Journal of Advanced Research in Embedded System
Volume 8, Issue 1&2 - 2021, Pg. No. 8-13
Peer Reviewed Journal

Article

Capacity building with Nanotechnology: Advanced trends under Make in India

DV Sreekanth[1], P Santosh Kumar Patra[2]

[1]Professor, Mechanical Department, St. Martin's Engineering College, Secunderabad, Telangana, India.
[2]Principal and Professor, CSE Department, St. Martin's Engineering College, Secunderabad, Telangana, India.

I N F O

Corresponding Author:
DV Sreekanth, Mechanical Department, St. Martin's Engineering College, Secunderabad, Telangana, India.
E-mail Id:
dvsrikanth@smec.ac.in
Orcid Id:
https://orcid.org/0000-0003-1736-0961
How to cite this article:
Sreekanth DV, Patra PSK. Capacity building with Nanotechnology: Advanced trends under Make in India. *J Adv Res Embed Sys* 2021; 8(1&2): 8-13.

Date of Submission: 2021-05-22
Date of Acceptance: 2021-06-06

A B S T R A C T

Its known fact that science is progressing at a very fast pace in current scenario. Everyone is looking eagerly for answers to manmade situations that are probably preventable or can be reversed to help environment, advance medicine, space applications et al. Research engineers in general and Mechanical engineers across the globe are engaged in finding answers that would resolve these global pressing problems. Nanotechnology is an emerging inter-discipline science with revolutionary potential for producing new materials (stronger and higher strength composites), improving energy efficiency, and creating new diagnostic tools and therapies for medical applications. Nano fibers, Solar cells, usage of light materials help immensely in space applications. Corrosion and prevention of such corrosion are other areas non-tech applications are being worked out that help Environment impact. We are using plasmas to produce nano-scale coatings with improved hardness and wear resistance. We are exploring applications of highly uniform semiconductor nanocrystals, as building blocks for more efficient lighting, solar cells, and thermo-electric devices and, we are working on new nano particle-based medical imaging techniques and cancer therapies. Concerns have been raised about possible unanticipated health effects associated with exposure to such nanomaterials. Researchers in the Mechanical Engineering Departments globally are working in all these areas. Our paper tries to illustrate emerging possibilities and thrust that can be provided in India under the current Make in India context. It tries to extend the conceptual application boundary that TERII (The Energy Research Institute of India) framework for emerging nano-technology development in India.

Keywords: Nano-Technology Trends, India Nano Technology, Mechanical Engineer, Nano Technology and Mechanical Engineering, Make in India, Emerging Nano Technology Trends India

Copyright (c) 2021 Advanced Research Publications

Introduction

Nanotechnology deals with "understanding and control of matter at dimension of roughly 100 nm and below, has a cross-sectoral application and an interdisciplinary orientation. At this scale, the physical, chemical and biological properties of materials differ from the properties of individual atoms and molecules or bulk matter, which enable novel applications. Nanotechnology research and development is directed towards understanding and creating improved materials, devices and systems that exploit these properties as they are discovered and characterized" (TERI,2010).[1]

'Nanotechnology' is the engineering of functional systems at the molecular scale. This covers current work and concepts that are more advanced. It is the design, characterization, production, and application of structures, devices, and systems by controlled manipulation of size and shape at the nanometer scale (atomic, molecular, and macromolecular scale) that produces structures, devices, and systems with at least one novel/superior characteristic or property.

Current Picture and Emerging Future Trends

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 complete, highly advanced products. The ability to see nano-sized materials has opened up a world of possibilities in a variety of industries and scientific endeavors. Because nanotechnology is essentially a set of techniques that allow manipulation of properties at a very small scale, it can have many applications. When it's unclear from the context whether we're using the specific definition of "nanotechnology" or the broader and more inclusive definition, we'll use the terms "molecular nanotechnology" or "molecular manufacturing." Molecular nanotechnology is an emerging, interdisciplinary field combining principles of molecular chemistry and physics with the engineering principles of mechanical design, structural analysis, computer science, electrical engineering, and systems engineering.

