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NANOTECHNOLOGY: A CONSCISE VIEW

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ABSTRACT

Nanotechnology, a multifaceted subject area of applicative devices that involves the Engineering of functional systems at the molecular level is considered the nerve centre of technological advancement of the 21st century and beyond. This field that focuses on controlling the configuration and exploiting the exclusive characteristics of Nano-materials having not less than one dimensional volume of material between 1nm to 100nm to produce nano-scale devices, components and systems is repeatedly seen as an emerging technology which could be employed to enhance current products and processes. This paper which is essentially a review discusses Nanotechnology, its development, impact, applications and advances.
Keywords: Nanotechnology, Nano-scale, Composites, Nano-materials, Nano-devices.

INTRODUCTION

Nanotechnology is the manipulation and management of materials at the sub-microscopic, molecular, and supra-molecular scales. It is repeatedly seen as an emerging platform technology which could be employed in improving current products and processes. Nanotechnology uses the exclusive characteristics of nano-materials which have not less than one dimensional volume of a material ranging from 1 nm to 100 nm to make nano-scale devices, components, and structures. Nanotechnology should not be viewed as a manufactory, a mono-technology or a sole division of examen. Nanotechnology as a division of learning is interdisciplinary, thus it is also viewed as a universal Engineering Science. Applications utilizing nanotechnology include manufacturing various products, measuring, envisioning and arranging materials on the Nano-scale. This field of study is so captivating to eggheads in the sector of Nano-composites, bio-composites, optical, biomedical, and electronic manufacturing. In Huang, Chen, Yan, and Roco, (2005), materials on the nano-scale differ in properties compared to their bulk equivalent materials for two reasons:

A. Nano-scale molecules possess comparatively bigger surface area per unit mass that is pivotal to increment mechanical modulus and other physical and chemical characteristics.
B. Basic attributes of material are transformed at Nano-scale hinged on the consequence of the domination of quantum effects and negligible defects.

NANOTECHNOLOGY DEVELOPMENT

The absence of a universally agreed, precise endorsed period for the commencement of nanotechnology emergence is adduced to the certitude that nanotechnology started so long ago when persons used it without knowing. However, the first reference made of deliberately designed and applied technological operation and methods, that eventually were called nanotechnology is normally tied to the popular discourse of Professor R. Feynman of Californian IoT, delivered in 1959 at the session of the APS. In the lecture titled “There is a Lot of Space Down There”, the prospect of devising nanosized devices using atoms as building molecules was brought to light. This lecture is always cited as the origin of Nano-technological paradigm. Huang et al (2005), Igami & Okazaki (2007).

The word “nanotechnology” was first mentioned by N.Taniguchi at the International Conference on Industrial Production in Tokyo in 1974, as a way of depicting the super-thin order to describe the super-thin transitioning of materials with Nano-meter accuracy and the formulation of Nano-sized gadgets. In the later segment of the 1980s to early 1990s, some significant findings and creations were made which brought about an important mark on the elaborate improvement of nanotechnology. After this time, a substantial rise in nanotechnological studies and designs have been employed and the proportion of work published on nanotechnological subjects increased sharply, with functional utilization of nanotechnology expanded. Financing of schemes in nanotechnology rose greatly, in addition to the count of institutions and nations engaged in it.

The beginning of the 2000s saw growth in commercial utilization of nanotechnology was grown. The NNI of the USA was certified in 2001. The philosophy of this programme was as follows: that the “National Nanotechnological Initiative defines the strategy of interaction between federal departments of the USA for the objective of highlighting nanotechnology development, which the economy and national safeness of the USA in the early part of the 21st century will be based on”. Western Europe countries carried studies in nanotechnology within the scheme of national programmes. In Germany for example, studies in nanotechnology were mainly backed by the Ministry of Education, Science, Research and Technology. In England, nanotechnology development was administered by the Council of Physics and Technology Research and the National Physical Laboratory. France’s nanotechnology development strategy was characterized by the National Center of Scientific Research. More attention is currently being accorded to the advancement of nanotechnology in China, South Korea and other emerging technology countries. Li, Lin, Chen, and Roco (2007).

