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APPLICATION OF NANO TECHNOLOGIES AND NANO MATERIAL IN ELECTRONIC WITH HEALTH HAZARDS

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ABSTRACT

Nanotechnology refers to technologies that operate at the nanometer level (one billionth of ameter). Nanotechnology is a growing scientific field with applications in many different areas,including in electronics. The production of electronic chips for mobile phones and computers that have lines etched on them only 65 or 90 nanometers wide has already been commercialized. Such uses of nanotechnology in electronics to miniaturize electronic components do not in themselves pose any threats to human health, although there may be additional concerns arising from novel processes and/or process chemicals necessary to carry out such nanoscale constructions[1]. Importantly however, there are uses of nanotechnology in electronics and electrical goods that dogive rise directly to environmental and human health concerns. This is the use of syntheticallyproduced nanoparticles in 'nanomaterials' to make electronic components or surface coatings for electrical goods. Nanomaterials are commonly defined as materials designed and produced tohave structural features with at least one dimension of 100 nanometers or less. In electronics, anumber of different nanomaterials are already being used commercially or are being used forresearch and development purposes. Some of the most commonly used nanomaterials forelectronic and electrical equipment are carbon nanotubes and quantum dots and, in the case ofsurface coatings, nanoparticles of silver.

Problem statement and approach- This article discusses the use of nanotechnology to produce smaller circuits , the use of nanoparticles in electronics and the use of nanomaterial coatings in electronic and electrical equipment. Also, looks at the toxicology of nanomaterials which are currently used in electronics and electrical equipment.

Keywords- *Nanotechnology, Nanomter etc*

I. INTRODUCTION

The term 'nano' is used in science as a prefix meaning one billionth (using billion in itsAmerican sense of a one followed by nine zeros). A 'nanometer' therefore means one billionth of a meter and it is exceedingly small – about 10 atoms across. Nanotechnology refers to technologies that are working at the nanometer level [1] and, as such, encompasses both a) techniques used to manufacture products with nano-scale characteristics and b) nanomaterials manufactured by whatever means. Both aspects have relevance in the fieldof modern electronics. Nanoparticles can theoretically be produced artificially from nearly any chemical. Presently, most nanoparticles that are in use have been made from transition metals, silicon, carbon (carbon nanotubes, fullerenes) and metal oxides (zinc oxide and titanium dioxide). In some cases, engineered nanoparticles exist as nanocrystals composed of a number of compounds such as silicon and metals (as is the case for quantum dots). In electronics, the present method used in the manufacturing of electronic devices is called "top down" (i.e. manufacturing nanoscale components and materials from larger starting materials) though scientists are now also developing a new approach based on self-assembly of atoms and molecules, the so-called "bottom up" approach. Top down nanotechnology has enabled the production of progressively smaller structures to be made using lithography and related techniques for the construction of electronic components and micro-electro-mechanical systems (MEMs) [2]. Top down nanotechnology has, for example, led to the hugely successful semiconductor- and information-andcommunications- technology- (ICT-) industries, as well as the manufacture of tiny micromechanical machines for sensing and actuation (MEMs). Bottom-up technology is a promising alternative to top down, one which enables building of nanodevices and/or nanomachines starting from molecular building blocks instead of lithographically carving bigger pieces of matter into smaller and smaller pieces [2]. The self-assembling properties of biological systems, such as DNA molecules, may be used to control the organisation of nanoparticles such as carbon nanotubes. This may lead to the ability to 'grow' parts of an integrated circuit, rather than relying on top down techniques [1].

Uses of nano materials in electronics-

Some of the existing or emerging uses of nanomaterials in electronics include:
- the use of carbon nanotubes in semiconductor chips;
- research into the use of a variety of nanomaterials in lighting technologies (light emitting diodes or LEDs and organic light emitting diodes or OLEDs), with commercial use expected in the near future;
- use of 'quantum dots' in lasers, along with ongoing research into application of other nanomaterials in laser technology;
- a variety of nanomaterials used in lithium-ion batteries, or which are being researched for this use;
- potential use of carbon nanotubes and other nanomaterials in fuel cells and by the solar industry for use in photovoltaics.
- research into use of nanomaterials to produce lead-free solder, as well as the development of solder-free assembly technology. In addition to the use of nanomaterials in electronics, some nanomaterials are also being used as surface coatings in certain electrical goods, primarily because they have anti-microbial properties. Products already marketed as having 'anti-microbial' nanomaterial coatings include refrigerators, vacuum cleaners, washing machines, mobile phones and computer mice.

