

Nanotechnology development status in Malaysia: industrialization strategy and practices

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Abstract

Malaysia has started its own micro-technology and nano-technology development since the early millennium year of 2000 and arise until this day. Some key plans have proven effective and others fairly not. Status about strategies and practices planned in Malaysia with some relevant finding through experiences in industries collaboration observations and UniMAP involvement in nanotechnology are presented in this paper. Some suggestion and ideas are also presented.

Keywords: Nanotechnology, R&D, Industry, Strategy, Practice, Malaysia.

1. Introduction

Nanotechnology has become a new industrial revolution and many countries are investing heavily in this technology to maintain their market competitiveness. Since this is new yet growing and emerging, there is still a scarcity of research in this, particularly in developing countries like Malaysia. In terms of investment amounts, the USA leads other countries by investing USD3.7 billion through its National Nanotechnology Initiative (NNI), followed by Japan with USD750 million and European Union with USD1.2 billion in investment. (source: MIGHT Report, September 2006).

Nanotechnology has caused a stir worldwide because of its potential. Big countries have invested in nanotechnology and taken a full concern over the development of nanotechnology. Malaysia has to have its own nanotechnology policies and initiative as well as strategic plan to manage the technology, as extensively stressed by the Deputy Prime Minister in his several meetings about this management of nanotechnology (for example: The News Straits Times, 20th of June 2007). To sustain the technology, major agencies are also needed to guide the direction of nanotechnology management. Currently, Malaysia is lack behind in this aspect because of the technology is still new to the Malaysian expertise. The Ministry of Science, Technology and Innovation (MOSTI) oversees the nanotechnology development in this country, and particularly to develop policies, initiatives and strategic plans for nanotechnology.

Malaysia aspires to become a developed nation by 2020. Harnessing the energy and ingenuity of our scientific community is essential for a prosperous and innovative future of

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Malaysia. The world changes rapidly and dramatically. With these changes, the world becomes all the more connected and integrated, where boundaries no longer exist. Economic growth is being driven increasingly by the application of knowledge and ideas, rather than the production and trade of physical goods.

The start of the 21st century will be remembered as the era in which nanotechnology flowered. We are seeing new technologies, ideas and things emerge in profusion, all of which are destined to bring about big changes in our everyday lives. But let's not forget that the groundwork has to be laid for this flowering of nanotechnology. It was about fifty years ago that the word "nanotechnology" was coined, and the latter half of the twentieth century could be considered as its incubation period. As first described in a lecture titled, 'There's Plenty of Room at the Bottom' in 1959 by Richard P. Feynman, there is nothing besides our clumsy size that keeps us from using this space. In his time, it was not possible for us to manipulate single atoms or molecules because they were far too small for our tools. Thus, his speech was considered at that time completely theoretical and seemingly fantastic. He described how the laws of physics do not limit our ability to manipulate single atoms and molecules. Instead, what was holding us back was our lack of appropriate methods to do so. However, he correctly predicted that there would inevitably come a time when atomically precise manipulation of matter would become a reality.

This is a new field of science and technology where the component parts can be measured in a billionth of a metre. This not only means that complex and sophisticated systems can be incredibly small, but because they work at the atomic scale, new principles of physics apply and novel and revolutionary applications are indeed possible. Nanotechnology is small science with huge and immense potential. Nanotechnology exploits benefits of ultra small size, enabling the use of particles to deliver a range of profound and important benefits.

Nanotechnology is defined as "the science of materials and systems with structures and components which display improved novel physical, chemical and biological properties; phenomena that exist in the nano size scale (1-100 nm)". A nanometer (nm) is one thousand millionth of a meter. For comparison, a single human hair is about 80,000 nm wide. People are interested at the nanoscale because it is at this scale that the properties of materials can be very different from those at a larger scale. Chemists have been making polymers, which are large molecules made up of nanoscale subunits. (source: NNI Report, May 2008). The properties of materials can be different at the nanoscale for two main reasons.

- First, nanomaterials have a relatively larger surface area when compared to the same mass of materials produced in a larger form. This can make materials more chemically active and affect their strength or electrical properties.
- Second, quantum effects can begin to dominate the behaviour of matter at the nanoscale particular at the lower end, affecting optical, electrical and magnetic behaviour of materials.

Nanotechnology includes various fields of sciences which are related to each other as shown in the Figure below. The convergence of various disciplines towards nanotechnology is clearly shown with synergistic effort between the nanoscience and nanotechnology disciplines.

