MANUAL ON CRITICAL ISSUES IN
NANOTECHNOLOGY R&D MANAGEMENT
AN ASIA-PACIFIC PERSPECTIVE

CHAPTER 4
Development and Commercialization of
Nanotechnology-based Value Added Products
Case studies from Asia and the Pacific

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**Manual on Critical Issues in Nanotechnology R&D Management: An Asia-Pacific Perspective**

Asian and Pacific Centre for Transfer of Technology (APCTT) of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)

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Table of Contents

1 Preamble 4
2 Problem description 5
3 World-wide scenario of nanotechnology 6
4 A brief introduction to nanotechnology 6
5 Nano-products in the market 7
6 Countries selected for case study of R&D institutes and industries involved in nanotechnology 8
7 Limitations in the study 9
8 Country-wise case studies 10
8.1 China 10
8.2 India 15
8.3 Indonesia 20
8.4 Islamic Republic of Iran 24
8.5 Japan 28
8.6 Republic of Korea 36
8.7 Malaysia 42
8.8 Pakistan 45
8.9 The Philippines 47
8.10 Sri Lanka 56
8.11 Thailand 61
9 Status of IPR policies nanotechnology in Asia-Pacific countries 66
9.1 What is IPR? 66
9.2 IPR considerations for nanotechnology in Asia-Pacific countries 66
9.3 Conclusion 71
List of Tables

Table 1: Legal status of NanoCarrier’s major patents .........................................................32
Table 2: Present patent status of AnyGen...............................................................................39

List of Figures

Figure 1: Puritech water filter candle fixed in Matka (Clay pot).................................................18
Development and Commercialization of Nanotechnology-based Value Added Products
Case studies from Asia and the Pacific

1. Preamble

Today the world has realized Feynman’s dream……………………………

“I want to build a billion tiny factories, models of each other, which are manufacturing simultaneously. . .The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big”

—Richard Feynman

………………………….and nanotechnology became a revolutionary field which has made huge impact on several areas of material sciences and has applications in every field of science. But the true realization of his dream has led to an explosive improvement in our understanding of nanoscience and has produced new possibilities for the investigation and application in various fields of science.

The prediction that a very large market for nanotechnology enabled products is in the offing, has made the world realize that with the help of this new technology many new jobs may be created. Thus, it will have potential economic impacts. No wonder, governments are developing strategies to promote the R&D and commercialization of nanotechnology.

Over the past three decades scientists, economists, policy planners, Government authorities, and industrialists are trying to understand and apply nanotechnology for the betterment of mankind.

The realization that bringing the fruits of nanotechnology to masses is possible only through the extensive research in this field; both public and private sectors are investing in this sector. No other technology in the past had received such huge investment in such a short time as nanotechnology has.

The second challenge is converting the outcome of research to production through industries. Like all the other products, most of the manufacturing competitors are located in the Asia-Pacific countries. Hence, the status of industries in nanotechnology in the Asia-Pacific countries demands an assessment.

Industries have also realized that advancement in the production of nanotechnology-based products is totally dependent upon R&D; therefore, in-house R&D of companies have also become very active. The R&D efforts have given them the understanding that nanotechnology can not only upgrade the
traditional industries by adding value to the product or by enabling new functionalities of production, but it can also converge with other technologies and create novel innovative products.

This chapter presents some case studies, which summarize the efforts of Asia-Pacific countries in the research & development and commercialization of nanotechnology-based value added products.

2. Problem description

With increase in world population, demand for all requirements are continually increasing, whether it is land to live, land for agriculture, land for industries, more consumable products, more food, consumable water, healthy environment, health-care products and industries that produce without creating pollution and toxic outputs…. the list is endless. This has created a demand for researching new approach and generation of efficient environmentally friendly products. Nanotechnology has entered into the arena to help in solving such problems.

_Lux Market Research Group (2004)_ estimated that the sales of products incorporating nanotechnology would rise from less than 0.1% of global manufacturing output in 2004 to 15% in 2014, totalling $2.6 trillion.

The global market for Quantum Dots (nano particles having <10 nm size) that has great commercial application in life sciences is projected to reach more than $700 million by 2013. The biggest growth sector will be in optics for QD-based lasers and other optical components in telecommunications. The other growth sector is in electronics for QD-based flash memory and optoelectronics in lighting and displays (electronics).

Agro-sector is in dire need of increased production. Advancement in controlling fertilizer, pesticide and herbicide inputs, crop improvement and solving plant pathological problems are also the need of the hour.

Health-care of mankind fighting with dreaded diseases like cancer and HIV is another area that is looking at novel innovative and less toxic therapy as well a diagnostic kits that can ensure early disease detection.

Research carried out so far has given strong indications that nanotechnology can contribute in solving these problems and requirements.

However, like all other technologies there may be the darker side of this technology pertaining to environment, long term effects on health, etc that needs a closure scrutiny and accordingly the strategies are to be formed.

3. World-wide scenario of nanotechnology

Right from the beginning, development of mankind has been through developing technology. Thousands of years ago the hunters and gatherers developed stone and wood armaments and then they developed cultivation technology. With the advancement the technology shifting towards the development of wheels and pulley, finally many machines, electricity and electronics came into
existence thus accelerating the very pace of growth and development. With the invention of atomic force microscopy (AFM), Scanning electron microscopy (SEM), transmission electron microscopy (TEM) and the vision of Feynman that “There is plenty of the room at the bottom”, a new branch of science and technology – NANOTECHNOLOGY evolved in mid-20th century.

Nanotechnology has now become a part of the rich tapestry of scientific knowledge. Although enormous advances in our understanding of nanoscience have occurred, their strategic applications still constitute a major growth area in nanotechnology. Last three decades has seen nanotechnology as an emerging technology that has attracted world-wide attention. Not only scientists are paying attention to it but governments of various developed countries like USA, European countries and Asian countries like China, Japan, and the Republic of Korea are also developing strategies and investing funds to promote research and industrialization of nanotechnology. Its emergence has been spurred by key inventions in instrumentation and sizeable R&D funding, the funding of new research centres and new agencies. Investment by private sector in both R&D and production is steadily increasing. The capabilities of industries are based on the access to R&D sources or their own in-house research.

Since one of the big markets, USA has adopted the policy of non-manufacturing, the scope for Asian countries with cheap labour and large scientific and technical man-power has increased.

Establishment of organizations like Nanotechnology Industries Association (NIA) by multinational companies active in Nanotechnology including Unilever, BASF, Smith&Nephew, Qinetiq with ~50 Registered Members (February 2010) based in Australia, Belgium, Finland, France, Germany, Portugal, Spain, UK and US are operating across Europe and liaising with US, Australia, Japan, Asia Pacific, etc. NIA is a sector-independent, responsible voice for the industrial nanotechnologies supply chains. It promotes the ongoing innovation and commercialization of nanotechnologies and promotes their safe and reliable advancement.

4. A brief introduction to nanotechnology

Nanotechnology refers to the applied part of nanoscience involving synthesis and use of nano-sized particles in the range of 1 to 100 nm. Nanoparticles are multi-atomic nanostructures straddling between atomic and bulk scale. All atoms functionally obey quantum mechanical principles; whereas bulk scale matters follow the principles of classical physics. Since nanoparticles are multi-atomic nano-structures they exhibit a blend of quantum behaviour and specific properties of nano-sized material, e.g. they exhibit dominantly statistical mechanical principles in which the energy is well quantized and discrete. This consequently leads to the dominion of surface energies due to the excited electrons of the surface atoms of nanomaterials. This has also intrigued material scientists to comprehend the unique nano-scale phenomena such as quantum confinement and quantum tunnelling which exhibits special characteristics to nanomaterials. The orchestration of small size, ability to confine resonant photons within its small size, complex organizational patterns, potential for very high packing densities, strong lateral interactions and high ratios of surface area to volume makes nanoscale materials a powerful armamentarium for a plethora of applications, e.g. single-electron
transistors (SETs) and light emitters, catalysis, optoelectronics, optics, photothermal therapy, reprography, non-linear optical devices and photo electrochemical applications, etc.

The elements of nano-scale products are sub-miniature compounds that are incorporated into ordinary materials during or after the original manufacturing process. Nanotechnologies hold the promise of breathing new life into these industries, primarily through the development of radically new products. The process of “molecular manufacturing,” that is, precisely building a material molecule by molecule, means near-perfect assembly. Molecular manufacturing also stands to greatly reduce the environmental impact of manufacturing. Waste can be practically eliminated; many current manufacturing techniques involve copious use of harsh chemical reagents which are often dumped into the environment in developing countries with lax regulations. Instead, the manufacturing precision afforded by Nanotechnology means that not a single atom has to go to waste. Any unwanted atoms can be neatly repackaged for recycling or be returned to their source.

According to the National Nanotechnology Initiative (NNI), USA, nanotechnology-based manufacturing processes are believed to lead up to 99% reduction of the energy and materials used today. However, initially heavy investment is needed for training manpower to develop and apply new technology, and capital investment in new manufacturing techniques and machinery. In addition to these costs, the largest expense is likely to be the investments in research and development needed to move from the current nanotechnologies to production.

5. Nano-products in the market

Nanotechnology Nanotechnology is an emerging scientific field creating materials, devices, and systems at the molecular level. By being able to work at this ultra-small scale, nanotechnology is being used to deliver innovations in industries including clean energy, environment, health and personal care, electronics, transport, construction, telecommunications, manufacturing and mining. One Indian entrepreneur said it best when he proclaimed:

“For entering into Nanotech products my industry needs senior managers and researchers with the frontier mentality found at Apple or Intel or Biotech start-ups.”

Many products endowed with extraordinary properties are made possible via nanotechnology. Possible end products that are envisaged and already in the market include: Textiles – having stain and wrinkle resistant garments and super strong fabrics that can be used for multiple purposes (e.g., astronaut suits, bulletproof vests, outdoor pavilion tents, etc.); Automotive requirements; Medicine, Therapeutics and Diagnostics; Environmental and Hygiene.

Some of the nano-products that are being envisaged as future possibility are:

- Agriculture and Food - Producing and preserving food through nanotechnology
- Nanotechnology in water management for safe and sufficient water
- Nanotechnology to make the environment sustainable
- Solar energy on one’s roof top through nanotechnology
- Effective and precise medical services, medicine and health care with nanotechnology
• Nanotechnology for easy to make, smart to trade, smarter to wear textiles
• Nanotechnology in automobile, electrical and aerospace
• Nanotechnology in electronics
• Nano materials in construction, i.e. beyond bricks and mortar
• Nanotechnology to change the chemistry and produce advanced materials

Initially the most commercially used nano-particle has been nano silver that is endowed with the antibacterial property. Another nano-particle that has found wide application in industries is carbon nano tubes often used as composites with polymers, in electronics, automobiles and sporting goods, etc. However many other nanoparticles and nanocomposites based products are in the market.

6. Countries selected for case study of R&D institutes and industries involved in nanotechnology

With the hype of nanotechnology during the last decade of 20th century, Governments from all the developing countries started investing in R&D of various aspects of nanotechnology. Emphasis was on developing technologies that would be applicable for the masses as well as in the economic development of the country.

Success of R&D efforts of any technology depends on its:

• Commercialization,
• Patents generated,
• Publications, and
• Collaborations.

At present world over, four types of research centres are functioning:

1. Government funded research institutes,
2. In-house research divisions of the industries,
3. Private research institutions, and
4. Collaborative Private and Government funded research institutions.

For the present case study, emphasis has been on the efforts and output of Government funded research institutes and commercialization of their innovative research efforts.

However, it must be mentioned that many of the well established companies, through their in-house R&D efforts, have either updated their products through the use of nanotechnology or developed new products and processes involving nanotechnology.

In this report at least two case studies of companies and/or R&D institutions involved in nanotechnology based products, from each of the selected countries have been reported. The case studies are drawn from 11 countries and cover a range of R&D institutes, company sizes, nanotechnology sub-areas and fields of applications. The countries selected for the case studies vary greatly in their implementation of nanotechnology. There are some Asia-Pacific countries that are at par with most developed nations like USA and Germany, e.g. Japan and the Republic of Korea;
whereas there are fast growing countries like China and Malaysia that are catching up with both R&D as well as industrialization of nanotechnology. There are countries that have contributed immensely research-wise but are comparatively slower at industrialization, e.g. India, and there are also countries in the nascent stage of entering into this field.

Nanotechnology is a rich branch of science which has inputs from all the disciplines of science such as physics, chemistry, electronics, biology and engineering. Hence, nanotechnology covers a broad range of applications and products. It is difficult to single out challenges which are truly specific to one type of nanotechnology output. Moreover, the findings may not necessarily apply to all sub-areas and application fields.

For the case studies, efforts made in the following countries are touched upon: China, India, Indonesia, Japan, Republic of Korea, Islamic Republic of Iran, Malaysia, Pakistan, Philippines, Sri Lanka and Thailand.

7. Limitations in the study

This report suffers from the limited access to reliable and comparable data. Due to the complex nature of nanotechnology, official statistics often link it to various different categories (e.g. risk regulation efforts involve not one but many sectors where it cannot be identified correctly or the definition is at least questionable).

Large scale survey dedicated to market prospects and the company data about nanotechnology faced limitations due to ignored response from the industries.

Data available on the respective website provided valuable information, but lack of comparability with data retrieved from other surveys. It has been attempted to draw a most complete picture with the data available and to draw conclusions on their basis. It was neither possible and nor the intention of the author to generate data.

Often surfing on web site for nano-products resulted in products having ‘Nano’ suffix, due to hype and attraction that the word ‘Nano’ has caused these days; but it has nothing to do with nanotechnology.

8. Country-wise case studies

8.1. CHINA

Government initiatives:
The People’s Republic of China entered into the realm of nanotechnology in mid-eighties through the efforts of Chinese Academy of Sciences (CAS) and National Natural Science Foundation of China (NSFC). The Government of China has very systematically implemented their plan to develop domestically crafted science and technology based output for export and domestic consumption.
By 1990, the Ministry of Science and Technology (MOST) realized the importance of nanotechnology and initiated “National Climbing-Project” on nanomaterials research. In 1999, 973 Program on “Nanomaterials and Nanostructures” by MOST was funded. Later in collaboration with NNI of the United States, they expanded their efforts and funding into various areas of nanotechnology having commercial potential. The most effective programme in China’s scientific research and development is the ‘863 Program’ for “Promoting the development of key novel materials (including nano-materials) and advanced manufacturing technologies for raising industry competitiveness” [2]. [Under this 863 plan, US$ 27 million were funded to over 1000 nanotech projects [3].

Main funding bodies of China are MOST, CAS, National Natural Science Foundation of China (NSFC), NCDR (National Commission of Development and Reform) and MOE (Ministry of Education). CAS and NSFC created many nanotechnology research centres in China. Apart from research funding keeping market demand in consideration, China also addressed priorities for the commercialization and development of (i) nano-materials, (ii) bio-nanotechnology and nano-medical technology, and (iii) nano-electronics and nano-chips. Moreover, some private industries of China also funded nanotechnology research, for example, the Tsinghua-Foxcom Nanotechnology Research Centre, Beijing was donated by the President of one of the largest private industry Foxcom Corporation of Taiwan province of China.

These initiatives have not only provided trained scientists in nanotechnology but also instigated Chinese scientists to train abroad and return to China. Moreover, such star scientists have played a pivotal role in international collaborations for the advancement of nanotechnology in China. It could be that low labour and infrastructure costs might have also helped.

The three above mentioned programmes were meticulously planned and monitored:

“863 National High Tech Research and Development Program” initiated in 1986, supported in meeting the growing technological and innovation gap between China and the West; for promoting the development of key novel nano-materials and advanced manufacturing technologies for raising industry competitiveness.

“National Climbing-Project” initiated in 1990, and implemented in 2001 was mainly to train and bring young scientists in to basic research. National Climbing Project covers 7 branches of basic research (Astronomy, Biology, Chemistry, Geography, Mathematics, Mechanics and Physics) and 8 branches of applied basic research (Basic Agronomy, Basic Medical Sciences, Energy, Engineering Science, Information & Computer, Material, Resource & Environment and Space Science).

“973 – The National Basic Research Program of China was implemented in 1997 - to organize and mobilize China’s scientific talents in conducting innovative research in (i) nanotechnology (ii) Proteome, (iii) Quantum control, and (iv) Reproduction. Two notable projects under the 973 Program that helped in the progress of nanotechnology research and commercialization were: (i) Standardization of measurement techniques, and (ii) Synthesis of nanometer-sized materials (Science and Technology Indicators, Organization for Economic Cooperation and Development (OECD), 2009).
Case-study of a health-care company in collaboration with CAS - Suzhou Nantong Bionanotechnology Co. Ltd. (NanoMed)

About the Company:
Suzhou Natong BioNanotechnology Co. Ltd, in Shanghai was founded in 2007. It is a clinical-stage medical product company focusing on developing and commercializing non-invasive drug delivery technologies. For its commercial venture, it was funded by Softbank’s SB China Venture Capital (SBCVC) in January 2010. This company has licensed two patents from the Xinjiang Technical Institute of Physics and Chemistry of CAS and has applied for 12 more patents for its intra-dermal FMA-TM technology, six of which have been granted, including one in the US and five in China. It has a strong research base and has launched a regional research division in the US also.

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Problem/Issue:
The most jeopardizing situation of a transformed biological cell is its impenetrability of chemotherapeutic agent due to its high diffusion rate and enhanced reticuloendothelial system (RES) clearance. This physiological change poses a hostile consequence of low retention of the drugs inside a solid tumour (Jain, 1999). This necessitates the development of tumour specific targeted drug delivery cargoes to ferry drugs, exploiting the leaky tumour-micro-vasculature. Targeting drugs to their sites of action is a challenge in pharmaceutical research. Most current cancer therapies are non-specific, with surgery, radiation and chemical ablation having the potential to cause damage to the surrounding tissue.

Solution:
Nanomedicine plays a gigantic role in the delivery of payloads to the target using specifically addressed nano-cargoes. Such nano-cargoes, due to size and surface properties can circumvent the problem of systemic toxicity of drugs. Moreover, they get anchored to certain tissues, thus decreasing the efficiency of diffusion and uniform tissue distribution. Targeting the nano-vehicle using the specific ligand facilitates balance between tissue penetration and cellular uptake leading to optimal therapeutic efficacy.