II. NANOTECHNOLOGY IN ELECTRONICS MANUFACTURE

Traditional electronic circuits are built by etching individual components into silicon wafers. Commercialisation of integrated circuits (IC) and the creation of the microelectronics industry began in 1965 using silicon processing technology [3]. Over time, there has been ever-increasing progress in the technology being used and, in parallel, a progressive reduction in size of circuits. Such rapid technological progress was first predicted in 1965 by Gordon Moore in the now famous 'Moore's Law', which stated that integrated circuit density and performance would double every 18 months. This has broadly held true, the improvements being brought about by reduced transistor dimensions, increased transistor counts and increased operating frequencies.Circuits have reduced in size over the years to such an extent that current generations of chips may carry circuits only 65 nm wide and more than a million transistors on a single piece ofsilicon a few millimetres across [1]. The field effect transistor (FET) was first scaled below 100 nm in the year 2000, inaugurating the era of silicon nanoelectronics [3]. The term 'nanoelectronics' (circuit dimension less than 100 nm) can therefore now be used instead of 'microelectronics'.Presently 65nm and 90nm process technology is being used to manufacture chips. According to research conducted by the Woodrow Wilson International Centre for Scholars inWashington DC, products on the market using 65 nm or 90 nm technology include:
- Intel Pentium D Processor, Intel Pentium 4 Processor, Intel Core Duo Processor and Intel StratFlash Cellular Memory by Intel;
- XBOX 360 by Microsoft;
- AMD Athlon 64 FX Processor and AMD Athlon 64 X2 Dual-Core Processor by AMD;
- IBM PowerPC 970FX/970MP Processor by IBM; and
- iMac G5 and IPod Nano by Apple Inc. (using memory chips from Samsung and Toshiba).

(Woodrow Wilson International Centre for Scholars 2006)

The same study also noted that many current flash memory chips are based on 90 nm fabrication technology.

III. NANOMATERIALS IN ELECTRONICS

While the manufacture of chips described above uses nanotechnology, it does not use nanomaterials in the sense of free or bound nanoparticles. However, such nanomaterials are also being used in electronics. Some of the most common nanomaterials being investigated and used are carbon nanotubes and quantum dots, a description of each of which is given below.

Carbon Nanotubes and Fullerenes

Fullerenes are a family of substances made of carbon in the form of a hollow sphere, ellipsoid or tube. Spherical fullerenes are commonly known simply as fullerenes (C60) or now less frequentlyas 'Bucky balls' (after Richard Buckminster Fuller who popularised in architecture the geodesicdome structures which these molecules resemble) and have been researched for use in electronicsand other applications. Tubular fullerenes, generally called carbon nanotubes, are considered as possibly the most famous objects in nanotechnology and possess extraordinary properties arising from their nanoscopic dimensions. They were discovered in 1991 in the insoluble material of arc-burned graphite rods. Carbon nanotubes are molecules which are composed only of carbon atoms and are markedly different from bulk graphite. They can be viewed as a graphene sheet rolled into a cylinder and seamlessly welded together. Carbon nanotubes exist in either of two forms, singlewall carbon nanotubes and multi-wall carbon nanotubes. Single-wall nanotubes consist of a single graphene layer while multi-wall nanotubes consist of multiple concentric layers . In addition to the synthetic production of carbon nanotubes for research and commercialpurposes, it has recently been discovered that multi-wall carbon nanotubes were present inparticulate matter collected from propane or natural gas kitchen stoves. Carbon nanotubes can be either 'metallic' or semi-conducting depending on the actual way in which the carbon atoms are assembled in the tube. The metallic forms possess electrical conductivities 1000 times greater than copper and are now being mixed with polymers to make conducting composite materials for applications such as electromagnetic shielding in mobile phones and static electricity reduction in cars. Their use has been demonstrated in supercapacitors for energy storage, field emission devices for flat panel displays and nanometer-sized transistors [1].

