CHAPTER 3
Best Practices on Commercialisation of Nanotechnology R&D Results

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By
Prabuddha Ganguli
This chapter was prepared by Dr. Prabuddha Ganguli, CEO, VISION-IPR, Mumbai, India and MHRD IPR Chair Professor, Tezpur University, Assam, India, under a consultancy assignment given by the Asian and Pacific Centre for Transfer of Technology (APCTT).

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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Best Practices on Commercialisation of Nanotechnology R&D Results

1. Introduction

The last few decades has seen the development of nanotechnology as a field that has intersected diverse fields of science and technologies. In this rapidly growing sector, development of concepts i.e., the generative phase has coalesced into the application and trading phases, thereby demanding reengineered thinking and newer landscaping of innovation processes. The trends have been in effecting the dynamic creation and operation of enabling teamwork in a complex and pulsating knowledge space. Several models of innovation processes are available that serve as learning points for adoption such that the generation and expansion of knowledge is in tandem with competitive knowledge diffusion and transfer. Effective management of Intellectual Property Rights (IPR) now is becoming a key driver in innovation processes to gain strategic ownership of knowledge domains with speedy knowledge sharing, value creation and realization.

The challenge is to design and operate institutional innovation processes that would preserve intellectual excellence and at the same time amicably fit into a disciplined Intellectual Property Rights system. This chapter reviews approaches adopted by academic and commercial enterprises in institutional management of IPR including the impact on global research dynamics related to nanotechnology.

2. Nanomarkets……estimates to guesstimates

Since the concept of building materials atom by atom by Professor Richard Feynman in 1959 and the christening of the term “Nanotechnology” in 1974, this field has rapidly got enriched in terms of basic science. Its transition to workable technologies have begun to reach the market place as products and processes are already impinging our lives with major futuristic promises of an array of disruptive applications in materials, manufacturing and man-machine interface. There is a global market potential of US$ 2.15 trillion as projected by the National Science Foundation in the United States (Figure 1).


The largest nanotechnology segment in 2009 was nanomaterials. The market for all nanomaterials is estimated to increase from US$ 10 billion in 2009 to almost US$ 19.6 billion in 2015, representing an

The Project on Emerging Nanotechnologies (PEN), reports that 1317 nanotechnology enabled consumer products have found their way into the market place and the illustrations from the same report highlight some of the key market realities as of March 2011(Figures 2-5).

Figure 1: Estimate / Guestimate of nano market by 2015
Starting with 54 nanotechnology enabled consumer products in 2005, the growth of the inventory has been 521%. USA leads in the global market of nano-enabled consumer products, followed by companies in Europe (UK, France, Germany, Finland, Switzerland, Italy, Sweden, Denmark, The Netherlands, East Asia (including China, Taiwan province of China, Republic of Korea and Japan), and elsewhere around the world (Australia, Canada, Mexico, Israel, New Zealand, Malaysia, Thailand, Singapore, The Philippines and Malaysia). The most common material mentioned in the product descriptions is now silver (313 products). Carbon, which includes fullerenes, is the second most referenced (91), followed by titanium (including titanium dioxide) (59), silica (43), zinc (including zinc oxide) (31), and gold (28).

Nanotechnology has reached its present position due to dynamic networking of diverse enterprises, and the overwhelming continued support of national governments (Figure 6). The Governments provide support through public funding of R&D and commercialisation including the creation and implementation of nanotechnology favouring national polices, extending funding to prototype and pilot manufacturing thereby reducing the risk for investments in nanotechnologies including the inbuilt inertia of commercial organisations to adopt new technologies involving new materials, products and processes.
due to high initial cost of entry, corporations funding R&D and commercialisation, corporate venture funds and venture capital through equity investments. Funding through stocks and bonds has also made a beginning in nanotechnology, though its contribution has not yet reached significant dimensions.

