UNIT 3 NANOTECHNOLOGY: BASIC IDEAS AND APPLICATIONS

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3.1 OBJECTIVES

Nano technology is an innovative development in science and technology. It has a convergence with many disciplines. It has revolutionary implications for society. It has even a potential to challenge the existing notions of reality. This unit provides the basic ideas and applications of nano technology. Further it explores the social ethical implications of this kind of technological developments in contemporary world situation.

3.2 INTRODUCTION

Nanotechnology involves working with matter at the atomic or molecular scale. Nano technology is a technology of rearranging and processing of atoms and molecules to fabricate materials to nano specifications such as a nanometre. Materials and devices designed and made at the molecular level would be quite different from those of daily use today. It is argued that the new products would be far superior in terms of strength, toughness, speed and efficiency. The products are considered cleaner, stronger, lighter and more precise. Nano technology is set to bring about a fundamental change in several areas- materials science, electronics, biology, medicine- and is expected to profoundly change the pattern and standard of life of people. The goal of research in nanotechnology is to discover and understand these unique properties and ultimately find a way to put these characteristics to use.

Nano science is a convergence of physics, chemistry, materials science and biology, which deals with the manipulation and characterization of matter on length scales between the molecular and the micron size. Nanotechnology is an emerging engineering discipline that applies methods from nano science to create products. Nanotechnology is an emerging range of technologies in which medicine and engineering meet physics and chemistry. Nanotechnology involves 'research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1 to 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size'. Materials of molecular and macromolecular scales have new and often unexpected properties. Nano technology poses a challenge to manipulate atoms individually and place them precisely where they are needed with predefined features.

3.3 NANO TECHNOLOGY: DEFINITION

There is no common agreement on the definition of nanotechnology. Many scholars and research agencies defined it differently. The current dictionary definition of Nanotechnology is 'the design, characterization, production and application of materials, devices and systems by controlling shape and size at nanoscale.' (E.Abad. et al., *Nano Dictionary*. Basel: Collegium Basilea, 2005) The Royal Society (2004) defines *Nanoscience* as the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. *Nanotechnologies* are design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale. US National Nanotechnology Initiative (NNI), one of the largest founders of nanotechnology research in the world uses the definition: nanotechnology is the understanding and control of matter at the dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. (NNI, 2008). US Foresight Institute came with a definition, "nanotechnology is a group of emerging technologies in which the structure of matter is controlled at the nanometer scale to produce novel materials and devices that have useful and unique properties."

3.4 HISTORICAL DEVELOPMENT OF NANO TECHNOLOGY

Though the term Nanotechnology was coined in 1974 by a Japanese scientist Norio Taniguchi, it has nothing to do with the present day usage. The prefix of nanotechnology derives from the unit of length, the nanometer, and in their broadest definitions these terms refer to the science and technology that derives from being able to assemble, manipulate, observe and control matter on length scales from one nanometer up to 100 nanometers or so. One nanometer is a billionth of a meter or one thousandth of a micrometer, sometimes called a micron, which in turn is one thousandth of a millimeter. It is abbreviated to 1 nm. Molecules, viruses and atoms are objects that range from less than 1nm to about 100 nm. For instance, a human hair is roughly 20,000 nm in diameter. A bacterial cell might be up to a few thousand nanometers in size. They are too small to see with the eye, or even with the microscopes that use visible light. New technologies are facilitating to visualize even these small particles. The technologies like the scanning tunneling microscope and the atomic force microscope are not only for seeing but also manipulating things at this small scale.