Quantum Dots

Quantum dots are semiconductor nanocrystals (2-100 nm) which have unique optical andelectrical properties. In structure, quantum dots consist of a metalloid crystalline core and a 'cap' or 'shell' that shields the core. Quantum dot cores can be formed from a variety of metalconductors such as semiconductors, noble metals and magnetic transition metals. The shells are also formed of a variety of materials. Therefore, not all quantum dots are alike and they cannot be considered to be a uniform group of substances . With regard to the cores of quantum dots, group III-V series quantum dots are composed of mixtures of compounds such as indium phosphate (InP), indium arsenate (InAs), gallium arsenate (GaAs) and gallium nitride (GaN). Group II-IV series of quantum dots are composed of mixtures of compounds such as zinc sulfide (ZnS), zinc-selenium (Zn-Se), cadmium-selenium (CdSe) and cadmium-tellurium cores (CdTe) .

Use of Nanomaterials in Chips

The company Nantero Inc. announced in November 2006 that it has developed the technology to produce semiconductors using carbon nanotubes on silicon wafers and has been issued patents on the process [4]. Nantero is developing a high density nonvolatile random accessmemory chip called NRAM (Nanotube-based/Non-volatile random access memory) chip. NRAM is slated to replace DRAM (dynamic RAM), SRAM (staticRAM), flash memory and ultimately hard disk storage. In other words, according to themanufacturers, NRAM is a universal memory chip suitable for countless existing and newapplications in the field of electronics [4].IBM has developed carbon nanotube transistors. They are working towards the development ofchips using nanotubes, and have announced in 2006 that they had succeeded in building acomplete electronic integrated circuit around a single carbon nanotube molecule. This was builtusing standard semiconductor processes and was described as "a critical step toward theintegration of the technology with existing chip-making techniques" (IBM 2006).Intel is looking at the possible replacement of copper wires inside semiconductors using carbonnanotubes. However, due to difficulties with the technology they say that use of nanotube interconnects in commercial chips is likely to be several years away .

Use of Nanomaterials in Lasers

Research is being conducted on making laser devices from arrays of semiconductor nano-dots and nanowires. If successful, this technology is expected to bring about miniaturisation and power efficiency improvements compared to other laser devices. The company Fujitsu, in combination with the University of Tokyo, has developed and commercialised a quantum dot laser. The company say that quantum dot lasers are significantly superior to conventional semiconductor lasers and it is anticipated that they will become a core technology to realize high-performance light sources for optical telecommunication.

Use of Nanomaterials in Batteries

The properties of carbon nanotubes make them potentially useful as an anode material or as an additive in lithium-ion (Li-ion) battery systems. In 2005, one article noted thatthe anode of Li-ion batteries is primarily made from various carbonaceous materials but thatcarbon nanotubes promise to boost this rate of growth, either by themselves or whenincorporated into appropriate composite material (Carbon Nanotubes Monthly 2005). Gröning(2005) wrote that the predominant part of commercially produced carbon nanotubes is used forthe manufacturing of porous conductive electrodes for Li-ion batteries.In 2005, Toshiba launched a rechargeable Li-ion battery which used ‘nano-particles’, although it is not clear whether carbon nanotubes or another nano-material is used. AltairNanotechnologies Inc. developed a nano-titanate material which it uses commercially in Li-ionbatteries (personal communication). A123 has developed and commercialised Li-ion batteriesbased on nanophosphate technology (A123 2006). Other nanomaterials under investigation foruse in Li-ion batteries are nanoparticles of vanadium, manganese and cobalt compounds.

IV. NANOTECHNOLOGY COATINGS

Coatings containing nano-particles are already being used in some electrical products.Coatings developed for anti-microbial properties generally contain silver nano-particles. Silverhas natural anti-bacterial and anti-fungal properties and silver engineered into nano-particle sizeincreases the surface area in contact with micro-organisms which, in turn, improves its bacterialand fungicidal effectiveness. Products using silver nano-particle coatingsinclude:

- Daewoo refrigerator – using “Nano Silver Poly technology”, in which particles of silver are mixed in plastic resin. It is applied to major parts of the refrigerator in order to restrain the growth and increase of a wide variety of bacteria and to suppress odours.
- Daewoo vacuum cleaner – the vacuum cleaner has a nanosilver-coated ‘cyclone canister’ that allegedly has the effect of removing bacteria and a plethora of dust particles, inhibiting odour, allergy-inducing spores, and other harmful debris.
- Daewoo washing machine – again uses Nano Poly Technology by which, according to the manufacturer, “many hurtful bacteria in clothes shall be sterilized perfectly” .
- Antibacterial mobile phones – LG Electronics use a Nano Silver antibacterial coating on their mobile phone . The Motorola i870 mobile phone has an anti-bacterial coating made from silver zeolite nanoparticles.
- Germ free wireless laser mouse by IOGEAR Inc. - coated with a titanium dioxide and silver nanoparticle compound. According to the manufacturer, “the special coating protects users from bacteria and germs by neutralizing the harmful microbes on the mouse”.