BASIC THEME OF NANOTECHNOLOGY

When materials are at nanoscale, quantum mechanics and statistical mechanical effects play a pivotal role. The laws governing quantum mechanics are at variance with those of classical physics, denoting that the characteristics of materials at the nanoscale are at variance with normal reasoning. These observed effects do not result from going from macro to micro dimensions, they only becomes prevailing as the nanometer dimension domain is entered. Additionally, many physical (mechanical, electrical, optical, etc.) characteristics are altered when contrasted with systems that are macroscopic. A rise in the ratio of surface area to volume at nanoscale changes the mechanical, thermal and catalytic characteristics of matter. For instance, as a result of a rise in surface area, melting points may be altered and opaque materials are transformed to transparent ones (copper); inert substances mutate to catalyst (platinum); stable substances become combustible (aluminium); solids become liquids at room temperature (gold); insulators change conductors (silicon). A substance like gold, that is chemically unreactive when in the normal dimension,can be used a powerful catalyst at the nanoscale. Li et al (2007), Wang, Xie, and Li (2009).

Generally, nanotechnology systems use less less energy, avoid material wastes, and aid in surveillance.

Approaches Employed in Nanotechnology

Two approaches are employed in nanotechnology:

a. Bottom-up approach:

   Here, substances and mechanisms are made from microscopic elements that gather together chemically by the principle of molecular recognition. Simply placed, minute constituents are placed into more elaborate constructions.

b. Top-down approach:

   Here, nano-stuffs are devised from weightier stuffs excluding the utilization of atomic scale oversight. Commonly placed miniature stuffs are devised by plying weightier stuffs to manage their construction.

IMPRINT AND UTILIZATIONS OF NANOTECHNOLOGY

Potential Environmental Effects

Nanoparticles are known to possess higher surface areas than bulk substances. This can result in more harm to both humans and the environment in comparison with bulk particles. Consequently, anxiety for the possible risks that can emanate from nanoparticles to the society has drawn both national and international attention. Nanoparticles are very beneficial in tailoring the attributions of polymeric composite materials and environment in air pollution monitoring, they also help in reducing material consumption and remediation. For instance, coatings that are hinged on carbon nanotube and grapheme have been formulated to lower weathering effects on composite materials used for the formation of wind turbines and aircraft. Graphene is considered to be a superior nanoscale addition to abate the degeneration resulting from UV exposure and salt. Employing nanotechnology in applying nanoscale coatings on existing substances makes such substances to be more durable last longer amid keeping their initial strength for a longer time when exposed to salt and UV. Carbon nanotubes have been employed in increasing the performance the performance of data information system. However, some concerns of possible hazards should be considered in using nanoparticles. Chen, Lin, Rooks, and Avouris (2007).

Carbon nanotubes are utilized in many substances for memory storage, electronics, batteries, have applications in many materials for memory storage, electronic, and batteries to mention but a few Chen, et al. (2007). But a number of scientists have worries over nanotubes due to some unfamiliar hazards to humans through inhalation. Preliminary evidence submits that the toxicity from carbon nanotubes are similar to those of asbestos fiber.

Negative Effects on Environment

Knowledge of the outcome and hazards associated with nanotechnology on the environment is very minute and conflicting. The likely hazards to the surrounding may be summed up as follows:

- Colossal energy needs for manufacturing nanoparticles resulting in enormous energy requirement
- Dispersal of poisonous, persistent nanosubstances causing environmental damage.
- Smaller rate of restoration and reuse.
- Environmental nature of various life cycles levels are not also clear.
- Absence of competent personnel instigation more worries.

Positive Effects on Environment

Nanotechnology gives possible monetary, communal, and environmental advantages. Nanotechnology additionally possesses the potentiality of helping to abate mankind's activities on the environment by giving a remedy to lessen energy depletion, contamination, and greenhouse gas release. In Kumar & Mohammad (2011), Nanotechnology offers possibilities for remarkable environmental advantages which include:

- Purer, more proficient production processes.
- Enhanced potentiality of detecting and preventing contamination by enhancing air, water, and soil quality.
- High accuracy fabrication by minimizing the quantity of waste.
- Pure available energy through more proficient solar cells.
- Elimination of greenhouse gases and other contaminants from the atmosphere.
- Reduced requirement for big manufacturing plants.
- Remediating environmental damages.

Utilizations of Nanotechnology

- Carbon nanotubes, a nano material, have uses in lots of substances used in memory storage devices, electronic, batteries, etc Chen et al (2007).
- Applied in Nano devices, Nanoelectronics, and Nanosensors.
- By employing nanotechnology in applying nanoscale coating, Graphene, on present substance, the substance will stay longer and also keep the primal sturdiness for a longer time when exposed to salt and UV.
- Medical applications-medical devices, drugs and diagnosis Ellenbogen & Love (2000), Orive, Hernandez, Gascon, and Pedraz (2005).

