Asian Journal of Agriculture & Life Sciences Vol. 3(1), January 2018: 35-43

Website: www.crsdindia.com/ajals.html e-ISSN: 2455-6149

ORIGINAL ARTICLE

Role of Nanotechnology in Addressing Major Developmental Issues

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Received: 10th Sept. 2017, Revised: 25th Nov. 2017, Accepted: 28th Nov. 2017

ABSTRACT

Nanotechnology is becoming vitally important in various industrial fields, contributing considerable wealth creating opportunities and immense development to standards of living. This paper describes the present state-of-the art, highlights its multi-disciplinary nature and expresses the throughout the world the huge impact of nanotechnology applications in sustainable development. Recently, nanoscience and technology have been developing rapidly and are already having a huge impact on the development of novel materials and products. The multidisciplinary nature of these technologies has created a novel breed of scientist/ engineer and even research laboratory. Engineers and scientists have conventionally, paying attention their activities on a single specialized technology. Their objective has generally been to assess and develop a meticulous technique to its acute capability. However, for new and successful micro and nano products to be created, it is critically important to employ researchers who are more than just attentive of the extensive range of enabling technologies, their efficiencies and practicalities. So that, novel hybrid devices/tools could be fabricate to take advantage of, and merge with latest progress in the whole range of new materials, modeling techniques, economy of the country.

Key words: *Nanotechnology, Sustainable Development, Higher Education, Socio-economic, Environment Engineering*

INTRODUCTION

Higher education institutions have implemented nanotechnology vision of education in entire syllabus, individual courses, and extracurricular research activities (Brundiers and Wiek, 2011). Nanotechnology symbolizes an extraordinary prospect to construct in a healthy role for the social sciences in a technology that remains at an early, and thus hesitating, stage of development. Nanotechnology is a branch of multi-disciplinary science which includes knowledge from biology, chemistry, physics and other disciplines (Manjunatha, *et al.,* 2016). Joseph and Morrison, (2006) defined Nanotechnology as the alteration or self assembly of individual atoms, molecules or molecular clusters into structures to generate materials devices with novel or enormously different properties. Nanoscale science and engineering advancements satisfy the human need for searching across science and technology limits. Nanotechnology has the potential to bring revolutionary changes in society and synchronize worldwide efforts towards a higher intention rather than just preceding a solitary area of science and technology, or a single geographical region (Roco, 2001). The development of methods and procedures to produce nanomaterials with characteristic size less than 100 nm, has led to the materialization of consumer goods (nanoproducts) containing these materials(1-3) at large scale.

Sustainable development (SD) means ‘‘Development that fulfills the requirements of existing generations without conciliating the capability of future generations to meet their requirements and obsessions’’ that can be practiced in various ways. Nowadays, in the squat and elongated period, SD is a prominent societal guiding model that asks for the incorporation of economic, public and environmental concerns. Therefore, the idea should be followed by everyone in a various ways. When it comes to the corporate background, commonly investigated ways are environmental and public policies on one hand and personal management systems like EMAS, ISO 14001, or SA 8000 on the other.

Sustainable development is a normative value system, on an equality with human rights, democracy and freedom which is intimately interlinked with all these systems. Thus, sustainable development is fundamentally a potent ethical/moral, assertion as to what should be done. We should call such an assertion which has a moral imperative (Holden et al, 2017). We claim that any concept of sustainable development should recognize environmental limits, as suggested by Our Common Future, various scholars (Meadows, *et al.,* 1992; Spangenberg, 2013) and the novel environmental boundary approach (Rockström, *et al.,* 2009; Steffen, *et al.,* 2015). Furthermore, we assert that trade and industry growth cannot be one of sustainable development's key goals (Holden and Linnerud, 2007, Stiglitz, *et al.,* 2010; Daly, 2007, Griggs, *et al.,* 2013, Meadowcroft, 2012, Holden, *et al.,* 2014). Rather, the important parameters of sustainable development which we claim to be the ethical imperative of fulfilling requirements, making certain equity and regarding environmental confines– represent restriction on human activities, for which we have to put our efforts to maximize financial value. Therefore, we consider that the proclaimed SDGs depend on incorrect premises as they look for to 'balance the three dimensions of sustainable development: the trade and industry, societal and ecological.