Besides using silver nanoparticles as coatings, Samsung have developed techniques for using them in the wash cycle – the so called ‘silver wash’ technology which is designed to improve the washing of clothes. According to Samsung, their ‘silver wash’ system:-

“…is an advanced washing technology with superb bacteria killing capabilities. Imagine 400 billion silver ions dissolved in water to make a super cleaning solution that affects your clothes at an almost molecular level. Its sterilizing ability of 99.99% and lasting antibacterial action will redefine your idea of purity. SILVER WASH utilizes 99.99% pure silver for a lasting investment for your health and garment.

“SILVER WASH uses nano technology to electrolyze pure silver during wash and rinse cycles. Over 400 billion silver ions are released and penetrate deep into fabric for effective sanitization…”

“Silver Nano particles are dispensed in the washing and rinsing cycles. These silver particles can sanitize and disinfect fabrics throughout the life of the washing machine... And not only does its effect protect your fabrics, it also disinfects your drum and all its internal parts”.

The commercialization of the silver wash by Samsung has led to concerns regarding toxicity risks to the environment and human health. Concerns have led to the withdrawal of Samsung’s silver washing machine from Sweden. Friends of the Earth are calling for its withdrawal from the market in Germany and Australia. The US EPA has announced it will move to introduce the world’s first nanotechnology-specific regulations. Under the EPA proposal, products which contain nano silver and claim to provide ‘anti-bacterial’ properties will be regulated as pesticides . However, the EPA's decision may not be effective, critics point out,because if the company deletes from its advertising the assertion that silver can kill bacteria, itwon't have to register the washer. Consequently, the Natural Resources Defence Council haveurged the EPA to review all consumer products containing nanosilver and require manufacturersto register such products as a pesticide .

V. EXPOSURE TO, AND TOXICITY OF, NANOMATERIALS

Consideration of the possible health risks of nanotechnology falls into two categories, those where the structure itself is a free particle and those where the nanostructure is an integral feature