Prior to invention of scanning tunneling microscope, the atomic structure of matter was quantitatively revealed by x-ray diffraction. The information they contain are not direct real space representation of matter. With them you cannot pinpoint the position in space of a given atom, molecule or cluster. With the development of Scanning Tunnelling microscope, not only could the individual atoms and molecules be imaged; they could also be individually manipulated. Through the inventions of scanning tunneling microscopy (STM), scanning force microscopy (SFM) in second half of twentieth century, images are obtained not by gathering reflected or refracted waves from a sample, as happens in conventional microscopies such as light or electron microscopy. Instead, a very fine tip is scanned across the surface of the sample, interacting with it in one of a number of possible ways. The picture is built up electronically by recording the changing interaction with the surface as the tip is scanned across it. New techniques – including scanning force microscopy – are capable of interrogating the properties of single molecules. It is the information about the properties of a single molecule provided by these techniques will be essential in the design of nano scale devices.

Today, nano technology has emerged as an important interdisciplinary subject with internalizing the recent developments in various fields. The nano technology has wider applications and products produced by nano technology have serious implications too for contemporary world- economically, ethically and politically. The world of nano technology is broadly divided into two major application areas- wet and dry areas. The wet area includes the biological domain, where nano structures may function within biological cells. The dry area includes hydrophobic architectures and strategies that govern improvement of materials including computer chips. Dry nano technology applications have preceded the biological use. Initially, biology and electronics are likely to be the major areas of application. Nano technology is also expected to provide a new tool to read the genetic code. The discoveries that have been made so far in the science of nano scale, offer new possibilities for a multitude of industries.

3.5 NANO TECHNOLOGY: NEW TECHNOLOGICAL REVOLUTION

Nanotechnology is being heralded as a new technological revolution. It is so profound that it will touch all aspects of economy and society. Through the developments in nano technology, energy will be clean and abundant, the environment will have been repaired to a pristine state, and any kind of material artefact can be made for almost no cost. Space travel will be cheap and easy, disease will be a thing of the past, and we can all expect to live for more years.

Current applications for nanotechnology are dominated by tools for scientists, and by new materials that are structured on the nanoscale. Such materials are used in cosmetics, health and medicine and in a variety of manufactured goods. The electronics and information technology industries are also a prominent driver for these new technologies. Carbon nanotubes have potential applications in electronics, improved materials, and drug delivery. Today we have already been witnessing a few commercial applications of nanotechnology such as improved hard-disks for computers, sunscreens, and improvements to telecommunications. Much of the potential for the translation of nanoscience into useful and viable products is likely to be realised within the next decade or two. As the knowledge and tools improve, it is likely that at least some of the possible applications will become commonplace in our everyday lives. For instance, new lithographic techniques to make nanoscale components for computers are highly likely to replace current methods and materials. Levels of public expectation that nanotechnology may bring about significant improvements in the length and the quality of life are high. In the field of bio technology and medicine, the public expectation on this new technology is high. The biggest economic driving force for nanotechnology now comes from information technology. Nanotechnology has the potential for smaller and faster computers with larger memories than current processes of making transistors and other components permit. In the long term, entirely new applications may emerge.

Technological optimists look forward to a world transformed for the better by nanotechnology. For them it will cheapen the production of all goods and services, permit the development of new products and self-assembly modes of production, and allow the further miniaturisation of control systems. At the same, there is strong criticism on the implication of nano technology in our society on different accounts. However, it is too early to predict its implications.

3.6 APPLICATIONS OF NANO TECHNOLOGY

Nanotechnology applications in development can be broadly divided into several thematic areas: the development of the tools that enable the research and ultimately the technology; applications relating to new or improved materials; applications within the sphere of electronics and IT; advances in health and medicine; improvements in cosmetic products and advances in food technology; developments in products for military and security use, and space exploration; and products and processes to improve the environment. Nano technology has tremendous development in the fields of material science, electronics, biomedical science, biotechnology, military and the environment. The computing and electro communications industries are driving large investments with the aim of maintaining the relentless technological advances that the structure of those industries seems to demand. In Biomedical science, the driving force for innovation is as much political as economic, as spending on medical research seems to be one of the most popular and widely supported forms of public spending in western economies.