Current utilizations of nanotechnology in consumer products (NCP) trans-continentally are shown in table 1.

Table 1
Current Applications of NCP trans-continentally

Automotive	**Clothing and Textiles**	**Cosmetics**
Air and Oil filters	Wrinkle and stain resistant apparel	Skin creams and moisturizers
Waxes, engine oil	Anti-bacterial and anti-odour clothing	Skin cleansers
Anti-scratch finishes	Anti-bacterial fabrics	Sunscreens
Car wax	UV resistant and protective clothing	Lipstick, mascara, make-up foundations, Make-up removal
Air purifier	Flame retardant clothing	
Catalysts to improve fuel consumption, Tires.		
Electronics	**Food, Food Additives and Food Packaging**	**Household**
Batteries	Energy drinks	Anti-bacterial furniture and mattresses
Display-electronics	Nutritional supplements	Anti-bacterial coating in appliances
Organic Light Emitting Diodes(OLED) and LEDs	Food storage containers	Filters
Data memory	Anti-bacterial utensils	Air purifiers
Anti-bacterial and anti-static coatings on keyboards, mouse, cell phones	Cutting boards	Self -cleansing glasses
DVD coatings	Plastic wrap	Anti-bacterial, UV resistant paints
MP3 players	Food packaging	Irons, vacuums
Computer processor and chips	Nano-tea, chocolate, shakes, canola active oil	Solar cells
		Cleaning products
		Disinfectant sprays
		Fabric softeners
Personal care/Health	**Sports Equipment**	**Toys and Children's Goods**
Hearing aids	Golf balls and clubs	Stain resistant plush Toys
Contact lenses	Tennis Rackets and balls	Anti-bacterial baby pacifiers, mugs and bottles
Body wash	Baseball bats	X-boxes and play stations
Cellulite treatment	Hockey sticks	anti-bacterial stuffed toys
Tooth powder	Skis and snowboards	
Shampoos, hair gels	Ski wax	
Deodorants	Bicycle parts	
Insect repellents	Wet suits	
Anti-bacterial creams	Shoe insoles	**Medical Applications**
Bandages	Anti-fogging coatings	Drugs
Home pregnancy tests		Medical appliances
Drug delivery patches		
Man-made skin		

NANOMATERIALS AND NANODEVICES

Nanomaterials

Nanomaterials are simply stuffs that are of average grain size lower than 100 nanometers; they may as well be described as materials that are made up of nanoparticles, and thus can provide enhanced characteristics like lesser mass and greater strength. One nanometer is one millionth of a millimetre, just about 100,000 times lesser than the breadth of a human hair. Nanomaterials form a link between atomic, molecular and bulk structures. Recent or enriched dimension- and pattern-dependent characteristics are revealed when juxtaposed with their correlative bulk substances. Nanomaterials fascinate in that at this scale, distinct and very distinguishable optical, magnetic, electrical, and other characteristics appear. These new characteristics that show up have the potentialities to enormously impact electronics, medicine, and other disciplines. The two fundamental reasons that account for the varying characteristics of materials at the nanometric size are the enlarged relative surface area and new quantum effects. Examples of Nanomaterials comprise: Carbon nanotube, Graphene, Fullerene, Nanoparticle, Nanofiber, Nanowire, Nano composite, Nano compound, dendrimers. Kumar & Mohammad (2011), Collins, Zettl, Bando, Thess, and Smalley (1997), Das & Ansari (2009).

Categorization of Nanomaterials

Nanomaterials are categorized as stuffs that have not less than one of their compositions in the nano-metric scale, beneath which there are remarkable disparities in the attributes of concern contrasted with microcrystalline substances. Siegel categorized nanostructured materials into four classes on the basis of dimensionality as zero dimensional, one dimensional, two dimensional, and three dimensional nanostructures Liu, Tabakman, Welsher, and Dai, (2009).

In this work, categorization is predicated on the count of dimensions, i.e classical or 'normal' dimensions that are not restricted to the nanoscale region (<100 nm):

1. 0-D: all dimensions are in nanoscale
2. 1-D: two nanoscale, and one macro scale dimensions
3. 2-D: one nanocale, and two macroscale dimensions
4. 3-D: all dimensions are in macroscale.

