

The Nanotechnology and its Contributions to Economic Development

Introduction

When you control atoms, you control just about everything," said Richard Smalley, the 1996 Nobel Laureate, who discovered buckyballs, referring to the possibilities of nanotechnology¹. The guiding vision of nanotechnology is atomic precision. In reality, nanotechnology is an enabling technology providing tools for the fabrication, manipulation and control of materials at the atomic level. At the heart of nanotechnology, it brings into collaboration ideas in chemistry, physics and biology mixed and blended with engineering and medicine². Scientists and engineers have shown an active interest in nanotechnologies because at sizes below 100 nm, the fundamental chemical or electrical properties of materials can change. For example, silver metal used in jewellery is typically inert, however, at the nanoscale, it becomes chemically more active possessing antibacterial properties. Such useful changes in property have become the catalyst for predictions of a range of fundamental new advances in chemistry and physics over the next 10 - 50 years, mostly in the domains of new materials, the environment, in medicine and information technology. Although the top and bottom of the nanoscale (ideally ranging from 1 to 100 nm) does not have sharp demarcations - especially the upper value, it excludes individual atoms on the lower end, and matter that can be seen with a very good optical microscope on the upper end. This harnessing of properties of matter at the nano scale was predicted by Richard Feynman's famous prophesy in 1959: "there is plenty of room at the bottom."

Applications of nanotechnology are enabled by nanomaterials, which have novel optical, electric or magnetic properties. The building blocks of nanotechnology are semiconductors, metals, metal oxides, carbon materials and organics. The emerging commercial growth areas in nanotechnology are nanomaterials and nanomaterials processing, nanobiotechnology, nanophotonics, nanoelectronics and nanoinstrumentation. Nanomaterials and nanomaterials processing companies develop the materials and methods to manipulate and manufacture products based on nano materials. Nanophotonics involves the development of highly integrated optical-communications components using nano-optic and nano-manufacturing technologies leading to rapid prototyping, high-performance advantages, smaller forms and lower costs. Nanobiotechnology is multidisciplinary combining areas such as biology and nanoelectronics to fabricate arrays of tiny diagnostic sensors that can detect specific biological molecules or individual strands of DNA. These devices will provide faster, cheaper and more comprehensive diagnoses of complex diseases. Nanoelectronics includes electronic and optoelectronic devices in which individual assemblies of nanometer-scale components function as active device elements. Potential nanoelectronics products include integrated memory logic, passive optical components, field emission devices, and flat-panel display and light-emitting diodes.

Global Business Outlook

Globally, nanotechnology is projected to be an all pervasive

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technology. It has been incorporated into tyres, toothpaste, sun cream, tennis rackets, shirts, trousers, CD players, etc. It makes day-to-day consumer goods smaller, lighter, faster and cheaper. However, nanotechnology, today, is in the interface between scientific reality and ambitious visions or between first accomplishments and future expectations. It is applied by scientists and research managers; policymakers, journalists, economists, investors and pressure groups narrate its usefulness. As projections are made about its growth, points of references evolve constantly and unconsciously.

Nanotechnology is estimated to make a great impact on the global economy, and as such an appropriate indicator of its significance can be market volumes. However, nanotechnology as an industry cannot be easily quantified although its contribution to improvements in the existing products and even to produce brand new products. Most global market forecasts of nanotechnology spans between the period between 2000 and 2015. According to the United State National Science Foundation estimate of 2001, the world market for nanotechnological products by 2015 will be around 1 trillion US Dollars³. On the other hand, the Lux Research Corporation estimated in 2004 that the same market to be 2.6 trillion US Dollars by 2014⁴. The latter which gives a

more optimistic economic scenario implies that nanotechnology would contribute more to the global economy than the information and communication technology and make the future biotechnology market insignificant by comparison. Contributing to the current market, nano-devices and nanobiotechnology tops the list followed by nanomaterials. However, in future markets, nanomaterials will expand significantly, nanoelectronics will emerge as a significant contributor followed by pharmaceuticals, chemical processing and aerospace industry.

The Lux Research Corporation report of 2004 shows a three-phase model for the development of nanotechnology. In the first phase (up to 2004), nanotechnology-incorporated high-tech products were introduced to the market. The next phase (up to 2009), nanotechnology breakthroughs were predicted to take place. In the third (2010 onwards), nanotechnology was forecasted to become commonplace in manufactured goods, such as, pharmaceutical and medical devices. It estimates that nanotechnology, in its varied manifestations, would reach 15% of the global manufacturing output by 2015. Nano-enabled drug delivery market is projected to grow 50% between 2005 and 2012. In 2012, the expected earnings from nanotechnology on drug delivery of approximately 4.5 billion US Dollars will capture a nanotechnology market share of 10% by 2020.