Nanotechnology is already developing toward becoming a general-purpose technology by 2020, on all sides of four generations of products with escalating structural and energetic complexity: (1) passive nanostructures (2) active nanostructures (3) nanosystems and (4) molecular nanosystems. By 2020, the increasing integration of nanoscale science and engineering knowledge and of nanosystems promises mass applications of nanotechnology in industry (Roco, 2011).

ACTUAL SUSTAINABILITY PROBLEMS:

Sustainability problems such as weather change, intense poverty, and outbreaks severely impact our society (Kates, *et al.,* 2001). These so-called "depraved" evils, which are urgent, long term, and highly complex, cannot be solved by simple remedies such as "scientific fixes" (Funtowicz and Ravetz 1993; Liu, *et al.,* 2007). Higher education institutions/universities identify that these problems are vital and have begun to convey their research and learning focus to balance basic research with applied research to decipher such "wicked" problems (Corcoran and Wals 2004; Cortese 2003; Elder 2008).

ROLE OF ENVIRONMENTAL ENGINEERING IN SUSTAINABLE DEVELOPMENT

Technologies based on environment have focused to develop such area of the world that can be achieved by sustainable development by improving various parameters such as sanitation, water management, recycling of wastes and use of renewable resources. Though, the fundamental skills and knowledge required for highly advanced environment based techniques have attained the goals of sustainable development like related to better health, weather, water, power, and food quality as well as safety, rich financially and declined of social inequalities.

Major Challenges Associated Environmental Engineering in Sustainable Development:

Environmental engineering major challenges for the developing world are: (1) understand the historical viewpoint of the discipline's association with community health as the field transitions forward; (2) incorporate the diversity encountered when operating over rural to urban locations; (3) address emissions of greenhouse gases and other important carbon-containing pollutants; (4) understand the connection between development and health to better connect health consequences and decrease in risk with ecosystem management and other development interferences; (5) address the complex interactions of water energy systems; (6) incorporate the synergy inherent in development/ sustainability goals of WASH, food security, and resource recovery; (7) switch to a green economy; (8) advance monitoring, estimation, and judgment activities that include life cycle assessment, (9) incorporate culture, insight, and behavior with advances in science and technology, and (10) educate internationally competent engineers. Our anticipation is that this talk leads to an improved world through colossal improvements in the environment and human well-being and drives novel innovations and opportunities in research, education, practice, and service (Mihelcic, *et al.,* 2017).

THE NEED FOR NANOSCIENTISTS AND NANOTECHNOLOGISTS

Significant challenge for nanotechnology development is the education and preparation of an innovative generation of skilled workers in the multidisciplinary perceptions essential for fast progress of the novel technology. The perception at the nanoscale (atomic, molecular and supramolecular levels) should infiltrate the education system in the subsequently decade in a manner similar to the method the microscopic approach made inroads in the last 50 years (Srinivas, 2014).

1. Challenges for Developing a Nanotechnology Workforce:

Since the physical infrastructure for nanotechnology education is still in formation, the main challenges are: (i) interdisciplinary and appropriate formation of nanotechnology technicians, engineers, medics and scientists. (ii) Associating and harmonizing basic, middle/high school, undergraduate, graduate and continuing education. At present, we are getting profit from islands of innovative and passionate groups, such as those at Northwestern University, Cornell University and the University of California, Los Angeles, to name a few. (ii) Flexible workforce able to cross disciplines areas of application and geographical lines. Escalating the international dimension of both nanotechnology R&D and industrial production would necessitate appropriate internationally oriented preparation for students. International partnerships between the US and the European Union, Japan, Taiwan, Korea and other countries have been developed or are under development. Finally, communication and generalization of optimistic consequences, their incorporation into the general syllabus and institutionalization of nanoscale science and engineering in K–12 and university education is required. Engineering plays a significant role in this process because of its integrative and interdisciplinary approach. School boards and school superintendents should be involved from the commencement in planning such actions. A systemic alteration can be made with persistent funding, long-range planning and good communication with the community and administrative and legislative branches of government. Interdisciplinary attention on nanoscale science and engineering education has started only in the past few years.