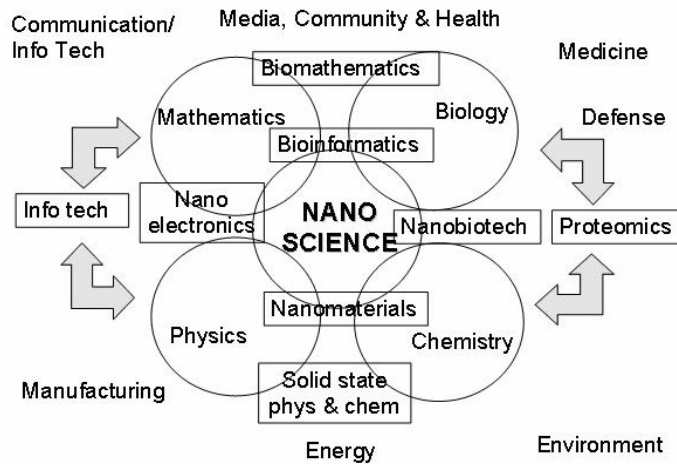


Fig. 1: The interdisciplinary field of sciences in Nanotechnology

Nanotechnology is about our future way of life. The worldwide annual industrial production in the nanotech sectors is estimated to exceed USD1 trillion in 10 - 15 years from now, which would require about 2 million nanotechnology workers.

2. The Economics of Nanotechnology

Virtually all industrialized countries have in development or have established a national strategy for nanotechnology. The focus varies from a general science-based strategy (for example the United States and France) to industry relevance-driven strategy (for example the European Community, Korea and Taiwan) from broad spectrum of areas (as in United States, Japan and Germany) to specific strengths. The level of investments in nanotechnology R&D has increased in most countries since 1997 (Table 1). A breakdown of other APEC economies are given in Table 2.

Year	1999	2000	2001	2002	2003	2004	2005
W Europe	179	200	~225	400	650	950	1050
Japan	157	245	550	753	800	900	950
USA	255	270	422	697	774	989	1081
Others	96	110	380	550	800	900	1000
Total	687	825	1577	2400	3024	3739	4081

Table 1: Estimated government sponsored R&D in USD million (Roco, J of Nanoparticle, 2005)

Year	2001	2002	2004
China	35.6	35.6	200
Korea	54	142	300
Singapore	7.5	9	-
Chinese Taipei	10	22	110
Australia	15	40	100

Table 2: APEC estimated nanotechnology R&D in USD million

Research spending on nanotechnology, mainly within the USA is large and growing as part of a National Nanotechnology Initiative worth approximately USD1000 million in FY2005. The largest US spender on nanotechnology research is the National Science Foundation (USD338 million), followed by the Department Of Defense (mainly the Defense Advanced Research Projects Agency (DARPA)) which is spending around USD257 million in the area. The next biggest spender is the Department of Energy (USD210 million) with the National Institutes of Health spending USD142 million.

Continental European research currently at USD175 million, is on the increase but does not match the level of US investment. Japan also has a substantial research programme funded by government to a level of about USD85 million. Within the UK the Research Councils are starting a number of initiatives in support of building expertise and knowledge in nanotechnology. The Engineering and Physical Sciences Research Council (EPSRC), and the Medical Research Council (MRC) are each already sponsoring a number of related grants together worth more than USD25 million and have both separately conducted 'theme day' conferences in the past year. Furthermore, they together with the Biotechnology and Biological Sciences Research Council (BBSRC) and Ministry of Defence (MOD) are considering sponsoring a small number of nanotechnology Interdisciplinary Research Collaborations worth a total of about USD5.2 million.

In Asia Pacific, almost all countries including Korea (July 2001), China (2002), Taiwan (September 2002), India (2003), Australia (2003), Singapore (2003) and Thailand (2003) have launched their National Nanotechnology Initiative. Asia countries have spent more than USD1.5 billion for nanotechnology development.

3. Malaysia Master Plan in Nanotechnology

Nanotechnology R&D started by government in 2001 and categorized as a Strategic Research (SR) program under IRPA in the Eight Malaysia Plan (8MP) which spans from 2001 to 2005 and funded by the MOSTI.

Malaysian government has taken a serious concern over the development of nanotechnology in the country. In the Third Industrial Master Plan (IMP3) that will span a 15-year period (2005-2020) is reported to recognize nanotechnology as the new emerging field. The Malaysia's National Budget 2006 unveiled the allocation of RM868 million to be provided under MOSTI for R&D. The focus will be on biotechnology, nanotechnology, advanced manufacturing, advanced materials, ICT, and alternative source of energy, including solar, to encourage innovation among local companies and developing new products.

However, the current development of nanotechnology in Malaysia still suffers from some shortfalls such as (Source: National Symposium on Science and Technology):

1. Linkages between the various projects
2. Lacks of central facility
3. No definitive plan to realized and develop nanotechnology industries
4. No clear road-map on nanotechnology R&D
5. Lack of efforts to promote awareness in nanotechnology
6. It should be noted that the important factors in that for further investigation can be categorized as having dedicated or specialized initiatives and plans. Furthermore, dedicated agencies were designed to implement those initiatives and plans.