To address the above problem, researchers from CAS under the guidance of Dr. Xu (2004 to 2007) carried out extensive research along with researchers in the Technical Institute of Physics and Chemistry of CAS to develop a novel drug delivery system using nanoscale MEMS fabrication technology. In 2007, Dr Xu was awarded “The Science and Technology Pioneer Award", from
Suzhou Industrial Park (SIP) for developing and commercializing his innovative intra-dermal drug delivery technology.

Moreover, Dr. Xu’s one of the concerns was to have a painless injection system of the drugs. As they believed that compared with the high risk (up to 90%) of developing new drugs, the risk of developing new drug delivery system using FMA-TM technology is almost zero.

The group successfully developed and commercialized this innovative intra-dermal drug delivery technology, also known as Functional Micro Array (FMA-TM) technology. The drug-delivery device uses a set of needles smaller than human hairs for painless injections. This is a non-invasive drug delivery technology, which has four distinct advantages compared to the conventional needle injection; it is painless, less toxic for potent drugs, has improved drug efficacy and reduced treatment time. This Micro Array FMA-TM Patch has found several potential clinical applications in the areas including delivering drugs for skin diseases, diabetes, tumours and pain relief. The products that are made using this technology are:

- **Liteclear-TM** In collaboration with Beijing PLA General Hospital using FMA technology, Liteclear-TM was developed to treat Acne. Liteclear-TM was launched in the market in March 2010 with funding from Softbank’s SB China Venture Capital and it received such good response that the company expected to break even in 2011, as total sales across all of China was expected to be around $1.5 million.

  Liteclear-TM reduces acne lesion size, diminished redness and pain in as little as 12 hours, eases inflammation in one week, compared to several weeks using conventional acne treatment technologies/products.

  The critical challenge for drug delivery into skin is penetration into the stratum corneum, the outermost layer of human skin. NanoMed’s FMA-TM Patch fabricated based on the MEMS technology is equipped with nanoscale needle tips and is capable of delivering painless injection in 10 seconds.

- **LidoFast** – This was the second product developed for pain relief. It is a FDA approved low concentration anaesthetic drug, IND filed in the United States.

- **InsuRite**: This is the third product based on Functional Micro Array technology. It provides basal delivery of insulin for patients depending on daily insulin injection.

No wonder NanoMed is regarded as the fast growing BioNanotech start-up Company in China. Now they are looking for collaboration with pharmaceutical companies all over the world to innovate their drug delivery system.

**Concluding remarks:**

Dr. Xu is a returnee to China after 20 years of education and training overseas. He could envision the unique advantages for building a successful Bionano company in China, as he realized that in China he is able to lower the operation costs and have access to a wealth of clinical resources compared with
that in North America and other developed countries. These efforts converted him into an entrepreneur; running a high-tech start-up in China. The shortage of financial and legal professionals has been quite a challenge for a scientist like Dr Xu, but by the end of January 2010, NanoMed signed a funding agreement with Softbank's SB China Venture Capital (SBCVC). This funding was seen as an important milestone for the company.

There are strict and stringent restrictions on monitoring and evaluation of the dose, therapeutic index or ratio of formulations and specific drug delivery system during clinical trials on human. Nanomaterials are developed for their unique (surface) properties in comparison to bulk materials. Since surface is the contact layer with the body tissue, and a crucial determinant of particle response, these unique properties need to be investigated from a toxicological standpoint. When nanoparticles are used for their unique reactive characteristics it may be expected that these same characteristics also have an impact on the toxicity of such particles. Although current tests and procedures in drug and device evaluation may be appropriate to detect many risks associated with the use of these nanoparticles, it cannot be assumed that these assays will detect all potential risks. So, additional assays may be needed. Since the work has been done in collaboration with a hospital, it is expected that such care must have been taken. Moreover, Poly(lactic-co-glycolic acid) (PLGA) being a polymer composed of lactic acid and glycolic acid, both are metabolic products of the living system; it is a well-accepted biocompatible and biodegradable material to be used in drug formulation or delivery and is not expected to be a toxic material.

Case-study of a nano-carbon related company in collaboration with Chinese Academy of Sciences (CAS) - Chengdu Organic Chemicals Co. Ltd & CAS (Timesnano)

About the Company:

Timesnano is the research and development centre for carbon materials. This centre belongs to Chengdu Organic Chemicals Co., Ltd, Chinese Academy of Sciences (CAS) and since 1996 it has been involved in CNT synthesis and application research. The Chengdu Organic Chemicals Co Ltd (CAS) was supported by the National High Technology Research and Development program of China, under Program 863 (the Basic Research Program of China). Their research has resulted in 80 publications and 33 patents.

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Problems/Issues:
With the discovery of carbon nano tubes by Iijima in 1991, all over the world there was onset of research activity in this novel class of materials [1, 2] because of their unique physical properties which span a wide range from structural to electronic. Possibility of its use for many applications came to the fore, e.g. pharmaceuticals, agriculture, medicinal, transport, fast moving consumer goods products, etc. This demanded mass production of different types of high purity nano carbon.

Solutions:
Realizing the need for mass production of nano carbon and demand of research to develop application of different types of nano carbon (carbon nano tubes, carbon nano fibres, carbon nano beads or spheres and other unique morphology of nano carbon), CAS focussed its attention in many of their labs, with government funding for programmes like ‘863’ in 2002.

One of the success stories of 863 Program is providing various nano carbon production technology to Chengdu Organic Chemicals Co. Ltd for commercial production of carbon nano tubes (CNTs) since 2003. CAS is the largest research institute in China and comprises of at least 80 national institutes.

Chengdu Organic Chemicals Co. Ltd. through Time nano is manufacturing many kinds of CNTs and related products. Timesnano is exclusive CNTs provider in the Chinese Academy of Sciences. (They have invented moving-bed catalysis technology for continuous production of high purity, low cost and consistent quality CNTs. Now, they provide hundred kinds of CNTs and CNT related products. Their products in the market are listed below:

- Single-walled carbon nano tubes at 100Kg/annum with purity>90% and 30T/a. Since it greatly improves the cycle performance, thermal safety and C-rate performance of Li-ion battery, lead acid layer battery and electrical double layer capacitor by forming robust electrical conductive network in the electrodes, it has a great demand in the market.
- Multi-walled carbon nano tubes with OD 20-30nm and purity >95% - Because of its high conductivity, transparency and adhesion to substrate, CNT thin film is being used in flexible touch screen, transparent antistatic packaging material and solar cell.
- Double-walled carbon nano tubes with OD 2-4nm having >60% purity
- CNT Dispersant
- CNT and polymer composite. It has high tensile strength and low density; therefore CNT with reinforcement is in demand for making light weight and high strength metal based composites and polymer based composites which have huge demand in the aerospace field, wind driven generators and automobile industries.
- CNT-conductive filter
- CNT functionalized with different functional groups (hydroxyl, carboxyl, etc)
- Graphene. They are concentrating on beyong Graphene, i.e. Graphane and Graphyne, which differs in chemical structure from graphene. This may give them interesting mechanical and electrical properties thus could provide an edge over graphene in certain applications.
- Graphene oxide
- Graphite Nanoplates
Nano-cellulose is their new product. This gel-like material obtained from plants has 5 – 20 nm lateral dimensions. It is light-weight, stiffer than Kevlar®, electrically conductive, non-toxic, the crystalline form is transparent, gas impermeable, very high tensile strength - 8 times that of steel, and highly absorbent when used as a basis for aero gels or foams. Nano-cellulose can be used in pharmaceuticals, food and medical industries.

Concluding remarks:
With various applications of carbon nano materials (CNM) in the market, it is needed by researchers and industries involved in CNM based applications. Invention of moving-bed catalysis technology for continuous production of CNTs with high purity, low cost and consistent quality has been one of the best contributions to mass production of carbon nano materials.

8.2. INDIA
Government initiatives:
The Government of India launched in October 2001, Nano Science and Technology Initiative (NSTI) for investment in variety of educational, HRD and R&D programs. Investment planned for first five years (2002 – 2007) was Rs. 60 Crore; for which active role of the Department of Science and Technology (DST), the Defence Research and Development Organisation (DRDO), the University Grants Commission (UGC), the Council of Scientific and Industrial Research (CSIR) and the Department of Biotechnology (DBT) for significant commercial results was envisaged. The emphasis of NSTI was on fundamental research program, focusing primarily on equipment for research. Other identified areas are nano drug delivery systems, energy, solar-cell, environmental and safety aspects of nanotechnology, and fundamental research program – focusing primarily on equipments research.

To further promote the activities of NSTI, Mission on nanoscience and technology (Nano Mission) was launched in May 2007. DST is the nodal agency for implementing the Nano Mission, with an allocation of Rs. 1000 Crore for the next five years. Apart from promoting research and research facilities, the Nano Mission is involved in establishing Centres of Excellence in nanotechnology, to promote industry-institution linked projects through increased public-private partnership and promoting entrepreneurship through the establishment of business incubators. So far Nano Mission has established 14 Centre of Excellence in nanotechnology all over India.

Moreover, the Indian Government is keen on solving nanotechnology related moral, ethical and other issues through drawing a regulatory framework taking into consideration - liability for environmental hazards, environ-health impacts, transparency and public involvement, right to information and legal obligation. For risk regulatory governance, coordination of Ministry of Science and Technology, Ministry of Environment and Forest, Ministry of Chemicals and Fertilizers, Ministry of Labour and Employment, Ministry of Health and Family Welfare, Ministry of Consumer Affairs, Non-Government Organizations like the Federation of Indian Chambers of Commerce and Industry (FICCI) and the Energy and Resources Institute (TERI) is being sought.
So far as commercialization of nanotechnology is concerned, India has tremendous possibilities for any technological intervention. But India has been slow to adopt technologies and even slower to experiment them. This has happened primarily because the risk taking ability of individuals, organizations and the governments and the level of confidence in the innovations has been low in India.

However, realizing the immense potential of nanotechnology, in the last two decades, India has gained not only confidence to try out new technologies but also to experiment and innovate. This is primarily because the entrepreneurial base as well as purchasing power has increased and India is ready to adopt and adapt to nanotechnology, as government support and funding is also offered extensively with initiation of organizations for nanotechnology studies. Umpteen numbers of universities and colleges even from remote areas have been given grants to work on projects in almost all the disciplines of nanotechnology ranging from chip design, nano medicine, nanomaterials, use of nano materials for drug delivery, diagnostic kits, improved water filters and sensors, solar-cells and for reducing pollution from vehicles. Moreover, many international collaborations for nanotechnology with countries like UK, USA, France, Spain, Italy, Germany, Sweden, Japan and the Republic of Korea has been supported by DST and DBT. There are many consultancy companies that have cropped up in India, e.g. SAiNSCE that are providing information related to nanotechnology.

In India, many nanotech products are not translating into market products due to weak links between Indian scientific institutes and industry and the domestic industry’s reluctance to manufacture large quantities of nanomaterials proven to have commercial application. Nanoscientists take more pride in declaring themselves as fundamental scientists than applied scientists. India needs to work on converting lab scale success into commercially viable, globally competitive relevant products. However, the sparks of entrepreneurship is now visible in business community and venture capitalists.

Case--study of a health-care company based on technology provided by ARCI, Hyderabad – SBP Aquatech Pvt Ltd.

About ARCI: The International Advanced Research Centre for Power Metallurgy and New Materials (ARCI) is based in Hyderabad India. It is an industry centric, autonomous R&D centre of Government of India’s Department of Science and Technology (DST) that became operational in 1996. It is involved in developing unique, novel and techno-commercially viable technology in the area of advanced materials and subsequently transfers them to industries. It has so far transferred 17 technologies to 30 entrepreneurs in India. It has technical collaborations with partners in 15 countries. Centre for Nanomaterials in ARCI has been created as the Centres of Excellence (CoE).

About SBP Aquatech Pvt. Ltd.: The Company was established in 2007 and registered in 2008. The company is Manufacturer / Exporters / Wholesale Suppliers of nano silver powder, domestic water filter, ceramic water filter, water purifier candle, drinking water purifier, drinking water filter, reverse osmosis systems, drip water filter, gravity water filter, nano silver water filter; having a turnover of approx. Rs. 0.5 to 2.5 Crore.
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Problems/Issues:
Although an overwhelming majority of the planet is composed of water, 97% of this water is constituted of saltwater. The freshwater that sustains human life is only 3% of the total amount of water on Earth. Of this 3%, slightly over two thirds is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is mainly found as groundwater, with only a small fraction present above ground or in the air. Fresh water is a renewable resource, yet the world's supply of clean, fresh drinkable water is steadily decreasing because of heavy pollution. The most common contamination of raw water sources is from human sewage and in particular human faecal pathogens and parasites. Most water require some type of treatment before use, even water from deep wells or springs. Appropriate technology options in water treatment include both community-scale and household-scale point-of-use (POU) designs. Presently there are various mechanisms of drinking water treatment such as reverse osmosis, sedimentation, membrane filtration, UV disinfection, ozone disinfection, distillation, use of activated carbon, etc. Though these technologies are used for the filtration of water, their requirement for water treatment is very high. Moreover, they cannot remove all the pathogens and for a country like India they are not very cost-effective. Hence, there is a need to develop a water purification system which will be cost effective, utilizes less amount of energy and has high efficiency.

Solutions:
Anti-microbial property of nano silver is a well-established fact. It is being used in many household equipments to get rid of bacteria. Therefore, using nano silver at ARCI, the conventional method of ceramic candle filtration has been combined with nanotechnology to produce nano silver coated ceramic candle filters. Nano silver-coated ceramic filter candle for disinfectant water-filter application was developed by a group comprising of Dr. K. Murugan, J. Revathi, Neha Hebalkar and Tata Narasinga Rao. The main advantage of this water filters and water filter candles are that they remove bacteria and other diseases causing pathogens present in water thus making the water drinkable.

This technology was transferred to SBP Aqua Tech Pvt. Ltd. The company signed a know-how transfer agreement with ARCI in June 2007. The company is owned by an entrepreneur Mr. Venu Gopal Cheekoti. He is now producing nano silver ceramic water under the brand name Puritech. Apart from removing turbidity, presence of nano silver kills the bacteria present in the water. It is one of the cheapest water filters in the market providing a low cost option and convenient solution.
Generally water filter prices in India ranges from Rs. 2,000 to 5000. But price of a Puritech filter candle is Rs. 70 only. In outside India market, it is US$ 2.5 only. By fixing this filter candle in Matka (Clay pot) used in most rural households for storage of water, a low cost water filter can be made (Figure 2):

![Figure 2: Puritech water filter candle fixed in Matka (Clay pot)](image)

Field testing done in forty villages in Andhra Pradesh has shown that maximum probable number (MPN) of *E. coli* ranging from 30 to 1600 has decreased to zero MPN by these candles.

**Concluding remarks:**

Of the more than 800 consumer products (food packaging materials and food supplements, odour-resistant textiles, electronics and household appliances, cosmetics and medical devices, water disinfectants, and room sprays) that contain nanomaterials, approximately 30% are claimed to contain silver particles. One of them is silver nanoparticles containing socks to kill the bacteria associated with foot odour. A recent study by Benn et al. (2008) revealed that the silver can easily leak into water during washing, thus potentially disrupting helpful bacteria used in wastewater treatment facilities, or endangering aquatic organisms in lakes and streams. They have also found that some brands of socks lose nearly 100% of their silver content within four washings, while some brands lost less than 1%. Use of Nano-silver in washing machines has recently been protested by Swedish Environmental Protection Agency, because wastewater may be contaminated with nano-silver. Recently, the United States Environmental Protection Agency (USEPA) has decided to regulate this specific form of
nanotechnology. Also, farmers are concerned that the antimicrobial activity of nano-silver will affect the beneficial bacteria in soil, which are essential for the soil used for farming. With this insight, there is a need to research and formulate the minimization of potential risks of nano-silver by collecting sufficient data on leaching of nano silver and to assess human health.

**Case-study of a health-care company based on technology provided by National Metallurgical Laboratory (NML) - Eucare Pharmaceuticals Pvt. Ltd. Chennai**

**About NML:**

The National Metallurgical Laboratory is one of the 38 laboratories of CSIR, formally inaugurated on the 26 November 1950 by Jawaharlal Nehru “in a spirit of hope and faith in the future”. NML was supported, in cash and kind, by (i) Tata Industries Ltd., (ii) Sir Ratan Tata Trust, and (iii) Sardar Bahadur Sir Indra Singh of Indian Steel and Wire Products (ISWP) Company. Dr. Balraj Nijhawan, the first Indian Director of the laboratory, set the pace for the rapid growth of the laboratory through the establishment of a number of pilot plants and R&D programmes.

**About Eucare Pharmaceuticals, Chennai:**

Eucare Pharmaceuticals was incorporated in 1996 as a Private Ltd. Co. registered under Indian Companies Act 1956. They are pioneers in collagen technologies and drug delivery system for burns, advanced wound management, surgical haemostasis and dental restoration. It has a manufacturing unit with WHO accredited cGMP facility, meeting ISO 9001: 2008 and ISO 13485:2003 Quality Management system with Class 10,000 Clean Room System and CE Marketing medical devices from DET NORSKE VERITAS Norway. Now they have entered into a new opportunity in dental and orthopaedic segment through tissue & bone regeneration.

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**Problem/Issues:**

Autogenous bone grafts are most frequently and routinely used filling up defects in dentistry. However, autogenous bone grafts are always associated with various adverse factors including donor-site morbidity and limited availability. The Xenograft although are available in abundance, there exists a risk of viral transmission, varied fusion and healing rates and other social factors. On the other hand, synthetic bone graft can have a desired consistency, particle size, porosity and strength with ready availability in sterile condition, totally eliminating donor-site morbidity and the risk of viral transmission with absolute social acceptance, thus preferred by the majority of surgeons as a material of choice.
Solution:

In the Material Science and Technology Division of NML, Jamshedpur, a biomimetic process was developed using globular proteins and synthetic polymers for the synthesis of (i) nano-sized hydroxyapatite, and (ii) bi-phasic nano-composite hydroxyapatite and beta-tricalcium phosphate. They transferred the know-how of these two nano crystalline products to Chennai based Eucare. These two products are under technology licence from CSIR - NML Jamshedpur, India. They are:

1. Synthetic Nanocrystalline Hydroxyapatite which is being manufactured and marketed by Eucare as brand name SYBOGRAPH™
2. Synthetic Nanocrystalline Hydroxyapatite and β-Tri-calcium Phosphate Composite, which is being manufactured and marketed by Eucare as brand name SYBOGRAPH™-Plus.