Nanomaterials are materials that are made distinct by ultra-fine grain size (< 50 nm) or by a spatiality restricted to 50 nm. Nanomaterials can be produced different variation of dimensionalities: zero (atomic clusters, filaments and cluster assemblies), one (multilayers), two (ultrafine-grained over-layers or buried layers), and three (nano-phase materials consisting of equiaxed nanometer sized grains) as presented in figure 1.

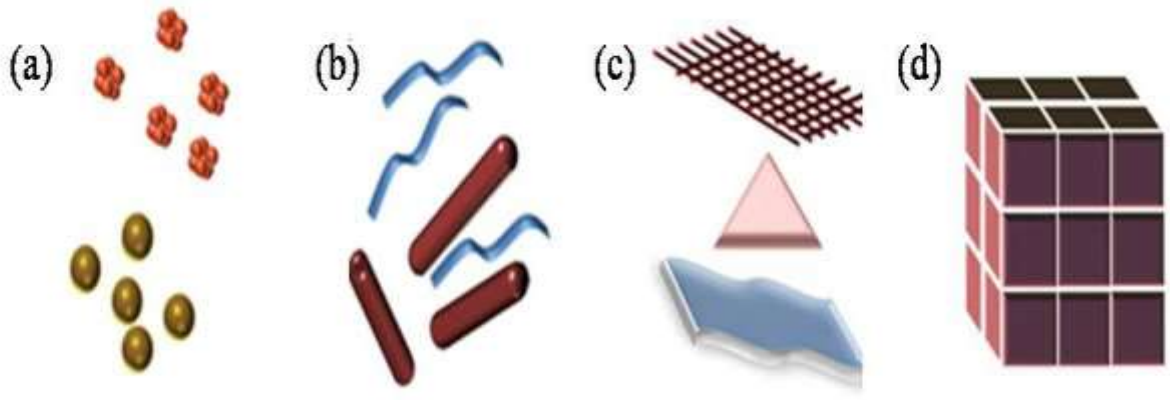

Figure 1: Classification of Nanomaterials: (a) 0-D Spheres and Clusters, (b) 1-D Nano-fibers, Wires and Rods, (c) 2-D Films, Plates and Networks, (d) 3-D Nanomaterials. Liu et al (2009).

Different Architecture of Nanomaterials

Since the attributes of nanostuffs are predicated on the surface area, one can cause surface changes in an assortment of ways to culmunate in a corresponding variation in their properties. Various architecture are here shown in figure 2 below.

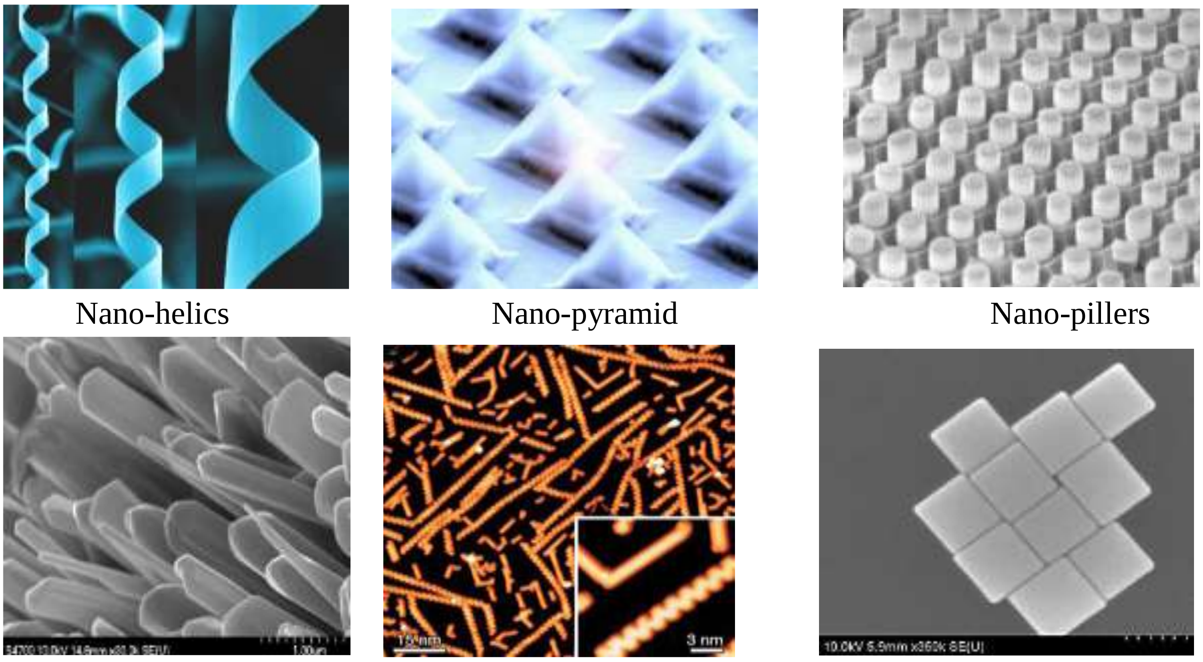

Figure 2: Different Architectures of Nanomaterials Liu et al (2009).