3.1 Strategic Analysis of Nanotechnology in Malaysia

Table 3 listed strength, weaknesses, opportunities and threats as proposed by Malaysian Industry-Government Group for High Technology (MIGHT) for Economic Planning Unit (EPU), Prime Minister's Department.

Strengths	Weaknesses
<ul style="list-style-type: none"> ▪ Government development policies towards nanotechnology ▪ Government policies in various economic sectors that can benefit from nanotechnology ▪ Political and economical stability and national unity ▪ Availability of research bases 	<ul style="list-style-type: none"> ▪ No dedicated policy for nanotechnology ▪ Need for short-term and long-term human resource planning ▪ Lack of private sector participation and investment ▪ Lack of facilities ▪ No world class companies to raise standards
Opportunities	Threats
<ul style="list-style-type: none"> ▪ Rapid global development in nanotechnology ▪ Opportunities in nanotechnology outsourcing services ▪ Enhancing products in agriculture, biotechnology, medicine, energy and environment ▪ Potential for technology transfer to provide business opportunities ▪ Better explanation of innovation at the national level through easier access to venture capitals 	<ul style="list-style-type: none"> ▪ Continued fragmentation of efforts in research ▪ Potential public perception on risks of the uses of nanotechnology ▪ Young researchers lost via brain drain ▪ China, India are ahead in nanotechnology R&D and businesses ▪ New nanotechnology materials/ products threaten Malaysia's current major exports.

Table 3: strength, weaknesses, opportunities and threats

Malaysia has for decades trained scientists capable of contributing to the national development in science and technology (S&T), where some pioneering work in nanotechnology were initiated since the Seventh Malaysia Plan (7MP). Current database indicates that there are about 150 local scientists directly involved in various areas of nanotechnology research.

The Intensification of Priority Research Areas (IRPA) programme of the Eighth Malaysia Plan (8MP), which is administered by MOSTE, identified nanotechnology as one of the 14 research priority areas, and is categorized under "Strategic Research" (SR) (see Table below). The SR projects are for a maximum period of 60 months, with potential for enhancing future competitive socio-economic development or new breakthroughs with commercial potential. Additionally, the projects must be multi-disciplinary, and have industrial linkages, with potential for commercialization.

Research Category	Allocation (%)	Priority Areas (% - Allocation)
Experimental Applied Research	30	Agriculture and Food Security Natural Resources and Environment Manufacturing and Services Social Transformation Knowledge Advancement
Prioritised Research	35	Manufacturing Plant Production and Primary Products Information and Communication Health Education and Training
Strategic Research	35	Design and Software Technology Nano-technology and Precision Engineering Specialty Fine Chemicals Technology Optical Technology

Table 4: Research categories and its allocations under IRPA; (source: MOSTI (2001))

At the end of Eighth Malaysia Plan, MOSTI has awarded about RM160 million to nanotechnology related research projects. The inclusion of nanotechnology as a priority area under IRPA for 8 & 9 MP is timely, and is poised to position the country in the long term to nurture a nanoscience research culture among researchers, and develop world class nanotechnology laboratories in Malaysia.

The short term strategy of Malaysia is geared towards identifying researchers in various areas of nanotechnology with specific expertise; upgrading and equipping nanotechnology laboratories with state-of-the-art facilities; and to prepare a comprehensive human resource development programme for producing nanotechnologists (Hamdan, 2002, Abd Hamid 2003). MOSTI is now entrusted to spearhead the planning and development of the National Nanotechnology Initiative (NNI).

4. Progress of Malaysian Nanotechnology

Some recent developments of Malaysia in nanotechnology are:

- Establishment of well-equipped nanoscience/nanotechnology research centres, for example: the Ibnu Sina Institute for Fundamental Science Studies (IIS), Universiti Teknologi Malaysia; Institute of Microengineering and Nanotechnology (IMEN), Universiti Kebangsaan Malaysia; Advanced Materials Research Centre (AMREC) of SIRIM Bhd; and the Combinatorial Technology and Catalysis Research Centre (COMBICAT), Universiti Malaya.
- Increased number of postgraduates in nanoscience/advanced materials. The government has introduced the National Science Fellowship (NSF) scheme, which is open to postgraduate studies in nanoscience and technology. There are more than 300 graduate students in the country actively pursuing research in nanotechnology;
- Commendable number of journal publications; Organization of national seminars on nanoscience and nanotechnology, for example, the Palm Oil International Congress (PI-POC), Electron Microscope, Advanced Technology Congress, Green Chemistry, SKAM, etc.;

- Categorization of nanotechnology as a priority area under IRPA of 8MP, where RM1 billion is available to IRPA under 8MP; and 9MP where a total of 2.5 billion is allocated.
- Collaborations with international research organizations.

