When small means big: the impact of nanotechnology

Technology

A revolution inscience and technology, which will significantly impact our daily lives, is looming in the horizon. The scientific community is now excited by changes that could be brought about by the multidisciplinary discipline of nanoscience and nanotechnology, which is comprehensively defined as

“[r]esearch andtechnologydevelopment at the atomic, molecular, or macromolecular levels, in the length of approximately 1–100 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 size. The novel and differentiating properties and functions are developed at a critical length scale of matter typically under 100 nm.

Nanotechnology research and development includes integration of nanoscale structure into larger material components, systems, and architectures. Within these larger scale assemblies, the control and construction of their structures and component devices remain at the nanoscale”. (National Research Council 2002, cited in Dreher 2004).

Although technically encompassing any device measuring at least 1, 000 nanometers—a nanometer (from Greek ‘ nano’, meaning dwarf) is one-billionth of a meter (The Royal Society & The Royal Academy of Engineering 2004)—much of the work being done presently focuses on materials smaller than 100 nm (Gupta et al 2003) since it is at this level that materials exhibit unique physical and chemical properties that can be harvested to convey improvements to engineered materials (i. e. enhanced magnetic properties, better electrical and optical activity, and superior structural integrity) (Thomas & Sayre 2005).

Ralph Merkle, as cited by Gupta et al (2003), noted that atomic configuration, to an extent, determines physical and chemical characteristics of materials, using as examples carbon in diamond, or silica from sand. From this perspective, the manufacturing techniques we are using today appear crude since we are moving molecules by heaps and mounds, and, therefore, are manufacturing devices that could still be improved for accuracy and precision (Gupta et al 2003). Nanotechnology, according to Gupta et al, aims to explore and exploit the possibility of designing at the molecular and atomic levels, and producing a generation of novel products that boast of greater strength, lighter weight and better precision (2003).

Technically nanotechnology is not something new. Ball (2003) notes that nanoscale devices have been, and are currently being, utilized by organisms in their daily functioning. He cites, for instance, the proteins that serve as motors to flagella of motile bacteria, as readers and interpreters of the genetic code, or as miniature solar panels in plants that gather sunlight for photosynthesis (Ball 2003). The possibility of harnessing this potential within theenvironmentand put them to practical use has been floated in the scientific community as early as the 1940s, when von Neumann forwarded the idea of manufacturing systems or machines that are capable of self-replication, which could potentially lower production costs (Gupta et al 2003).

Richard Feynman in 1959, in an address to the American Physical Society entitled ‘ There Is Plenty of Room at the Bottom’, advanced the possibility that, similar to what we are doing at the macroscopic scale, we could maneuver atoms to where we want them to be, and produce materials that would solve the problem of manufacture and reproduction (Buxton et al 2003; Gupta P et al 2003). In 1986, K Eric Drexler provided a picture of nanotechnological use in the future in his book Engines of Creation, where humans are utilizing self-replicating nanoscale robots in daily life processes (Ball 2003).

The move from the drawing board to actual application, however, has been very recent—as evidenced by the relatively few nanotechnology products—fuelled by theoretical and laboratory progress which showed that, indeed, systems can be built from molecules and atoms maneuvered at the microscopic scale (Gupta et al 2003). L'Oreal recently introduced in the market sun creams that contain nano-sized grains of titanium dioxide, which absorbs ultraviolet light, but without the ' smeared chalk' appearance of regular creams (Ball 2003). This same technology, according to Ball (2003) was taken a step further when it was found that titanium dioxide particles become reactive when exposed to ultraviolet light, leading to the development of self-cleaning tiles and glasses—titanium-coated tiles and glasses that use the sun's energy to burn up dirt stuck to their surfaces. In the filed of medicine, nanotechnology is currently being utilized with state-of-the-art technology to combat genetic diseases (Dunkley 2004).

In addition to these, researches are currently undergoing, exploring the various possible applications of nanotechnology in various fields. For instance, in the medical sciences, the development of nanorobots could aid in precise, and rapid, cellular repair and regeneration, delivery of drugs at the site where it is needed, destruction of cancerous cells, or unblocking of clogged blood vessels (Dunkley 2004). The capacity to detect disease through alterations in body chemistry or physiology is also a possibility through nanotubes or nanowires coated with detector molecules (Buxton et al 2003). Molecular imaging, according to Buxton et al (2003) will also provide us with a view of the human body beyond gross anatomic structures, since this would utilize molecules that would home to tissues affected by specific disease processes. Environmental problems we face today, such asair pollutionor oil spills, could be remedied through nanorobots designed to clean these toxic elements from the air we breath or the water we drink (Dunkley 2004).

The material sciences will also significantly benefit from nanotechnology, with the promise of development of stronger and lighter plastics, computers with faster processors and increased memory storage, ion storage for batteries (which will improve performance), quick-charging battery cars, and fuel cells for motor-driven devices that are environment-friendly and energy efficient (Gupta et al 2003). Perhaps a bit too far in the future, Dunkley even forwards the idea that it might be possible, with nanorobots moving atoms and molecules, for us to create common and everyday things from our own backyard, moving manufacturing to the domain of the household with a wheelbarrow and a shovel (2004).

