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Role of Nanotechnologies and nanomaterials in electrical and electronic goods: A review of uses and health concerns

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Abstract - Nanotechnology refers to technologies that operate at the nanometer level (one billionth of a meter). 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 commercialised. Such uses of nanotechnology in electronics to miniaturise 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 (Walters *et al.2006.*Importantly however, there are uses of nanotechnology in electronics and electrical goods that do give rise directly to environmental and human health concerns. This is the use of synthetically produced nanoparticles in 'nanomaterials' to make electronic components or surface coatings for electrical goods. Nanomaterials are commonly defined as materials designed and produced to have structural features with at least one dimension of 100 nanometers or less. In electronics, a number of different nanomaterials are already being used commercially or are being used for research and development purposes. Some of the most commonly used nanomaterials for electronic and electrical equipment are carbon nanotubes and quantum dots and, in the case of surface coatings, nanoparticles of silver.

Key Words: *Nanotechnology,Nanometer,carbon nanotube, Quantam dots*

1.INTRODUCTION

The term 'nano' is used in science as a prefix meaning one billionth (using billion in its American 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 (Whatmore 2006) 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 field of modern electronics.

Nanoparticles can theoretically be produced artificially from nearly any chemical (Dreher 2004). Such engineered nanomaterials are commonly defined as materials designed and produced to have structural features with at least one dimension of 100 nanometers of less. 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 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) (Dreher 2004)

2. Nanotechnology in Electronics Manufacture

Traditional electronic circuits are built by etching individual components into silicon wafers (Appell 2002). Commercialisation of integrated circuits (IC) and the creation of the microelectronics industry began in 1965 using silicon processing technology (Gargini 2004 Over time, there has been ever-increasing progress in the technology being used and, in 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 (Bohr 2002).

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 of silicon a few millimetres across (Whatmore 2006). The field effect transistor (FET) was first scaled below 100 nm in the year 2000, inaugurating the era of silicon nanoelectronics (Gargini2004). 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 (see list of products below). According to the company Intel, the next two process generations, 45 nm and 32 nm, are due to be produced in 2007 and 2009 respectively. Intel is now producing more than half of its mobile, desktop and server microprocessors using 65 nm process technology (Intel2006).

According to research conducted by the Woodrow Wilson International Centre for Scholars in Washington 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).

3. 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.

3.1 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 (C_{60}) or now less frequently as 'Bucky balls' (after Richard Buckminster Fuller who popularised in architecture the geodesic dome structures which these molecules resemble) and have been researched for use in electronics and 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, single-wall 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.

3.2 Quantum Dots

Quantum dots are semiconductor nanocrystals (2-100 nm) which have unique optical and electrical 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 metal conductors 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) (Hardman 2006).

4. 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. Silver has natural anti-bacterial and anti-fungal properties and silver engineered into nano-particle size increases the surface area in contact with micro-organisms which, in turn, improves its bacterial include:

 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

 Antibacterial mobile phones – LG Electronics use a Nano Silver antibacterial coating on their mobile phone (Woodrow Wilson International Centre for Scholars 2006). The Motorola i870 mobile phone has an anti-bacterial coating made from silver zeolite nano-particles (Motorola 2005).

"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…"

5. 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 (EC 2006). In consideration of health risks, the latter case would not be considered to pose immediate risks to human health or the environment from the nanotechnology itself. For instance, in electronics, the use of nanotechnology to build smaller circuits down to the

nanoscale, 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 chemicals necessary to facilitate such nanoscale constructions.

6. CONCLUSIONS

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.

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BIOGRAPHIES

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