of a larger object . In consideration of health risks, the latter case would not beconsidered to pose immediate risks to human health or the environment from the nanotechnologyitself. For instance, in electronics, the use of nanotechnology to build smaller circuits down to thenanoscale, that is, using 65nm and 90nm process technology in the manufacture chips, may not
be considered in itself to present substantial risks to the environment or human health, although
there may be additional concerns arising from novel processes and/or process chemicalsnecessary to facilitate such nanoscale constructions.Conversely however, the manufacture, use and disposal of materials comprising or containingfree or bound nanoparticles, for the production of nanomaterials such as carbon nanotubes ornano-silver, does give rise directly to human health and environmental concerns. This is becausenanoscale materials typically have markedly different properties (e.g. chemical, mechanical,electrical, magnetic, biological) to the original (chemically identical) material at larger scales.vThese properties may in turn lead to biological activity that differs from, and cannot be predictedfrom, the bulk properties of the constituent chemicals and compounds .The assessment of the toxicity of nanomaterials (‘nanotoxicology’) and their environmental fateremains very much in its infancy, well behind the commercial development and ongoing use ofsuch materials in applications (including hundreds of consumer products) which ultimately resultin releases of free nanoparticles to the environment. Deliberately manufactured nano-materials are likely to enter the environment from
manufacturing effluent or from spillage during shipping or handling. Within products such as
electronics, the extent to which nano-materials may leak out or be worn off over the period of
use is not known as no research has been done on this subject. It is possible that nano-materials
from electronics may also reach the environment when they are disposed of, during recycling,
disposal in landfills or by other methods. With regard to humanexposure, occupational exposure during manufacturing process may arise from particles in nanomaterialsbecoming airborne and then being inhaled. Research into the potential occupationalhealth risks associated with inhaling engineered nano-structured particles is only just beginning. Inhalation may be the major route of occupational exposure butingestion and dermal exposures during manufacture, use and disposal of engineerednanomaterials also needs to be considered .Particular concern regarding exposure and potential health impacts of nanomaterials has arisendue to past knowledge of the hazards of exposure to nano-sized particles generatedunintentionally as a component of air pollution, either in the work place or in the urbanenvironment. Exposure to these so called ‘ultrafine’ particles (defined as particles <100 nm) cancause inflammatory responses in the lungs in laboratory animals and has been associated withadverse respiratory and cardiovascular effects in humans resulting in illness and mortality insusceptible sub-groups within the human population. In animals, suchparticles have been shown to be deposited in the lungs after inhalation and can enter the bloodand lymph circulation to reach other organs of the body such as the bone marrow, spleen, lymphnodes and heart . It has been noted that, because nanoparticles can passthrough biological membranes, they could affect the physiology of any cell in an animal body. Recently it was found that multi-wall carbon nanotubes werepresent in samples of particulate matter from outdoor air, with one possible source being vehicleexhaust fumes. Given their toxicological properties, it has been suggested that multi-wall carbonnanotubes could contribute to the adverse respiratory and cardiovascular effects of particulate airpollution, although this will require further study .Other research that has given rise to concerns in relation to nanomaterials, specifically to fibreshapedmaterials such as carbon nanotubes, is the substantive body of information regardingasbestos. The concern arises from the fact that there are structural similarities between nanotubesand asbestos fibres. Both are long, durable and have potential to reside in the lungs for longperiods of time . Fibre-shaped nanomaterials mayrepresent a unique inhalation hazard and their pulmonary (lung) toxicity should therefore beevaluated as a matter of urgency . Inhalation of asbestos can lead to increasedrisks of both non-malignant (asbestosis) and malignant lung diseases (lung cancer andmesothelioma) .
The size of a particle and its surface area are important characteristics of a material with regard
to its toxic potential, and nowhere more so than at nanoscales. As the size of a particle decreases,
its surface area increases in relation to its mass and this allows a greater proportion of atoms or
molecules to be displayed on the surface rather than the interior of the material .The increased number of active sites at the surface gives increased potential for biologicalinteraction and the intrinsic toxicity of the particle surface will beemphasized . Therefore, an engineered nanoparticle may have verydifferent properties and toxicological potential than its original macro-scale counterpart, despitebeing chemically identical. Even two nanoparticles made of the same elements but of differentsizes or chemical architecture may have drastically different properties .Therefore, the toxicity of a substance, such as pure carbon, is likely to differ from an engineeredcarbon nanomaterial such as carbon nanotubes.Because of their unique properties, including their possible toxicity, the hazards of nanomaterialsmust be assessed separately. The safety evaluation of nanomaterials cannot rely on thetoxicological and ecotoxicological profile of the bulk material that has been determinedhistorically using conventional toxicology. Since each engineered nanomaterial may havedifferent

toxicological properties, the safety assessment for engineered nanomaterials must beperformed on a case by case basis. Studies assessing toxicity of nanomaterials used inelectronics/electrical equipment, namely carbon nanotubes, fullerenes, quantum dots.

VI. CONCLUSION

The brief synthesis of data provided here indicates that nanomaterials are already receiving diverse and extensive usage by the electronics industry. Production is predicted to increase as research and innovation increases further the range of application on electrical and electronic equipment, as well as in many other commercial, medical and industrial products.Large scale production of nanomaterials will bring with it the likelihood of widespreadenvironmental contamination as well as possible exposure of manufacturing workers. Oncereleased into the environment, the ultimate fate and effects of nanomaterials remain poorlyunderstood and difficult to predict. Presently little is known about the environmental and healthhazards of nanomaterials, though the research on the toxicity of some nanomaterials as reviewed briefly above already gives rise for concern.Under these circumstances, where use of nano materials presents unknown but possibly detrimental environmental and human health hazards, it becomes logical to bring the precautionary principle into action. In this regard, Greenpeace is calling for an immediatemoratorium on the release of all nano materials and nano-products. It is deemed necessary that evaluation/assessment of proposed nano materials is conducted on a precautionary basis such that the “burden of proof” is reversed. This means that all nano materials are assumed hazardous, and regulated accordingly, until such time as sufficient evidence becomes available that the nano materials present no potential for hazards to ecosystems or human health. Implementation ofthe precautionary principle places the responsibility on industry and regulators to establish whether a product meets health, safety and ecological criteria before being approved for use andrelease. In the light of the ‘late lessons’ learned in the last decade from the failures in management of hazardous chemicals, the continued widespread commercial development and deployment of Nano materials in electronics (as in other sectors) without effective regulatory controls and in advance of completion of fundamental research and the development of essential assessment techniques can only be seen as an unjustifiable and irresponsible approach.

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