

**Problems and Prospects of Nanotechnology:
Implications for Marketing Innovations**

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**A Research Paper
Submitted for Presentation
At The Academy of Business and Administrative Sciences
Conference, Quebec City, Canada
July, 20 – 22, 2005**

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Abstract

The world of science seems to be ever churning up new ways and methods to produce products. Among the recent scientific advances, nanotechnology is attracting the attention of many researchers, investors, and marketers for its enormous potential. Basically, nanotechnology is the construction and use of functional structures designed from atomic or molecular scale with at least one characteristic dimension measured in nanometers. This scientific breakthrough could affect the production of virtually every human-made objects from mundane everyday items such as automobiles, electronics, to advanced diagnostics, medicine, surgery, tissue and bone replacements. Currently, the focus has been on discovering new materials, novel phenomena, new characterization tools, and fabricating nanodevices by the integration of engineering, science, and biology. Like past innovations, the new technology has problems even though its prospects look bright. The entire success of this new scientific endeavor depends on creative marketing of these products by countering their real or perceived drawbacks encountered by wary consumers.

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Introduction

Throughout the ages, the quest for riches have taken many forms. Invasions, discovery, mining, the Fountain of Youth are only a few examples of the of humankind's endeavor. Paramount among these pursuits was alchemy. Gold has had a magical influence on homo sapiens since time immoral. Once in a while a substitute source of riches other than gold emerges to dazzle the imagination equally and to create high expectations from its use. Some are exuberant over its potentials; others seem to exercise extreme caution. Nanotechnology seems to be one of the latest discoveries to promise immense profits by its applications to a number of important areas. Ponce de Leon would have been consoled to have discovered nanotechnology, even though he searched in vain for his ultimate prize --the elusive "Fountain of Youth."

Essentially, nanotechnology is the art of manipulating materials on a very small scale in order to build microscopic machinery. Nan(n)os is a Greek noun for "dwarf, little old man." The present meaning of nano, of course, stands for a symbol representing something extremely small, one Billionth (10^{-9}) or O nano-second. According to the U.S. National Nanotechnology Initiative (NNI) standards, nanotechnology involves all of the following procedures as listed in Table 1.

Table 1**A List of Primary Procedures Involved in Nanotechnology**

- I. Research and technology development at the atomic, molecular, or macromolecular levels, approximately 1 -100 nanometers in length.**
 - II. Creation and use of structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size.**
 - III. Ability to control or manipulate on the atomic scale.**
-

Source: Based on U.S. National Nanotechnology Initiative (NNI), 2004.

The origin of the concept of nanotechnology is due to two individuals. Richard Feynman (1960) presented a speech in 1959 titled “There’s Plenty of Room at the Bottom.” In this speech, Feynman anticipated by several decades the making of some materials through the manipulation of atoms. In 1974, Taniguchi at the University of Tokyo used the term “nanotechnology” for the first time to refer to the ability to engineer materials precisely at the nanometer level, driven by electronics industry needs. Fortunately, in 1981, the invention of the scanning tunneling microscope made it possible to see atom clusters. Later, in 1991 IBM demonstrated the ability to arrange individual xenon atoms by means of an atomic force instrument.

The Royal Society and the Royal Academy of Engineering has an all encompassing definition of nanotechnologies as being the design, characterization, production, and application of structures, devices, and systems by controlling shape and size at the nanometer scale. This broad definition connotes the fact that the field is wide open for opportunities to create small things of use and interest from a variety of sciences such as condensed-matter physics, engineering, molecular biology and chemistry (Stix 2001).

In this paper, a typology of nanotechnology and nanomaterials is first presented, followed by the problems and prospects of this technology along with examples of innovation of promising products. Finally implications of this scientific lightning rod are discussed, especially for marketing the products and services of this frontier technology.

Typology of Nanotechnology

Based on Jones (2004) approach to organizing nanotechnology, three major typologies emerge each with a specific function as shown in Table 2.