2. The Vision for Nanotechnology R&D:

At the end of 1996, we have identified nanotechnology as a latent opportunity with colossal potential, and we started the process of establishing a dream for the field, what one should be achieved, and how to reach the paramount results. Invasive technical drivers toward the nanoworld and the pledge of high societal return were the reasons. Innovation of new material structures with vitally novel properties, tools representative nanoscale phenomena, new molecular assembling and constructing techniques leading to nanoscale manufacturing, were data signifying a united set of universal principles for a diversity of disciplines and fields of application. The promise to improve nature, an innovative world of products that are not feasible otherwise, highly proficient manufacturing of almost all human made objects, molecular medicine and an avenue to long period sustainable development were the main public drivers. Education will progress from the microscopic to molecular concepts at all levels, and universal and inventive research will be inspired. A major advantage is the synergism among disciplines and areas of significance. Nanotechnology R & D should promote studies on public and educational insinuations. Present scientific advances act as interior stimuli for further nanotechnology R & D. Nanoparticles and nanolayers with various functions, tubes and wires of a variety of materials, three-dimensional molecular assemblies and tissue replacements, have been prepared. Novel apparatus such as the nano-mechanical tweezers and diverse microscopes have been developed. Quantum performance at room temperature and quantum corral has been demonstrated. Novel processes such as guided self assembling, biomimetic templating and construction with atomic precision. Ultra small devices have been designed and checked, such as molecular electronics devices, nanobiomotors, nano-electro-mechanical systems (NEMS). The main *scientific drivers* are innovation of novel phenomena at nanoscale, methods of measurements and modeling of large number of nano-objects, understanding the connection between nanostructure and function, alteration with atomic and molecular precision, assembling and connecting at nanoscale, understanding modern biology and the synergism with information technology. The promise of nanoscale science and engineering for understanding the nature, improving health, wealth, sustainable development and peace acts as an exterior incentive for the field (Roco, 2011). There are various examples based on research in progress or predicted byprivate sectors which are given below:

a) Manufacturing:
The nanometer scale is a highly efficient length scale for manufacturing. Materials exhibiting high performance, unique properties and functions can be produced with the aid of nanotechnology which cannot be possible by other conventional techniques.

b) Electronics:
Nanotechnology based projects have been anticipated to produce approximately $300 billion annually for the semiconductor industries.

c) Improved Healthcare:
Nanotechnology can play a significant role in enhancing the life span by improving the qualities as well as exceptional human physical capabilities.

d) Pharmaceuticals:
About half of all production will be reliant on nanotechnology– affecting over $180 billion per year in 10–15 years.

e) Chemical Plants:
Nanocatalysts can be used in the petroleum and chemical processing industries and expected annual yield impact wiil be $100 billion in future 10–15 years.

f) Sustainability:
Applications based on nanotechnology can increase the crop yield for expanded population which provide more inexpensive filtered water without any salting residues, assisting the use of natural energy resources like conversion of solar energy, reduced requirement of limited resources and making the pollution free environment. For instance, within 10-15 years nanotechnology based projects will reduce the global expenditure of energy by more than 10% that reflects the annual income of $100 billion dollars and minimizes the carbon emission by200 million tons. Hence, there is a lightning vision of nanotechnology in elevating the income of developed countries. Technology based drivers involve extension of Moore's law behind microelectronics, biologically based devices and biomimetics, novel functional materials such as constructive, catalysts, pharmaceuticals, etc., quantum technology and transportable electronic devices.