Properties of Nanomaterials

While the attributions of most micro-structured materials are same as their equivalent bulk materials, the attributions of nanomaterials within the nanometric scope are remarkably dissimilar to those of atoms and bulks materials. When materials are at the nanoscale, attributes like electrical conductivity and mechanical strength are quite different from their corresponding bulk size. At nanoscale electronic structure of materials changes dramatically too. This is substantially because the nanometer size of the stuffs confers on them these characteristics:

a. large portion of surface atoms;
b. high surface energy;
c. spatial confinement;
d. lower deformities that are absent in equivalent bulk materials.

In sync with surface-area effects, quantum effects control the attributions of matter as the dimension diminishes to the nanoscale. This can impact the optical, electrical and magnetic features of materials, especially as the structure or particle dimension gets hither to the lower limit of the nanometric size.

Generally, characteristics displayed by nanostructured substances are electrical, structural, chemical, magnetic and catalytic characteristics, including metals and semiconductor plus their electronic and optical characteristics. Ziolo (1992).These fascinating characteristics enable the nano-structured materials to be plied in new implementations in the sector of information storage, magnetic refrigeration and as ferro-fluids etc. Norton, McIlroy, Corti, and Miller (2009), Raj, Moskowitz, and Casciari (1995), Shull (1993).

Nano-Based Devices

Nanodevices are the crucial facilitators which shall enable humankind to make excellent use of the eventual technological potentialities of electronic, magnetic, mechanical, and biological systems. Albeit now, the prime model of nano-based devices are allied to the information technology manufactory, the capability for such appliances is profuse. Nanodevices will eventually impact largely on our capacity in improving energy conversion, pollution control, food production, and add to our wellness and life expectancy. Nanodevices include: Quantum dot, Photonic crystal, MRAM, and Spintronics. Dalvinder (2018),Worner (1998) .

Classification of Nano-based Devices

At the likelihood of establishing a few perplexity, in this paper, nanodevices are categorized by their main feature nanodimensions, i.e. number of nano-scale dimension(s) set against their macro-scale dimensions that were used in classifying nanomaterials. In this categorization, we have that:

1. Zero-dimensional (0-D): three dimensional nanotechnologies
2. One-dimensional (1-D): two dimensional nanotechnologies
3. Two-dimensional (2-D): one dimensional nanotechnologies

Thus, two- dimensional systems like two-dimensional electron gases and quantum wells concerning classification of Nano-devices are one-dimensional nanotechnologies, nanowires are two-dimensional nanotechnologies, and quantum dots are three-dimensional nanotechnologies. Some examples are high electron mobility transistors, heterojunction bipolar transistors, resonant tunnelling diodes, and quantum well optoelectronic appliances such as lasers and detectors.

ADVANCES IN NANOTECHNOLOGY

Nanotechnology is gaining importance rapidly as a very powerful technology. Its tremendous plausibility assures the prospect of momentous transformation in the nearest future anytime the prime equipment - the Universal Assembler and the Nanocomputer are put together. Some progress in the area of nanotechnology are listed as follows Virji, Kojima, Fowler, Villanueva, Kaner, and Weiller, (2009), Wang, et al. (2009), Ferrari (2005):

Energy Harvesting for Self-Powered Nanosystems

Other than the popular solar cell and thermoelectrics that have the capability of energizing nanosystems, other energy harvesting technologies exist. Piezoelectric nanogenerators is built by utilizing aligned ZnO nano wires arrays Thurn-Albrecht, Schotter, Kastle, Emley, Shibauchi, Krusin-Elbaum, and Russel (2000). It is a prospective technology which could be employed in transforming the energy generated from mechanical movement. A prominent benefit of nano-based gadgets and systems is their capability of typically working with extremely smaller power almost nW to µW. Consequently, the energy gathered from the surrounding would be enough to energize the system. Biochemical fuels are mechanical energy, vibrational energy, chemical energy, and hydraulic energy. If a little portion of these energies may be transmutted into electrical energy, it would possibly be enough to energize miniature gadgets for biomedical utilizations Wang, et al. (2009).