There are many applications of nanotechnology such as in medicine (bio-medical devices and equipment's), space science (applications and allied manufacturing), chemistry and environment, energy, agriculture, information and communication, heavy industry, and consumer goods, et al. The possible potential of this technology has garnered the attention of both developed and developing countries across the globe. Sudden thrust is provided across globe to capitalize on this futuristic potential that can revolutionize technological progress and application of science to meet global needs.[2]

India as we all know has potential to capitalize on this upcoming area. More so, in the areas where there is a growing need in our Indian context- such as space science, bio-medical needs, infrastructure building, telecom and allied industries etc. It is a pleasure to know that The Energy and Resources Institute (TERI) conducted a 3-year study (2007-10) to institutionalize governance framework for this upcoming area of research. Since then, there are number of initiatives in various fields that are emerging to utilize government support in developing nano-technology applications.

Capacity building is one of the key concerns in Indian context. When it comes to manufacturing that too utilizing cutting-edge technology development, we lag our Asian peers. There are dedicated tech parks in China, Japan, and Taiwan that produce cutting edge manufacturing products for global requirements at a cost-effective way. Thankfully, the current incumbent government in India is focusing on bringing manufacturing sector to life under the make in India concept. This initiative is a boon to making India a manufacturing hub provided, dedicated tech parks are created, nano technology is utilized and helps them grow. One of the fallacies of India is that there is limited interaction and also collaboration in co-creating value between research and development organizations and industry. This gap although seems to be small, makes dent in utilizing the research experience and also products and bring them to commercialized manufacturing.

Trends in Nanotechnology

Stronger materials/ Higher strength composites: The next generation of graphene and carbon nanotube-based devices will lead to even lighter but stronger structures than has been made possible by carbon fiber and will become increasingly obvious in cars, bicycles, and sporting equipment, says Clint Landrock, chief technology officer of Nanotech Security.

Dr. Samuel Brauer, founder Nanotech Plus, an alliance of consultants offering analysis and operational assistance about the business of nanotechnology, cites as one area of advancement the development of carbon nanotube pre-impregnated materials which offer better conduction, overcoming one of the major challenges of conventional carbon fiber/epoxy composites. He notes that carbon nanotube meshes have already flown on some space missions, for example, the Juno probe to Jupiter.

Scalability of production: One big challenge is how to produce nanomaterials that makes them affordable. According to Dr. Timothy Fisher, Purdue University professor of mechanical engineering, technologies that can impact grand challenge problems such as food, water, energy, and environment must be scalable.

"The main reason that these problems are so grand is that they are ubiquitous and therefore the related commercial markets have become commoditized. Very often, a technology that exploits a unique attribute of a nanomaterial can offer improvements in functional or engineering performance, but almost as often, these technologies require scarce materials (and therefore expensive) or slow or complicated manufacturing processes (and also expensive)."[3]

That limited scalability often hinders application despite outstanding functional performance in the laboratory or prototype stage, he explains.

More commercialization: Over the next several years, significant advances are expected in carbon nanotube manufacturing technology, specifically in controlling the purity and structure, and in reducing costs due to economies of scale, according to David J. Arthur, CEO, South West Nanotechnologies, a producer of carbon nanotubes.

"Advances will make the use of carbon nanotube materials even more compelling for mechanical engineers," he says. In addition to transforming the automotive, aerospace, and sporting goods fields, nanotechnology is facilitating so many diverse improvements: thinner, affordable, and more durable flat panel displays; improved armor materials to protect soldiers; sensors for medical testing; more humane and effective treatments for cancer patients; enhanced cathode materials for safer and longer life Li-ion batteries; and the list goes on.

Sustainability: One main goal of the National Nanotechnology Initiative, a U.S. government program coordinating communication and collaboration for nanotechnology activities, is to find nanotechnology solutions to sustainability. Mike Nelson, chief technology officer, Nano Ink Inc., says nanomaterials and nanostructured surfaces are increasingly employed in many advanced energy storage and conversion projects, and nanomaterials and nanomanufacturing contribute to products that are more energy efficient in both production and use.

Dr. Eric Majzoub, associate director, Center for Nanoscience, University of Missouri - St. Louis, says this is done by controlling thermodynamics of solid-solid reactions through nanoscale size reduction and it can improve energy-storage materials including batteries, supercapacitors and hydrogen storage.