3. A Role of Nanoengineer:
A nanoengineer encompasses the integration of interdisciplinary sciences such as physics, chemistry, biology and engineering sciences for investigation and handling of simultaneous phenomena in multibody assemblies. The manipulation of large molecules of a system is very difficult for a thermodynamics engineer because it is single electron physics researcher (Roco, 2003). Hence, it requires the collaborative efforts of scientists belonging to different areas or disciplines. There are a number of motives for an imperative role of engineering which are listed below:

1. In architectures, hierarchical incorporations of the nanoscale system comprising of various components in hundreds or thousands or tens of thousands and makes them distinct from other systems by their combined behaviour.
2. A number of phenomena work in synchronize manner and nanotechnology incorporated such analysis methods for different areas to distinguish macroscopic phenomena, describe transport coefficients, optimize processes and design products
3. Nanotechnology exhibits the capability to modify the object at nanoscale. Key issues include designing of tailored structures at the nanoscale and combination of the bottom-up and top-down approaches to form nanostructured tools based systems. Moreover, incorporation of living and non-living structures, reproduction and eventually self-reproduction methods at nanoscale and development of novel ideas for increasing the economy of industries are some other big challenges.
4. Development of tools and processes to measure, calibrate and manufacturing of materials. Nanoscale engineering aimed to prepare such engineers for improving the phenomena and processes at the atomic, molecular and macromolecular levels; and resolve the related issues. While, interdisciplinary nanotechnology R&D where engineering can play an imperative role (Roco, 2011). A number of applications of nanotechnology in various discipline for sustainable development have been shown in Figure1.

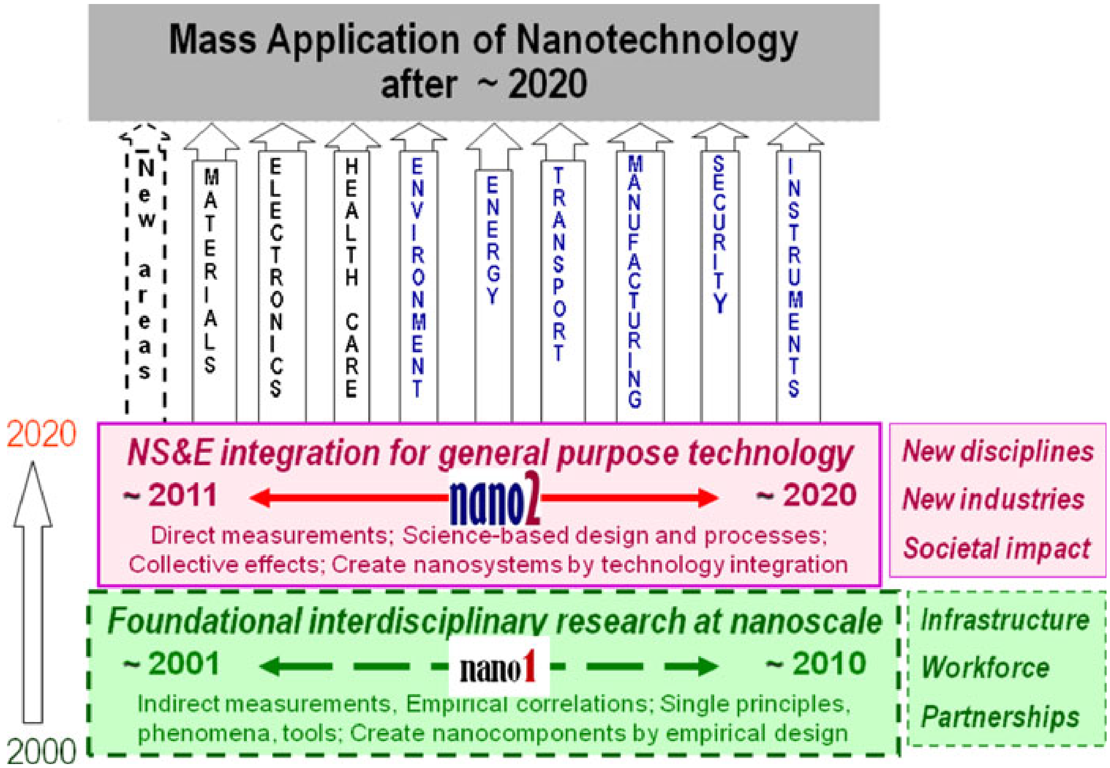

Fig. 1: Creating a new field and community in two foundational phases (''NS&E'' is nanoscale science and engineering)