Both these products are: biocompatible as per EN ISO 10993 standards; non-toxic, non-allergenic, non-pyrogenic, has No BSE / TSE issues and are highly porous.

Concluding remarks:

Intellectual property is a big concern about novel unique discoveries. CSIR has positioned itself from being reactive to giving proactive IP protection by random patenting to planned patenting and designing patenting portfolios based on business plan with commercial and strategic considerations. It has filed 183 patents (unique inventions) in India and 404 patents abroad (multiple jurisdiction) during 2008-09. It now has a portfolio of 1910 patents in India and 2689 patents abroad

8.3. INDONESIA

Government initiatives:

Following the global trend, the Indonesian Ministry of Research and Technology has focused its attention on nanotechnology, with emphasis on its application in food and energy. With the advent of “Masyarakat Nano Indonesia (MNI) in 2005, the government of Indonesia started exploring the possibility of marriage between nanotechnology and bio-nanotechnology and initiated and invested in research in top universities and research institutes. The government laboratory, the Research and Development Centre for Material Science & Technology (RDCMST) has initiated the establishment of cooperative program in nanotechnology research.

With an intention of the Ministry of National Education to provide $26.5 million and the Ministry of Industry to contribute $1.59 million to promote the industrialization of R&D output on applications for industry including ceramics, textiles, food, environment, energy, and information technology and communications, Indonesia is well on its way for entering into the commercial arena. Following are institutions engaged in nanotechnology research covering areas like nanostructures, nano-encapsulation, Ag nanoparticles, nanocomposites and nano carbon:

- University of Indonesia, Jakarta
- Institute of technology Bandung (ITB)
- Institute of technology Surabaya (ISB)
- University of Gadjah Mada Yogyakarta (UGM)
- Indonesian Institute of Sciences (LIPI)
- National Nuclear Energy Agency for Indonesia (BATAN)
- Aeronautics and Space (LAPAN)
- Agency for the Assessment and Application of Technology (BPTT)
- Pusat Penelitium Elmu Pengetahuan Dan Teknologi (PUSPISTEK)
- Eijkman Institute
- Mochtar Riady Centre (MRC)

About Mochtar-Riady Centre for Nanotechnology and Engineering (MRCNB):

The biggest investment in uplifting the status of nanotechnology in Indonesia, with an investment of US$ 20 Million, is by Mochtar Raidy & LIWPO group; to conduct innovative research on cancer prevention and new understandings of the cause, early diagnosis, control and cure of cancer. MRCNB is luring talents from Indonesia and overseas to conduct innovative research on cancer prevention and new understandings of the cause, early diagnosis, control and cure of cancer.

They founded Mochtar-Riady Institute of Nanotechnology (MRIN) with the aim to conduct innovative research in cancer. Their Scientific Advisory Board consists of members from USA, France, Singapore, Hong Kong, Australia and eminent scientists from Indonesia. The Centre also runs short term training courses and Ph.D. Program. This rich Centre has very well equipped labs and equipment. They have both international and national collaborations. International collaborations are with Shanghai Cancer Institute, Shanghai; Jiatong University, Shanghai; South East University, Nanjing; Hong Kong University of Science and Technology and Faculty of Medicine, National University of Singapore. National collaborations are with University of Indonesia, Jakarta; Cipto Mangunkusumo Hospital Jakarta, Hasanuddin University, Makassar; National Cardio-vascular Centre Harapan Kita, Jakarta, etc.

Case--study of a knowledge and technical help providing company - Nanotech Indonesia, Supported by PUSPITEK, Serpong

About PUSPITEK:

PUSPISTEK was founded in 1976 with the aim to support the process of industrialization in Indonesia. The Company then was designed to be a synergy between the educated and trained human resources, research tools and most comprehensive technical services in Indonesia as well as technology and expertise has been accumulated for more than a quarter century. It has a huge campus spreading over an area of 600 ha encompassing Research and Development, General Services, Housing and Environment as well as Utility Group; all having enough electricity and water supply and centralized solid and liquid waste processing systems.
MNI signed a MoU with research institution in PUSPIPTEK, with an intention to initiate research in nanotechnology. The result was a successful commercial set up – ‘Nanotech Indonesia’ - to provide support and knowledge related to nanotechnology.

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**Problem/Issue:**

Every country that has entered into the field of nanotechnology has felt the need of high quality nanotechnologists along with sophisticated equipment and their handling, especially to ensure the quality and capability of the national industries with the laboratory testing services.

**Solutions:**

Nanotech Indonesia was established with the purpose as a partner for the industries in supporting their growth and delivering technical solutions. With the support from experts and advanced facilities in PUSPIPTEK, Serpong, Nanotech Indonesia started following activities:

- **Laboratory Testing** – Using high-tech equipment, they provide (a) Microscopic Test – Optical, SEM and AFM; (b) Composition Test (Solid) EDS, XRF and XRD; (c) Composition Test (Solvent) – AAS, FT-IR and GCMS; (d) Particle Size Analysis; (e) Zeta Potential Test; (f) NDT (Non Destructive Test); and (g) Mechanical Properties Test–Hardness, Bending, Impact, Tensile, Compression and Fatigue.
- **Technical Training** - Applied technical training services for enhancing technical capability:
  - Failure analysis; (b) Risk base inspection; (c) API 579 and ASME 8; (d) SEM, GCMS, FTIR and PSA; (e) Nanotechnology training; and (f) Specific measurement instruments.
- **Technology and Management Consultancy** – (a) Product Development - PT. Gizi Indonesia; (b) Product Development - PT. Qolbi Herba Alami Sejahtera; (c) Processing machine for catechin in West Sumatera; and (d) Policy study for investment on electronic and automotive products.

Since founded in 2009, Nanotech Indonesia has become a partner for eighteen major industries in technology solutions and innovations. They are also in the business of trading nano machines and material processing.
Concluding remarks:
Efforts of Nanotech Indonesia are commendable, as they started the work with least funding and generated money through many training courses. They would have initially needed huge amount of spending on training equipments, but for that they took the help of PUSPITEK. Starting a R&D set-up is being supported by the government.

Case-study of a floor treatment company - NANOCORE Indonesia

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Problem/Issues:
Demand for hard, polished, smooth surfaces is rapidly increasing. It is required for metal, cement, ceramic, plastic, mineral and glass surfaces. Apart from hard polished surface, there is a demand for better quality too.

Solutions:
To provide better floor, has been the aim of NANOCORE Indonesia. Today they are floor treatment specialists, with many innovative products developed with the help of nanotechnology. Some of their patented and nano lithium fortified products are:

- **Pentra-Finish™** (Li) - This lithium fortified finish offers deep penetration, increased surface hardness and superior reflectivity. The reactive micro-impregnating Nano Lithium™ polymer creates greater protection and greater gloss with less labour. The unique treatment is environmentally friendly and meets CSMA floor polish slip resistance requirements employing ASTM test method.

- **Pentra™ Protective Coating** - It is a hybrid inorganic/organic Nano Lithium™(topcoat finish and surface hardener). This lithium-silicate water-based formulation has very low polymer odor and provides long-lasting surface protection. It is perfect for protecting concrete floors, ferrous metal, concrete block, aluminum/non-ferrous metal, asphalt and previously existing coatings.

- **Pentra-Sil (NL)** – A concrete chemical hardener, sealer and densifier is a Nano Lithium™ surface treatment. It forms a surface that is breathable, abrasion-resistant and extremely hard. It is excellent for concrete floors needing long-term protection against heavy wear and abuse, moisture, dirt and grime buildup, as well as protection against alkalinity and salt residue. Pentra-Sil (NL) is V.O.C. compliant and environmentally safe to use..

- **Pentra-Guard™** (HP) - High performance industrial flooring surface hardener and protective clear coat is a “micro film forming hybrid inorganic/organic nano lithium™
surface treatment” that hardens and seals concrete floors, producing a very hard, dust repellent, chemical resistant and water tight surface.

Concluding remarks:
In a country where nanotechnology is in juvenile state of commercialization, efforts of NANOCORE and Nanotech Indonesia are unique and innovative. It has given a good start and boost.

8.4. ISLAMIC REPUBLIC OF IRAN

Government initiatives:
The Islamic Republic of Iran has realized that in the near future Iranian enterprises possess no option but to utilize novel technologies to increase its share of the future global market and to improve the level of nation’s economy. To achieve this, in 2001 Iran has developed a comprehensive Iran Nanotechnology Initiative Council (INIC). Under INIC a National Nanotechnology Initiative (referred to as Future Strategy) was initiated in 2005, to support the nanotechnology development, which made significant leaps in nanoscience and technology advancement. Under this initiative, the national government is in charge of promotion of R&D and industrial production of nano-related products. An action plan for ten years that is up to 2015 has been chalked out.

This 10-year programme includes 33 activities divided into six categories:

1. **APAC** (Advocacy and Public Awareness Committee) is created to collect and distribute information regarding current and future potentials of nanotechnology to general public.

2. **HRDC** (Human Resources Development Committee) to promote manpower in the field of nanotechnology. More than 50 universities and research institutes are engaged in this.

3. **IRDC** (Research and Development Infrastructures Committee) to develop necessary infrastructures for the support of R&D in academic as well as industrial institutions. T

4. **INLN** (Iran Nanotechnology Laboratory Network) established in 2004 covers 42 advanced laboratories nationwide, and **INSC** (Iranian Nanotechnology Standardization Committee) and more than 10 patent offices in 2006 that has established Intellectual Property and Technology Licensing Office (IPTLO) in 2005 and Nanotechnology Standardization Committee in 2006.

5. **TDPC** (Technology Development and Production Committee) is in charge of promotion of research and development and industrial production of nano-related products.

6. **INBN** (Iran Nanotechnology Business Network) to support commercialization, investment, technology development, marketing, branding and the private sector start-ups entering into the market. Iranian funding between 2004-2008 has been US$ 135 million (US$ 40 million from State Fund, US$ 25 Million from Public Organizations and US$ 70 million from Private Fund). There are more than 50 active companies working in the field of nanotech in Iran, to them INBN provides both non-material and material support.

Following are the examples of research outputs:

- Hydro conversion of heavy crude oil into light crude oil using nanocatalysts. A pilot plant with a capacity of 200 barrels/day is being built.
The Research Institute of Petroleum Industry (RIPI) is able to produce 8 kg CNT per day.

Breast cancer diagnostic kit for the early detection of breast cancer is being produced and undergoing clinical test by NanoSina Co.

Nano additive for improving the performance of motor oil is already being produced and marketed by Pishgaman Nano Arya Co.

Nano silver incorporated garments and textiles are being produced by two companies (Pars Nano Nssb Co. and Noavaran Catalyst Co.)

Nanotechnology Systems Co is producing and exporting Scanning Tunnelling Microscope.

Antibacterial nano products for treatment of air/water/soil, nano air-conditioning filter and photo-catalytic application are being produced by Nanopac Persia Co.

Case-study of instrumentation and devices company - Nanotechnology Systems Corporation (NATSYCO)

About the Company:
NATSYCO is a University based spin-off company formed by a group of scientists and researchers. It was supported by the Iran Nanotechnology Initiative Council (NIC) at various stages of development. Iran Nanotechnology Laboratory Network (INLN) has financially supported the manufacture of the advanced equipment needed for nanotechnology research.

Though initially NATSYCO was established as a research team in 2003, in 2006 it became a full-fledged production company involved in research, production and marketing of nanotechnology, instruments, devices and materials.

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Problem/Issue:
Growth and development of nanotechnology depends on availability of characterization facilities and equipment. Though earlier the concept of nanotechnology was not there, but nanotechnology was still existing and being used since 4th century B.C. Gold was not only known and exploited for its ornamental adornment but their sols and colloids were also a matter of excitation in the medieval age. “Soluble” gold appeared around 4th century B.C. in Egypt and China. This enigmatic behaviour of gold colloids led to the curious endeavour of using it as a pigment for coating glasses, enamel and chinaware in the mid-17th century. Andreus Cassius, a painter and sculptor, developed coloured solution of gold sol which was purple in colour and hence named it as “Purple of Cassius” which had been painted on the glasses of many houses and Churches. These special characters were due to nano
size. This was found out or rather seen after the discovery of electron microscope and many other supporting high-tech equipments.

**Solution:**

Importance of characterization devices and equipments cannot be emphasized enough. Without them nanotechnology would not have progressed. This realization was the reason for the genesis of Nanotechnology System Corporation (NATSYCO) which manufactures a wide variety of equipment and laboratory devices in the field of nanotechnology:

- Scanning Tunnelling Microscope – designed and produced by NATSYCO under the brand name NAMA-STM.
- AFM (Atomic Force Microscope)
- Nano-Bio-Sensor
- Magnetometer

The company has continued to gain an effective presence in hi-tech market outside Iran also due to these four products.

**Concluding remarks:**

Manufacture of highly specialized equipment like Scanning probe microscope NAMA-STM is a star product of Iran. It has given a very special status to the nanotechnologists of Japan. So much so that the Iranian President Mahmoud Ahmadinejad has presented it as official gift to Qatari Emir Sheikh Hamad bin Khalifa Al Thani of Qatar, Brazilian President and Venezuelan Presidents; during his visit to the respective countries.

**Case-study of instrumentation and nano material producing company supported by INIC – Payamavaran Nanotechnology Fardanegar (PNF)**

**About PNF:**

Payamavaran Nanotechnology Fardanegar (PNF Co.) was established in 2006 as a manufacturing company.

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**Problems/Issues:**

The previous company NATSYCO discussed above was about manufacturing equipments for characterization and visualization of nano materials. Obviously the next issue that comes to mind is how to make nano-materials. Should one depend on imported nano material and imported equipment for mass production of nano materials, was a major issue under consideration.
Solutions:

PNF is also in equipment manufacturing business related to nanotechnology. But they manufacture equipments for the synthesis of various forms of nano-particles. They manufacture equipment for the industrial mass production of various metallic and metal oxide nano-particles, i.e. Nano Colloid Maker and Nano Powder Maker. These are very high-tech precision machines. The design of these machines is the result of their various R&D projects in the field of nanotechnology processes and also modification of nano-products.

The Plasma Nano Colloid Maker is a special equipment by EEW technique in liquid media. It produces different ranges of metallic nano colloids. In this methodology using extra-high electric voltage or current, the metal wire is converted into nano metal oxide powder via explosive process.

Pulse Electrical Explosion (PEE) Maker is also by EEW technique in gas media and it produces nano metals and nano metal oxide in powder form. By this technology, any type of thin conducting metal wire can be transformed into nano particles. By using above mentioned methods, a wide range of nano powders and nano colloids have been produced by PNF Co.

Nano-Dispenser Machines developed by PNF are used to disperse dry nano powders in various kinds of liquid media to meet the requirement of high quality nano-products. The nano dispenser machines use the nano cavitations technology to de-agglomerate and disperse the nano particles in any liquid media.

Concluding remarks:

Nanotechnology Fardanegar Co., producer of electro-spinning and electrophoresis equipment, is supported in many ways by INIC. One of the goals of INIC is to introduce and present the latest scientific/technological achievements of knowledge-based Iranian companies at the international platforms. In order to support nanotech commercialization in Iran, ‘Tech-Market Corridor’ was established in 2010. It provides range of services to start-up companies, SMEs, large scale industries in the areas of nanoscience audit, IP, Technology Readiness Level Assessment (TRLA), business plans, licensing and tech-monitoring, market evaluation, venture capital, marketing, legal advisory and production consultation. INIC has made many promotional attempts for marketing the products.

Success of Nanotechnology in Iran is due to planned entry into the development area of nanotechnology. Infrastructure network was set up in 2004 covering 42 advanced laboratories nationwide and INBN was set up in 2007 connecting 110 nanotech companies. The embargo on Iran has motivated Iran industry to develop its own technology and products including STM, water purification system, air filters, industry scale quantity CNT and others

8.5. JAPAN

Government initiatives:

Comprehending the potential economic impacts of nanotechnology and the key challenges in its commercialisation, Japan was the first country in the world that started a major ten year
nanotechnology program (the Atom Technology Program) in 1992. The Japanese government invested a huge sum of US$ 250 million for R&D in various fields of nanotechnology. Today, it is at par with USA in the development of nanotechnology.

One of the most valued nano particle single walled carbon nanotubes and multi-walled carbon nanotubes were discovered by Japanese scientists Bethune (1993) and Iijima (1991) respectively. Even the word nanotechnology was coined by a Japanese scientist Norio Taniguchi. Umpteen numbers of carbon nanotubes and metal oxide companies mushroomed in Japan during the last two decades. The carbon nano tube companies of Japan boast of best quality products.

Two main funding Ministries of Japan are:

1. MEXT (Ministry of Education, Culture, Sports, Science and Technology) – It funds through JSPS (Japan Society for the Promotion of Science), JST (Japan Science and Technology Agency), NIMS (National Institute for Materials Science) and RIKEN (Institute of Physical and Chemical Research). JSPS supports basic research with grant-in-aid for scientific research, and JST coordinates challenging research which will need 10 to 20 years for industrial application. NIMS and RIKEN are mainly in charge of generic technology.

2. To encourage interdisciplinary, inter-organizational, and international collaboration among researchers, the Nanotechnology Support Project was started by MEXT in April 2002 and Nanotechnology Business Creation Initiative (NBCI) in 2004.

3. The Nanotechnology Researchers Network Centre of Japan is responsible for informational support, and 14 universities and national research institutes are responsible for common use facility support.

4. METI (Ministry of Economy, Trade and Industries) - METI has a funding agency, New Energy and Industrial Technology Development Organization (NEDO) and one research institute, National Institute of Advanced Industrial Science and Technology (AIST)]. Both organizations are in charge of flagship type research which will need 5 to 10 years for industrial application. The leading projects by METI are Focus 21, the nanomaterials and Processing Sub-Program by NEDO.