Like any technology, nanotechnology's advances will depend on available venture capital funding. Risk debates related to possible dangers of nanoparticles which emerged around 2000, still remain in the public domain. All this might make some investors to take a cautious approach and wait for more indications of the outcomes. Today, there are

business indices tracking the progress of nano-based companies (i.e., LUX Nano Index)⁵.

The emergence of new companies is a salient indicator of the economic significance of a new technology. In nanotechnology, new companies typically are start ups where they hold patents on new nanotechnologies which they can exploit or license out to other companies with better capabilities of production and marketing. Venture capital is a valuable source of funding in this high-risk sector. The United States National Science Foundation estimates that about 2 million nanotechnology employees will be needed globally by 2015. The large majority of these workers will be in the USA followed by Japan, Europe, and the Asia Pacific. In addition, about 5 million support jobs would be created. Many of these jobs would be in new SMEs (small and medium enterprises), but several companies, such as, Bayer, BASF, Carl Zeiss, Agfa-Gevaert, General Electric and Philip's who would also employ many, were created prior to 1900. About 30% of these companies are in nanomaterials. An approximately equal number is active in nanobiotechnology and the rest are in nanotools and nanodevices. The USA is active, roughly equally in all sectors, while Germany is stronger in nanotools⁶. The UK is well-known for nanobiotechnology while Japan being strong in nanomaterials, and nanotools is less active in nanobiotechnology. The USA has, by far, the largest number of SMEs and startup companies, in Europe and Asia, university and research centres play a more prominent role. While in Japan, the UK, China, France, Austria, Australia, Spain, Italy and Poland, universities and research institutes outnumber companies, in US, Germany, Switzerland, Israel, Taiwan, South Korea and Finland, the number of companies far outnumber Universities and research

institutes. Countries, such as, China, India and Russia, are emerging in nanotechnology and are poised to overtake Europe. Although none has notable companies doing nanotechnology, they could become keen competitors for products, research and production sites⁶.

Nanotechnology Patents and Publication Scenario

For any country, economic success is not possible without scientific and technological excellence. The two main parameters measuring scientific and technological excellence are patents and publications. Patents are a measure of the ability to transfer scientific research into technological applications. Therefore, patents reflect the potential for economic exploitation of research findings emanating from researchers, research organisations and countries. The United States Patent Office (USPTO) ranks number one in terms of nanotechnology patent applications followed the European Patent Office (EPO). Both the USPTO and the EPO have developed ways of categorising nanotechnology patents into families of inventions to aid the patent examiners and to identify developments in this emerging technology⁷. On the other hand, scientific publications reflect scientific excellence in nanotechnology. The number of publications alone can lead to misleading analysis and other important indicators, such as, citations, quality of a given publication and its impact on the scientific community, must be taken into consideration. The top cited journals are the European 'Nature' and the US 'Science' and more recently 'Nature Nanotechnology' all of which are published in English and cover multidisciplinary research. The largest numbers of nanoscience high-impact journals cover the fields, such as, physics, chemistry and material science⁷.

Sri Lankan Initiative and its Impact on Economic Development

Only about 0.14% of Gross Domestic Product (GDP) was spent on research and development in Sri Lanka last year, which, in relation to the average of about 1% contributed by most developing countries and over 2% allocated by developed nations, is an insignificant amount. An axiom generally agreed up on worldwide is that research and innovation leads to the prosperity of a nation. For example, Sri Lanka has had a record of less than two patents filed at the USPTO compared to thousands filed by developed nations. Such a low number of patent applications clearly correlate with the low expenditure on research and development. Thus, up to now, research has played a minimal role in the Sri Lanka's development. Therefore, since independence in 1948, Sri Lanka has not been able to come out of its commodity mindset, and of all our exports only 1.5 % arise out of advanced technology products⁸. It is also noteworthy that Sri Lanka has not taken an active role in any of the technological waves that has swept the planet for the past two centuries. In this backdrop, it is pertinent to ask how nanotechnology, considered as the fifth industrial revolution, can contribute to the enhancement of the Sri Lankan economy.