4. Consistency with Other Science and Engineering Mega Trends:

Six increasingly interconnected megatrends in science and engineering have been evident in leading the scene for the subsequently decades:

(i) Information and computing (ii) Nanoscale science and engineering (iii) Biology and bio-environmental approaches (iv) Medical sciences eventually enhancing human physical capabilities (v) Cognitive sciences concerned with exploring and enhancing scholarly abilities (vi) Collective behavior and system approach to study nature, technology and society

Above mentioned innovations can be made possible by converging diverse areas with minimum deviations. For instance, computer based technology helps to simulate and visualize the nanoworld, and nanoscale tools for manipulated DNA.

Nanoscale science and engineering has anticipated assisting the progress by digital revolution in synergism with modern biology. Nanoengineering helps to investigate the expected progress and provide a situation for the development in the next 10–15 years. Primary innovation and novel innovations at nanoscale can generate a strain among the society's queries for better management over nature in the future, and public strong requirement for consistency and inevitability in the present.

Besides, precise signs of the nationwide investment in nanotechnology have augmented significantly in the US since 2000. The precise yearly Federal R&D nanotechnology expenditure per capita has also been raised from about $1 in fiscal year (FY) 2000 to about $5.7 in 2010.

The part of the Federal R&D nanotechnology speculation as compared to all authentic Federal R&D expenditures has increased from 0.39% to 1.5% in 2008. Qualitative alterations have been used to evaluate the impact of the NNI such as (1) the generation of a dynamic interdisciplinary, cross-sector, international society of professionals and organizations engaged in diverse dimensions of the nanotechnology enterprise; (2) modification in the research culture that are coming through revitalizing interdisciplinary intellectual research associations and the medical field; and (3) combined concepts for engineering complex nanostructures ''from the bottom up'' for novel materials, biology and medical techniques and digital information technologies. The first foundation phase (2001–2010), was focused on inter-disciplinary research at the nanoscale. The major outcomes of this phase were invention of novel phenomena, properties and functions at the nanoscale; fabrication of annals of components as building blocks for probable future applications; tool advancement; and improvement of accessible products by integrating comparatively simple nanoscale components. This phase, conquered by a science centric ecosystem, may be called as "Nano 1." The subsequent foundational phase has started from 2011 till 2020. This phase will be depends on nanoscale science and engineering approaches and aims for direct measurements with better time resolution, scientific strategies to invent basically novel products and huge exploitation of nanotechnology. The goal of R&D and applications is to progress in the direction of new multifaceted nanosystems, innovative disciplines of implication and fundamentally new products (Roco, 2011; Roco, 2008). This phase can be predicted by an R&D ecosystem driven by socio-economic considerations and called as "Nano 2." The switch from the Nano 1 phase to the Nano 2 phase has focused on accomplishing direct measurements at the Nanoscale. Various applications of nanotechnology that decipher the sustainable development have been shown in Figure 2, 3 and 4.