Material Science

The science of metals, ceramics, colloids and polymers, has always concerned itself with controlling the structure of materials on the nanoscale. Here, nanoscale science and technology will largely facilitate incremental advances on existing materials and technologies. The improved control over nanoscale structure, and better understanding of relationships between structure and properties, will continue the long-run trend towards materials that are stronger and tougher for their weight. Some specific areas in which Nano science technology is contributing to materials science now include: new forms of carbon; nanocomposites; quantum dots and wires; and nanostructured materials produced by self-assembly. The cosmetics and paints industries are perhaps perceived as being the most developed in incorporating nanoparticles into their products, for example, the shampoos, skin creams, and sunscreens already being used by consumers.

Medical

The medical area of nanoscience application is projected as one of the most potentially valuable, with many projected benefits to humanity. With the advent of new materials, and the synergy of nanotechnologies and biotechnologies, it could be possible to create artificial organs and implants that are more akin to the original, through cell growth on artificial scaffolds or biosynthetic coatings that increase biocompatibility and reduce rejection. These could include retinal, cochlear and neural implants, repair of damaged nerve cells, and replacements of damaged skin, tissue or bone. The diagnostics and drug delivery is likely to benefit from the development of nanotechnology. With nanoparticles it is possible that drugs may be given better solubility, leading to better absorption.

Cosmetics

Cosmetics and personal products companies have been extremely active in using nanotechnology to improve their existing products and to develop new ones. Cosmetics companies were among the first to get products that were labelled as being nano-enhanced to market. Shampoos and skin creams, containing nanoparticles with the ability to deliver the desired ingredient to where it is needed.

Military

In the field of military, improved materials, lighter but with tough, heat resistant properties, are being used in the design and construction of spacecraft and satellites, and this process will gain from nanotechnology. There is also the possibility of nanotechnology facilitating improvements in civilian security equipment. The Institute of Nanotechnology suggests fingerprinting will become cheaper, quicker and more effective using DNA techniques involving nanotechnology, and there is also the possibility that nano-based sensors could be used as electronic detectors (‘sniffer dogs’) for improved airport security. Quantum dots, fluorescent nanoparticles which glow when exposed to ultraviolet light, may be used as tags and labels to prevent theft and counterfeiting, and to trace the course of drugs within the body.

Biotechnology

In the field of biotechnology researchers are looking to nanotechnology as the basis of new implants that will replace lost hearing or vision, as new ways of delivering ‘smart drugs’ to parts of the human body, and as ways of carrying ‘body repair’ cells to areas where tissue has been damaged. As researchers master this new field, revolutionary concepts such as replacement arteries, nanofibre bone reinforcements, powerful microscopes the size of a pen, and new diagnostic technologies are becoming more and more probable.

Green Technology

Nanotechnology can be used to prevent, monitor and alleviate a wide range of environmental problems, while significantly reducing cost and improving performance. Current and future applications of nanotechnology will allow us to:

- Develop new “green” processing technologies that minimize the amount of undesired by-products;
- Detect and remove the finest contaminants from air, water, and soil, which

would enhance the ability of governments to respond to terrorist threats and ensure the safety of water supplies;

- Attain sustainable development by reducing the use of raw materials;
- Design cars that are lighter and more resistant to denting and scratching, resulting in fuel savings and increased longer-lasting vehicles;
- Extend the shelf life of food and beverages by creating barriers against water vapor and oxygen;
- Save energy through "smart" insulation and construction materials

Hi-Tech

Nanotechnology provides unprecedented control of light and power. Light emission and/or absorption are crucial for optical communications, display technologies, information storage, solar energy collection, genome sequencing, and even targeted drug delivery. The integration of organic/inorganic/mechanical properties can result in self-intelligent systems and self-correcting systems with internal control. Miniaturization is a critical concern for microelectronics, computing and telecommunications industries. Optical routers, large-scale displays, and ultra-dense molecular memory are only some of the short-term applications. A cool flat-panel screen will replace your bulky television set at an affordable price, thanks to carbon nanotechnology. This technology will produce better displays at a lower cost, for home theatres, office equipment, portable computing tools, and many other applications. Based on a fusion of biology and photonics, there are also potential applications in non-invasive cancer therapies, laser tissue welding, drug delivery, and diagnostics.