Chip Fabrication

Intense ultraviolet lithography utilizes mirrors to guide light with a wavelength of 13nanometers to print features at 32-nanometer dimension. The smaller dimensions will give rise to very high speed chips Chen, et al. (2007), Collins et al (1997), Worner (1998).

Batteries

Lithium ion batteries made with multiwalled nanotubes guarantee more safety and are more effective; they possess more lifespan reaching 10 times added to more power up to 5 times above the power on hand. They are at the moment available for sale. Li et al (2014).

DVDs

Quantum dots-semiconductor crystals which are only a handful of nanometer broad give the desired accuracy for Blu-ray and HD DVD blue lasers. Grewal (2018), Hyunwook et al (2011).

Aerospace Materials

Unmistakably, many benefits will exist of stuffs that are sturdier than available stuffs 100 times. Tools fabricated out these materials would be about 100 times more underweight, utilizing 100 times shy of the proportion of material. This feature could be elevated close to 250 times if diamondoid composite is used. Thence, ultra-light autos, Lorries, locomotives, airplane, and spacecraft will consume very little energy, particularly with atomically polished skin to lower inner drag pls air resistance wastes. The amount spent on space travel could be lowered significantly employing by-products of nanotechnology Worner (1998), Globus, Bailey, Han, Jaffe, Levit, Merkle, and Srivastava (1998).

Nanovector

A hollowed-out solid system, having dimension within 1-1000 nanometer region which could be loaded with anticancer medicine and location agents. Orive et al (2005). Targeting moieties could be fastened to the exterior. Nanovectors would be plied in directed gene treatment. Liposome, a kind of nanovector is composed of lipids encircling a water nucleus.

Nanowires

Semiconductor nanowires are one- dimensional systems, with exclusive electrical and optical characteristics, that are employed as the constituents in nanoscale appliances. Stripped or 'superlatticed' nanowires can operate as transistors, LEDs plus more optics- based electronic appliances, alchemical sensors, heat-pumping thermoelectric systems, or all the mentioned devices having identical measure of wire Tian, Zheng, Kempa, Fang, Yu, Yu, and Lieber, (2007).

Single Molecule Logic Gates

A MLG is a molecule which carries out a logical process on either one or many logical inputs and gives a single logical output. Characteristic MLG operates with input signals predicated on chemical procedures and with out-turn predicated on spectroscopy. Quantum mechanical computations are carried out to classify lots of the electrical features of the molecular diodes switches. Clear constructional designs are depicted for AND, OR and XOR gates that are created from molecular wires and molecular diode switches. These models harmonise with conductive monomolecular circuit systems which will be lesser in area by a million times than their equivalent micron-scale digital logic circuits built on traditional solid-state semiconductor computer chips. Ellenbogen & Love (2000), Hyunwook et al (2011), Oyubu & Kazeem (2020).

Nanopens and Nanopencils

Also known as atomic pencil, it is comparable to making use of a quill pen; however, in the neighbourhood of a billionth scope. It has the potentiality to redefine dip-pen nanolithography. It enables drawing electronic circuits which are by far smaller compared with the present-day types by a factor of 10^3. The "pen" is an AFM. Fulekar (2010), Shafiq & Chan (2011).

Nanoplotter

A multi-tip nanopen is appliance which can create small and slight markings of 30 molecules broad, with the height of a mono- molecule. It creates eight similar markings per time and lengthens them. Nanolithography hinged on dip-pen is a move geared into the mass fabrication of nanometric gadgets plus circuits by transforming serial operations into parallel ones. (This could be employed to diminish electronic circuitry, configure accurate arrangements of organic biomolecules such as DNA and cram thousands of variety of medical sensors in a region far lesser in comparison with a pin head) Hong & Mirkin (2000).

CONCLUSION

Nanotechnology which is perceived as the nerve centre of technological advancement in the 21st century and beyond will undoubtedly continue to progress plus benefit mankind and the surrounding in diverse ways. The potential utilizations in multifarious sectors including electronics, communication, medicine and health care system, manufacturing, textile and clothing, automotive industry among others make it an exciting technology which has the answer to revolutionize everything. It is the morrow of advanced development that may be plied to improve current inventions and procedures which will ultimately impact global life style, human behaviour, and society at large.

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