Strategic priority in R&D to basic research and 4 prioritized areas in funding are:

- Life sciences,
- Information and telecommunications,
- Environmental sciences, and
- Nanotechnology and materials science/technology

In 2001, nanotechnology and materials science, CSTP exemplified 4 fields:

- Nano-devices and materials for next-generation communication systems (information technology),
- Materials for the environment and energy-saving (environment),
- Nano-biology for new medical care technologies and biomaterials (biotechnology), and
Underlying technologies such as fabrication and analysis/simulation technologies (generic technology), and novel materials with innovative functions (materials).

Case-study of a health-care company started with the research efforts of University of Tokyo, Tokyo Women's Medical University and Jikei University - NanoCarrier (Japan)

About the Company:
NanoCarrier Japan was established in June 14, 1996 in Setagaya, Tokyo, with the purpose of applying new block copolymers to develop pharmaceuticals and put them into practice. In August 1997, it formed partnership with Nippon Oil & Fats Co., Ltd. (now NOF Corporation) on joint development and supply of a new block copolymer (afterwards entered into a supply agreement on exclusive manufacture and supply of polymer on December 2003). Head office and Lab in Chiba was started in October 1999 and a new Tokyo office was established in Chuo in July 2003. NanoCarrier got listed in Tokyo Stock Exchange in March 2008. At present its capital is ¥ 3,576 million (as of March 31, 2012). It has 29 employees involved in R&D and production of pharmaceuticals using micellar nanoparticles technology. The company has now planned to raise a capital in excess of ¥3.7 billion.

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Problems/Issues:
Prevalence of human suffering from dangerous diseases like cancer, and enhanced suffering due to increased doses of drugs has arrested the attention of scientists. There is a need to contribute to the betterment of human health of cancer patients by producing new drugs utilizing innovative nanotechnology.

Solutions:
This problem needed multidirectional research and approach
NanoCarrier's core technology, micellar nanoparticles technology, was proposed to tackle the problem and has been researched by Professor Kazunori Kataoka of University of Tokyo, Professor Teruo Okano of Tokyo Women's Medical University and Associate Professor Masayuki Yokoyama of the Jikei University. The aforementioned professors demonstrated that when drug-encapsulating micellar nanoparticles were intravenously administered, the particles could function as stable drug carriers in the bloodstream and they accumulated in cancerous tissues.
Prof. Kazunori Kataoka works on use of nano size (<100 nm) polymeric micelles as drug carrier for cancer therapy, in collaboration with Professor Teruo Okano whose research interests lies in the use of intelligent biomaterials for biomedical research applications such as micro-domain structured polymers, stimului-responsive polymers, hydrogels, polymeric micelles, modulated drug release, targetable drug carriers, blood compatible polymers, cell engineering, tissue engineering, and artificial organs as well as others. Another research partner is Dr. Masayuki Yokoyama who is working on developing a nano-carrier system with novel polymer chemistry for the delivery of anticancer drugs and diagnostic imaging agents and immunity to nano-carriers, such as polymeric micelles, liposomes, etc.

Since oncology was the focus area of NanoCarrier and as pioneer of micellar nanoparticles technology, they jointly utilized the work of these three above mentioned Nano-Bio-technologists and entered into harnessing the potential of micellar nanoparticles technology to their product development. NanoCarrier Co. Ltd. was founded in 1996 by Dr. Nakatomi, CEO of the Company, together with Professor Kazunori Kataoka and Professor Teruo Okano. Their research resulted in January 2001 in the development of “Polymeric micelle containing cisplatin enclosed therein and use thereof” from the Centre for Advanced Science and Technology Incubation Ltd. (now TOUDAI TLO, Ltd.). Later in June 2002 they out-licensed Paclitaxel Micelle to Nippon Kayaku Co., Ltd.

NanoCarrier has been developing on advanced biomaterials and technologies for drug delivery using its proprietary technology called “Micellar Nanoparticles”, invented mainly by Professors Kataoka and Okano. NanoCarrier has obtained over 40 patents, including worldwide substance patents to cover the use of polymeric micellar drug carrier as functional nanoparticles (Table 1). The company’s product portfolio includes mainly intravenous formulations of various low and high molecular weights of therapeutic compounds, which in turn, improve the efficacy and safety profile of original drugs as well as patient’s quality of life. It contributes to advance the treatment of cancer and other intractable diseases.

**NanoCarrier has been continuously expanding their commercial horizon**

In 2005 March and August, a partnership was signed with Debiopharm S.A. for DACH-Platin micelle (NC-4016), and with TOUDAI TLO, Ltd for “discovery and development of drugs with high usability for treatment of solid cancers” respectively.

In June 2006 NanoCarrier obtained exclusive license of “Electrostatic bonding type macromolecular micelle drug carrier and drug carried thereon” from TOUDAI TLO, Ltd. Another important step in 2006 August was in-licensed “Physical trapping type polymeric micelle drug preparation”, for the research and development of paclitaxel micelle (NK105) with Japan Science and Technology Agency. In February 2007, a new block copolymer for preparation of pH-sensitive polymeric micelle and a production process thereof” from the University of Tokyo and TOUDAI TLO, Ltd was in-licensed.

According to NanoCarrier News - Orient Euro Pharma co Ltd. and NanoCarrier sign a new agreement on 7th November 2012 to conduct registration trials of Nanoplatin™ and to set up a manufacturing site in Taiwan province of China. By in March 2008, NanoCarrier Co., Ltd. became one of the leading biotech companies listed on Tokyo Stock Exchange (Code: 4751).
2008 was also a very fruitful year for NanoCarrier as it got exclusive license agreement signed with Toudai TLO, Ltd. on incorporated nucleic acids into micelles; license and co-development agreement of Nanoplatin (NC-6004) with Orient Europharma Co. Ltd.; and IND Application of Nanoplatin® for Phase I/II study was approved in Taiwan province of China. In-licensed "Cationic Polyamino Acids" from the University of Tokyo and TOUDAI TLO, Ltd was achieved in 2009.

In 2010, collaborative research agreement was signed with National Cancer Centre to initiate a preclinical study of Epirubicin Micelle (NC-6300).

In September 2011, worldwide license and co-development agreement of Epirubicin Micelle (NC-6300) with KOWA Company Ltd, and collaborative research agreement with Eisai Co. Ltd were signed. In 2012, they got Japan Substance Patent allowed for new DDS of VELCADE® and Docetaxel Micelle. In 2012, NanoCarrier has signed further extension of research collaboration with University of Tokyo.

It is worth mentioning the steady progress of clinical trials of their output that started progressing from 2006:

- In May 2006 they started phase I Clinical trial of Nanoplatin® (NC-6004) in U.K.
- In November 2007 Nippon Kayaku Co., Ltd. started phase II clinical trial (gastric cancer) of Paclitaxel Micelle (NK105).
- In March 2009 started phase I clinical trial of DACH-platin Micelle (NC-4016) in EU.
- In August 2010 Nippon Kayaku Co., Ltd. started phase I clinical trial (breast cancer) of Paclitaxel Micelle (NK105).
- In July 2011 started phase II clinical trial of Nanoplatin (NC-6004) in Taiwan province of China and Singapore.
- In July 2012 Nippon Kayaku Co., Ltd. started phase III clinical trial (breast cancer) of Paclitaxel Micelle (NK105).
- In 2012 Phase III global clinical trial with Paclitaxel Micelle (NK-105).

Concluding remarks:

As compared to Nano carbon and electronic products using nanotechnology, application of nanotechnology in health care has been comparatively less in Japan. Efforts of NanoCarrier in collaboration with three research departments of different universities are a very good example of interdisciplinary research leading to commercialization. After a prolonged successful technical and commercial achievement, NanoCarrier has again extended the research collaboration with the Tokyo University showing the success of intention of Japanese government in the field of nanotechnology.
Table 1: Legal status of NanoCarrier’s major patents

<table>
<thead>
<tr>
<th>Pipeline</th>
<th>Title of the invention</th>
<th>Applicant/Patentee</th>
<th>(R: registered; UP : under prosecution)</th>
</tr>
</thead>
</table>
| Paclitaxel Micelle    | McKellar preparation containing sparingly water soluble anti-cancer agent & novel block Co-polymer | NanoCarrier Co. Ltd. Nippon Kayaku Co., Ltd. | R in 18 nations, including US & EU countries  
UP in 3 regions including US & EU countries |
|                       | Physical trapping type polymeric micelle drug preparation                               | Japan Science and Technology Agency | R in 12 nations including JP, US and EU countries                                                      |
|                       | Production process for polymeric micelle composition encapsulating a drug               | NanoCarrier Co. Ltd. | R in 10 nations including JP, US and EU countries                                                      |
|                       | Production process for polymeric micelle composition encapsulating a drug               | NanoCarrier Co. Ltd. | R in JP & 8 nations including EU  
UP in including US                                                      |
| Nanoplatin® (NC-6004) | Polymeric micelle containing Cisplatin enclosed there in & use there of                | TOUDAI TLO Ltd. | R in 23 nations including JP, US & EU countries                                                      |
|                       | Pharmaceutical composition & combined agent                                            | NanoCarrier Co. Ltd. | Patent pending  
(PCT application)                                                      |
| DACH-Platin Micelle   | Coordination complex of DiaminocyclohexanePlatinum (II) with block polymer containing Poly Carboxylic acid segment & anti-tumour agent comprising the same | TOUDAI TLO Ltd. | R in 34 nations including JP & EU countries  
Accepted in 1 nation  
UP in US countries                                                      |
|                       | Process for production of polymerized coordination compound of Platinum complex.       | NanoCarrier Co. Ltd. The University of Tokyo | R in 2 nation including US  
Accepted in 1 nation  
UP in 6 regions including JP & EU countries                                                      |
|                       | Coordination compound composed of DiaminocyclohexanePlatinum (II) & Block copolymer & anti-cancer agent comprising the same | The University of Tokyo | UP in JP, US & EU countries                                                      |
| Protein Micelle       | Electrostatic bonding type macromolecular micelle drug carrier & drug carried thereon | TOUDAI TLO Ltd. | R in 11 nations including JP & EU countries  
UP in US  |
|                       | Physiologically active polypeptide, polymer micelle having protein enclosed there in& process for production of the polymer micelle | Nanocarrier Co. Ltd. | Patent pending  
(PCT application)                                                      |
| siRNA Micelle         | Electrostatic bonding type macromolecular micelle drug carrier & drug carried thereon | TOUDAI TLO Ltd. | R in 11 nations including JP & EU countries  
UP in US  |
|                       | Composition containing fine particles as carrier for biologically active substance & method for preparing these | TOUDAI TLO Ltd. | R in 6 nations including JP and EU countries  
Accepted in US                                                      |
<p>|                       | Polyethylene glycol/Polycation block                                                  | The University of | R in 3 nations including JP &amp; EU countries  |</p>
<table>
<thead>
<tr>
<th>Product Name</th>
<th>Description</th>
<th>Collaboration Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copolymer</td>
<td>The University of Tokyo</td>
<td>Patent pending (PCT application)</td>
</tr>
<tr>
<td>Sensor Linked Micelle</td>
<td>The University of Tokyo</td>
<td>R in JP Patent pending (PCT application)</td>
</tr>
<tr>
<td>pH-Sensitive Micelle</td>
<td>The University of Tokyo</td>
<td>UP in JP</td>
</tr>
<tr>
<td>Docetaxel Micelle</td>
<td>The University of Tokyo</td>
<td>R in 12 nations including EU, UP in 8 regions including JP &amp; US</td>
</tr>
</tbody>
</table>

Case study of laser & optical equipment company in collaboration with University of Tokyo funded by METI & NEDO - Alnair Labs Corporation

Alnair Labs Corporation is one of the best examples of university and industry collaboration as well as the role of Japanese government in funding and promoting commercialization of nanotechnology based and related products.

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Problem/Issue:
With the advent of nanotechnology and the understanding that nano particles possess unique and novel optoelectronic properties, a need for advanced equipment was being felt.

Solutions:
Contribution of research by Prof. Kikuchi Kazuro, was thought of as a solution to the above problem. It was utilized by the visionaries of Alnair Labs Corporation. Prof. Kikuchi Kazuro was a specialist in optoelectronics and worked in the Department of Electrical Engineering and Information Systems and Department of Advanced Interdisciplinary Studies of University of Tokyo. His work has been on the
optical communication system. He is currently involved in all-optical signal processing devices and their applications to ultrafast optical communication systems. He is also interested in coherent optical communication systems that realize multi-level modulation formats with high spectral efficiency.

Alnair Labs Corporation was established on 29th August 2001 in Kawaguchi, Saitama-ken, Japan (which later shifted to Tokyo in 2010) as one of the first venture companies to commercialize the photonics technologies developed at the University of Tokyo. Its capital increased to ¥200 million by December 2001. One of their directors is Prof. Kazuo Kikuchi of University of Tokyo. And their technical advisor Prof. Shinji Yamashita is also from University of Tokyo. In 2002 they got R&D grant from the Ministry of Economy, Trade and Industry for the "Development and Practical Realization of Tunable Dispersion Compensating Devices", and in the same year Alanir Labs released its first mode-locked pulsed fiber laser product based on proprietary carbon-nanotube technology.

In the second rounds, venture capital investment increased their capital to ¥320 million. In 2005 Alnair Labs got another R&D fund from NEDO for "Development of 3D Measurement System using High Repetition Rate CNT Femtosecond Pulsed Fiber Laser". By 2007, its capital increased to ¥350 million and it got ISO 9001 certification. In 2008, its capital increased to ¥413 million. Looking at their very successful performance, NEDO again funded a venture R&D innovation grant to Alnair Labs, this time for "Development of High-Precision E-field Sensing Systems for Near-Field Measurement of Electro-Magnetic Field Emitting Media".

Now Alnair Labs is the leading manufacturer of ultra-short pulse laser systems and solutions based on proprietary carbon-nanotubes photonic technology. Their products are:

- Optical measurement equipment for measuring the optical properties of nano materials (Optical sampling Oscilloscopes, Bit Error rate Tester, Short Pulse Autocorrelator)
- Lasers and amplifiers (Carbon Nano Tube Femtosecond Laser, 10 GHz Mode-locked Laser, Low Noise Optical Amplifier)
- Tuneable filters (Band-width Variable Wavelength-Tuneable Filter, Wavelength-Tuneable Narrow-band Filter, Wide-band Dispersion Compensator)

Concluding remarks:
Commercialization of these optoelectronic equipment using nano materials and for the characterization of nano materials is not only a joint effort of collaboration with university research centers but also involves funding by Japanese government. It should be followed by other countries for the growth and development of nanotechnology based industries.
Case study of nano carbon company - Nano Carbon Research Institute Co. Ltd. (NCRI); Shinshu University

About NCRI:

It is a nano-sized R&D company; hence has the smallest possible organization with only 3 employees. However, NCRI has powerful connections with academic and governmental research organizations all over the world. The Company was established and registered at the Hall of Chosei village, Chosei-gun, Chiba, on April 26, 2001. Later the registration was transferred to Ueda, Nagano. Its Capital value is ¥ 3,000,000. Prof. Eiji Ōsawa is the executive director and president (Professor Emeritus of Toyohashi University of Technology) of NCRI. The Company holds 4 patents related to nano Carbon and nano size particulate graphite.

The activity of the Company includes:

- Research and developments of nanocarbon materials
- Production and sales of nanocarbon materials
- Consulting in nanocarbon science and technology

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Web: http://nano-carbon.com

Problem/Issues:

Discovery of C_{60} in 1985 triggered a world-wide surge of research activities towards nano carbons. These invisible ultra-small particles are insoluble, non-volatile, non-melting, and non-subliminal gigantic molecules having extremely large surfaces of the orders of a few hundred m^{2}/g, are difficult to handle and purify. Hence, nanotechnology needs extensive research on the fundamental aspects of nanoparticles and then enter into commercialization.

It is realized by the scientists of the NCRI that for commercialization of carbon nano materials there will be four pre-requisites or issues: (i) low production cost, (ii) biocompatibility, (iii) high crystalline order in the atomistic structure, and (iv) the predictable existence of large market.
Solution:
The approach of NCRI in solving the above mentioned 4 problems were systematic:

1. To reduce production cost, Dispersed Ultra Nano-Crystalline Diamond (DUNCD) were isolated from soot produced by exploding a popular military explosive Composition B (TNT+RDX) in water or other inert media. Note that the expired military explosives have negative price.

2. To confirm biocompatibility, careful studies on the cytotoxicity were undertaken, which confirmed total absence of cytotoxicity in DUNCD.

3. To get ordered atomic structure, the primary particle of DUNCD was found suitable because it is a single cubic diamond crystal containing about 5000 carbon atoms. With such a large number of constituent atoms, DUNCD was found to retain most of the properties known to bulk diamond. Due to the closest packing, diamond has long been rated as the best general-purpose industrial material known on earth, especially excelling in hardness, Young’s modulus, transparency, chemical inertness, thermal conductivity and doping possibilities.

4. Marketability – Since the dispersed single-nano diamond particles or DUNCD retain most of the properties of bulk diamond, and are still amenable to the known processing technology of nanoparticles, it will prove to be a highly versatile material for a variety of applications, thus making it a marketable possibility.

So we can see that the DUNCD satisfies all the four requirements as mentioned above.

In November 2011, NCRI was authorized as the private research organization by JSPS, entitled to apply competitive funding for international programs of exchanging researchers.

Their products include:

- Dispersed single-nano diamond particles of 4 nm average size – it is produced by detonation method using TNT+ RDX/water as raw material. It is NCRI’s breakthrough achievement.
- Ultra High Quality Carbon Nanotubes (both MWCNT and SWCNT).

NCRI markets their products through two Japanese agents, namely New Metals and Chemicals Corporation Limited and Bravus Japan Corporation Limited.