UniMAP recently has announced its newly establishment Institute of Nanoelectronics Engineering which will serve as an excellence landmark for the university specifically in the field of nanotechnology engineering research, and will function as one of the regional reference centers focusing in Nanoelectronic Engineering, for the northern Malaysia Super Corridor. This establishment will be in-line with National Nanotechnology Initiative effort. As for the beginning, the Institute will establish five research groups namely nanobiochips, photonics, non-volatile memory devices, novel devices and smart sensor. In addition, its will complement with the existing nanotechnology research group in the country.

5. Nanotechnology Activities in Malaysia

The potential benefits of nanoscience and technology are pervasive, as illustrated in the burst of interest and effort worldwide in several fields outlined below: materials and manufacturing; nanoelectronics and computer technology; medicine and health; aeronautics and space exploration; environment and energy; biotechnology and agriculture; national security; and science and education.

There are many groups actively involved in nanotechnology R&D in Malaysia. The list is far from comprehensive, as virtually all IHL and GRI are actively engaged in such research. The committed support from the government, seen in the increased R&D funding to MOSTI for nanotechnology R&D, enabled the growth of a significant number of research centers pursuing nanoscience and technology:

- Material and Manufacturing
- Nanoelectronic and Computer Technology
- Life Sciences/Medicine and Health

5.1 Material and Manufacturing

One of the major areas pursued by Malaysian scientists, in tandem with governmental funding through research and educational sponsorship by the MOSTE, is the generation of nanomaterials. summarises some of the major effort undertaken by various research groups in Malaysia.

Application	Areas	Head/Institute	Funds
Metal Industry	Metal Composites	AMREC	MOSTI
Chemical industries - acrylic acids - oleochemicals - surfactants	Catalysts, Catalyst support, Adsorbent	COMBICAT, UM	MOSTI
	Catalyst Adsorbent	Institut Ibnu Sina, UTM	MOSTI MOHE
Nanoelectronics	Chemical sensor	UTP	MOSTI

Table 5: Examples of projects in advanced materials and sensors

5.2 Nanoelectronic and Computer Technology

This area of nanotechnology is the main driver of the field. It is embedded into the current production strategy of the industry and is a major single source of innovation. It is thus important for the country for Malaysia to pursue some research activities with international visibility.

Applications	Areas	Head/Institute	Funds
Automotive	MEMS and Microsensors/ Organic Electronics	IMEN UKM, UPM, VLSI	MOSTI
GMR	Electronics	AMREC	MOSTI
Blue Light Emitting Devices	Electronics	USM	MOSTI
Advanced optical crystal for electro-optic application	Electronics	UTM, UM, UPM	MOSTI

Table 6: Examples of projects in electronics and communications

5.3 Life Sciences/Medicine and Health

Living systems are governed by molecular static and dynamical properties at nanometer scales, where the disciplines of chemistry, physics, biology, and computer simulation all now converge. There is one area of development in life-sciences with Malaysia's active participation: the design and synthesis of biologically functional nanostructures by genetically modified living systems.

Application	Areas	Head/Institute	Funds
Biopharmaceutical proteins for human therapeutics drugs and vaccines	Nanomedicine	UPM	MOSTI
Bone graft substitutes	Nanomaterial	MINT, SIRIM, USM, UKM, UIA	MOSTI
Diagnostic kits for infectious diseases	Nano-device Molecular Nanotechnology	USM	MOSTI
Antioxidants in preventing degenerative damage in Down syndrome and ageing	Nanomedicine	UKM	MOSTI
Vaccine production against infectious dis- eases	Nanomedicine	USM	MOSTI
Oncology: Liver cancer	Nanomedicine	UM	MOSTI
Diagnostic kit for diabetic vasculopathy	Nanomedicine	UM	MOSTI
Antibiotic resistance	Nanomedicine	UM, USM, VRI, MOH	MOSTI
Drug Synthesis	Nanomedicine	UiTM	MOSTI

Table 7: Examples of projects in medicine and health

6. The Way Forward

Although Malaysian nanotechnology is still at infancy stage, it is imperative that the approval of NNI by the Government will drive Malaysia towards forming the National Nanotechnology Centre (NNC). This will stimulate and accelerate the progress of the development of home grown nanotechnology into beneficial technologies.

The strategies of NNI focus on: (a) improve Malaysian economic competitiveness to face global challenges, (b) accelerate scientific breakthrough on selective beneficial nanotechnologies, (c) enhance societal and environmental contribution.

The following actions have been implemented by MOSTI:

- Incorporation of nanotechnology as a national priority in the Ninth Malaysia Plan by the Cabinet
- Proposed establishment of National Nanotechnology Centre (NNC) by MOSTI

7. Establishment of National Nanotechnology Centre (NNC)

It is recommended that NNC is established and administered under the auspices of the Ministry of Science Technology (MOSTI). With the establishment of NNC, a management team will be appointed to administer and plan the National Nanotechnology Initiative.

