agency engaged in the development of nanoscience and nanotechnology. It is at the helm of the principal program, the Nanoscience and Technology Mission (NSTM) established to develop India as a key player in nanoscience and technology. While it will steer this initiative between the years 2007-2012 it also hosted the flagship program, the Nanoscience and Technology Initiative (NSTI) that was pioneered in 2001 until 2006 Public sector R&D institutions play a predominant role in nanotechnology R&D. Research in nanoscience and nanotechnology is being carried out in various academic and scientific institutions. Foremost are the, 'Centers of Excellence (CoE) for Nanoscience and Technology' established under the NSTI by DST. The CoEs consist of eleven "Units of nanoscience" that were created to pursue basic research in several broad areas of nanoscience/ nanoscale systems and technology. Whereas seven "Centers for nanotechnology" were also initiated that could focus on R&D in niche areas or in specific dimensions sch as nanoelectronics (IIT Bombay) or nanoscale phenomena in biological systems and materials (Tata Institute of Fundamental Research-TIFR).

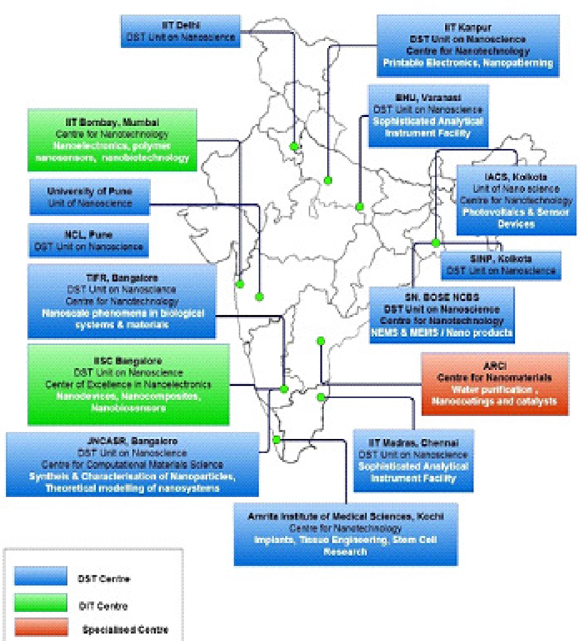

Fig. 9. Nanotechnology in India.

The "Centers" seeks to undertake R&D to develop specific applications in a fixed period of time. Another "Center for Computational Materials Science" has also been established. The S.N. Bose National Centre for Basic Sciences (SN Bose NCBS), Association for the Cultivation of Science (IACS), the Indian Institute of Science (IISc), Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) and IIT Kanpur, each host a Unit of Nanoscience as well as Centre for Nanotechnology.

X. CONCLUSION

Nanotechnology has potential applications in many sectors including paints and coatings, textiles and clothing, cosmetics, food science, catalysis, etc. In addition, nanotechnology presents new opportunities to improve how we measure, monitor, manage. Nanotechnology has emerged as a growing and rapidly changing field. New generations of nanomaterials will evolve, and with them new and possibly unforeseen issues. Nanotechnology is the future of advanced development. It is everything today from clothes to foods there are every sector in its range we should promote it more for our future and for more developments in our current life.

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