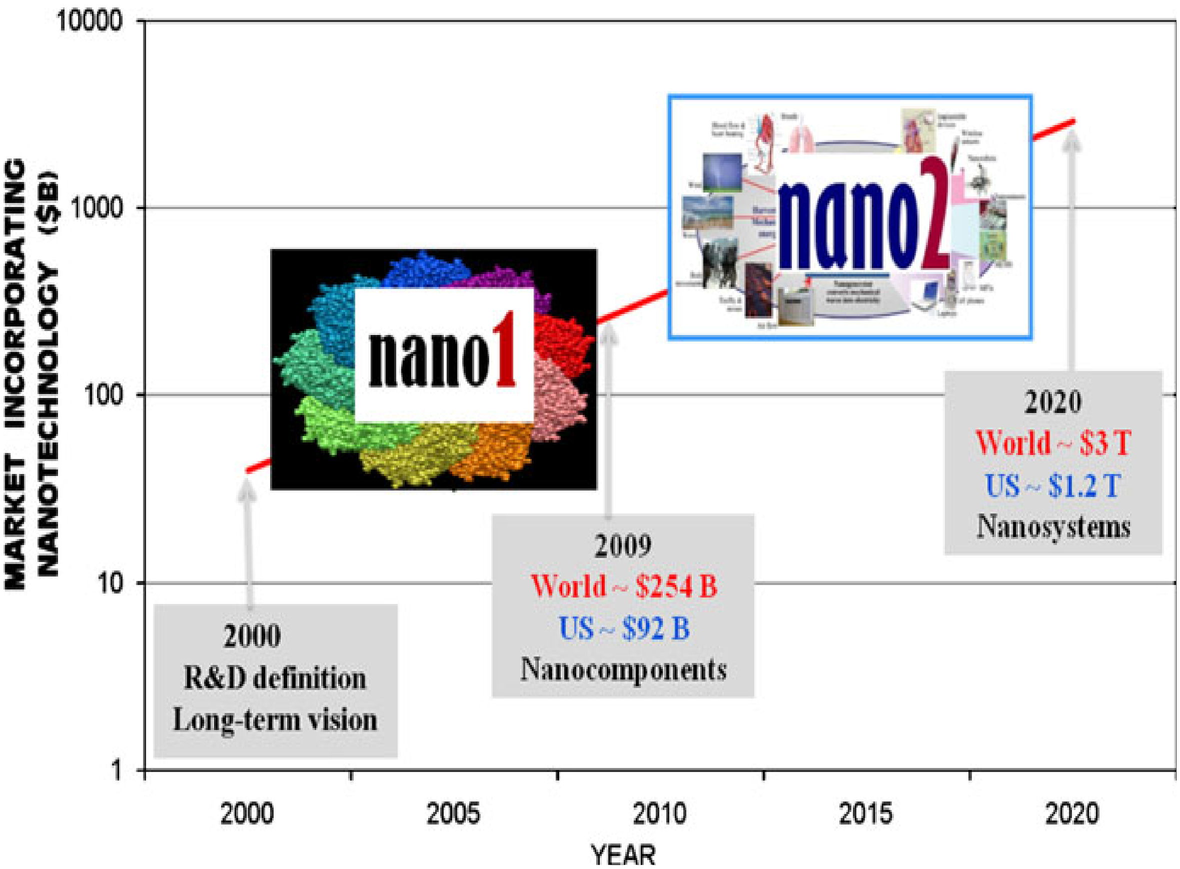

Fig. 2: Market of final products incorporating nanotechnology: the longterm vision for 2000-2020 (solid line) and outcomes in 2009 (survey by Lux Research, see Chapter 13 of the study). The R&D focus evolves from fundamental discoveries in 2000-2010 (Nano1 in the figure) to applications-driven fundamental and nanosystem research in 2010-2020 (Nano2) (Roco, 2011)

4.1 Two foundational steps in nanotechnology development:

In 2000, it was anticipated that nanotechnology nurture in two foundational phases from passive nanostructures to complex nanosystems by means of fabrication techniques. The first foundational phase (2001–2010), has focused on multidisciplinary research at the nanoscale, and become possible in the first decade after defining the long-term vision.

Secondly, a number of R&D targets for achievement by 2020 have been presented in Figure1. Following second phase 2020, nanotechnology R&D is expected to develop emerging and converging technologies, creating novel science, engineering fields and industrialized paradigms (Roco 2002).