Check Your Progress I

Note: Use the space provided for your answers.

1) Define nanotechnology.

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2) Discuss the applications of nanotechnology.

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3.7 DISCOURSE ON NANO TECHNOLOGY

The debate on nanotechnology is founded on a range of conceptions of what this emerging technology encompasses, and judgments on what it may mean for society. The scientific community too divided on the potential and future of nano technology. Some of them attributed radical departure from science and technology and visualized revolutionary implications of nano technology. Some of the scientists are skeptical about the potential of nano technology and even critical about the ongoing research and propaganda about nano technology.

The term nano technology was popularized by a book written by K. Eric Drexler, nanotechnology visionary in a book of 'future history' called *Engines of Creation*. Drexler used the word to describe his vision of a world where molecular manufacturing would allow people to manufacture *anything* they might need – from automobiles to pieces of beef – simply by feeding waste material into a box that would use nano scale assemblers to re-configure it into the necessary form. Jamie Dinkelacker, in his paper *Transitions to Tomorrow* (2002), Nanotechnology heralds a new industrial era, a 'Molecular Epoch' that involves major social changes. The advances in science have been achieving near total control over the structure of matter. He viewed that the era of nano technology promises "novel materials and capabilities, leading to novel living patterns, new ways of socializing, and yielding fresh approaches to cooperation and competition. He speculates that nanotechnology offers the potential for global material abundance, and it is the loss of scarcity that has the "potential for dramatic social change. Especially, the molecular nano technology has the ability to "programme matter with molecular precision". In *'Why the Future Doesn't Need Us'*(2000), Bill Joy, chief scientist of Sun Microsystems, also adopts the radical conception of nanotechnology, where the "replicating and evolving processes that have been confined to the natural world are about to become realms of human endeavor". Joy accepts that nanotechnology, coupled with advances in genetics and robotics, is highly revolutionary and transformative.

George M Whitesides, an experimental surface chemist and pioneer of new nanotechnology techniques, in his article *The Once and Future Nanomachine* (2001), is much more skeptical about the radical view of nano technology. He contends that nanotechnology could learn much from biology. Rather projecting the magnitude of nano technology and the nano machines, he appraises the developments in biology and chemistry, on which nano technology is based. Whitesides seems reluctant to believe that new forms of sophisticated nanoscale machines are feasible, particularly not from scaling down macro-machines. Instead, "biology and chemistry, not a mechanical engineering textbook" may hold solutions for nanotechnology. Whitesides is skeptical that the Drexlerian vision of molecular manufacturing is possible, though he does not explicitly rule it out.

Richard E Smalley, chemist and the Nobel Prize winner for the discovery of fullerenes in 1996, in *Of Chemistry, Love and Nanobots* (2001) too is skeptical as Whitesides. For Smalley, chemistry is the most effective method of molecular manipulation, as atoms perform a "complex dance involving motion in multiple dimensions" in chemical reactions. He argues that nanobots or assemblers "are simply not possible in our world", due to constraints imposed by the limitations of the scale. In his view, the need to control all the atoms surrounding the reaction site would require so many manipulators that there would not be room, while the atoms forming the nanobot would themselves bond with the atoms to be manipulated. Whitesides, and Smalley represent the scientific argument against the radical viewpoint; they are particularly skeptical that the Drexlerian vision of molecular manufacturing is feasible. These highly respected scientists argue that this conception of nanotechnology does not fit within the laws of physics and chemistry as they operate on the nanoscale, or is redundant due to the superior power of biological processes.

