Nanotechnology Enabling Sustainability and Innovative Economy

Lerwen LIU, PhD, Managing Director, NanoGlobe Pte Ltd (lerwen@nano-globe.biz)

Jing JIANG, PhD, Senior Analyst, NanoGlobe Pte Ltd

Mark FOLEY, PhD, Senior Consultant, NanoGlobe Pte Ltd

1. Introduction

The genesis of nanotechnology can be traced back to Richard Feynman's famous lecture "There's Plenty of Room at the Bottom" which he delivered to the American Physical Society in 1959. This lecture has inspired scientists and engineers worldwide to develop technologies to image and manipulate atoms and molecules, and to fabricate structures and devices atom by atom, molecule by molecule.

Today nanotechnology is commonly defined as the understanding and control of matter at nanoscale dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, manipulating and fabricating matter at this scale. A nanometer is one-billionth of a meter. A DNA molecule is about 2.2 nanometers wide, the typical size of bacteria is in the order of 1000 nanometers (1 micrometer) and the size of human hair is about 100 micrometers.

Nanotechnology is on its way to revolutionize how we make things and change the way we live. It is able to transform multiple industries including aerospace, agriculture, automotive, chemical, energy and environment, food, information and communication, medicine and health care, security and transportation. Nanotechnology offers so many possibilities such as providing cheap and clean energy, clean water, lighter and stronger materials, faster, more powerful and energy efficient computers, an exponential increase in information storage capacity and transmission speed, lotus-like self-cleaning surfaces, butterfly wing structural colors, the reduction or elimination of pollution, and early detection and treatment for cancer and other diseases.

The word "Nano-technology" was coined in 1974 by Norio Taniguchi (a professor at the Tokyo Science University in Japan) where he defined the process that consists of the processing, separation, consolidation, and deformation of materials at the level of one atom or one molecule." Manufacturing (in Japanese *Monotsukuri*, meaning making things) has been a focus of the Japanese industry policy. It is known that nanotechnology enables the transformation of advanced manufacturing to make better, cheaper, and greener products. For the last two decades, Japan has been committed to the use of nanotechnology in manufacturing to stay ahead of its competitors. Today, economies in Asia including South Korea, Taiwan, and mainland China are making significant progress in adopting nanotechnology in their manufacturing.

Since 1999 there have been significant changes in nanotechnology development worldwide. The announcement of the US National Nanotechnology Initiative (NNI) on 21st January 2000 created a strong response from the rest of the world, with a number of countries placing nanotechnology as a priority area in their science and technology policy. Figure 1 shows the timeline of national nanotechnology initiatives and programs in the 15 economies reviewed in this article with reference to the US NNI and the European Commission (EC)`s 6th Framework Program (FP6) where

“Nanotechnologies and Nanosciences, Knowledge-based Multifunctional Materials, New Production Processes and Devices” was included as one of the seven priority thematic areas.

In 2001 Japan, China and New Zealand all began major programs focusing on nanomaterials. The following year, Korea, Taiwan, Thailand, Australia, Hong Kong and Vietnam launched national and regional nanotechnology initiatives. Subsequently in 2006, Iran launched its national nanotech initiative program, followed by Malaysia and Indonesia.

As funding has experienced a significant increase over the past decade, nanotechnology is becoming mature for commercialization. The Russian government intends to take a leadership position by launching a ten-year, USD 5 billion nanotechnology commercialization initiative in September 2007 managed by the Russian Corporation of Nanotechnologies (RUSNANO).

2. Nanocarbon Materials Providing Game Changer Products

Scientists and engineers today are able to make all kind of nanomaterials and nanostructures in metals, polymers, oxides, carbons, semiconductors, and other materials.

Nanocarbon materials are the most appealing today for their far superior properties in strength and conductivity. Nanocarbon materials include graphene, carbon nanotubes and fullerene. There is great focus on graphene and carbon nanotubes as, due to commercial availability and superior properties, they are being implemented into multi-functional materials and products today.

Graphene is a single sheet of graphite, is most easily visualized as an atomic scale honeycomb lattice made of carbon atoms. Graphene is also the basic structural element of carbon nanotubes and fullerenes. The Nobel Prize in Physics for 2010 was awarded to Andre Geim and Konstantin Novoselov at the University of Manchester "for groundbreaking experiments regarding the two-dimensional material graphene".