The nanotechnology initiative in Sri Lanka launched through Nanotechnology Company (NANCO) and the Sri Lanka Institute of Nanotechnology (SLINTEC) in 2006, is unique among such initiatives worldwide, where the government and the private sector have invested equally. The spirit of this initiative is to make research findings directly contribute to national development. SLINTEC, which started research in August of 2009, provides platform research solutions based on

nanotechnology to the Sri Lankan industries. The participating industries, namely, Brandix, Dialog, Hayleys, Loadstar, and MAS Holdings, who are also the joint venture partners, are national leaders in terms of export revenue or in market capitalisation in their respective sectors having established niche markets for their globally competitive products. It is envisaged that these companies would benefit from nanotechnology differentiators provided by SLINTEC to their product line up. Significantly, thus far, SLINTEC has applied for three patents at the USPTO to cover the innovations for its joint venture partners. Specifically, two of the patents cover a slow release nano-fertiliser formulation developed by SLINTEC which releases nitrogen to the soil in a slow and sustained manner. The loss of nitrogen (up to 50 %) due to evaporation and leaching out by rain water is a major economic loss in the agriculture sector. In Sri Lanka, the current fertiliser subsidy allocation by the government in the paddy and tea sector is Rs. 30 billion⁹. Even if the SLINTEC slow release nano-fertiliser formulations saves 30% of the current loss it would amount to Rs. 9 billion in savings. The third patent application is on an environmentally friendly, value-added solid rubber tyre based on nano-materials.

Another key area SLINTEC has been pursuing since inception is adding value to Sri Lankan natural resources with nano-applications. For example, making a significant research breakthrough, SLINTEC has applied for two more patent applications, firstly to make carbon nano-tubes using unique Sri Lankan vein graphite (mined underground only in Sri Lanka) mined by Bogala and Kahatagaha mines and secondly for physical method to make nano-magnetite from naturally occurring magnetite ore found in Matale. Carbon nanotubes are used to manufacture

integrated circuits, semiconductor chips used in computers and have applications in nanoelectronics amounting to a global business of several billion US Dollars. On the other hand, nano-magnetite, among its manifold uses, is an important ingredient in magnetic resonance imaging contrast enhancement, magnetically controlled transport of anti-cancer drugs and microwave devices. The global market for nano-magnetite is growing and currently 25 g is sold at Rs. 19,000. In addition, SLINTEC has championed the cause for making Titanium Dioxide from ilmenite found in Pullmodai in Sri Lanka without exporting the raw sand. Importantly, globally, Sri Lanka has the 9th largest ilmenite reserve containing up to 65% of Titanium Dioxide which ranks 3rd in terms of purity. Sri Lanka exports approximate 80,000 tonnes of ilmenite, earning about 8 million US Dollars annually. The same amount of ilmenite is converted into Titanium Dioxide, by the multinational companies who purchase them, having a value of 120 million US dollars. In this imbalanced trading, because Sri Lanka has not invested in technology needed to convert ilmenite to Titanium Dioxide, the nation loses a significant amount of foreign exchange. What also is salient in this effort is, in addition to making a strong national case for making Titanium Dioxide from ilmenite in Sri Lanka, SLINTEC has conceptualised a process route for converting ilmenite to nano-Titanium Dioxide, which, in terms of value addition, is 1:250. The last nano-material that SLINTEC has turned its attention to is Montmorillonite (MMT) clay or nano-clay. MMT is a little known Smectite clay mineral in Sri Lanka. It is found in mainland India and in many countries in the region. In Sri Lanka, MMT had been recorded in small amounts in dry zone soils and is believed to be formed as a result of weathering of micaceous minerals, such as, biotite,

phlogophite and muscovite. In our current efforts to locate new mineral deposits with nano-applications, SLINTEC has applied for an exploration permit (with a view to secure mining rights), at the Geological Survey and Mines Bureau, for a large MMT deposit found in Murunken, Mannar District, Northern Province, the first of its kind found in Sri Lanka. Although the global market for MMT currently is only about one billion US dollars, its use in clay polymer nano-composites is growing globally. With the Sri Lankan deposit in Murunken, estimated to be over 75 million tonnes, SLINTEC not only hopes to solve supply chain issues in nanotechnology research solutions it provides to the industry where MMT is used as a raw material but also work with companies who interested in exploiting the reserve for export as well as to position itself as a provider of bentonite (70 % pure MMT) to the proposed Sri Lankan oil exploration efforts where bentonite can be used in large quantities in the stabilisation drill holes.

It is with the value of these resources in mind and with the understanding the growing importance under the newly-emerging nano arena that SLINTEC and NANCO have proposed to the national nanotechnology policy the value of safeguarding these resources by not allowing these to leave our shores without significant value addition.