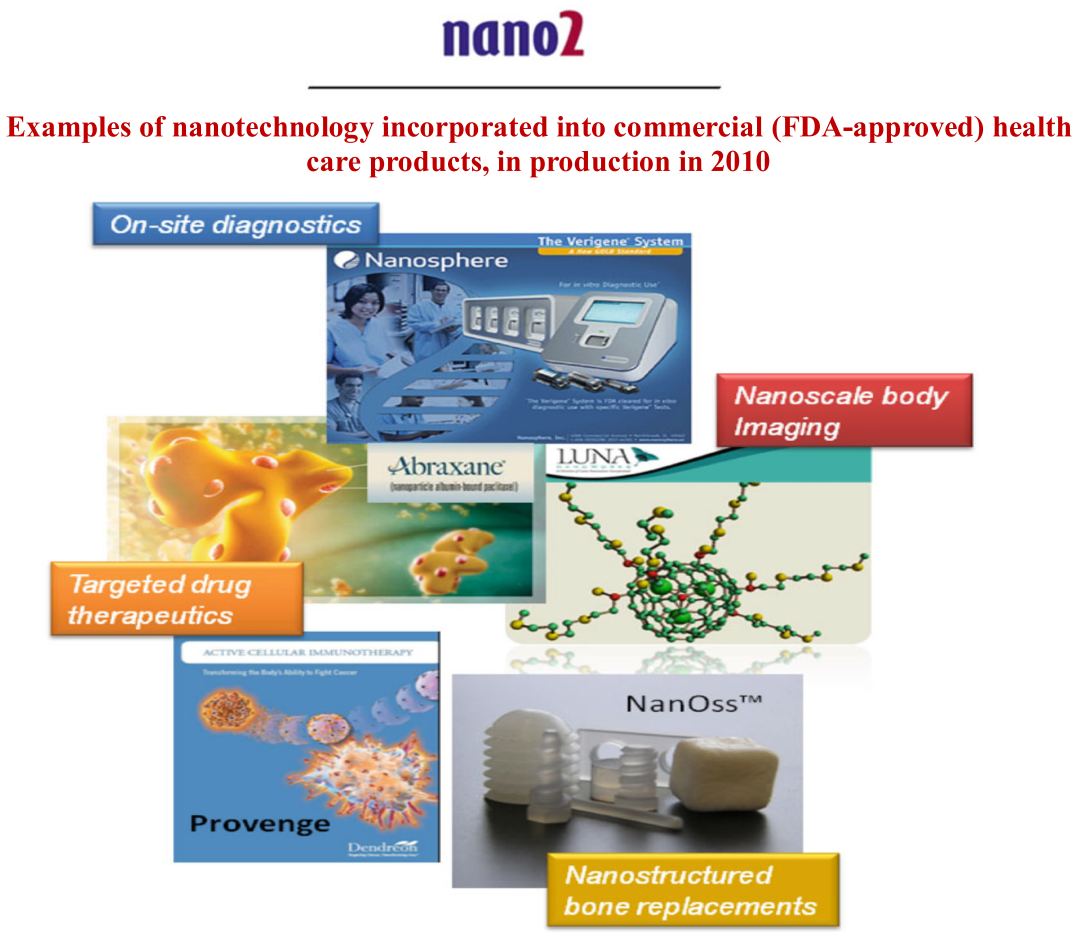

Fig. 3: Illustrations of current nanotechnology applications in nanoscale medicine (Roco, *et al.,* 2011)

4.2 Transformative and Responsible Development of Nanotechnology:

Transformative and responsible development of nanotechnology can be achieved by focusing on the decisions of NNI which includes the identifying the investment followed by inspiring the concerned authority, permitted ratio of profit to loss and apprehensions of society should also be considered. The aim of transformative nanotechnology require pertaining new ways of funding for innovation, resource-sharing, and communication with different institutions and organizations, beside basic and application oriented towards R&D and investment strategy. In 2002, NNI agencies has started to manufacture materials at Nanoscale and simultaneously, NSF has initiated a research project on the topic of ''Nanomanufacturing'' and consequently, established to four Nanoscale Science and Engineering Centers (NSECs) on nanomanufacturing and the National Nanomanufacturing Network (NNN). NNN has started project with manufacturing sectors and intellectual community, programs of the National Institute for Standards and Technology (NIST), National Institutes of Health, Department of Defense (DOD), and Department of Energy (DOE) in 2006. Furthermore, NNI has revolutionized the previous approaches for healthy communication between groups of diverse discipline which led to better former sculpts: the Consultative Boards for Advancing Nanotechnology (CBAN). DOE, NIST, DOD, and similarly other agencies have also started individual programs for advanced nanotechnology R&D (Roco, *et al.,* 2011).