It should be noted that the functions of each type of nanotechnology are the primary ones which do not preclude the inclusion of lesser known and yet undiscovered uses of this growing science.

Nanotechnology has spawned a plethora of products and services. Of hundreds of possible materials, some examples are given in Table 2 for each type of technology. Again, it should be borne in mind that we are being exemplary rather

Table 2**Typology of Nanotechnology and Their Primary Functions**

Type	Functions
I. Incremental Nanotechnology	Enhancing the properties of materials by controlling their basic nanoscale structure.
II. Evolutionary Nanotechnology	Transending the redesigning simple materials by designing nanoscale devices that do something interesting
III. Radical nanotechnology	Inventing nonoscale machines by combining nanotechnology, biotechnology, information technology, and cognitive technology.

Source: Based on Jones (2004) categorization of Nanotechnology

than exhaustive in presenting the examples of materials based on this promising, albeit controversial pursuits of researchers.

Problems and Prospects of Nanotechnology

Prospects

Prospects for discovering new materials, novel phenomena, new characterization tools and fabricating nano devices are bright to some observers of Nanotechnology. Pharmaceutical companies are betting that nano's greater absorption rate will lead to far more efficient dosages of drugs, many delivered as

nano specks. Baker and Aston (2005) indicate that by making the particles chemically reactive, scientists are building exquisitely sensitive sensors that can detect individual molecules. Revolutionizing materials will be available for use in electronics, automotive, and raw materials. See examples of materials in Table 3.

Table 3
Examples of Nanomaterials of Today and Tomorrow
Under Each Type of Nanotechnology

Type of Technology	Examples of Materials
I. Incremental Nanotechnology	Nanoceramic powders add durability/toughness to hulls; Polymer nanocomposites to increase hardness and permeability of polymer; Nano-structured plastics to produce ultrafine-grained structures.
II. Evolutionary Nanotechnology	Carbon nanotubes (CNT) electrical transmission lines and thermoelectric conversion devices; faster chips; semiconductor nanowires for diagnosis and treatment in medical applications; CNT for high-efficiency solar energy conversion.
III. Radical Nanotechnology	Nanofibers for Military uniforms to defend against chemical and biological weapons; to provide ballistic protection; to monitor health, administer medical aid, and provide communication capabilities.

Some products are also in the offing which may allow us to increase our defensibility for modifying cells around the wound. Interestingly enough, some companies are experimenting with hair dye, which, instead of dying, one would put materials into follicles to produce different pigment.

Investments in R&D and the proliferation of nano-based products will go through three main phases as is shown in Table 4.

Table 4

Growth Prospects in Three Main Phases

High-end products: \$8.5 billion used in automotive and aerospace application.

Through 2009: commercial breakthroughs in electronics and IT applications will dominate as microprocessors and memory chips built using nano-chips.

From 2010: commonplace in manufactured goods (revenue rising to \$2.6 trillion in 2014- Healthcare, medicine).

Source: Baker and Aston (2004).

As a result of all these innovations, there will be more jobs. It has been estimated that there will be 10 million manufacturing jobs worldwide in 2014, which will establish nanotechnology as the third industrial revolution through groundbreaking advances in nanotechnology which are expected to spread through the economy, shaking up entire industries.

Seven Wondrous Innovations

CANCER CURES

Sensors will be able to detect a single cancer cell and will help guide nanoparticles that can cook tumors from the inside out, leaving healthy cells alone.

Nanoshells – “sphere a few nanometers (billionths of a meter) in diameter, that is made of an insulator (silica) that has been coated with a conductor (gold)” with electrical properties (West 2003). “Nanoshells...naturally concentrate in tumor sites because tumors are very leaky...can heat up the nanoshells to kill the cancer” (Kulinowski 2004).

The results of recently explored applications of this innovation now can be used in “nanostructured water-filtrator membranes” and in “remediation of pollution” (Kulinowski 2004).