Nelson sees the greatest near-term impact in sustainability coming in the areas of transportation (more efficient and lighter materials for autos and aircraft, requiring less fuel) and in three other related areas: lighting, photovoltaics, and energy storage. "The types of nano technologies being employed in all three of these are similar in terms of using nanostructured surfaces or materials to improve efficiencies from an electronic performance perspective whether it's batteries or solar cells or LED lighting," he adds.

Nano medicine: Nowhere is the application of nanotechnology more exciting than in the biomedical field, where advances are being made in both diagnostics and treatment areas. Houston-based Nano spectra Biosciences has been developing a new therapy using a combination of gold nano shells and lasers to destroy cancer tumors with heat. Based on work done by Rice University professors, Dr. Naomi Halas and Dr. Jennifer West, the technology promises to destroy tumors with minimal damage to adjacent healthy tissue.

John Stroh, Nano spectra CEO, says he is hoping for European approval in the second or third quarter of this year and FDA approval early next year after 10 years of ongoing development and testing. In the diagnostics area, nano sensors that can detect, identify, and quantify biological substances in body fluids are leading to early disease detection and earlier treatments as well as the ability to detect environmental contaminants in the body. While there is a thrust under make in India initiative, India still is behind many countries that have already taken up manufacturing as their hub of activity.

Top engineering areas of interest and how nano-tech can help?

Following areas interest students of engineering especially from mechanical department. We notice how nano technology can help these areas broadly.

Bio-medical devices and equipment's: Under biomedical nanotechnology three applications of nanotechnology are particularly suited to biomedicine: diagnostic techniques, drugs, and prostheses and implants. Interest is booming in biomedical applications for use outside the body, such as diagnostic sensors and "lab on-a-chip" techniques, which are suitable for analyzing blood and other samples, and for inclusion in analytical instruments for R&D on new drugs. For inside the body, many companies are developing nanotechnology applications for anticancer drugs, implanted insulin pumps, and gene therapy. Other researchers are working on prostheses and implants that include nano-structured materials.

Synthesis and use of nanostructures. • Applications of nanotechnology in therapy. • Bio-metric nanostructures, which are synthetic products developed from an understanding of biological systems. • Biological nanostructures. • The electronic–biological interface. • Devices for early detection of disease. • Instruments for studying individual molecules. • Nanotechnology for tissue engineering.

Space and allied manufacturing: Nanotechnology may hold the key to making space flight more practical. Advancements in nanomaterials make lightweight solar sails and a cable for the space elevator possible. By significantly reducing the amount of rocket fuel required, these advances could lower the cost of reaching orbit and traveling in space. In addition, new materials combined with nano sensors and nanorobots could improve the performance of spaceships, spacesuits, and the equipment used to explore planets and moons, making nanotechnology an important part of the 'final frontier.'

Environment: Pollution and energy shortage are two current major global challenges. In the past two decades, the evolution of nanotechnology represents an ever-improving process in the design, discovery, creation, and novel utilization of artificial nanoscale materials. To meet the major challenges in environmental sustainability, these nanomaterials in various hierarchical fashions are stimulating various important practical applications in the environmental sector. The rapid development in materials and catalysis science has led to significant advances in understanding the controlled synthesis and structure-activity relationship of the nanomaterials. The design, synthesis, and modification of novel nanomaterials allow for enhanced performance for environmental related applications.

Few examples of utilizing nano technology in environment includes-absorption and optimization of environmental degrading particles and carbon sequestration; application research in organic pollutant degradation, heavy metal removal, and NO reduction with NH_3 ; morphological control of environmental materials; power transformer with nano modified cellulose insulation paper; "Removal of hazardous pollutants from wastewaters: applications of TiO_2-SiO_2 mixed oxide materials" reviewed the different removal techniques employed for wastewater treatment and the factors that influence the degradation efficiency. The application of TiO_2-SiO_2 binary mixed oxide materials for wastewater treatment needs to be extensively covered to help in waste management.