Concluding remarks:
This set up is more like a University’s effort of entering into production through a company that is marketing its products through agents. Shinshu University’s Faculty of Engineering Textile Science and Technology and Education, School of Medicine, and Institute of Carbon Science and Technology, is actively involved as the leader in research and development of smart devices using nanocarbon (i.e., to create new composite materials using carbon nano tubes and other carbon materials, energy applications, composite platings, development and practical application of composite materials, as well as bio applications and to construct new devices in collaboration with Yamagata University, Matsumoto Dental University and Nagaoka University of Technology.
8.6. REPUBLIC OF KOREA

Government initiatives:

Government’s awareness and activities to advance the nanotechnology R&D and production became evident more than a decade ago in 2000 when Korean National Nanotechnology (NT) Initiative was started and approved by the National Science and Technology Council (NSTC) in December 2001 and finally the Nanotechnology Development Promotion Act was passed in 2002.

Within five years of first phase (2001 – 2005), with the help of nearly four thousand researchers, 214 nanotech based companies and KRW 277.2 billion investments by 2005, the Republic of Korea came up with 1431 paper publications and 979 foreign patents (Korea NT Annual 2005, KISTI).

They are continually increasing funding R&D and basic research in nanotechnology since then in the areas that include terabit-class nano devices, nano-structured materials technology, nanoscale mechatronics and manufacturing, NT-based core technology development, basic research for nano semiconductor instrument development.

The Republic of Korea has 5 nanotech related projects supported by US universities and European institutions.

According to Korea NT Annual 2007, KISTI, by 2007 there were 274 nanotechnology-related companies (37-large, 92 small to medium and 145 venture companies) with an investment of Korean Won 281 Billion, 2236 publications and 1769 foreign Patents.

Korean nanotech policy and assessment and funding agencies are:

- Ministry of Science and Technology (MOST)
- Ministry of Education and Human Resource (MOEH)
- Ministry of Commerce, Industry and Energy (MOCIE)
- Ministry of Information and Communication (MOIC)
- Ministry of Health and Welfare (MOHW)
- Ministry of Environment (MOE)
- Ministry of Defense (MOD)
- Ministry of Agriculture (MOA)
- Office for Government, Policy Coordination (OGPC)

Excluding Japan, the Republic of Korea has been the highest funding country for the development of nanotechnology. The Republic of Korea likewise is a good mix of high government and corporate nanotech spending levels and strong technology development, with 16 percent of GDP from high-tech manufacturing and 3 percent of GDP invested in R&D
Case-study of nano health-care Company, a venture company of Gwangju Institute of Science and Technology (GIST) - Anygen CO. LTD.

About GIST:
GIST is eventh in the QS World University ranking 2012. It ranks No. 1 in Asia and No 1 in the Republic of Korea for last five consecutive years. It was founded in 1993 by the Korean Ministry of Science and Technology to meet the nation’s demand for advanced research and enhanced higher education in science and engineering. In 2010, it started undergraduate courses. GIST is situated in the Gwangju Science and Technology Park in northern suburb of Gwangju, i.e. about 200 miles south of Seoul.

GIST is having research collaboration and partnership with many universities and research institutes of Australia, China, Finland, France, Germany India, Israel, Japan, Malaysia, Romania, Turkey, Ukraine, Uzbekistan and Viet Nam. Recently GIST scientists have reported polymer light emitting diodes (PLEDs) with a solution-processable graphene oxide (GO) interlayer. The GO layer with a wide band gap blocks electron transport from an emissive polymer to an ITO anode while reducing the exciton quenching between the GO and the active layer in place of poly(styrenesulfonate)-doped poly(3,4-ethylenedioxythiophene) (PEDOT:PSS).

About AnyGen Co. Ltd.:
It was established as the first bio-venture company in 2000 by professors at the Gwangju Institute of Science and Technology (GIST). The company focuses on developing new bio drugs and essential materials based on physiologically active peptides, biologically functional materials, and chemical nano materials. The company got registered in September 2005. Today AnyGen provides services to facilitate the research efforts of investigators at both academic institutions and pharmaceutical/biotechnology companies, with 50-100 employees. It has an annual turnover of US$ 5,000,001 - 10,000,000.

The company obtained two ISO certifications (ISO 2001, ISO 14001), and the company was awarded the “INNO-BIZ” award by the Korean government for its innovative products.

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Republic of Korea
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**Problem/Issues:**

AnyGen has established itself well as manufacturers of highest purity peptide available in the market (98% vs. 95% for most competitors) and specialist in difficult and long sequences for peptide synthesis. ISO certified, it is the first Korean peptide manufacturer to obtain GMP (Good Manufacturing Practice) status for its production facility. Looking at the expertise available with them through GIST scientists, and their interest in cancer therapy they were in search of more comfortable cancer therapy.

**Solution:**

AnyGen’s passion to develop bio-new drugs and essential materials, especially new drug candidates based on physiologically active peptides, biologically functional materials, and chemical nanomaterials resulted into production and sales of nano medicine - oral anticancer drug. “Peptide-based drugs offer the advantage of low toxicity, no complications, low therapeutic costs and high-biological activity,” said Dr. Jae-Il Kim, C.E.O. of AnyGen. Peptides have the inherent ability to block and/or enhance signal transfers in the human body.

Support from GIST was their great asset. GIST – according to 2012 QS GIST - is world’s 7th in university ranking and in Asia 1st for 5 consecutive years. To support for successful commercialization of and application of basic research capabilities into the region specific industries in Gwangju and the Cheonnam province, in 2005 GIST Technology Institute (GIT) was founded.

Their IPR status (Table 2) is also commendable with the following patents:

- 10/586,780 (Registered) – USA
- 2006-550940 (Applied) – Japan
- 05710825,0 (Applied) – Europe

However, for their nano medicine - oral anticancer drug - that contains Paclitaxel their Intellectual PCT is as follows:

- Domestic: 0791414(registered), 0766820(registered)
- US: 11/847,237 (applied)

**Table 2: Present patent status of AnyGen**

<table>
<thead>
<tr>
<th>R&amp;D field</th>
<th>Domestic registered</th>
<th>Domestic applied</th>
<th>International registered</th>
<th>International applied</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound/Nanomedicine</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>New peptide medicine</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Peptide/Protein manufacturing technique</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>9</strong></td>
<td><strong>4</strong></td>
<td><strong>10</strong></td>
<td><strong>37</strong></td>
</tr>
</tbody>
</table>
Some of their other achievements are:

2008  AnyGen got occupancy agreement for Jeollanam-do Nanobio Research Center

2009  AnyGen was selected for small business technology transfer development (200 million for 1 year) and investment from KDB capital, Nexus investment, Hyundai patented technology venture investmen and, CKD venture capital firm.

2010  Selected as “the top 20 best venture company” in Korea venture investment.

Relocated their headquarters to Jangseong-gun. Jeollanam-do.Jeonnam Nano Bio Research Centre was selected for product technology development industry of small business.


2011  Received peptide APIs GMP certification for the first time in Korea and got selected for Small and Medium Business Administration Technology Innovation Development Project (700 million for 2 years)

**Concluding remarks:**

Nanotechnology is a multidisciplinary field, which recently has emerged as one of the most propitious field in cancer treatment. Nanotechnology is a medical boon for diagnosis, treatment and prevention of cancer disease. It supports and expands the scientific advances in genomics and proteomics and builds on our understanding of the molecular underpinnings of cancer and its treatment.

**Case-study of a nano health-care company supported by SMBA** - Advanced Nano Products Co. Ltd.

**About SMBA:**

The Small and Medium Business Administration (SMBA) founded in 1996, is a major policy player in promoting growth of SMEs and the Korean economy at large. Republic of Korea’s SME policies have supported the increase in SME’s R&D activity and the growth of the venture business. SMBA has developed a variety of SME promotion measures, combining financing, marketing, technology, business start-up, micro-enterprises, etc. In terms of jurisdiction, SMBA belongs to the Ministry of Knowledge Economy. However, it has its own jurisdictional authority as a semi-independent agency. Above all, those programmes designated to SMEs are under the responsibility of SMBA. The focus of SMBA’s technology policies includes reinforcement of industry-academia-research institute networks, commercialisation of developed technology and establishment of digital infrastructure. The main policy initiatives decided by SMBA in 2011 are (a) raising the role of SMEs and strengthening their core capacities, (b) creating fair business environment, (c) increasing the self-sustainability of small merchants and manufacturers, and (d) creating jobs and stimulating the foundation of new business.
About ANP (Advanced Nano products Co. Ltd):

ANP is a company that manufactures and supplies chemically processed crystalline nano materials (metal and metal oxide, ultra-fine powders, sol, paste and coating solution) as well as their chemical precursors for coating and powder processing applications.

ANP Corporation, a SME company that started in 2000, knew or rather realized that the Small and Medium Business Administration (SMBA), since its foundation in 1996, has been in the driver’s seat of Republic of Korea’s SMEs-led innovation. SMBA has developed and implemented SME promotion systems, combining financing, marketing, technology, business start-up, micro-enterprises, etc. It received the Excellent Technology Award from Techno-Business-Incubator Association and got an Encouragement award from the venture enterprises exhibition and contest by SMBA.

Looking at the brief history of ANP Corporation, it becomes clear that the Korean government’s planned financial support to new innovative field of nanotechnology has played a pivotal role in its advancement and success. ANP received support from Technological Credit Guarantee Fund, started its own R&D and completed ITO powder and sol development within a year in 1999 which is an example of further support received by SMBA.

By 2001, ANP established its R&D Centre having 950 m² R&D analysis labs equipped with ICP, BET, Particle size analyzer, UV-VIS Spectrophotometer, Rheometer, Zeta potential, 3D surface analyzer and thickness measurement system, cell efficiency analyzer, etc. There are 32 R&D engineers involved in the research activities related to:

- Basic research for procuring original technique of nano material
- Application research for product development and industrialization
- New process development research for cost effectiveness

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Problem/Issues:

Increased demand for specifically synthesized nano materials, especially metals and their oxides in powder, slurry or paste form for various devices was being felt in late 1990s. The demand for nano metal oxides is on rise as it has found wide variety of applications like anti-microbial activity, Li-ion batteries, as catalysts, in ceramics, etc.

Solutions:

Based on their own research output ANP has successfully completed commercialization of nano size material products for manufacture of metal and metal oxide, ultra-fine powder, paste, sol and coating
solutions. They are marketing the CMP slurry for STI application as well as the hydrophobic and antibiotic coating solution.

Same year they developed ITO paste, ATO paste and TRB paste (for window-films application), that was followed by ITO sputtering target and got registered as CleanANP brand in 2003. CMP slurry that they had developed in 2001 was developed as slurry for ILD application in 2004 and got selected as the Promising Export Small Business in 2005. The following nano-items are listed in their product list:

- Indium TIN oxide, Indium Gallium Zinc Oxide,
- ZrO\textsubscript{2} nano powder (5-10nm)/slurry (15 nm),
- TiO\textsubscript{2} Powder (5-10nm)/slurry (15 nm),
- Aluminium Zinc Oxide\textsubscript{Al\textsubscript{2}O\textsubscript{3}/ZnO;}
- GZO (Gallium Zinc Oxide)/ ZnO Target,
- CeO\textsubscript{2} Powder (40, 80,120 nm),
- Silicon oxide, and
- Silver paste

These products are being used for

- Materials for display (ITO, IGZO, Target, ITO Tablet,ZrO\textsubscript{2} & TiO\textsubscript{2})
- Materials for solar cell (ITO, Sputtering Target, ZnO & TiO\textsubscript{2}
- Materials for semiconductor (CeO\textsubscript{2} Slurry)
- Materials for functional-material (TRB paste, Silver paste, ATO & ITO)
- Materials for printed electronics (T Silver paste, Silver paste (offset), Silver-jet ink)

**Concluding remarks:**

The achievements of this company show that apart from technical support, the financial and policy support by the Government is equally important and has resulted in faster commercialization of R&D outputs.

8.7. MALAYSIA

**Government initiatives:**

Realizing that the key drivers of growth are labour, knowledge and innovation, nanotechnology has been identified as one of the new sources of economic growth by the Government of Malaysia. The following initiatives were taken in this regard:

- Malaysian National Nanotechnology Initiative (NNIM) was officially launched in September 2006 with a budget of MYR 20 million.
- The fund injected by the Government in nanotechnology in Malaysia during 2006-2010 was US$35.26 million.
- In2010, the National Nanotechnology Directorate (NND) was officially formed under the Ministry of Science Technology and Innovation (MOSTI).
The Academy of Sciences Malaysia (ASM) is now a focal point for nanoscience and nanotechnology. Malaysia has also set up the National Nanotechnology Technical Committee, with SIRIM Berhad as its secretariat. The country currently has 300 researchers in the field of Nanotechnology.

Efforts have been made to identify nanotechnology experts from overseas to collaborate with Malaysian researchers.

Malaysia is in the process of setting up its National Nanotechnology Centre (NNC) having its research focus on nanoparticles, CNT, dendrimers, aerogel, OLED, quantum dot, nanomagnetic, single electron transistor and DDS.

Malaysian agencies in nanotechnology were formed to integrate all existing local nanotechnology activities; coordinate and plan the R&D activities; prepare a platform for commercialization and transfer of new technology to generate economic returns for the general public; develop educational resources, skilled labour, expertise and nanotechnology infrastructure; and provide facilities and nanotechnology research support services. These agencies comprise of:

- The Academy of Sciences Malaysia (ASM)
- National Nanotechnology Technical Committee
- SIRIM Berhad
- Malaysia Nanotechnology companies are developing CNT nanocomposites, biosensors, nanocatalysts and biofertilizers. At present, the funding is conventional collateralized by tangible risk capital, particularly assets venture capital.
Case-study of silver nano material producing company in collaboration with Japan and Republic of Korea - Nano Silver Manufacturing Sdn Bhd (NSM)

About the Company:
NSM was established in June 2004. It is a high technology Company which focuses on research, development, production and marketing of nanotechnology products. NSM Research and development team consists of expertise from Malaysia, the Republic of Korea and Japan, of which five members of the team are full time research professors specializing in nanotechnology. They have successfully applied nanotechnology in the field of agro-based products, poultry, water treatment and others.

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Problem/Issues:
Even though ordinary or bulk silver is known to have superior antibacterial and antibiotic characteristics, there has been limitation on the application because of its darkening at high temperature and high cost. Whereas now-a-days nano-silver is a synonym with anti-bacterial technology, according to Samsung the silver nano technology sterilizes over 650 types of bacteria

Solutions:
Nanotechnology or rather nano sized silver, solved all these two problems at the same time and retains its anti-microbial activity. Nowadays, nano silver technology is used in coating the surface of electronics, carbons or carbon blocks, textiles, metals, woods, ceramics, glass, papers, mixing with plastics resin, using in fiber and many others. Utilizing these unique qualities of nano-silver, NSM has come up with a range of healthcare products such as dressings for burns, scald, skin donor and recipient sites, acne and cavity wounds, and female hygiene products – panty liners, sanitary towels and pants. Some of the nano-silver products of NSM are:

SilverSol™ is the colourless, tasteless, and odourless colloidal solution suspended in the distilled water. It is between 3-5 nano meters (nm) as compared to common colloidal silver which is 8nm-10micron. NSM produces more than 20 tons of nano silver a day at very low cost.

Silver sol coated carbon - Activated carbon has been widely used in water purification due to its high adsorption rates and capabilities. The inherent drawback of carbon materials, however, is that they
have excellent biocompatibility with bacteria. To address this problem, NSM has developed a safe and effective product - silver sol coated carbon having 99.9% antibacterial and antifungal activities.

NanoGreen™, a natural antibacterial agent produced from natural minerals through the use of nanotechnology. It is free from harmful chemicals, thus not jeopardizing the human body, animals as well as plants. It can be a replacement for chemical fertilizers to be sprayed on plants and crops. Moreover, NanoGreen™ is also a unique product for wastewater treatment.

ECS has enhanced antibiotic efficacy and is used for feeding the broiler chickens.

Concluding remarks:

NSM’s effort in manufacturing colloidal silver along with many nano silver related agro-products is a commendable effort. This is done with the international collaboration involving scientists from Japan and the Republic of Korea. However, environmental concerns relating to nano silver should not be ignored. Recently The German branch of Friends of the Earth, Bund für Umwelt und Naturschutz Deutschland (BUND), has criticized the use of nano silver as it has a toxic effect on different kinds of living cells and they may be a threat to soil, water and human health.

Case-study of photocatalytic coating material producing company - Arc Flash Corporation (M) Sdn Bhd

About the Company:

Arc Flash Corporation (M) Sdn Bhd., is a Malaysian owned trading company which has been appointed by a Japan based manufacturer as the sole distributor of the brand, NanoYo PHOTOCATALYST Coating, from Malaysia. The Company was established in 2004. The Company is having 15 – 30 employees and has ISO 9001:2000 Management Certification.

Problem/Issues:

Before entering into commercialization of any new field or product it is important to know whether it will be accepted in the market or not?

Solution:

Arc Flash Corporation (M) Sdn Bhd. took up the role of exploring the task of distributing, promoting and expanding the market for the NanoYo photocatalyst products and services in its allocated regions. One year later, the company reported to the manufacturer, stating that the product actually has great potentials locally in Malaysia as well as the rest of the countries in this region. Therefore, the company was offered the role of sole distributor of the brand and product in the region.

The company started marketing the product from the end of 2005 in Malaysia. Within six months, the company had managed to gain its access in three other countries in the region (Indonesia, Brunei and Cambodia). Now they are exporting to other countries also. Their total annual sales volume is now < US$ 1 Million and export percentage is 71 – 80%.
As mentioned above, they are trading photo catalyst coating under brand name, NanoYo (NanoYo is a Japanese company founded more than 18 years ago).

It is a liquid paint and contains an active ingredient, an n-type semiconductor TiO$_2$ (Titanium dioxide) nano particle that is responsive to light. When it is sprayed on the interior and exterior surfaces of buildings, and when it is exposed to light or even normal room temperature, it acts as self-sanitizing-bacteria and viruses, deodorizer, anti-fungal agent, anti stains and is self-cleaning.

**Concluding remarks:**

Trading a product that is manufactured by some other country, may not exhibit the countries progress but it does help in the economy of the country, especially when it is exporting >70%. However, little is known about the toxicity of titanium dioxide nanoparticles, In an experiment conducted by Saber et al (2012), using titanium dioxide nanoparticle UV-Titan L181 (NanoTiO$_2$), pure or embedded in a paint matrix showed pulmonary inflammation and DNA damage in mice instilled with sanding dust from NanoTiO$_2$ paint; however, pure NanoTiO$_2$ caused greater inflammation than NanoTiO$_2$ embedded in the paint matrix. Whereas, Servin et al (2012) has shown entry of Nano TiO$_2$ in cucumber plant roots. The impact of TiO$_2$ on the plant is still to be researched.