NNC shall be entrusted to drive the NNI, coordinate national R&D in nanotechnology, strengthen present nanotechnology research centres to become National Nanotechnology Research Centre (NNRC) with state of the art research facility and liaise with industries to address business and economic agenda and develop international networking. Detailed functions and coordination activities of NNC Working Committees are as follows:

- (i) Form the organizational structure of NNC
- (ii) Draft a National Nanotechnology Policy
- (iii) Formulate financial implication strategies for R&D, education and national nanotechnology management grants
- (iv) Establish national nanotechnology niche areas and conduct nanotechnology foresight exercises
- (v) Manage nanotechnology research and development activities
- (vi) Provide, enhance and monitor the national nanotechnology infrastructure and research facilities
- (vii) Training and human resource development
- (viii) Update the national nanotechnology database
- (ix) Create and strategize national nanotechnology education programme
- (x) Assist the national nanotechnology commercialization and investment activities
- (xi) Extend the national and international collaboration and networking to develop local human capital and expertise in nanotechnology
- (xii) Monitor the potential health, environmental and societal impacts of nanotechnology
- (xiii) Formulate nanotechnology standards and specifications
- (xiv) Manage nanotechnology Intellectual Properties and legal matters
- (xv) Undertake commercialization and industrial collaboration activities

The above recommendations should be implemented in phases to ensure that adoption, adaptation and innovation of the technology is a gradual process and, transformation and dissemination of the technology is well infused to the Malaysian way of life.

8. Key Actions of NNC

It is recommended that the key actions are implemented in phases to ensure that actions taken are reviewed and evaluated. The phases are short term (5 years), medium term (5 to 15 years) and long term (above 15 years) action plans. The detailed activities and action plans proposed for each term is shown in the Figure below:

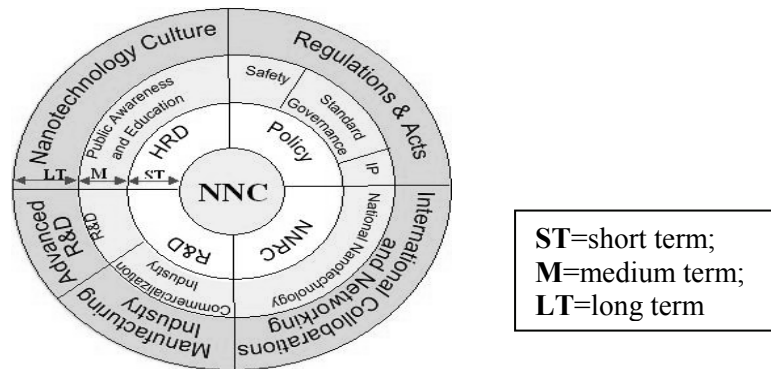


Fig. 2: Detailed activities and action plans proposed for short-term, medium-term and long-term for NNC

8.1 Short Term

Action I: Identify and Strengthen Existing Nanotechnology Research Centres to become National Nanotechnology Research Centres (NNRC)

In Malaysia, a series of internationally-renowned research centres in nanotechnology exist in the present key areas of technological relevance: nanoelectronics; nanobiotechnology; and nanomaterial science. These research centres will be identified by the NNC and given full support to develop nanotechnology research and activities at the national level.

Action II: Identify and Embark on Strategic Research

The NNRCs should actively pursue 3 categories of research namely:

1. New fundamental research that will lead to breakthrough in nanotechnology,
2. Commercialization of research with emphasis of Malaysian primary industry and,
3. Advancement in existing manufacturing into nanomanufacturing and industrial applications

The outcome of the nanotechnology foresight and niche areas identification studies will prioritize the nanotechnology areas for the country.

Action III: Integration of Technical and Human Resource Infrastructure

Most crucial recipe to the success of the R&D is the human resource factor. In summary NNC requires internationally-competitive level of technical and human resources infrastructure to warrant success in the R&D.

Recommendations to create a knowledge based society that will generate interest in advance scientific research especially in the field of nanotechnology are as follows:

1. Promote Greater Public Awareness on the Impact of Nanotechnology in Future Economy, Societal and Environment. Successful campaign in nanotechnology will generate similar interest by the public.

2. Develop and introduce nanoscale concepts into mathematics, sciences engineering in Primary and Tertiary Education. It is imperative to develop interdisciplinary perspective to students to enhance their disciplinary skill.
3. Educate and train new generation of scientists and supporting teams in nanotechnology which include societal implications.
4. Inculcate the concept of mobility within nanotechnology research community. The infrastructure, quality and efficiency of NNRC must be enhanced to attract researchers from diverse expertise to perform prioritized nanotechnology research.
5. Integration and collaboration among institutes of higher learning and between institutes of higher learning and the industry to combine resource and expertise.
6. International strategic partnerships must be intensified by pursuing collaborative research programmes, with shared responsibilities and resources, and fair distribution of scientific and economic revenues.