When tested on human breast-cancer cells and “When mixed with nanoshells and exposed to infra-red light, these cells were satisfactorily destroyed” (West 2003). They could also put to use in “detecting previously invisible biotoxins and chemical warfare agents in the human body” (The Engineer 2004).

The negative side of “overreaction to both hype and fear” is that studies have shown that high concentrations of (nanoparticles) can cause cellular damage” (Kulinowski 2004).

MEDICAL DIAGNOSTICS

Nano-based diagnostics equipment with greater accuracy will hit the market within three years. But treatments carry far higher risk. Perhaps testing and government approvals will delay them for the next decade.

ENERGY TRANSFORMATION

Nano-enhanced solar panels will feed cheap electricity onto superconducting power lines made of carbon nanotubes. Next-generation panels will emerge this decade in Japan, which leads in the technology and suffers from higher energy prices.

SILICON REPLACEMENT

Carbon nanotubes will take over when silicon peters out, leading to far faster chips that need less power than today's products. [IBM](#) has built working nanocircuits, but in the factory chipmakers must be able to make billions of them. The transition is unlikely before 2015.

In terms of corporate support, although most, if not all, of the major semiconductor manufacturers are exploring a number of next-generation nanoelectronic technologies, some are getting more attention than others from the corporate sector. “Technologies adopted by companies such as IBM and Hewlett-Packard are far more likely to reach the marketplace than otherwise very promising technologies left to flourish in academic laboratories.” (Rittner 2004).

One way to avert a looming crisis in semiconductor industry, “\$15 billion flash-memory industry is already approaching its technology limits” (Arensman 2004).

The small firms in the nanoelectronics business are, for the most part, pursuing a similar ultimate goal: the displacement of current memory devices (DRAM, flash memory, and SRAM) with a faster, smaller, higher-density nanoelectronic memory technology (Rittner 2004).

IBM has demonstrated that nanotube transistors can outperform the leading silicon transistor prototypes, and separate highly publicized studies by researchers from IBM and the Delft University of Technology demonstrated that carbon nanotube FETs can be used to form simple circuits (Rittner 2004).

Nanoelectronic memory products will enter the market within the next year and by 2008, they could generate an estimated \$30 billion. With the advantages of non volatility, ultrahigh memory density, and low cost, nanoelectronic memory products will increase their penetration of both the volatile and nonvolatile memory market segments during the next ten years, and by 2013, a total market of about \$200 billion is possible (Rittner 2004).

ENHANCED COATING

New product innovations will include polymer to coat textiles. You can pour water on a piece of cotton that's been treated, and the water doesn't wet the cotton

at all (Gleason?) One can buy nano-enhanced sunscreens, and even self-cleaning windows that use similar nano-engineering to keep dirt from sticking to glass.

Soon there will be trousers for sale that use nano-hooks to attach small fibres to cotton, letting it repel stains more effectively than was previously possible. Some vehicles come with body parts made stronger, lighter and cheaper through the use of nanocomposites. Some tennis balls bounce higher for longer, thanks to a special nanocoating. Then there are "quantum dots", nanodevices that are generating a lot of buzz in biology and computing (The Economist 2003).

SPACE TRAVEL

Podlike "crawlers" will carry cargo thousands of miles up a carbon-nanotube cable to a space station -- for billions less than rocket launches. Today the longest nanotubes are mere millimeters. To make miles of cable, scientists must learn how to weave these into threads. A working cable is at least 20 years away" (Baker and Aston 2004).

DEFENCE TECHNOLOGY

ISN (International Security and Network) hopes to replace the protective suit worn by soldiers to shield them from damaging chemical and biological agents. While the suit provides protection, it also impairs sight, movement, hearing, communication, and comfort. Ideally, the uniform of the Future Warrior would incorporate the capabilities to detect harmful agents in the air and protect the

soldier from them automatically, leaving the soldier free to concentrate on other tasks and reducing the amount of gear that the soldier must carry (Roncone 2004).