**8.8. PAKISTAN**

**Government initiatives:**

To promote nanotechnology a National Commission on Nanoscience and Technology (NCNST) was formed (APCTT-ESCAP, 2010).

On 1st January 2006, the Ministry of Science and Technology of Pakistan approved a project worth Rs 195.867 million for research and fabrication of scientific devices by application of nanotechnology and also to contribute to human resource development by imparting higher education in the area of nano-materials to meet the needs of this emerging sector. Many universities have upgraded their curriculum to introduce nanotechnology.

Another fund of Rs 3.2 billion was allocated for new-materials and nanotechnology in the Medium Term Development Framework (2005-2010). Obviously the multifaceted utility of nanotechnology has been well recognised by the Pakistan Government.

Moreover, Pakistan Council of Scientific and Industrial Research (PCSIR), which was established in 1953 has now a fully functional Nanotechnology Centre, mainly focusing on R&D activities related to nano-coatings, nano-materials and nano-powders and plans to undertake cooperative research with local and foreign R&D organizations and commerce-industrial outfits (Paper by Mr. Shahzad Alam, Director General, PCSIR, Lahore, APCTT-ESCAP, 2010).

Apart from PCSIR, Pakistan Institute of Nuclear Science and Technology (PINSTECH) and Pakistan Atomic Energy Commission (PAEC) have also been roped in for time bound R&D work.

Some of the leading institutes working in this area are:

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**Development and Commercialization of Nanotechnology-based Value Added Products**

**Case studies from Asia and the Pacific**

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• Pakistan Council of Scientific and Industrial Research (PCSIR);
• NINVAST, Quaid-e-Azam University, Islamabad;
• Commission on Science and Technology for Sustainable Development in the South (COMSATS);
• University of the Punjab-Solid State Physics Departure;
• University of Engineering and Technology, Nanotechnology Research Centre, Department of Physics,
• Some other universities are also coming forward (Source: partly from APCTT-ESCAP, 2010).

R&D efforts of Pakistan have come up with outputs that can be thought of as commercial venture, e.g. aluminum-diamond nano-composites, Al-SiC composites, Zinc Ferrite Nanoparticles (ZnFe2O4), electrolytic synthesis of thin sheet of nano-porous alumina, electro-deposited nano structured Ni-Zn and Ni-W alloys, etc. But at present they are in infancy and still conducting seminars and conferences as well as proposing recommendations for commercialization of nanotechnology. Emphasis is being given to international collaborations. Commercialization of research output from Pakistan has yet to fully reach the industries. In the demanding fields of nanotechnology like therapeutics, diagnostics and carbon nanotechnology hardly any work is being done at commercial level. At present they are mostly involved either in importing the desired material and equipment directly or through the traders. Three main traders of Pakistan are:

• Cloud 9 – A trading company is one of the supplier company form Lahore, which apart from nano calcium carbonate (the only nano product they deal with) also supplies caustic soda flakes 99%, caustic soda, soda ash light, caustic soda liquid, corned beef, calcium carbonate, calcium carbonate, hard calcium carbonate and plastic. This company has about 11 – 50 employees. Their main customers are - Halliburton’s, Kuwait Petrochemical Company, Ashaye Chemicals Japan and they have an Annual Sales volume of US$ 2.5 – 5.0 million. They are having HACCP & ISO 9001:2000 Management Certification.
• Maira Trade International - A trading company from Lahore are supplier of carbon nano fibre. It is in professional exporting and importing business for nearly three decades, running as a marketing company with government’s license. Apart from carbon nano fibres, their mail products include valves, fittings, pipes, sheets, stainless steel products, mild steel products, thermocouples, felts, carbon products and high temperature products. They boast of having trade relations all over the world in order to bring best products and services for customer in Pakistan. They are dealing with more than 50 countries like Germany, England, Sweden, USA, Canada, China, Dubai, Ireland, Norway, Italy, etc.
• Global Traders - A trading company is supplier of TiO2 Photocatalyst Sol coating imported from Shanghai.

Concluding remarks:
A report published on 7th May 2012 ENn (Flickr/nic221) will perhaps summarize the delay in Pakistan’s entry in commercialization of nanotechnology.
[KARACHI] Nanotechnology research in Pakistan, which had shown a trend of higher publication numbers over the last decade, has suffered from the country’s present financial crisis, a study said.

In 2008 the government did not extend the term of the National Commission for Nanoscience and Technology, initially set up in 2003 for three years and later extended for two more years.

The study, published online on 29 March in *Scientometrics*, said research publications in the field had grown from seven in 2000 to an impressive 542 papers in 2011, registering a 29 per cent annual growth rate.

This is higher than the average annual growth rate of 23 per cent registered globally, said Rizwan Sarwar Bajwa, research associate at the Preston Institute of Nanoscience and Technology in Islamabad who, together with his colleague Khwaja Yaldram, had carried out the study.

Much of the contribution came from 13 universities while only two state-owned research and development institutions in the country participated in nanoscience and nanotechnology research.

The study attributed the spurt in research and publications to heavy government spending on manpower training and procuring the latest equipment for laboratories working in the field.

"Unfortunately, the present financial crunch faced by the country could have a negative impact on the progress achieved so far," the study concluded.

"The publication shows that despite availability of funding, the research and development institutes contributed very little in the field of nanoscience and nanotechnology,"

Bajwa, lead author of the study, told *SciDev.Net*

### 8.9. THE PHILIPPINES

**Government initiatives:**

The government’s awareness and initiation of efforts are visible in their intention to enter in this new field. The government bodies of Philippines that are involved in promoting nanotechnology includes: Department of Science and Technology (DOST) and Philippine Council for Advanced Science and Technology Research and Development (PCASTRD).

The DOST has identified scientists interested in nanotechnology and nano-biotechnology research. The priority area that the Government has chalked out encompasses:

- Nanomaterials and nano-composites,
- Solar energy devices,
- Nano-designed sensors and actuators,
- Nano-based delivery systems,
- Nano-composite films and membranes,
- Nano-sensors,
- Nano-porous filters, and
- Nano-based environmental remediation systems.
PCA STRD through various government agencies has funded many nanotechnology related projects viz.

- Development of nanosensors for antibiotic, based on molecularly imprinted polymer coupled with piezoelectric quartz crystal (ITDI-DOST);
- Development of gold (111) and platinum (111) single-crystal substrates for nanomaterials – preparation, characterization and applications (UST);
- Synthesis and characterization of carbon-based nanostructures using horizontal vapour phase deposition (DLSU);
- Production of recycled polycarbonate/organoclay nanocomposites (ITDI-DOST);
- Imaging of quantum-dot labelled mouse embryos using multi-dimensional spectral microscopy (UP Diliman);

Engineering Research and Development for Technology (ERDT)-funded nanotechnology-related projects are:

- Nanomaterials from indigenous sources of the semiconductor and electronics industry (UP Diliman); and
- Production of CNTs in the presence of magnetic field and other external factors by microwave-enhanced vapour deposition (DLSU)

There are some Universities and Research Centres, which are involved in various aspects of nanotechnology related research like molecular modelling, quantum dots, nano-sensors, synthesis of polymers, dendrimers, etc. Researchers in the public and private sector, faculty and graduate students are also involved in Nanotechnology R&D.

- Universities (Ateneo de Manila University, Mindanao State University-Iligan Institute of Technology, De La Salle University, University of the Philippines-Diliman, University of the Philippines Los Baños, University of Santo Tomas); and
- Government research institutes (Industrial Technology Development Institute, Metals Industry Research and Development Centre, Surfaces and Coatings Research and Development Centre).
**Case-study of developing a commercially viable technology for sensor using SnO₂ Nanowire by De La Salle University (DLSU)**

**About DLSU:**

DLSU-Manila has also been recognized as one of the best universities in the world and within Asia at the start of the new millennium. The De La Salle University Science Foundation serves as DLSU's repository of research funding providing research grants to faculty and scholarship grants to students.

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**Nanotechnology R&D:**

The Physics Department is recognized by the Commission on Higher Education (CHED) as a Centre of Excellence. The Department is chaired by an eminent Physicist Dr. Gil Nonato G. Santos. Fabrication and characterization of Nanomaterials is one of the forefront researches of the department.

The Solid State Physics Research Laboratory of DLSU, under the leadership of Dr. Gil Nonato C. Santos has been able to establish a good research laboratory with suitable staff. This group is mainly concentrating on synthesis of various metal oxides, sulphides, nitrides etc and trying to study their applications. This group has been able to:

i. Develop C-Ag Composite for making an electrode in a battery.

ii. C-Ag Composite was grown on carbon rod using horizontal vapour phase crystal growth technique. The precursors were flame annealed prior to HVPCG for higher yield of deposited nano materials thus improving battery characteristics.

iii. To synthesize semi-conducting nanowire of SnO₂ using Wang et al’s (of Georgia Institute of Technology) HVPG method. This very thin nano wire of tin oxide can be used as a biosensor, for which they have taken one patent.

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1 *This case study has been prepared on the basis of information and material collected by APCTT during a study visit.*
iv. Apart from nano wires they have also synthesized nano belts and cluster like nano-cauliflowers of SnO$_2$

Some of their other research activities in the field of nanotechnology are:

- Characterization of nanomaterials including different nano forms of carbon, ZnS, SnO$_2$, ZnO, CdO, In$_2$O$_3$, Fe$_2$O$_3$, TiO$_2$, GaN, Gold, MgB$_2$, Ag-C composite, Bi$_2$S$_3$, etc
- Understanding the growth behavior and characteristics of nanomaterials
- Device fabrication of photoluminescence nanomaterials for:
  - Environmental nanomaterial sensors
  - Bio nanomaterials
  - Solar nanomaterials
  - Nanocoatings

Researchers from several other departments of the De La Salle University are also actively engaged in research and development activities related to nanotechnology applications. The departments are – Biomedical Physics Department, Molecular Biology Department, Chemistry Department, and the Chemical Engineering Department.

The intellectual property policy:

De La Salle University-Manila acknowledges the necessity to provide policies to promote and encourage excellence, creativity and innovation in research and other scholarly works by identifying and protecting the rights of the University, its faculty, staff and students. These policies are intended to provide the basic framework for the treatment by the University of Intellectual Property Rights (IPR). They are stated in broad terms in order for the details of the policies to evolve from their interpretation and application in individual cases.

The DLSU Intellectual Property Office (DIPO) acts as the Technology Licensing Office (TLO) of the University established to implement the IP policies of the University. The DIPO assists researchers in the drafting of contracts, agreements, affidavits, patent applications, and other documents which are necessary to protect the intellectual property rights of the University. The office also assists in the evaluation of the commercial potential of research works, technology commercialization activities, and in the negotiation of licensing agreements, joint ventures, spin-offs, and other similar contracts referred to it by the University.

Concluding remarks:

But at present, the entire work is at the research level only, though it has a great commercial potential and possibility. DLSU has put in place a policy framework for the protection and commercialization of intellectual property.
Nanotechnology R&D at the Industrial Technology Development Institute (ITDI), Philippines

About ITDI:
The Industrial Technology Development Institute or ITDI is one of the research and development institutes (RDIs) under the Department of Science and Technology. ITDI is multidisciplinary with a unique blend of scientific disciplines, enabling the Institute to carry on its role as one of the active leaders in the country's industrialization program. Its R&D programs are anchored on its vision of propelling development while addressing the national call for job creation to help alleviate the plight of the less-privileged sector of society. R&D activities are focused on seven major areas, namely: food processing, materials science, chemicals and minerals, electronics and process control, fuels and energy, microbiology and genetics, and environment. The Materials Science Division (MSD) of ITDI is engaged in R&D activities related to the development of several nanotechnology-based value added products.

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Fax: (632) 837-3167 & 837-6150  
E-mail: msd@dost.gov.ph, babasilia@dost.gov.ph  
Web: http://www.itdi.dost.gov.ph

Nanotechnology applications:
ITDI has developed several nanotechnology applications through intensive R&D efforts. Some of those are briefly described below:

- **Biodegradable nanocomposite films for green packaging:** The nanocomposite films are made from cornstarch and local-nanoclay to form the biodegradable nanocomposites. These are cost-effective barrier materials, intrinsically biodegradable and suitable for food packaging applications.

- **Halloysite nanoclay-filled epoxy molding component for integrated circuit packaging:** The nanoclay fillers for epoxy molding compounds (EMCs) are made of local halloysite

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2 This case study has been prepared on the basis of information and material collected by APCTT during a study visit.
nanoclay. It has applications in the IC packaging with improved thermal properties of IC packages.

- **Reused polycarbonate-layered silicate nanocomposites**: The polycarbonate-layered silicate nanocomposites (PLSN) have been developed from recovered post-consumer waste compact discs (CDs). They were reinforced with locally synthesized nanoclay for prototype products, i.e., plastic tiles/slabs, plastic caps for current voltage equipment and printed circuit boards (PCBs). These products find wide application in the manufacturing sector.

- **Local bioactive polymer nanofibrous scaffold for tissue engineering**: Through the application of nanotechnology, third-generation biomaterial for in-situ tissue regeneration and repair has been developed. The biodegradable nanofibrous scaffold using local carrageenan and polycaprolactone was processed by electrospinning. It is efficient, low-cost and uses local, indigenous raw materials. The scaffold is used in medical procedure/operations and needs only minimally-invasive surgery for treatment. It is a welcome development for tissue engineering.

- **Nanostructured fibrous membrane for wastewater treatment**: This product is fabricated from polymethyl/methacrylate impregnated with local nanoclay. The technology offers option for the treatment of wastewater that may contain organic contaminants.

- **Nano-inorganic mineral filled self-cleaning paint for architectural applications**: A new self-cleaning organic paint/coating suitable for exterior concrete walls and structures is currently being developed. The formulated paint, when applied on exterior concrete panels/walls forms paint films on the surface of the concrete after drying. The dry paint film modifies the surface of the concrete into becoming more hydrophilic which prevents adhesion or accumulation of airborne contaminants such as lipophilic dirt, oils, emission gases, dust particles, etc.

- **Water purification system using ceramic pot-type filter (WPS/CPF)**: The CPF is specially formulated with red clay and coated with nano anti-microbial agent. It is used to purify tap water, deep well water, and raw water from ponds and springs. The CPF-filtered water samples are claimed to confirm to the Philippine National Standard (PNS) for drinking water.

- **Nano-clay – A multifunctional nanomaterial additive for nanostructured polymer-based nanocomposites**: Synthesized from bentonite ore, the nanoclay is a nano filler in polymer-based nanocomposites for different matrices such as thermoset, thermoplastic and rubber. It has applications in the automotive industry (bumpers, interior and exterior panes, etc), construction industry (panels, boards, etc), electronics industry (electrical housing, printed circuit boards, etc), and packaging industry (packaging films, containers, etc).

**Technology transfer and commercialization:**

ITDI is a recognized player in technology generation through R&D, technology transfer and a reliable provider of technical services. The institute offers training and technology transfer services under various schemes. ITDI has fostered collaborations and partnerships with academic institutions, professional organizations and industry associations at local and international levels. The networks and linkages have bolstered research collaboration, capacity building, among others, for the benefit of the researchers and the institute in general.
The Technological Services Division (TSD) of ITDI has been established to: diffuse, transfer Institute's generated technologies, promote public awareness of the Institute's technologies/new services, establish and main linkages with mass media, scientific and technology-based institutions and other organizations involved in industrial development for the promotion and transfer of technologies, enhance and maintain databases/documentation system of original ITDI research outputs and related researches from other sources for global access/information service and contribute in the planning and implementation of the Institute's programs/projects.

Technical support to industry:

The Institute provides various services or interventions to industry to help modernize the production sector and improve their productivity:

- **Research and Development (R&D):** Multidisciplinary applied research in the fields of industrial manufacturing, mineral processing, energy and environment, using local raw materials.
- **Technology Transfer and Contract Projects:** Transfer of mature technologies with techno-economic viability, from product/process development to techno-assessment to commercialization.
- **Tests and Analyses:** Recognized as the national agency for tests and analyses, ITDI plays a critical role in product standardization and testing by providing analytical and testing services to industry and government agencies for various products and materials. The government’s Department of Science and Technology recently established the ADMATEL (Advanced Device and Materials Testing Laboratory), a national center for advanced materials characterization for the Semiconductor and Electronics Manufacturing Industries. This center houses new/advanced facilities which will be used for materials analysis/characterization and product development of nano-based products for the electronics and semiconductor sector and other industries. The Laboratory will benefit not only the local semiconductor industry but also attract potential investors seeking for a more conducive business environment. This would ensure shorter turn-around times especially for companies who cannot afford to put up their own FA (failure analysis) and characterization laboratories. This would be less expensive for manufacturers who need not have to send their materials and samples abroad.

Concluding remarks:

The nanotechnology R&D activities being conducted at ITDI are mostly demand-driven from the industry. This provides a good opportunity for the Institute to forge research collaboration with the industry to develop and commercialize nanotechnology-based applications. The mechanisms for intellectual property protection and technology transfer have been put in place by the Institute. The competency level of researchers involved in nanotechnology R&D at ITDI appears to be fairly good.
Case study of environment-friendly nano product company - INERGI Philippines, Inc.

About the Company:
INERGI Group, founded in 2005, was initially an energy management and engineering services company. But now it has changed its focus to an effective green solutions provider. This privately held company has 1-10 employees. Inergi has two divisions (i) Agro sciences, and (ii) Green lighting.

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Problems/Issues:
The world is facing “climate destabilization” caused by man-made emissions of greenhouse gases onto the atmosphere, and the gradual contamination of our arable land and water resources through rampant use of toxic chemicals in agriculture and industries. Food supply and safety had been a cause for concern in climate deterioration. Food safety is very much affected because of the use to chemicals at toxic levels. There is not only a need to develop effective pollution prevention and energy efficiency solutions to our environment but also to enhance the food safety and productivity.