Drexler's vision for nanotechnology is one of the atomic precision and perfect and complete control over molecular reactions. It is essentially an engineer's vision. Smalley's vision in turn, insists on production of detectable and controllable phenomena, and takes a crucial part of scientific activity the manipulation and stabilization of the phenomena. This is essentially a chemist's vision. The writing on nanotechnology has been discussed in terms of two dimensions: its conception of nanotechnology and its perception of the possible social and economic effects. There is an emerging concern that the needs of society to be considered as part of the development process and that nanotechnologists not be left alone to dictate what materialises. This implies that any assessment of possible social and economic effects be incorporated into this process as early as possible, and hence that social science, as a major provider of such understanding, can help shape the future of nanotechnology.

3.8 SOCIAL AND ETHICAL IMPLICATIONS OF NANO TECHNOLOGY

Many of the applications arising from nanotechnology may be the result of the convergence of several technologies. The technological development and its implementation do not operate in a vacuum, and nanotechnology will be influenced by other scientific developments, social reactions, and local and global politics. The extreme supporters claim that nanotechnology can rebuild the human body from within and effectively abolish death, while its critics fear that instead, it could do away with life, by turning the surface of the Earth into an uninhabitable grey mass. However, the social science reading can help us understand nanotechnology in a better way than technological deterministic view. Nanotechnology in relation to society has to explore the driving forces behind the technology development process and the issues of inequities and economic divides and how society deals with risks under uncertainty. There are further apprehensions about nanotechnology since its closeness to market forces and research is mostly carried by the interests of advanced nations and market forces in corporate laboratories. Nano is a big business. National Science Foundation of USA predicts that nano-related goods and services could be $ 1 trillion market by 2015. It is the fastest growing industry than any other in the recent history.

While nanotechnology offers opportunities for society, it also involves profound social and environmental risks, not only because it is an enabling technology to the biotech industry, but also because it involves atomic manipulation and will make possible the fusing of the biological world and the mechanical. There is a critical need to evaluate the social implications of all nanotechnologies. There is a possibility that domination of nano-robos in every day life will make human intervention difficult, if not impossible. Another risk is that the hazard posed to human life and health by nano particles inhaled in the factory and elsewhere. Environmentalists also question the safety of nanoparticles. The first concerns the biological and chemical effects of nanoparticles on human bodies or natural ecosystems; the second concerns the issue of leakage, spillage, circulation, and concentration of nanoparticles that would cause a hazard to bodies or ecosystems. The potential dangers of nano technology include rampant nano-devices, military weapons, or invasive surveillance. On ethical side, the issues of intellectual property as well as the access of nano technology to developing countries have to be addressed. The public policies to protect our society from harmful developments are another concern based on strong foundations of ethics.

If technology is fascinated towards control and over taking of nature, nanotechnology is mainly concerned with the control of nature at the most basic level, i.e. level of atomic building blocks. However, Nanotechnology has been generating new ethical dilemmas and in future we have to necessarily negotiate with a big deal of uncertainties. The ethical theories have to be reformulated with changing context that had predominantly influenced by nanotechnology. Nanoethics have emerged as a new field of applied ethics that looks at the issues of right and wrong in the development and application of nanotechnology. (Lin and Allhoff, 2007)