nano2

Examples of nanotechnology in commercial catalysis products for application in oil refining, in 2010

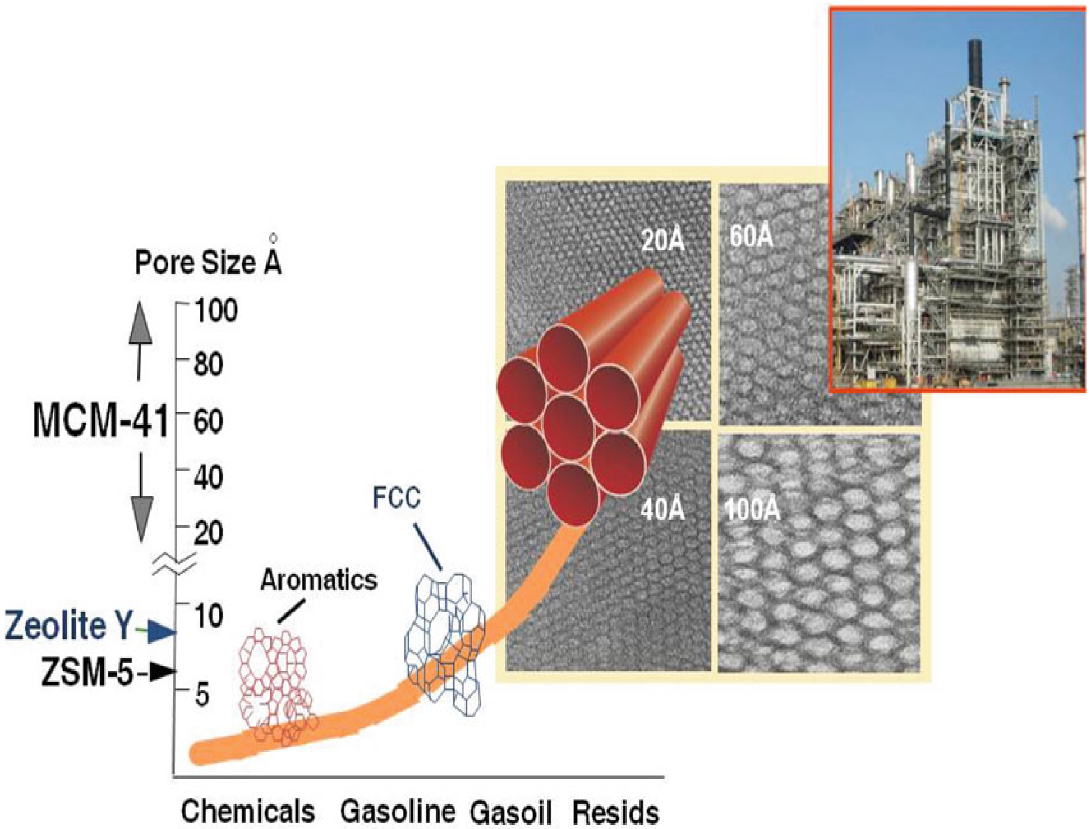

Fig. 4: Illustrations of current nanotechnology applications in catalysts (Roco, *et al.,* 2011)

CONCLUSION

Nanotechnology has played a significant role in betterment of life of human beings by resolving the issues of present and future by collaborating existing as well as efficient partner in the respective discipline. There is a need of continued efforts made by scientific community for method analysis and fabrication of novel nanomaterials and nanosystems, since nanotechnology is still in the initial phase. Nanotechnology based approaches has opened a new hope in the area of sustainable development by managing water, energy, minerals, and other resources. The efforts made by nanoengineers will increase the growth rate of R&D and education, business, organizations and manufacturing industries. Here, states and regional nanotechnology associations will play a significant role. Nanotechnology's success not only depends on by successful analysis in academic and industry laboratories or by individual education agenda, but also by the creativity of individual researchers, skilled students in nanoscale science and engineering, collaborations among organizations, patent regulations, physical infrastructure, legal aspects, state and centralized policies, and intercontinental assistance.

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