Solutions:
Focused on delivering “positive changes” to “climate destabilization, the INERGI Group has managed to combine innovative products and services to deliver effective pollution prevention and energy efficiency solutions to our environment.

Efforts of innovative researches of INERGI AgroScience Corporation Limited, has brought non-toxic, environmentally friendly products to enhance food growth and quality whilst at the same time, encourage sustainable farming to reduce the damage done by the use of conventional toxic agrichemicals to the arable lands. The product that they have developed is NutraGreen™.

NutraGreen™ is a concentrated colloidal micelle solution engineered from a mixture of food safe, environmentally friendly bio-based chemicals. It is highly soluble in water and applied in recommended dilution range with water. It has no known toxicity to the environment, nor ill health to humans, animals and marine life. NutraGreen™ contains micelle structure at nano-scale size less than one nano-meter. Together with bodies of chemicals that predominantly contribute to NutraGreen™, i.e. fatty acids, organic alcohols and various forms of glucose that combine to promote plant cell metabolism so as to allow plants to grow and reproduce, maintain their structures and respond to their environment more effectively. NutraGreen™ facilitates photosynthesis which converts carbon
dioxide from the atmosphere into simple sugars – the main building blocks that form the key structural component of plants.

The other division of this company is Green Lighting Nanoflex Limited, which is producing Nanolux®. This technology of energy efficient green light was developed in Hong Kong for bringing quality illumination for the built environment. Nanoflex provides high efficient optical reflectors and reflective components that raises the system efficiency of light fixtures by 15% to 30% depending on the light source, while improve the quality of reflecting light distribution.

**Concluding remarks:**

Keeping agriculture and environmental concerns like reducing electrical consumption is a very befitting approach for a developing country like Philippines. Hang Seng Bank has used Nanoflex lighting system in their building and in a press release they have credited Nanoflex® technology in reducing their electricity consumption of ATM by 330,000 kWh per year, an energy saving of 33 percent.

**Case study of a health care company - G-CORE Group Inc**

**About the Company:**

G-CORE Group Inc has 70 years of experience in the field of business and industry management. It is dedicated to find solution of relieving pain. GCORE is a marketing corporation duly registered with the Securities & Exchange Commission with a License to Operate granted by the Bureau of Food and Drugs. G-CORE is the exclusive marketing partner of CAStech Research and Development Company which is responsible for the design, research, development and manufacturing of patented invention products related to health, energy conservation, alternative fuels and environmental protection.

**Contact address:**

G-CORE Group Inc  
South triangle, Quezon City - 1103  
Manila, Philippines

**Problems/Issues:**

Since this company already had interest in natural products derived from plants, they also felt the need of a safe, side effect free all natural therapy for relieving the pain. Nanotechnology in medicine involves application of nanoparticles currently under development, as well as longer ranges research that involves the use of manufactured nano-robots to make repairs at the cellular level (sometimes referred to as nanomedicine). Moreover, since most of their products are plant based, their interests were also on a nanotechnology supported plant growth material.
Solutions:

The use of nanotechnology in medicine offers some exciting possibilities. Some techniques are only imagined, while others are at various stages of testing, or actually being used today.

Approach of G-CORE Group Inc. was to create a medicine for relieving pain utilizing the nanotechnology and natural products. The theory behind their approach was that nanoparticles can be easily taken up and body can assimilate and absorb it faster, thus speeding up the process. They also wanted an access to profitable and stable business that will answer to their financial worries. The application makes G-CORE products more effective. According to their claim, it also helps in alkalizing the more oxygen into the cellular matrix. Moreover, their products are affordable to most Filipinos.

The product they have developed consists of basic and naturally fundamental elemental process-energized by the latest most advanced science-lab techniques e.g. fluid thermodynamics, biotechnology, nanotechnology and hydrogenics.

The resultant products are first of its kind conglomeration of inventions, marvels in health food supplements, energy conservation, alternative fuels, pollution control, bio-cosmetics, physical revitalizer and pheromones, all of state-of-art quality from package to processing.

Now their main products are: instant pain reliever, nanotech energy booster, memory enhancers, immune system booster, hair re-growth natural solution, slimming product, beauty secrets in 10 minutes, smart drops, height enhancer and pheromones, etc.

In these natural products where nanotechnology was used are:

- **Beauty Secret Astringent** - that uses state-o-art nanotechnology energized water instead of alcohol.
- **Slim Pro** – produced by using nano-sized particles of minerals that due its size easily gets absorbed by the body with an ionic effect. This allows slimming process to rapidly take effect, causing body fats to burn faster to make the body slim.

As mentioned above, their interest lies in plants and plant growth and they are pioneers in marketing high quality products processed through nanotechnology. One such agro product is SeedGROWTH. As mentioned above, their interest lies in plants and plant growth and they are pioneers in marketing high quality products processed through nanotechnology. One such agro product is SeedGROWTH, the first liquid organic fertilizer/soil conditioner processed through nanotechnology.

Nutrients of SeedGROWTH are processed by tri-atomic processors to become one billion times smaller than a meter. This gives SeedGROWTH the capability to penetrate plant cells three times faster than other farm inputs. This also rapidly neutralizes soil acidity and balances soil pH level, especially when applied during land preparation.

SeedGROWTH has been found to be very good for rice, corn and other grains, vegetables, fruits, fruit-bearing-trees, flowers, orchids and many other crops.
**Concluding remarks:**
Climate change, urbanization, sustainable use of natural resources and environmental issues like runoff and accumulation of pesticides and fertilizers are the hot issues for today's agriculture. Efforts of G-CORE to combine the nanotechnology and natural products by Philippine’s extraordinary product like SeedGROWTH is commendable.

8.10. **SRI LANKA**

**Government initiatives:**
For promoting nanotechnology, the Sri Lankan government took a unique step and created SLINTEC.

**Case study of Sri Lanka Institute of Nanotechnology (SLINTEC)**

**About SLINTEC:**
The Sri Lanka government took a unique step and created SLINTEC for promoting Nanotechnology in the country with the help of 5 joint public private partnerships namely...........

1) Brandix Lanka Ltd. – 409, Galle Road, Colombo – 3, Sri Lanka
2) Dialog Telecom Plc. - DTL Cooperate building, Union Place 475, Colombo 00200, Western Province, Sri Lanka
3) Hayleys Plc. - Hayleys Group, No.400, Dean's Road, Colombo 10, Sri Lanka
4) Loadstar Ltd.- Load star Pvt. Ltd. Head office, regents Court, 218 Minuwangoda Road, Ekala, Ja Ela, Sri Lanka
5) MAS Holdings Plc – AS Holding Pvt. Ltd., No. 7th Lane, Off Borupana Road, Kandawala Street, Ratmalana, Sri Lanka.........................

In 2007, to implement the National Nanotechnology Initiative (NNI) the Cabinet of ministers approved the setting up of the Sri Lanka Institute of Nanotechnology (SLINTEC) and the Nanoscience Park, with a Government commitment of Rs. 5.6 billion over a five year period and by April 2008 it was incorporated. After completion of infrastructure and installation of equipments, science projects commenced on 12th August 2009 and in the same year their website was also launched. Today it has a production facility called NANCO. There is a strong effort in “Concept to Commercialization”, by formulating strategies and policies keeping in mind the challenges to be met. Members of the National Nanotechnology Committee (NNC) were involved in the following nanotechnology policy development objectives:

- To develop a world class environment for nanotechnology research, innovation and commercialization;

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This case study has been prepared on the basis of information and material collected by APCTT during a study visit.
To develop human resource needed for a viable and innovative Sri Lankan nanotechnology industry;

To promote industry oriented collaborative R&D through public private partnership to transform the generated knowledge into innovative products/services & provide a competitive edge to the local nano-industry;

To significantly increase the Sri Lankan intellectual property in nanotechnology and establish a framework to safeguard and exploit these for economic development; and

To establish a regulatory framework for promotion of nanotechnology to suit the needs of our society and industry while paying attention to ethical, environmental and safety aspects with regular monitoring, evaluation and public debate.

After a visit to SLINTEC in 2009, the World Bank Reported that the SLINTEC model is: “Leveraging high technology to drive innovation and competitiveness in key export industries & building the Sri Lankan knowledge economy”.

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Nanotechnology R&D and commercialization:

The research focuses of SLINTEC are based on the market demands of the industries that has supported it formation. They are:

- Textile and apparel;
- Solid tyres;
- Fertilizer;
- Rubber gloves;
- Activated carbon;
- Biosensors;
- Blue sky project; and
- Nanomaterials

However, looking at the research interest and research publication, it is certain that they will enter into other domains of nanotechnology based products.

To promote research:

- SLINTEC and the Nagarjuna Fertilizers and Chemicals Limited of Nagarjuna Group India entered into a strategic collaboration of US $ one billion to develop the next generation of Nanotechnology based plant nutrition solutions. SLINTEC will carry out research and Nagarjuna will develop the product.
With an intention to enter into market driven developments in Nanotechnology, SLINTEC has signed a deal with Japan International Cooperation Agency’s (JICA). JICA will provide expertise as well as equipments.

On 28th October 2009, SLINTEC signed an agreement for collaborative research with the Research Organization of the Science and Engineering of the Ritsumeikan University, Kyoto, Japan.

The unique and novel efforts of SLINTEC has been appreciated by all the experts and world leaders in science who visited their establishment e.g. Dr. Mashelkar from India, Hans Wijayasuriya from Sri Lanka, Hugo Van de Wiele from Luxembourg, Wim Swyzen from Netherlands and Prof. A.P. de Silva of Belfast. Even Nano-Globe has written in its column that “I am most impressed by the Sri Lanka Nanotechnology policy is its emphasis on private - public partnership (PPP) and incorporating responsible development and regulatory framework. (http://www.nano-globe.biz)

Due to fast track research activities, SLINTEC’s has acquired five international patents in nanotechnology in its first year of operations in a drive to commercially exploit the technology. The first IPP – 4 – 2010 was files on 12th August 2009 and four more provisional patents in December 2010; two in the area of agro-chemicals (that include carbon nanotubes, nano fertiliser), one relating to solid rubber tyres and another of self-cleaning antibacterial fabrics (Lanka Business On-line, 22.4.2011).

Having considered the fact that many research findings arising from research and experimental development projects are confined to laboratories without progressing into commercial applications and also with a view to develop an entrepreneurial culture among researchers, scientists, engineers in the research institutes and universities, the grant scheme “Support for start-up businesses based on novel Technologies (Start Ups)” is established by the National Science Foundation of Sri Lanka. The scheme provides an opportunity for researchers/scientists/engineers to start up businesses by establishing start-up companies or spinoffs using their university/institute-based new technologies

Concluding remarks:

With the efforts of SLINTEC, other Government organizations and their collaboration with Indian company and Japanese University, Sri Lanka would very soon be introducing many industries based on nanotechnology products. With this first movement of nanotechnology, Sri Lanka believes that nanotechnology will facilitate the differentiation of Sri Lanka's commodity exports and will also shift towards a knowledge based economy. It will soon redefine Sri Lankan industry and establish them as the trailblazers of our age.

For a country which has limited funding from the government [i.e. only 50% funding from Sri Lanka National Science Foundation (NSF)] has shown its commitment in developing nanotechnology with a unique –public-private partnership and passionate scientists.
Case study on the development of nano-coated self-cleaning ceramic tiles for commercialization by Industrial Technology Institute (ITI)\(^4\)

About ITI:
The Industrial Technology Institute (ITI), Sri Lanka is engaged in the applied research and development in the area of nanotechnology. The Materials Technology Section of ITI, initiated a project for the development of a nano-coated self-cleaning ceramic tile in collaboration with a reputed tile manufacturer in Sri Lanka. In this mutual agreement the Materials Technology Section of ITI was identified as the technology research and development group whereas the ceramic industry as the financial support and materials and infrastructure provider of research and development until the technology transfer. The initial concept and the project proposal were prepared by the Institute. The project duration was three years starting from October, 2006.

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Nanotech R&D:
ITI performed all preliminary lab trials within a period of 18 months. In addition selection of suitable material for coatings, coating trials, firing and characterization and property analysis etc. were also tried out. ITI researchers attempted to adopt a coating technique suitable to the factory since designing of a new processing unit was expensive. Yet, adapting a method to the factory requirements created some problems because of high kiln temperature at the main factory. Some other basic requirements for coating were also not available at the factory. The factory allocated another site for low temperature firing. This has led to find new raw materials to suit the low temperature kiln which took more than a year.

Pilot scale trials at the factory level were carried out for the coating technique using new raw materials as per the agreement with the industrial counterpart. The technology transfer, however, was delayed as there were new trials with new formula.

\(^4\) This case study has been prepared on the basis of information and material collected by APCTT during a study visit.
Industrial experience:
The experience of ITI researchers in working with their industrial counterpart during the factory level trials includes the following:

- *Occupational problems* - Because of limited facilities and potential health hazard of nanomaterials based spray coating, the factory requested for an alternative coating method other than that developed by ITI. The Institute optimized the factory’s available method for coating tiles through laboratory and pilot trials.

- *Development of new formula* - A new formula was developed suitable for the coating method that was available at the factory. Additional chemicals were also used in the new method thus optimizing the formula.

- *Change of the new formula* - Due to unavailability of chemicals, the factory again requested ITI to change the formula using new chemicals. The laboratory optimization was initiated before pilot trials.

- *Change of the coating technique* - The management requested to try out another coating technique also that is available in their factory to study as there were some problems of the appearance of the tile edge. ITI researchers realized that and the process optimization was again carried out.

- *Property analysis* - After successful pilot trials, upon request of the factory management, the ITI researchers conducted studies to prove the effectiveness of self-cleaning properties of the tiles in an actual situation. However, the industry has requested for a second commercial trial at their new kiln premises before the technology transfer is made.

Concluding remarks:
ITI is currently developing guidelines for the development, protection, and commercialization of its intellectual property. The draft has been approved by the ITI Board. ITI has signed a MoU with SLINTEC to share the research facilities on payment basis. There is a need to build capacity of the nanotechnology researchers of ITI in the areas of intellectual property protection and commercialization, and collaboration with industry.

8.11. THAILAND

Government initiatives:
The National Science and Technology Development Agency (NSTDA), a cell of Ministry of Science and Technology (MOST) of Thailand realized the importance of this emerging field of nanotechnology and founded National Nanotechnology Centre (NANOTEC) in August 2003 as an autonomous body committing US$ 25 million during 2004-2008. NANOTEC’s missions were to create nanotechnologies that would enrich Thai industries, give rise to niche innovative products, processes and competitiveness in the global market, they have decided to concentrate on following objectives:
Conduct and promote R&D in nanotechnology as enabling tools to improve the competitiveness of Thai industries;  
Develop human resources in the field of nanotechnology;  
Establish R&D collaboration among academics, industry and government – both a national level and internationally; and  
Promote public awareness and understanding of nanotechnology.

The responsibilities allotted to NANOTEC are:

- To work as a national R&D centre;  
- To fund R&D work pertaining to nanotechnology;  
- To provide services in nano-scale measurement and characterization using state-of-art equipment to the academics, industry and government;  
- To serve as the Secretariat of National Nanotechnology Policy Committee chaired by the Prime Minister;  
- To provide direction, strategy, research plan and development of Nanotechnology; and  
- To do the assessment of risk and nano-safety, and accordingly provide information on regulations, standards or procedures of nano-safety to key stakeholders. They would also collaborate with national and international organizations to ensure safety.

Their priority area of nanotechnology research are food packaging; cosmeceuticals - (nano-emulsion and nano-capsule, skin care nano-emulsion with Thai herbs service, controlled sustained release technology, textile (technical and functional, bio-component fibres for medical application, apparels and nonconventional), Flexible polymer solar cells, Health-care (therapeutics, drug delivery system and diagnostics).

NANOTEC has:

- In-house central laboratory, including 11 labs, 65 scientists and 200 other staff;  
- University-based Centres of Excellence (COEs) in 8 leading universities, focused networks on textile (in 3 universities), cosmeceuticals (in 5 universities) and computational nanoscience;  
- Research grants are given to universities and other agencies for > 30 projects  
- Moreover, NANOTEC operates 11 laboratories in Thailand Science Park.

The output of NANO TECH in 2009:

- Published 92 articles in international journals;  
- Filed 21 patents (mostly domestic);  
- Signed 14 contracts with industries;  
- Held 57 discussions with industries; and  
- Provided services to industry/labs (~13,000 tests)

To regulate the standards of nanotechnology applications in different fields, the following bodies were made responsible:
Concluding remarks:

Good efforts have been made by the Thai government however, commercialization has not picked up the speed but some companies have entered in this arena with great success.

Case study of a company involved in nanotechnology for industrial and consumer products – Creative Technology Solutions Co.Ltd. (CTS)

About the Company:

CTS were established in 1996. The company specializes in die-cutting services assembly and business services of industrial products. In die-cutting services, they produce a wide range of components and parts for electronic equipment, automotive, audio visual products, construction, and other industrial components. Material used are plastics, felt, paper, fiber, tape, EVA, rubber, polyester film, EPDM, polyurethane form (PE & PU), PVC, copper (foil and embossed), and other materials requested by their customers.

With the vision of creative technology, in the year 2004, CTS started to study and cooperate with well-known research labs in both Republic of Korea and Thailand to come up with world-changing products using their licensed Nano Technology and in 2004, the CTS GROUP was established in Thailand and pioneered nanotechnology in various industries simultaneously.

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Problems/Issues:

2004 was the year when NANOTEC of Thailand Government decided to create nanotechnologies that would enrich Thai industries, give rise to niche innovative products, processes and competitiveness in the global market. It was the same year when CTS decided to enter into a new nanotechnology based product.
Solution:

Confirmation that nano particles of silver have anti-bacterial, anti-fungal, anti-molds, anti-viral and deodorizing (VOC reduction) properties, CST decided to produce various consumer goods utilizing the nanotechnology approach:

- Filters for the air conditioner and air purifier. They developed a nano-silica core with nano silver and coated it onto the mesh of the filter. Apart from nano silver; nano copper, nano gold and photocatalysts were also used.
- Nano Silver Masterbatches is another product that CTS offers; it is anti-microbial with a wide variety of applications across many industries.
- Nano silver solution and
- Nano-ceramic balls.