8.2 Medium Term

Action I: Establish National Nanotechnology Laboratory

Action II: Enhance Nanotechnology Research in the Proposed Areas

Drug delivery system, new drugs, nanosensors, dental materials, biomimetic and biological materials, optoelectronic, water purification.

Action III: Review Malaysia Regulatory Frameworks (Governance of Nanotechnology) to ensure that Innovation in Nanotechnology is regulated and Controlled.

It is recommended that the NNC takes the following stand without jeopardising the research and development and application of nanotechnology: -

1. Form a special task force to review National Nanotechnology Regulatory Frameworks and introduce regulations, laws and legislations specifically for the manufacturing and application of current and future nano based technology.
2. Monitor the development of nanotechnology policies, regulations, bylaws and legislations abroad.
3. Develop Malaysian Nanotechnology Standard through joint effort between NNC and SIRIM Berhad.

Action IV: Create Public Awareness and Interest in Nanotechnology

It is recommended that NNC adopt the following approach in propagating the importance of nanotechnology: -

1. Educate the public through media, publication, journal and forum.
2. Emphasize on the health, safety and environmental implications of nanotechnology to the public.

8.3 Long Term

Action I: Inculcation of Nanotechnology Culture to the Society

Action II: Commercialization and Industrialization of Nanotechnology

Action III: Advanced Level Nanotechnology R&D

9. Nanotechnology and the Question of Development

Nanotechnology is a field that incorporates a wide range of activities including manufacturing, synthesis and processing of functional nanostructures with designated properties, the chemistry of supramolecule and nanomolecule, self-assembly and replication techniques, sintering of nanostructured alloy, the application of quantum effect, template and chemical

and biological sensor, modification of surfaces, membranes, thin films and measurements of nanostructures (see Figure below).

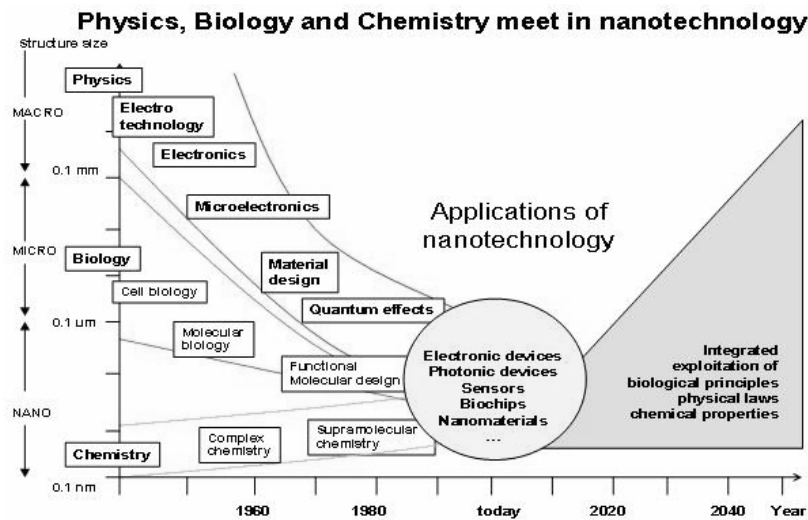


Fig. 3: Research approach in Nanotechnology (Tegart, G, Nanotechnology: The Technology for the 21st Century, Vol II the Full Report, APEC Center fo Technology Foresight (2002)

Malaysia is fortunate in that it has a leadership that is fully committed to develop a nation that is progressive, resilient and competitive. Malaysia’s national vision, namely Vision 2020, was introduced in 1990 with the goal of attaining a developed nation status by the year 2020. One of the key challenges of Vision 2020 is to develop a strong foundation for science and technology such that Malaysia will not only be a user of but also a contributor to scientific and technological advancements.

Malaysia has just fifteen years to go to achieve its national vision. It is gearing itself for the transformation into a knowledge-based economy or **K Economy**, that is, an economy driven by knowledge and innovation. Strategies and approaches for a K Economy would have to be different from those adopted to develop an industrial or production-based economy. Physical infrastructure that is critical for an industrial economy is no longer a major determinant for success in the K Economy. Instead, the K Economy requires investments in the **Knowledge Infrastructure**.