Material science: Nano science and Nanotechnology involve the design, fabrication, characterization, and implementation of materials with at least one dimension smaller than 100 nm. Although small, the promise for modern technology is tremendous, due to enormous surface areas, improved ratios of functionality to weight (or volume), the emergence of totally new properties, and diminished energy consumption during manufacturing. These enhancements are already strongly leveraged in the energy, aerospace, biomedical, semiconducting, and communications sectors, with the market only continuing to grow. MS&E faculty particularly emphasize novel nanoscale characterization, modelling, and applications. Areas of focus include nanoparticle/polymer synthesis, optical and electronic sensing, flexible electronics, nanocomposites and coatings, sustainable materials, biomedical engineering and targeted drug delivery.

Materials scientists and engineers have made significant developments in the improvement of methods of synthesis of nanomaterial solids. A brief review of future trends in nanotechnology developments is given in this article.

Future Trends in Nano Technology

Unprecedented opportunities are arising for re-engineering existing products. For example, cluster of atoms (nanodots, macromolecules), nanocrystalline structured material (grain size less than 100nm), fibers less than 100nm in diameter (nanorods and nanotubes), films less than 100nm in thickness provide a good base to develop further new nanocomponents and materials.

The Buckyball (C_{60}) has opened up an excellent field of chemistry and material science with many exciting applications because of its ability to accept electrons. Carbon nanotubes have shown a promising potential in the safe, effective and risk-free storage of hydrogen gas in fuel cells, increasing the prospects of wide uses of fuel cells and replacement of internal combustion engine. The potential of nanotubes can be further exploited in oil and gas industry. The nanotube market is likely to hit 1.35 billion dollars in 2005. Nanotechnology offers a myriad of applications for production of new gas sensors, optical sensors, chemical sensors, and other energy conversion devices to bio implants.

Solar Cells

Nano porous oxide films such as TiO_2 are being used to enhance photo voltaic cell technology. Nanoparticles are perfect to absorb solar energy and they can be used in very thin layers on conventional metals to absorb incident solar energy. New solar cells are based on nanoparticles of semi-conductors, nanofilms and nanotubes by embedding in a charge transfer medium. Films formed by sintering of nanometric particles of TiO_2 (diameter 10-20 nm) combine high surface area, transparency, excellent stability and good electrical conductivity and are ideal for photovoltaic applications. Non porous oxide films are highly promising material for photovoltaic applications. Nanotechnology opens the opportunity to produce cheaper and friendlier solar cells.

Nanofibers

In China and U.K., nanocarbon fibers have been produced. The production of nanofibers offers the potential of using the woven reinforcement as body armor. The future soldier's uniform would incorporate soft woven ultra-strong fabric with capabilities to become rigid when a soldier breaks his legs and would protect him against pollution, poisoning and enemy hazards.

Sensors

Nanotechnology offers unlimited opportunities to produce new generation pressure, chemical, magneto resistive and anti-collision automobile sensors. Many of the novel applications such as new sensors, better photovoltaic cells, lighter and strong materials for defense, aerospace and automotive are already in use, and applications such as anti-corrosion coating, tougher and harder cutting tools, and medical implants and chips with 1 nm features may be developed in another 5-15 years. Nanostructured materials for nanoelectronics components, ultra-fast processors, nanorobots for body parts are still in the state of infancy.

Spending and Investment

Despite the hype surrounding nanotechnology, the progress achieved in the last five years is remarkable as shown by dramatic public spending in recent years. The total global investment in nanotechnology is currently around 5 billion euros, two billion of which comes from the private sector.

Ultra-Light Materials

Nanotechnology is viewed as a key technology for the development of ultra-light materials which would result in energy, fuel and materials savings and development of spectacular materials with complete control over structure and properties at a subatomic level not hitherto known to scientists and engineers. With the future development of nano catalyst, diesel oxidant using nanoscale layers of Pt, Pd, the major environmental killers' smog, pollution and toxic pesticide would be eliminated and humans will be able to breathe in healthy air. Improvement in nano filters would enable bacteria less than 30 nm to be filtered and achieve water purity of 99.999997. The future avalanche of nano-age involves replacement of existing chips by super chips, plastic semiconductors, stronger and lighter jet fighters, amazingly invisible clothing for soldiers, super fuel cells and super batteries. The next twenty years would unleash a new era of nanotechnology when a fullerene molecule (C6) would be described in a high school chemistry book and all materials science textbooks would contain chapters on nanomaterials.