When graphene sheet(s) roll into cylindrical nanostructures, they are called buckytubes, more commonly called Carbon Nanotubes (CNT), when a graphene sheet forms a hollow sphere, it is called buckyballs.

Nanocarbon materials (CNT and Graphene) are known to be 5-7 times stronger than steel, 10 times more thermally conductive than copper, 1000 times more capacity to carry electric current than Copper. These amazing properties of nanocarbon materials have been utilized by scientists and engineers in realizing multifunctional materials such as conductive and stronger plastics; high performance composites and tires; battery and super capacitor electrode materials; high performance cements; multifunctional coatings for windows, steel etc; and many more. Nanocarbon materials can be flexible and transparent which can be used as electrode materials in touch screens, LEDs, solar cells and the emerging flexible electronics industry. See figure 2 for more examples of nanocarbon material adoption today, and within 5 years from now in different industries.

Nanotechnology promises ‘consuming less for more’ due to the superior properties of its nanostructured materials, as well as lower energy consumption and greener manufacturing processes. Nanotechnology offers cost and performance competitiveness in products and in many cases offering a game changer solution. We see enormous business opportunities for industry leaders and investors as nanotechnology has entered our daily life through various consumer electronics, automotive, aerospace, sporting goods, marine, water and energy industries. And it is entering construction and healthcare in the next few years. For those who are interested in the Asian efforts in Nanotechnology, please refer to our book “Emerging Nanotechnology Power: Nanotechnology R&D and Business Trends in Asia Pacific Rim” which can be order online at www.worldscibooks.com/nanosci/7224.html .

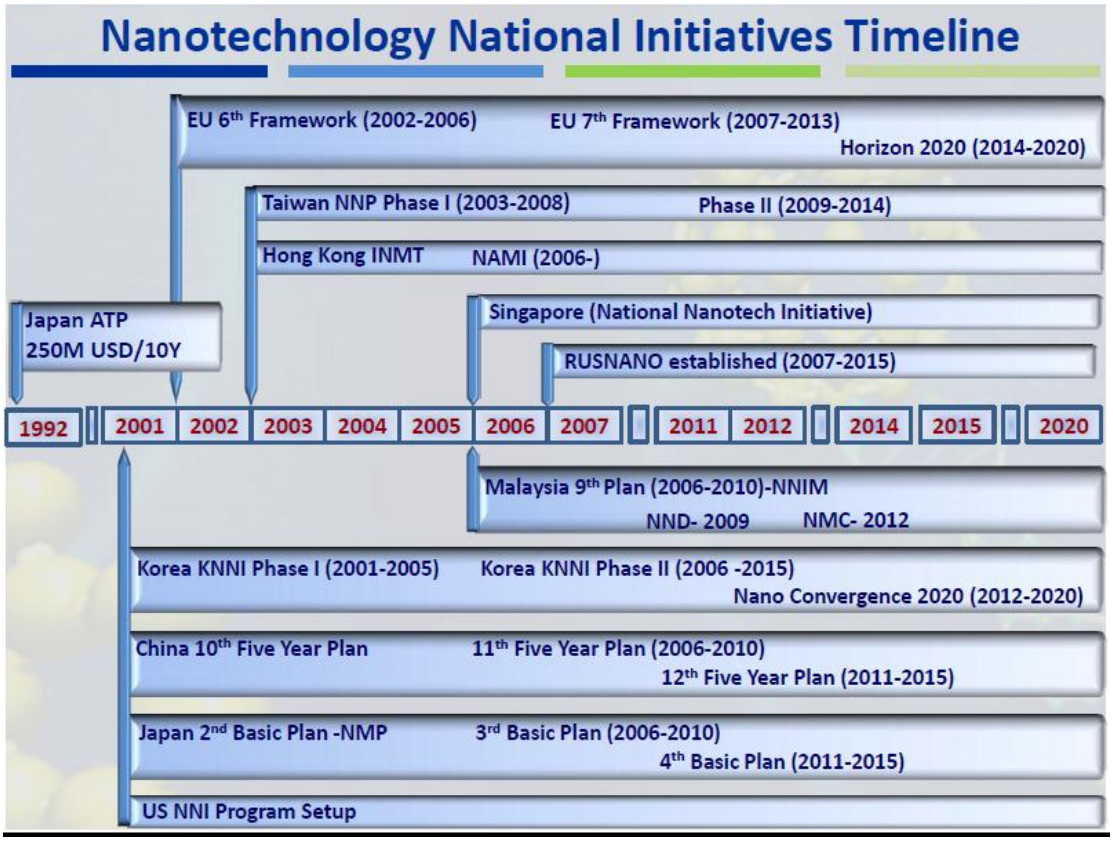

Figure 1. Timeline of national nanotechnology initiatives and programs in the leading economies.