Sustainability and Societal Issues

The Millennium Ecosystem Assessment carried out by the United Nations in April 2005 indicated that "...the ability of ecosystems to sustain future generations can no longer be taken for granted¹⁰." When we take a look at nanotechnology through the

window of sustainability, considering the enormous challenges faced by the human race in the coming decades, it becomes clear that nano-scale-manufacturing platforms could make geography, raw materials, as well as labour, irrelevant. By employing nanotechnology to build from the bottom-up rather than processing down, the quantity of raw materials required could be sharply reduced. In short, nano-scale technologies are poised to become the strategic platform for global control of materials, food, agriculture and health in the immediate years ahead. With respect to nanotechnology, emerging dictum for the developing world should be: *more from less for more*.

Although iconic advances in research looming in the horizon would give rise to economic benefits, nanotechnologies are fraught with potential risks, many shrouded in uncertainty. If common elements exhibit different chemical properties when fabricated at the nano-scale, they might also manifest unforeseen health and environmental hazards. One of the most urgent concerns here is the potential toxicity of inhaled-manufactured nanoparticles. Public participation in nanotechnologies is often described as 'upstream' in nature, reflecting its occurrence before commercialisation in real-world applications and before significant social controversy¹¹. Thus, potential problems are being addressed while research on nanotechnology continues so as not to embrace the controversies that genetically modified (GM) foods were subjected to. Risk perception analysis indicates that technology's acceptability will depend upon people's perceptions of both benefit and risk, with the balance between the two depending upon the particular technology or

the context within which judgments are formed¹¹. Nanotechnology survey carried out in the USA and the UK to date shows two clear findings. The first is that most people know little or nothing about nanotechnologies. Second, notwithstanding this, many feel that nanotechnology's future benefits will outweigh its risks. The latter highlights the bias that we carry within ourselves that all technologies in the past have been good for the mankind.

Conclusions

The long-term vision of all nanotechnologists has been the fabrication of a wider range of materials and products with atomic precision. However, experts in the field have had strong differences of opinion on how rapidly this will occur. It is uncontroversial that expanding the scope of atomic precision will dramatically improve high-performance technologies of all kinds, from medicine, sensors, and displays to materials and solar power.

The current trend in nanotechnology research is towards selective capitalisation, rather than thematic research. Companies are taking a more pragmatic approach towards nanotechnology, rather than pursuing nanotech for its own sake. These companies focus on specific applications that fit with corporate activities, and are on the lookout for ways where nanotech can add value in those areas. Nanotechnology, being an enabling technology, will more often enable improvements to the existing products.

In Sri Lanka, through the National Nanotechnology Initiative, NANCO and SLINTEC have been set up to provide platform research solutions based on nanotechnology to the Sri Lankan industry and thereby make the fruits of nanotechnology innovations contribute to the Sri

Lankan economy. Government for its part, through this initiative, has recognised that scientists can play an enormous role in national development by helping to exploit good technologies. However, nanotechnology should be implemented with care in synergy with the environment and life-cycle analysis.

Footnotes:

¹ S. E. Miller, *The Frontier of Science: A Conversation with Big Leaders in the Small World of Nanotech*, *New York Law Journal*, 233 (21), (2005).

² *Nanoscience and Nanotechnologies: Opportunities and Uncertainties* (London: Royal Society and Royal

Academy of Engineering), RS/RAE, (2004).

³ National Science Foundation (NSF) 2001, cited by TedHerring, *The Biotechboom: the view from here*, online article of 5th November, (2001).

⁴ Lux Research, *The Nanotech Report 2004*, (2004).

⁵ Lux Nanotech Index, www.m\nanoTsunami.com.

⁶ A. Hullmann, European Commission, DG Research, Unit "Nano S & T-Scovergent Science and Technologies, Version:28 November (2006).

⁷ A. Hullmann, M. Meyer, *Publications and Patents in Nanotechnology: An overview of previous studies and state of the art*, in *Scientometrics*, 58 (3), pp 507-527 (2003).

⁸ *Science, Technology & Innovation Strategy for Sri Lanka, 2011-2015*, Ministry of Technology and Research, August (2010).

⁹ P. C. Rodrigo, *Sri Lanka's Fertilizer Subsidy Rising*, News 360. Lk, September, 23rd (2010).

¹⁰ United Nations, *Millennium Ecosystem Assessment*. New York, NY, May, pp. 219, (2005).

¹¹ I. C. K. Pidgeon, B. H. Harthorn, K. Bryant and T. Rogers-Hayden, *Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom*, *Nature Nanotechnology*, 4, 95-98 (2009). ■