3.9 DEMOCRATIZATION OF TECHNOLOGY

Philosophers are concerned about the technology and came with different perspectives of philosophy of technology. Two dominant streams in this regard are theories of technological determinism and social construction. The interface of technology and society and rational and ethical understanding of that situation is the main concern of the philosophers. The Marxists though find technology as a means of liberation argues for a socialization of its wealth by abolition of classes. They view a harmony between man and nature against the alienation. The phenomenologist Heidegger considers technology is not a simplification of artifacts, but an all encompassing world view that revealing the world. Objects enter into our experience only in so far as we notice their usefulness in the technological system. He also believes that releasing from this needs a new mode of revealing, but he has no idea how revealing come and go. The pragmatic thinker John Dewey considers scientific theories and logic are tools used in a certain social practices. So the success of technology depends upon its usefulness. Herbert Marcuse, the Frankfort school thinker in *One Dimensional Man* (1964) argues that technology leads to a new form of domination in industrial society. He forwards a view that restoration of harmony of man and nature through new science and technology. It requires the abolition of class society. Hebermas contests the Marcuse's new science and technology as a romantic myth. He argues that problems of capitalist modernity are due to obstacles it places in the way of rationalization in its moral- practical sphere. Andrew Feenberg by consolidating these debates in *Questioning Technology* (1999) argues that society is organized around technology. Technological power is the principal form of power in the society. Feenberg's major focus and distinctive position within current debates on technology has an emphasis on democratic potential for the social reconstruction of technology. Feenberg rejects both neutralist positions which see technology as a mere instrument of human practice, amenable to any and all projects and uses, and determinist notions which see it as an instrument of domination in the hands of ruling elites whose very construction determines the uses, limits, and applications of technology. Instead he sees technology as a contested field where individuals and social groups can struggle to influence and change technological design such that the very construction of technology is subject to democratic debate and contestation. He proposes for a possibility of alternative rationalizations, alternative modernity through alternative politics. Feenberg is interested in the possibility of *alternative rationalizations*, particularly forms of rationalization necessary for socialism, which would embody responsibility for humanity. He strongly proposes that a technological society requires a democratic public sphere sensitive to technical affairs.

Most of these perspectives are evolved from the reflections on industrial society. These views have relevance for the context of nanosociety too. Nano technology has not only going to change significantly but also producing inequalities in society through monopoly of technology and control over many nations and social groups. Democratization of the nanotechnology is an immediate concern as raised by the conscious scholars and civil society organizations. Rather negating the technology per se, we can shape the technology with our social and ethical concerns emerged out of our struggles for democracy. Currently, corporations, developed nations, entrepreneurs and technologists are the main driving forces behind nano technology. Mostly the research and its products are market oriented. There is a need to understand the driving forces and the process of decision making in relation to nano technological development. Nano technology is invariably related with information technology and biotechnology. As a result, nanotechnology has become crucial for economic growth of nations. At this juncture, political regulation and consensus is required to control technological change.

There are consensus and campaigns in civil society from different sections on the issue of nano technology for its future implications to humanity. Their concerns are mainly for democratization of technology and egalitarian social order. It is argued that the point is not that the technologies are bad… [but] the evaluation of powerful new technologies requires broad social discussion and preparation". Sue Mayer(2002), who sees parallels between the emergence of nanotechnology and of genetically modified (GM) 15-20 years ago. The lack of democratic consultation keeps the assessment of any risk within the realm of the 'expert'; the public is then considered ignorant, and the authorities attempt to calm any fears with 'sound science', a concept that to Mayer is shaped "not by scientific facts but by its political, social, economic and cultural context". Mayer's concerns, however, extend beyond the lack of democracy in technological development to the effects that this may have over the safety of nanoparticles for humanity and the environment. Moreover alternatives will not have been explored and the economic benefits of nanotechnology may be less than they would be if the public had been involved in its design. The perceived lack of democratic consultation also raises concerns regarding the control and ownership of the technology, the possibility of its monopolisation and the "implications of corporate control over matter." ETC, *Action Group on Erosion, Technology and Concentration* envisages that the recent trend of the control of technology development being lost to the public arena, the "privatisation of science and a staggering concentration of power in the hands of giant multinational enterprises" will be further reinforced by nanotechnology. In ETC's picture of the future, the "control of the technology will accrue to those with power and the commercialisation of the technology will inevitably give them greater monopoly control". ETC does not trust big business, or governments, to use this knowledge, power and control ethically. Allied to these issues of monopoly and control is the negative vision that nanotechnology will reinforce global inequalities between rich and poor. It dismisses the eradication of poverty as a myth propagated by the enthusiastic nanotechnologists. The commercial forces are purely concerned with profit. Comparing the dawning of a nanotechnology revolution to previous industrial revolutions, ETC raises the question of "a decline in the well-being of poor people and increased disparity between rich and poor", as only those with sufficient wealth may have access to the technology. In other words, ETC predicts a future in which the ruling elite has "unlimited surveillance capacity" at the nanoscale leading to an Orwellian scenario of "Big Cyborg Brother".