As knowledge is the most critical factor for competitive advantage in the K Economy, the infrastructure must enable knowledge generation, acquisition, and the utilization of knowledge to produce goods and services that are competitive in the global market. Thus, Malaysia would need to invest in the Knowledge Infrastructure that consists of:

- (i) an **education system** designed to produce a large pool of qualified and skilled workforce in science, technology and engineering and other innovative, creative and enterprising professionals;
- (ii) a **research and development (R&D) system** able to generate knowledge at the frontiers as well as new technologies demanded by the production and services sectors;
- (iii) a strong **intellectual property (IP) regime** that provides effective protection and appropriation of intellectual property rights;
- (iv) a **technology transfer system** that ensures efficient transfer of knowledge and technology from the R&D system to the industry and business sectors;
- (v) a critical mass of **innovative firms and entrepreneurs** to exploit knowledge to produce goods and services for the local and global market;
- (vi) a **financial system** that promotes investment in high risk ventures; and
- (vii) an **eco-system** that facilitates knowledge flows and promote interaction between and among the systems mentioned above.

Malaysia has just recently launched its Ninth Malaysia Plan which sets out the development plan and strategies for the period from 2006 to 2010. This is the first step in the next fifteen years journey towards a developed nation status. These are the strategies and measures that have been identified to implement the national development plan.

Firstly, Malaysia will focus its attention on strengthening the **National Innovation System (NIS)**. The **National Innovation Council (NIC)** with the Honourable Prime Minister as Chairman will provide the leadership to set the direction and the implementation framework for the **National Innovation Agenda**.

A strong NIS will facilitate Malaysia's integration into the global technology and knowledge creating network. As technologies become increasingly complex and the cost of creating new knowledge and technology rises, firms adopt strategies to reduce cost through outsourcing of some of their innovative activities.

Developing countries with relatively low cost but highly qualified human resource can take advantage of this opportunity to undertake the outsourced activities. In this respect, Malaysia is developing the infrastructure and capability to take advantage of these outsourcing activities.

In the ICT sector, cost competitiveness, highly educated and skilled workforce, pro-ICT government and world class infrastructure make Malaysia an obvious choice for activities such as **shared services and outsourcing (SSO)**. A.T. Kearney ranked the SSO cluster in the Multimedia Super Corridor (MSC) at number three in the world after China and India. The MSC initiative launched in 1996 was aimed at attracting leading ICT companies to locate in the MSC and undertake research, development of new products and technologies and export from this base. A set of innovative incentive package comprising fiscal and non-fiscal incentives are provided to MSC status companies.

As an '**open economy**', Malaysia has attracted large inflows of **foreign direct investments (FDIs)** and **transnational corporations (TNCs)** especially in the electrical and electronic sectors. The infrastructure and incentives to attract FDI in the knowledge based industries are different from that required for the production economy. It is vital that Malaysia strengthens its NIS to compete with countries such as China and India for FDIs. Recent trends that point to increasing internationalization of R&D activities of the TNCs will benefit those countries that have the enabling environment, in particular the availability of human capital and R&D infrastructure as well as to incentivise TNCs to conduct their R&D in the host countries. In this regard, human capital development is central to Malaysia's development plan, in

particular human capital to enable effective harnessing of science and technology for wealth creation and societal well-being.

At present Malaysia lacks the critical mass of qualified scientists, engineers and related professionals that are much needed to drive the K Economy. In 2004, Malaysia had only 21 research scientists and engineers (RSEs) for every 10,000 workforce. The target set in the Ninth Malaysia is to **achieve 50 RSEs per 10,000 workforce by the year 2010**. The shortage of RSEs will be somewhat mitigated, in the short term, with the implementation of the National Brain Gain Programme. The objective of this Programme is to attract scientists and engineers worldwide to conduct R&D in Malaysia.

Malaysia views international strategic partnerships as an effective means to assess frontier knowledge and accelerate scientific and technological advancements. In this regard, Malaysian universities and research institutions have been actively engaged in **collaborative research and technology development with centres of excellence in both the developed and developing countries**. We look forward to enhance our cooperation with EU countries. While the acquisition of knowledge through collaborative R&D projects as well as attachments of Malaysian scientists and researchers in reknown research centres are further expanded, at the same time, significant allocations are devoted to developing Malaysia's own centres of excellence in areas of strategic importance. For example, three new centres of excellence in genomics, agriculture biotechnology, and pharmaceuticals and nutraceuticals have been established recently to catalyse the development of a strong scientific base in biotechnology. Just a few years ago, the Government of Malaysia launched the National Nanotechnology Initiative.

The Government of Malaysia realizes that building a strong scientific base and increased investments in R&D are not sufficient to drive the transformation of the K Economy. An equally if not more crucial requirement is to promote the creation of a large pool of innovative firms and entrepreneurs. It is the private enterprises that have the capacity and business aptitude to exploit knowledge and new technologies for economic gains. It is therefore crucial that **private enterprises are incentivised to exploit knowledge and technology generated from research laboratories** to generate new products and services for the local and global market.

The Government of Malaysia provides various types of **fiscal and non-fiscal incentives** to private enterprises to promote their involvement in R&D and innovative activities. The R&D and commercialization funding mechanism was recently restructured to plug the financing gaps, in particular financing for development and pre-commercialization activities. Three new funds have been created namely Science, Techno and InnoFund. These funds are open to both the public institutions and private sector enterprises. Firms that undertake R&D are also eligible for double tax deduction.