There are other highly profitable areas in nanotechnology to produce products which would be in great demand. Table 5 gives some examples as an introduction to the vast potential of this technology.

Table 5

Examples of Technologies For Examination And Explorations for High Profits

- * Superstrong Aerogels - to let human settlements withstand hurricanes, earthquakes, and tornadoes without causing environmental damage.**
 - * Self-Assembling Solar Cells - that help us tolerate environmental shocks with a stable energy supply.**
 - * Nanobiotic Treatments - which have been shown to be effective in combating infectious environmental contaminants implicated in many prevalent diseases (Mulhall 2004).**
 - *Silicon Nanowire – for efficiency in printing technologies.**
-

While promises of new products are bright as we shall see later, there are some problems facing the nanotechnology industry, which may slow down the maturation of the science.

Problems

For the safety of nanotechnology, it is incumbent upon us to examine ways to use advanced technologies to adapt to newly found natural threats at macro and nano scales. We need to summarize such threats, list technologies that may help us adapt to them, then determine how risk assessment might be upgraded to evaluate such threats and responses

From human standpoint, most people may not want to give their autonomy to machines. Unsafe new product failure may increase the possibility of regulation. The government may stifle our ability to innovate and develop the next industrial revolution. Moreover, there are problems which may derail commercialization as indicated in Table 6.

Implications of Nanotechnology for Marketing

New ideas, technologies, innovations seem to attract skeptics early on to discount the true merits of a nascent science for progress. Nanotechnology is no exception.

Critics contend that products like Viagra, Vikiden, etc. are precarious, not well tested for their serious side effects. Companies choose to prevaricate rather than address the potential dangers of their products out of greed.

Table 6

**Problems Which May Keep Companies Far Away From
Commercialization Of Nano-Based Products and Services
In the Foreseeable Future**

Insufficient investment capital

Intellectual property issues impeding commercialization progress

Process scalability

High cost of processing

Societal benefits of nano not yet recognized (Miller 2005)

Liability can extend back to manufacturing process

May negatively impact manufacturers' current technology of silicon chips

Pharmaceutical companies have shown the proclivity of marketing products prematurely to skim the market of huge profits.

Nanomaterials and products appear to be a goldmine for marketing to exalt their efficiency and durability. On the other hand, these products could be a

hornet's nest. Law suits against their defects and unsafe characteristics would straight jacket marketing.

Nanotechnology may also negatively impact manufacturers of current technology of silicon chips. Nano-memory chips may have technical problems such as leaky storage capacitors, increasingly complex structures, susceptibility to soft errors. Arensman (2004) contends that there may be a "...race for 90 nanometer supremacy among chip makers." Such a keen competition may make manufacturers overlook sides effects for the sake of being first to market nano-based products and services.

Carbon and other nanotubes may have toxic properties similar to asbestos fibers, but previous studies suggest that they may not escape into air as individual fibers" (Arensman, 2004). Such a condition obviously would complicate matters for the new innovation to make it marketable.

Marketing has also to deal with other potential dangers such as social, environmental and ethical dangers of unleashing nanotechnology-based products and services into the world before they are fully understood - a situation similar to that surrounding genetically modified organisms today.

The introduction of novel nanomaterials into the ecosystem, for example, could have unexpected dire consequences for the quality of the environment (e.g., deterioration from toxicity), and the merger of biological and non-biological materials into new products and processes could affect human health and the environment in ways that are unknown or unexpected. The prospect of self-assembling nano-devices raises these concerns to an even higher level.

The hype and the hue and cry of Nanotechnology is not unique. Almost all sciences and technologies had to go through these types of passage of rite. Without trying new methods of producing and handling products and services, human progress would lag behind the population explosion the world is facing in the 21st century. There will be too many mouths to feed and new technologies should be encouraged as an avenue to curb world hunger, disease, and war.

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