Check Your Progress II

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1) Explain the nature and scope of nanotechnology.

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2) Critically examine the social and ethical implications of nanotechnology.

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3) Evaluate the perspectives of philosophy of technology with reference to nanotechnology.

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3.10 LET US SUM UP

Nanotechnology is an important development in our society that going to revolutionize our lives in a grand way. Nanotechnology involves working with matter at the atomic or molecular scale. It is a technology of rearranging and processing of atoms and molecules to fabricate materials to nano specifications such as a nanometre. It is a result of convergence of several technologies. Nano technology is set to bring about a fundamental change in several areas- materials science, electronics, information technology, biology, medicine- and is expected to profoundly change the pattern and standard of life of people. Apart from advantages, it has serious social ethical implications. Nanotechnology projects a new world and also brings with it new social problems. From these ethical dilemmas evolved a new discipline called nanoethics. Philosophers are predicting that we have to negotiate with a big deal of uncertainties and chaotic situation with the advent of nanotechnology. Apart from the risks and threats of nanotechnology, control and monopoly of this technology in the hands of advanced nations and corporate companies' interests is another critical concern. Democratization of nanotechnology, in its design and application, is the prime concern in the discourse of philosophy of technology and the struggles from civil society.

3.11 KEY WORDS

Nano technology, Nano scale, Atomic rearrangement, Scanning Tunneling Microscopy, Nano particles, ETC group, Philosophy of technology, Technological Determinism, Social construction, Democratization, Public participation

3.12 FURTHER READINGS AND REFERENCES

Drexler, K. Eric *Engines of Creation, The Coming Era of Nanotechnology.* Oxford: Oxford University Press, 1996.

Feenberg, Andrew. *Questioning Technology*. Routledge, 1999.

Hans Fogelberg and Hans Glimell. *Bringing Visibility to the Invisible: Towards a Social Understanding of Nano Technology.* Goteborgs University, STS Research Reports. No.6. 2003.

http://unesdoc.unesco.org/images/0014/001459/145951e.pdf

http://www.esrc.ac.uk/_images/challenges_of_nanotechnology_tcm8-13557.pdf

http://www.etcgroup.org/en/issues/nanotechnology

http://www.sts.gu.se/digitalAssets/1030/1030390_STS_report_6.pdf

Lin and Allhoff, Fritz. *Nanoethics: The Ethical and Social Implications of Nanotechnology.* Wiley Interscience, 2007.

Marcuse, Herbert. *One Dimensional Man, Studies in the Ideologies of Advanced Industrial Society.* Boston: Beacon, 1964.

Mathuna, Donald P.O'. *Nanoethics-Big Ethical issues with Small Technology*, London: Continuum International Publishing Group, 2009.

Mohan Sunder Rajan. *NANO:The Next Revolution.* Delhi: National Book Trust, 2009.

Richard E Smalley. *Of Chemistry, Love and Nanobots.* American Scientific. September,2001.

Schummer, Joachim and Davis Baird. Eds. *Nanotechnology Challenges, Implications for Philosophy, Ethics and Society.* Singapore: World Scientific Publishing, 2006.

Stephen Wood, Richard Jones and Alison Geldart. *The Social and Economic Challenges of Nano Technology.* ESRC. Economic and Social Research Council Report, 2006.

UNESCO Report. *Ethics and Politics of Nano Technology.* 2006.