The lack of **entrepreneurs** has been identified as one of the weaknesses of the Malaysian innovation system. The Government of Malaysia has introduced various programmes to address this weak link in the NIS. For example in the ICT sector, a technopreneur development programme has been implemented in the MSC. With respect to the technology-based sectors, technology incubator facilities have been provided by the Government to create the critical mass of entrepreneurs as well as to catalyse the creation of new technology based firms.

While attention is turned to developing new technology based enterprises, the Government gives **equal attention to the small and medium enterprises (SMEs)** that make up more than 90 per cent of enterprises in Malaysia. With respect to SMEs, the emphasis is on upgrading their technological capabilities to enable their integration into the global production network. One of the measures taken is through support programmes that enable SMEs to use new and advanced technologies including ICT in their production and business processes. A

new element in the SME blueprint is the development of SMEs in the knowledge-based industries.

In transforming Malaysia's economy to one driven by knowledge and innovation, the Government of Malaysia is fully aware of the possibility of creating economic and social divide among regions as well as its population.

10. The Outcome and its Significance for Development

So far Malaysia has spent more than RM140 million IRPA grants on a number of nanotechnology-related research projects. Nanotechnology research is conducted by separate research groups without central coordination and planning. Malaysia is fortunate to be part of the Asia Nanotechnology Forum. Japan started the national nano science and technology program since the mid 1980s and many of our ASEAN neighbours (including Thailand, Singapore, Vietnam) have already embarked on nanotechnology since the early millennium. In 2003, Asia contributed over USD1.5 billion, - half of global nanotech funding - and it is continuously raising its role in the global nanotech arena. Along with the Asia Nanotech Forum for building the Asia Nano Science and Technology Initiative, Malaysia must play our role in order to enhance the global competitiveness and contribute to the prosperity of the nation.

The government has expanded its actions beyond previous initiatives in science and technology, engaging business, industry and community in the drive to become more innovative and forward looking. Recognising the importance of integrated nanotechnology, I am pleased to learn that the Ibnu Sina Institute is proposing the creation of the Malaysian National Nanotechnology Initiatives or Inisiatif Nanoteknologi Nasional (INN). A Malaysian Nanotechnology Centre will reflect the central role of nanotechnology in Malaysia's economic development in the coming decades.

The government is very much interested in promoting Nanotechnology as one of the top priority areas in Science and Technology. One of the most important tasks of INN therefore will be to prepare Malaysia's National Master Plan on Nanotechnology. One of the key performance indices of the success of nanotechnology is strategic alliance including the mechanism of integration and co-ordination between the R & D players or scientists, the policy makers, the technology developers and industries, the financiers and of course, most importantly, the public who will benefit from it. Some of the key issues that must be addressed include identifying key organisations, strategic research areas, building interdisciplinary research projects, education programs and management of the nano programs.

Nanotechnology is about innovation at the atomic or molecular scale. Innovation means finding new or better ways to do things, creating new products and technologies. The Malaysian government will continue to commit to innovation in nanotechnology at every level of the economy and community. Part of the INN will be the enhancement and extension of world-class nanotechnology research institutions, strong expenditure on R&D in nanotechnology, a competitive business environment, a robust education and training system, a highly skilled, educated and diverse workforce, efficient infrastructure and integrated involvement in nanotechnology activities.

11. Conclusions

Currently in Malaysia there are research activities of world class standing being conducted by our local scientists in the universities and research institutes. They are currently working on important areas such as nanostructured mesoporous materials, hybrid catalysts and others. In addition, there are many young Malaysian scientists undergoing post-graduate studies in areas of nanotechnology locally and overseas.

This new wave of industrial innovations requires early integration of science, technology and manufacturing to achieve world class product and services. That means 'skilling up' and improving access to education and training. Nanotechnology is about people. It is about making sure we educate, integrate ideas, technology and knowledge to produce better products with novel properties at the nanoscale which enhances our environment and standard of living.

It is therefore critical that young people and the broader community recognise that nanotechnology-related careers are integral to the development of a successful economic future. Many sections of the community need to understand nanotechnology and the government is keen to ensure that nanotechnology is understood by the society. Pursuing nanotechnology is a global trend and requires global cooperation. We must therefore be integrated into the global nanotech community. In this context, we are honoured to be a network member of the Asia Nano Forum and are keen to work closely with ANF network and contribute to the regional and global advancement in nanotechnology.

Becoming more innovative and creative will ensure that Malaysia not only keeps abreast with the rest of the world, but it will become a global player in nanotechnology that will drive future economic growth. The outcome of many of the nanotechnology endeavours will not happen overnight. Industries must be at the forefront in adopting this emerging technology so that when the time comes, the country is well prepared.

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