Following are the companies that are using nano-filters or other products manufactured by CTS: Toshiba / Carrier (Thailand), Hitachi Consumer Products (Thailand), SMS Aluminium (Thailand), SaijoDenkei (Thailand), Thai Thavorn Metal (Thailand), Samsung Electronics Malaysia, LiproSdnBhd (Malaysia), JK Wire Harness SdnBhd (Malaysia), Matsushita Electronics (Malaysia), Kyoshin Sdn Bhd (Malaysia), Hill Industries Sdn Bhd (Malaysia), Gallant Electronics Sdn Bhd (Malaysia), Sanden Air Conditioning (Malaysia), Tan Chong Motor (Malaysia), Honda Auto Parts MFG (Malaysia), Gallant Electronics Sdn Bhd (Malaysia), Teck See Plastics Sdn Bhd (Malaysia), Daiel Interplas (M) Sdn Bhd (Malaysia), Creative Technology (Singapore) and PCA Technology Ltd. (Singapore).

Concluding remarks:

Whenever use of nano metal particles is discussed, the darker side of the nanotechnology comes to mind, which usually industries do not want to talk about. If we look at one of the recent research that has confirmed that fish exposed to very low concentrations of nano particles, within 48 hours after being exposed exhibited brain damage that resembles Alzheimer's disease. This remark is not only for CTS Co, but all those companies involved in nano particles that have anti-biological activity. It is imperative that leaching of nano-particles and their impact must be taken into consideration.

Case study of a company involved in manufacture of nanoparticles for industrial applications – Nano Materials Technology Co., Ltd

About the Company:

A company known as Navapatarakit Co., Ltd. has operated zinc business since 1994. Later the company jointed business with Dr. Pachernchai Chaisit, of Science faculty, Ladkrabang King Rama Five University, and researched the manufacture of zinc oxide nano particles with spray pyrolysis method. It becomes Zinc oxide (ZnO), which have nanometres molecules. The research result succeeded in 2007, and the Company then got registered under a new name Nano Materials Technology Co. Ltd. in 2008. Since then it is in manufacture and
distribution of ZnO nano particles. Nano Materials Technology Co., Ltd synthesized ZnO of micrometers molecule level also by French process method. The result of process is zinc oxide in 0.5 micrometers molecule level with high purity in premium grade for the manufacture of rubber, polymer, ceramic, plastic and animal feedstuff industries.

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Thailand

**Problems/Issues:**

Since ancient times, ZnO was referred to as Calamine in Egypt, which is a natural mineral Smithsonite with ZnCO$_3$ as its main compound. But the mode of action of ZnO in curing the disease was not known, though its use was prevalent. Hence it always had a big market. With the global changes in the situation, it has become necessary for industries to develop products having increased efficiency. Nanotechnology has come to the rescue or one can say a better solution to such problems.

**Solutions:**

One of the reasons of higher efficiency of nano particles is its higher surface to volume ratio (SVR). All the chemistry happens at the surface of the molecule. Hence, the concept of SVR is enhanced when the size of the material is very small. Hence, the concept of SVR is enhanced when the size of the material is very small and higher numbers of sites are available for bonding with other molecules. Moreover, nano-size is known to alter the melting point of the substance, it has higher photocatalytic rate, altered optical and magnetic properties, etc.

Keeping these novel properties in mind, Nano Materials Technology Co., Ltd entered into developing a methodology to produce nano particles of ZnO with the help of a scientist Dr. Pachernchai Chaisit.

They developed an innovative spray pyrolysis method to produce ZnO nano particles. It was manufactured for its use against fungus, bacteria and also protection from UVA and UVB. Zinc oxide is a stable material in terms of anti-bacterial agent, which in nature is not poisonous. Instead of just killing the bacteria, the entire purpose is to prevent bacteria from happening in the first place, which lets bacteria have no opportunity to transform. As a result, ZnO has become one of the major forces for inorganic anti-bacterial agent. Synthesis of ZnO is also being done by co-precipitation, sol-gel and hydrothermal methods.

Nano Materials Technology Co., Ltd is marketing their products as:

- Transparent ZnO nano colloids for coating of clothes, for UVA-UVB protection and anti-fungal as well as anti-bacterial properties;
- ZnO white seal micro-fined powder; and
- Zn oxide NP Powder having photocatalysts properties, which decomposes organic products that cause fouling dirt, degrade and eliminate odour.

**Concluding remarks:**

At the end it can be said that ‘Smaller is Better and Faster.’ Nanotechnology is an enabling technology that allows doing new things in almost every conceivable discipline from electronics to medicine.

> In thinking about Nanotechnology today what’s most important is understanding where it leads, what Nanotechnology will look like after we reach the assembler breakthrough.

> K. Eric Drexler

9. **Status of IPR policies affecting nanotechnology in Asia-Pacific countries**

9.1 **What is IPR?**

Intellectual property (IP) is a legal concept which refers to creations of the mind for which exclusive rights are recognized. Under IP law, owners of the creation or discovery are granted certain exclusive rights, such as discoveries and inventions; musical, literary, and artistic works; words, phrases, symbols and design, etc. Under IPR the owner can get copyright, trademarks, patents, industrial design rights and in some jurisdictions trade-secrets. Except for trademark, intellectual property law is needed to promote progress.

Industrial property includes patents. A patent is an IPR granted by an inventor “to exclude others from making, using, offering for sale, selling and importing the invention” for a limited time, in exchange for public disclosure of the invention when the patent is granted. Differences in the patenting systems do result in subtle economic differences, e.g. the Japanese patenting system is designed in part to promote greater intra-industry knowledge spillovers than the U.S. system. At present patent remains the most preferred form of IPR protection of nanotechnology innovations.

*Is there a need for a new patent regime in Nanotechnology?* This has been a consideration in many countries and has been tackled differently by different countries depending on their existing IP laws.
9.2 IPR considerations for nanotechnology in Asia-Pacific countries

Since this report revolves around the commercialization of innovative nanotechnology research, it is imperative to discuss the techno-legal aspects of nano-related innovations to aid their effective integration into businesses. There are several available definitions of nanotechnology pertaining to IP related issues one of the most accepted one is:

“The term nanotechnology covers entities with a geometrical size of at least one functional component below 100 nanometres in one or more dimensions susceptible of making physical, chemical or biological effects available which are intrinsic to that size. It covers equipment and methods for controlled analysis, manipulation, processing, fabrication or measurement with precision below 100 nanometres.”

All the available definitions underline three characteristics of nanotechnology:

- Materials or processes for which minimum one component is of nanometre-scale.
- The control, handling and manipulating at nano scale, excludes all “accidental” nanotechnology.
- Acceptance of the fusion of nanotechnology and adjacent scientific disciplines, e.g. biotechnology.

Input of almost all the branches of science, viz. chemistry, physics, engineering, electronics, health care related biosciences and agro-science are accepted in nanotechnology and this makes formulating a IPR policy for nanotechnology all the more complex. Many believe that when it comes to patents, nanotechnology does not differ much from other technologies, hence, there is no need for a new patent regime in nanotechnology. The next few paragraphs are a peep into the IPR policies of nanotechnology developed by different countries.

9.2.1 China

Up to 1977, Chinese dissemination of R&D results for commercialization was totally controlled by the government. Protection of IP law has been established by government legislation, administrative regulations, and decrees in the areas of trademark, copyright and patent under a comprehensive legal framework to protect both local and foreign IP. Despite this, copyright violations are common in China. The legal framework for protecting intellectual property in the PRC is built on three national laws passed by the National People's Congress: the Patent Law, the Trademark Law and the Copyright Law. By the beginning of eighties, the government realized the importance of Open Door Policy and started de-centralizing R&D and engineering, and universities and research institutions became more autonomic. Though in comparison to other industrialized countries, the Chinese government still substantially affects its domestic innovation system. China has realized that foreign companies would not transfer their technological knowledge to China without offering legal protection for their IP. Hence in 1980, the Chinese Patent Administration was founded and in 1985 China joined the World Trade Organisation (WTO); in 2002 China acceded to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).
9.2.2 India

In India, the involvement of the Department of Science and Technology (DST) with nanotechnologies started in 1997/98, and in October 2001, DST launched a Nano Science and Technology Initiative (NSTI) as national funding programme. In March 2007, the Bureau of Indian Standards (BIS) established a Nanotechnologies Sectional Committee (MTD 33) comprising of DST, Department of Information Technology (DIT), different CSIR laboratories, some academic research outfits and a few private sector corporations to work with the International Organization for Standardization’s Technical Committee on Nanotechnologies (ISO/TC 229).

A data of 2007 shows that Indians held 167 patents on nanotechnology, 39% of these patents are held by government institutions, 27% by industry, 22% by individuals and 6% by academic institutions, with the remainder being joint patents between government institutions and industry.

In a “National Conference on Nanotechnology and Regulatory Issues” organized by TERI in January 2009, and attended by various experts from industry, civil society and science, it was decided that “No new law on nanotechnology is needed but amendments to relevant legislation are necessary and no new regulatory authority is needed but that an expert committee should be formed”.

Nanomaterials risk assessment in India is so far mostly limited to a few individual toxicity programmes and studies.

9.2.3 Indonesia

It has been difficult to enforce IP laws in Indonesia. The experts have given following reasons for that:

- The origins of the existing IP regime in Indonesia does not lie and has never been developed in Indonesia, but rather in Western countries that have different economic interests and cultural norms from those of Indonesia.
- The IP laws are incompatible with Adat (an extensive system of Indonesian norms).
- The weak legal enforcement in the field of IP law.
- The laws are not appropriate for their economic and technological development.

However, according to the report, Indonesian authorities made positive efforts in 2011 to strengthen IPR protections, and some rights holders reported good cooperation with enforcement authorities.

9.2.4 Islamic Republic of Iran

The Islamic Republic of Iran has not signed the PCT (Patent Cooperation Treaty). PCT is an international patent law treaty, which provides an integrated procedure for the filing, searching, and examination of applications for the protection of inventions and for rendering special technical services. However, in 2011, Iran has been granted almost 70 patents in the United States and Europe and 37% of all patents belonged to the nanotechnology field.
Iran Nanotechnology Initiative Council (INIC) launched a programme to overcome existing shortcomings and encourage nanotechnology researchers to protect their inventions in the country and particularly, overseas. In 2008, the patent law was reformed and the new law entitled “Patent, Industrial design, Trademarks Act” was created. According to the new law the inventor has the right to claim priority, based on a prior filing in any Paris Convention member state. But the government will have the right to grant a compulsory license under certain conditions.

9.2.5 Japan

Japan is signatory to most of the international treaties concerning IPR. Some of them are:

- Trade Related Aspects of Intellectual Property Rights 1994
- Paris Convention for the Protection of Industrial Property 1883
- Patent Cooperation Treaty 1970
- International Convention for the Protection of New Varieties of Plants 1961
- Nice Agreement of International Classification of Goods & Services for the Purposes of Registration of Marks 1991
- Trademark Law Treaty 1994
- Protocol Relating to the Madrid Agreement Concerning the International Registration of Marks 1989
- Berne Convention for the Protection of Literary and Artistic Works (Paris Act) 1971
- Universal Copyright Convention 1971
- Rome Convention for the Protection of Performers, Producers of Phonograms and Broadcasting Organizations 1961
- Geneva Convention for the Protection of Producers of Phonograms against Unauthorized Duplication of Their Phonograms 1971
- WIPO Copyright Treaty 1996
- WIPO Performance and Phonograms Treaty 1996
- Convention Establishing the World Intellectual Property Organization 1967

In Japan the term of a patent is generally 20 years from the date of application. IPR in Japan primarily consist of (1) patents (2) utility model rights (3) design rights (4) trademark rights, (5) copyrights (6) protection of trade-secrets and (7) protection from unfair competition.

9.2.6 Republic of Korea

Republic of Korea's nano industry came into existence in 1990s and by 2002 Nanotechnology Development Promotion Act was legislated and in 2002, and in 2003 Enforcement Decree of the Nanotechnology Development Promotion Act was passed. Koreans applied for 979 International
patents during 1990-2003 making them world’s 5th nation. And by 2004 (according to a report of the WIPO the Korean Intellectual Property Office) it became the third largest recipient in terms of the number of patent application, i.e. next to Japan and USA. The IP system in the Republic of Korea includes patent, utility, trademark, design and copyright system. The Republic of Korea has been continually improving their patent system of 1961 by removing unreasonable elements and for complying with international patent systems and principles and harmonizing with them. Such efforts make the patent system in the Republic of Korea hold several features: (i) to enlarge patentable subject matters; (ii) to increase effectiveness of patent examination; (iii) to strengthen patent protection such as extension of patent protection term; (iv) to control misuse of patent right; (iv) to join international agreements on patent; and (vi) to comply with international trend for patent protection.

9.2.7 Malaysia

The Patent Act of 1983 and the Patent Regulations of 1986 was revised in 1995 to speed up the processing and granting of patents in accordance with the Paris Convention and to extend the protection of patent rights. The Act was again revised in 2000 to extend coverage from 15 to 20 years to incorporate Malaysia's accession to the multilateral TRIPS Agreement to allow for parallel imports and to limit the Government's power to exploit patents only during emergencies. The Act was revised in 2003 to enhance the management of IPR. A new multilateral agreement is being negotiated with the USA by Malaysia to adopt a much harsher IP policy on offenders.

9.2.8 Pakistan

As far as Science and Technology is concerned, the global system of IPR is designed to protect the scientific discoveries, technological innovations, and traditional knowledge by Pakistan Council for Science and Technology (PCST), Ministry of Science and Technology, Government of Pakistan. It ensures financial benefits for individual inventors and R&D organizations. The IPR regime in Pakistan has been strengthened after signing the agreement on TRIPs under WTO. The Intellectual Property Organization (IPO) of Pakistan was established in 2005 and its legal position was defined through an Ordinance of the Government of Pakistan in 2007.

9.2.9 Philippines

State Policies to protect IP according to Philippine Constitution is provided in Art. XIV, Sec.3. The IP Code R.A, 8293 of the Philippines, is an act prescribing the IP code and establishing the IP office, providing for its powers and functions. Other laws protecting IPR are Protection of Layout Designs of IC, i.e. R.A 9150, Optical Media Act R.A. 9239 and Plant Varieties Act R.A. 9168. So far no specific code is given to nanotechnology. Hence it is assumed that standard S&T policies of IPR is applied to nanotechnology. The Philippines IPR includes: copyright and related rights, trademarks and service marks, geographic indications, industrial designs, patents, layout designs (topographies) of integrated circuits, utility models, and trade secrets.
circuits, and protection of undisclosed information. Now the the Bureau of Patents, Trademarks and Technology Transfer has been replaced by the Intellectual Property Office of the Philippines (IPO) for the implementation of the Intellectual Property Code.

In a unique development in 2003, the University of Philippines formulated its own guiding principles and policies on IPR. It is bounded by the constitutional mandate to maintain the academic freedom of its faculty and of the university as a whole and the provisions of the Intellectual Property Code (Rep. Act No. 8293, 1997) and other laws pertaining to intellectual property rights such RA 9168 etc.

9.2.10 Sri Lanka

The current IP system in Sri Lanka is governed by the IP Act No 36 of 2003 which makes provisions for a variety of IPR and their acquisition, management and enforcement. The law relating to the registration and enforcement of patents in Sri Lanka is contained in the Code of IP Act No.52 of 1979, which is modelled on the WIPO Code. In 1991, the Governments of the USA and Sri Lanka signed an agreement for effective protection and enforcement of IPT in patents, trademarks, copyrights, trade secrets, and layout designs for integrated circuits. Though Sri Lanka has amended the code of IP in 2001 to suit IT industries, no such amendment has yet been noted for nanotechnology.

Sri Lanka conducted a detailed review and orient the Sri Lankan IPR regime with a special focus on nanotechnology innovation led economic growth. The challenges faced by them were low number of international patents filed from Sri Lanka and absence of an efficient framework for IP management with sufficient controls and necessary facilitation so that Sri Lanka could benefit from nano patents.

9.2.11 Thailand

National Committee on IP Policy was established in 2009 under the Ministry of Commerce to protect IPRs, Reform & Modernize IP laws. IP Law encompasses Patent Act, Trademark Act, Optical Disc Act, Geographical Indications Act, Trade Secret Act, Copyright Act, Protection of layout design of integrated circuit act and traditional knowledge.

Following are the international treaties signed by Thailand:

- Berne Convention (Copyright) in July 1931
- WIPO Convention in December 1989
- TRIPS Agreement in January 1995
- Paris Convention in January 2008
- PCT (Patent Cooperation Treaty) in December 2009
- Madrid Protocol - to be member by 2015 under ASEAN Economic Community (AEC) Blueprint
- Hague Agreement (Industrial Design)
Manuel on Critical Issues in Nanotechnology R&D Management: An Asia-Pacific Perspective

. Nanotechnology is not yet included in their strategic sector. However, Science, Intellectual Property and Energy Policy (Section 86) is formed.

9.3 Conclusion
Intellectual Property Rights (IPRs) have a vital role in the knowledge and technology transfer, and commercialization of new technologies. Introduction of new products to market needs successful knowledge, and technology transfer from universities and research laboratories to “high tech” companies, and technology utilization in these companies. The commercialization of new technologies provides a potential source of income for universities and research organizations, thus promising to reduce their dependency on public funds. In many countries, these institutions encourage their scientist employees to make and disclose inventions, which can then be patented and licensed to commercial firms, and/or to organize spin-off firms. Moreover, there is a need to look into and avoid patent thicket and a patent monitoring system specific to nanotechnology should be there for an applicant to search prior to applying for a patent. Commercial nanotechnology, however, is at a nascent stage. Patents are already shaping the rapidly evolving field of nanoscience and nanotechnology and will play a critical role in the success of the global nanotechnology revolution

There is no doubt that creativity is the most important human resource of all. Without creativity there would be no progress, and we would forever be repeating the same patterns.”

– Edward de Bono

References
4. The United States Environmental Protection Agency (USEPA), Nanosilver - a threat to soil, water and human health?
Confirmation of the Uptake and Translocation of TiO$_2$ Nanoparticles in Cucumber (Cucumis sativus) Plants”, *Environmental Science and Technology*, Vol. 46 (14), pp.7637- 7643