Figure 2. Examples of Nano Carbon adoption and applications within 5 years.

3. Nanotechnology Driving Innovative Industry

With the benefits Nanotechnology promises, it is critical that the Islamic Development Bank (IDB) member economies are able to adopt nanotechnology innovation and solutions in industry sectors such as transportation, construction, security, oil & gas, water, renewable energy and agriculture to enable sustainable economic development (See Fig. 3). The key points to keep in mind are the following:

a) Transportation-vehicles such as boats, cars or planes that are made of nanomaterials (carbon nanomaterials) enhanced composites are much lighter and stronger resulting in consuming much less energy, and lower significantly carbon footprint.

b) Construction- concretes and other construction materials that contain nanomaterials (carbon nanomaterials) are much stronger and have self-cleaning properties resulting in using less concrete and maintenance free.

c) Security – Nanotechnology (with nanocomposites, MEMS based sensors and propulsion system) enables much smaller (nanosatellite), multi-functional and high precision controlled satellites in imaging and communication; Nanomaterials provides transparent conductive films/composites that are used to shield electro-magnetic interference to ensure building and “tough book” computer security.

d) Oil & Gas – Carbon nanomaterials finds application in drilling as the multifunctional nano coating on the drill bit enhancing significantly its durability and anti-corrosion property; Functionalised nano-graphene alleviates the clogging of oil-producing pores in newly drilled wells.

e) Water- nanomaterials enable multi-functional membrane systems in application of water reused, recovering expensive solvents for chemical, pharmaceutical, and electronics industry; separating toxic chemicals (e.g. Aniline) and heavy metals from water.

f) Renewable Energy- Nanotechnology enables cheaper solar cells by making higher efficiency and lower cost wafers, more cost effective electrodes and self-cleaning surface coating.

g) Agriculture- Nanomaterials (ZnO2) enable higher Zn content in crops and higher yield with damaging the soil.

We recommend the IDB members the following for developing the capability and adoption of nanotechnology:

1. Invest in R&D infrastructures and activities in topics relevant to the priority of the country to building strong innovation capability
2. Establish international partnership in R&D and technology transfer to ensure a more efficient capability development and adoption
3. Invest in education of nanoscience and technology for developing the future innovation capacity
4. Provide incentive for adoption of nanotechnology and related products enabling conservation of energy, water, environment and health

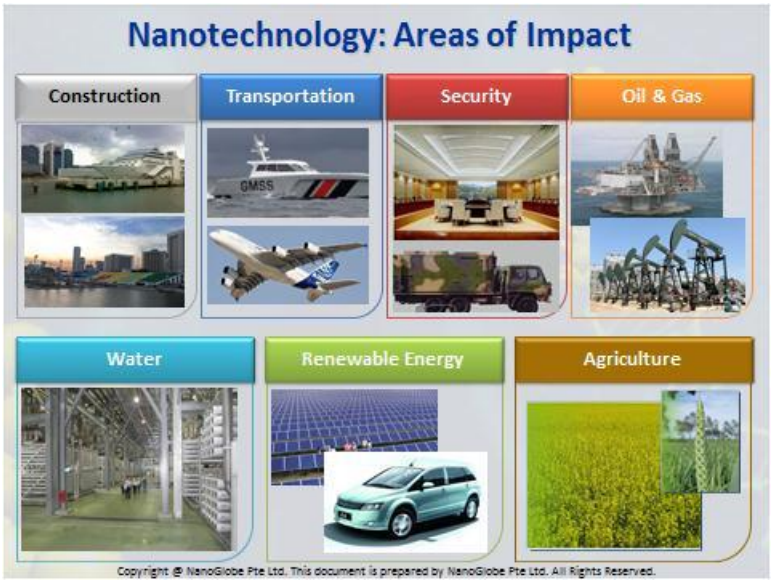

Figure 3.Summmary of Economic Impact of Nanotechnology Relevant to IDB Member Economies