The stakeholders and beneficiaries in the global nanotechnology dynamic networks span from the universities, academic and national R&D institutions, industries including the manufacturers, suppliers, SMEs, technology integrators, university start-ups, corporate spin-offs, governments, institutional investors, venture capital funds and the consumers in the markets. The additional stakeholders are consortia (such as The Inno.CNT alliance), industry associations in various countries (e.g. in the US and Europe ---- the NanoBusiness Alliance and the Nanotechnology Industries Association). The interlinking of these participants in real time and working in unison and scaling up adaptations and/or integration along the nano value chain with minimum time-lag from concept to market, is the key to the creation of innovations and their successful translation to the markets as products and processes.


- 2009 has been a turning point at which corporate investment (2009: US$ 8.4 bn, 2010: US$9 billion) equalled and then exceeded public investments (2009: US$ 8.4 billion, 2010: US$ 8.2 billion), the difference remains minor, and may not have persisted in 2011 due to the economic downturn having a greater effect on corporate investment.

- The amount of funding coming from venture capital is low (2009: 0.822 billion, 2010: US$ 0.646 billion) which is only 4% of total global funding.
• The majority of nanotechnology development occurs at established firms. The level of venture
capital funding is a product of supply – the number of investors willing and able to fund
nanotechnology ventures – and demand – the amount of nanofirms with sufficiently high
growth potential.

Table 1 has been reproduced from the OECD report (which quoted a Spinverse analysis of the data
reported in European Nanotechnology Landscape Report, Observatory Nano,
http://www.observatorynano.eu/project/catalogue/3EN/) shows the sources of funding for companies
using nanotechnology in Europe.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Companies</th>
<th>% receiving external funding</th>
<th>% receiving public funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanomedicine</td>
<td>16</td>
<td>13</td>
<td>88</td>
</tr>
<tr>
<td>Transportation and Aerospace</td>
<td>24</td>
<td>21</td>
<td>75</td>
</tr>
<tr>
<td>Electronics</td>
<td>16</td>
<td>44</td>
<td>88</td>
</tr>
<tr>
<td>Energy</td>
<td>11</td>
<td>55</td>
<td>82</td>
</tr>
<tr>
<td>Materials</td>
<td>26</td>
<td>15</td>
<td>88</td>
</tr>
<tr>
<td>Food and Food packaging</td>
<td>8</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>Others</td>
<td>30</td>
<td>7</td>
<td>67</td>
</tr>
</tbody>
</table>

It is interesting to note the high funding of companies especially in fields of nanomedicine, electronics,
energy and materials.

3. Investment criteria of various funding agencies

Public funding is generally based on national policies to promote science, technology and innovative
culture, to build human resources and infrastructure for the development of nanotechnology and also to
derive benefits from international cross border collaborations, create demand and awareness for
innovative products, establish regulatory frameworks for environment, health and safety as well as act to
reduce the risk of investments especially by SMEs in new technologies by directly reducing costs, etc.

Corporate investments are generally guided by the need to build human resources and infrastructure for
the developmental activities related to nanotechnology, enhance capability to absorb and adapt
technologies from publicly funded institutional domains, ensure their industrial scale ups and building
production facilities, and provide increased revenue from new or improved products in new or current
markets, further existing markets, and/or to improve profitability by manufacturing reducing costs.
Corporate investments are also done in an identified portfolio of technologies thereby mitigating the risks
of investing too narrowly. In addition to the technology feasibility and market potential of a technology,
corporate decisions are also guided by strategic considerations related to the status of intellectual property rights (e.g. portfolio of patenting, value that may be realized by licensing out technologies to other firms, acquisition of patents, etc) and assured return on investment (ROI) through increased sales via enlargement of market share, entering a new market, and reduced costs.