Corrosion and Corrosion Prevention

Despite the progress in understanding the structure of nanomaterials, there is no evidence to show that nanomaterials are more resistant to corrosion than their conventional counterparts. A typical feature of nanomaterials is the defect core structure, which is caused by incorporation of vacancies, dislocations, grains or interphase boundaries, which alter the density and conduction in defect core regions where 50% of the atoms are located. All misfits are concentrated in the grain boundary.

The grain boundary is associated with high diffusivity and higher electrical resistivity. Solute atoms with little solubility also segregate into the boundary regions. Summing up, the grain boundary region is highly active in nanomaterials. Nanograin size, enhanced diffusivity and concentration of defects would make grain boundary sensitive to attack by corrosion. Increased electrical resistivity due to electron scattering would enhance corrosion resistance. Increased number of grain boundaries would also lead to development of more anodic sites for nucleation of corrosion. Theoretically, the structural evidence does not present an optimistic picture of corrosion resistance. There is no clear evidence to prove that nanomaterials are more resistant to corrosion than conventional materials. This is in contrast to the corrosion prevention of nanostructured materials as the studies on coatings have proved. Nanoparticles incorporated in coatings have shown a dramatic resistance to corrosion of the substrate due to their hydrophilic, anti-wear, anti-friction and self-cleaning properties. Engine components are subjected to severe environmental stimulus for corrosion. Diesel engines produce sulfuric acid and formic acid as combustion products. Nano Zirconia powder has been used to coat engine components by plasma spray with success. Nano coatings create a lotus effect and properties, which keeps corrosion away.

What products/equipment's/components etc. can be produced in India to increase its available capacity under MAKE IN INDIA CONTEXT to strengthen India as a manufacturing hub?

Conclusion

By all counts and with proven results, it is no wonder that nanotechnology is an emerging inter disciplinary science with a potential to produce efficient tools which can be used in the medical field, space and allied manufacturing, material science, manufacturing technology. The unique properties of nanotechnology and their convergence with the current treatment technologies present great opportunities to revolutionize the treatment in the medical field.

Notes

The 21st century has seen a massive explosion in the applications of nanotechnology. These applications cover all areas of Science, Technology, Engineering, and Mathematics (STEM). The advantage of nanotechnology comes from the fact that it has revolutionized the miniaturizations of many products that are useful to the well-being of society. A typical nanotechnology application example in biomedical engineering is its usage as drug eluting interfaces for implantable devices, such as vascular stents, orthopedic implants, and dental implants. The purpose of this chapter is to discuss the various applications of nanotechnology to biomedical engineering. Some of the future nanotechnology applications in biomedical engineering include healthcare/ medical, consumer medical goods, environmental, and electronics. The impact of nanotechnology applications to biomedical engineering is in many ways enabling humans to survive different ailments that otherwise could have been very difficult to manage.

In Nanoscience and Nanotechnologies (2004) and Knowles (2006), Nanometer, nanoscale and nanoscience are defined as follows: One thousand millionths of meter are called a Nanometer (nm). An example is that of a human hair that is about 80,000 nm wide; a red blood cell is about 7,000 nm wide; and a water molecule is about 0.3 nm wide. In the case of Nanoscale, it is the size range from 100 nm down to 0.2 nm. The study of the phenomena and manipulation of materials at atomic, molecular and macromolecular scales where properties of the materials can be quite different from those of larger scales are called Nanoscience. Nanotechnology as well as nanoscience concern very important materials called nanomaterials or nanotechnology materials.

References

1. TERI (2010), Nanotechnology development in India: the need for building capability and governing the technology, The Energy and Resources Institute-Briefing Paper.
2. Dwivedi, Abhishek, Dwivedi A. Emerging Trends in Nanotechnology for Modern Industries. *International Journal of Engineering and Innovative Technology (*IJEIT) 2012; 2(6): 4-13.
3. Biomedical application of nano technology, https://bwn.ece.gatech.edu/nanos/papers/biomedical%20applications%20of%20nanotechnology.pdf