Because of the great promise held by nanotechnology, governments worldwide are investing in nanoresearch, to further refine our understanding of this small world. Global investment in nanotechnology has been estimated to be €5 billion, according to the Royal Society and the Royal Academy of Engineering (2004). The European Union pledged to spend €1 billion (Ball 2003), whereas Japan allocated $800M in 2003 (The Royal Society & The

Royal Academy of Engineering 2004). The United States is willing to spend nearly $3. 7 billion for nanotechnology from 2005 to 2008, with nearly $500 million allocated for research funding (Dunkley 2004; The Royal Society & The Royal Academy of Engineering 2004; Thomas & Sayre 2005).

The considerable change nanotechnology can bring, as well as the huge sums ofmoneygovernments worldwide are currently spending to make this a reality, has sparked some questions from various sectors on the impact of nanotechnologies, not only to the scientific fields to which it will be applied, but to the society in general. In the biological sciences, for instance, the primary concern is the possible toxicity exposure—and chronic exposure, at that—to nanoparticles can bring about, since these materials have the capability of interacting with cells and cellular organelles, and hence, alter body physiology (Ball 2003; The Royal Society & The Royal Academy of Engineering 2004).

Dreher (2004), and Thomas and Sayre (2005) have recently reviewed the evidence on thehealthimpact of nanotechnology exposure, and found that there is a paucity of evidence to encourage or preclude use of nanotechnologies in humans pending full investigations and detailed evidence supporting or debunking the same. Ball (2003) notes that, in the same way as new drugs or devices, nanotechnology must be viewed as a potential health hazard unless proven otherwise. Large scale production in the future would necessitate hazard-testing and human exposure assessment, to minimize risks (The Royal Society & The Royal Academy of Engineering 2004).

The significant economic impact of nanotechnologies, according to experts, may not be felt in the short-term, although this must be viewed with caution, since it is entirely difficult to predict what impact a developing technology that has not yet realized its full potential will have (The Royal Society & The Royal Academy of Engineering 2004). The differing capacities of developed, developing and underdeveloped countries to participate in the nanotechnology race has also raised concerns that it might intensify the economic gap between these nations, leading to what is referred to as a ‘ nanodivide’ (The Royal Society & The Royal Academy of Engineering 2004). Finally, patenting of nanotechnology—which is advantageous since it would, though economic incentive, encourage other individuals to contribute to scientific progress—may stifle creativity or innovation when a broad one is granted (The Royal Society & The Royal Academy of Engineering 2004).

Another area of concern is military and defense capability. The development of new devices—pervasive sensors, improved clothing and armor, and enhanced information andcommunicationexchange—could be viewed both as opportunities and threats, depending on who uses them, and how they are used (The Royal Society & The Royal Academy of Engineering 2004). But more than this, the Royal Society (2004) cautions that the secrecy coupled with development of technologies for defense use might fuel public distrust, and heighten the understanding that nanotechnology is being developed primarily, if not entirely, for military ends.

Ethical issues pervading the socio-cultural impact of nanotechnologies are also a concern. For instance, development of new nanodevices may cause a significant change in employment patterns, role perception, educationpatterns, and eventuallyfamilylife (Dunkley 2004). The end result, still according to Dunkley (2004) would be a shift in our present definition of inequality, poverty, and class, and finally, the way we construe society in general.

If what Dunkley predicted would come true (i. e. manufacturing at our own backyard), then the capacity to produce would be entirely dependent on having the necessary resources for this production, which brings to fore the concern of concentration of the harvests of nanotechnology in the hands of a few. Although nanomanufacturing could present the solution to hunger and homelessness, the question remains whether it will alter our perception of the material world where we move (Dunkley 2004).

The possibility of devices being used to store personal information, although enhancing personal security on the one hand, also raises the possibility of violation of civil liberties, especially when collection and distribution of the same is made without the consent of the person involved, or access to these information could be limited to the hands of the few who could develop and control personal information databases or systems (The Royal Society & The Royal Academy of Engineering 2004).

Finally, the possibility of radical human enhancement, or the creation of humans in the future, through nanotechnology (in conjunction with biotechnology and information technology), though a remote possibility, still carries with it the burden of resolving whether these creations are really human, and whether they also possess souls like we do (Dunkley 2004). In the same vein, this new capability would radically change, if not totally abolish, our perception of religion and morality (The Royal Society & The

Royal Academy of Engineering 2004). On a lesser plane, the possibility of nanotechnology extending human longevity to hundreds of years will definitely alter our view of aging and death (Dunkley 2004).

What, then, lies in store for us in the future with nanotechnology? Actually, no one can tell, since nanotechnology is but a frontier—which, to Melbin is a pattern of sparse settlement in space or time—or what Dunkley (2004) describes as relatively ‘ unsettled and a wilderness waiting to be discovered’. Until such time, therefore, that the full potential of nanotechnology has been realized, or at least understood through research, we may endlessly speculate about how nanotechnology will affect our daily lives and society in general, who will benefit from its, what and capabilities will it provide us. The concerns, however, raised in this paper are valid considerations of the impact the future application of nanotechnologies will have, and this necessitates caution and vigilance on the part of all stakeholders.

References

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