Venture capital (VC), both active and passive generally get involved through independent venture capital funds and corporate venture funds via equity participation thereby receiving shares of ownership of the funded company, although other forms of investments such as convertible loans and senior debt are also used. Nanotechnology related active VCs bring in know-how and networks and invest mainly in familiar industries or technology fields, while passive VCs contribute money and general business acumen. VCs generally make calculated investments with the expectation of generating returns of ten or more times the original investment within a planned period. VCs judiciously combine several parameters such as profile of the company’s management team, the market potential and business model, the development stage of the company and its technology, the state of technological and market readiness, and ability to achieve objectives and react positively to setbacks, how quickly the company can start demonstrating value and generating returns, the exit plan and the valuation of the company to guide them in their investment decision making. In addition to investments through funding, Corporate VCs also evaluate their options to feed in from their parent company, knowledge, knowhow, resources and other expertise into the promising venture to access potential disruptive technologies, or by funding and creating a portfolio of companies to drive demand for the parent firm’s products.

Institutional investors including banks, insurance companies, pension funds and mutual funds have not been too involved in nanotechnology by way of investing in shares of publicly listed companies, corporate bonds, and venture capital funds, essentially due to the inconsistent and largely disappointing performance of publicly listed nanotechnology companies.

The inclusive nature of nanotechnology encompassing diverse aspects of material science and engineering has led to a continuous evolution and in several cases a burst of disruptive convergence of technologies leading to borderless applications of nano-enabled products and processes. The simultaneous challenge has also been in establishing reproducibility and cost effective up-scaling to manufacturing levels of the nano-enabled products and processes. The objective has been to bring about the sought after coalescence in the time gap between discovery and invention, and their coupled transformation into novel and useful applications.

The challenge has been and will continue to lie in crystallising the “plausible” into affordable “marketable tangibles” for profitable and sustained businesses. This is the acid test of practical commercialisation of R&D results.

The purpose of this chapter is to illustrate approaches taken by various workers in commercialisation of nanoscience and technology that involve production, translation and transfer of knowledge resulting in the transformation of research findings into innovations culminating into successful businesses.
4. Models of R&D in nanotechnology

The field of nanotechnology has also been the testing ground for a range of business models ranging from the classical modes of intense conceptualisation and knowledge generation and plausible applications development in centres of excellence within the academic environment and transfer of technology to commercial enterprises, to sprouting of start-ups within the academic domain and in several instances in organised science parks, creating and supporting spin-offs within commercial enterprises and then backward / forward integrating with them in due course, involving angels / venture capital for early stage support, SMEs taking up targeted technologies for commercialisation, large businesses adapting newer technologies within their businesses and/or discontinuing older technologies in favour of more effective newer replacing technologies and in recent times governments getting involved in public–private partnerships and consortia modes. A recent review titled ‘The Future of Nanotechnologies’ by Vincent Mangematin and Steve Walsh, 1 - 9 Jan 2012 and references therein, presents an overview of the modes of technology development, transfer and commercialisation in the field of nanotechnology (http://halshs.archives-ouvertes.fr/docs/00/65/80/34/PDF/future_of_Nanotechnologies.pdf).

The main findings are of the OECD Study in 2010 titled ‘The Impacts of Nanotechnology Companies: Policy Insights from Case Studies’ by OECD in 2010 (http://dx.doi.org/10.1787/9789264094635-en) are:

- Nanotechnology is an enabling technology (or set of technologies) and the company case studies show that this feature is a major reason for their entry into the field. Nanotechnology allows for both the improvement of existing and the development of completely new products and processes, and sometimes new services as well. Companies often experiment with multiple applications at the same time, many of which are still in the research phase. Several nanotechnology applications are also largely demand-driven as new functionalities of existing materials create new market opportunities even in some traditional industries such as textiles, energy, health care, water treatment, etc.

- Nanotechnology may best be described as a “science-based and demand-driven field”. While all of the case study companies undertake in-house R&D, collaboration with universities and “star scientists” are also important sources of innovation and knowledge, especially for small companies. Larger companies in relatively mature nanotechnology sub-areas appear to focus more on applications which are driven by market demand and tend to collaborate with a broader range of organisations to leverage their in-house R&D.

Nanotechnology has been a fertile ground for nurturing of academic entrepreneurship involving the “best in class scientists” with high-impact publications. This is a recognition that tacit knowledge and knowhow is of immense significance in the transfer of technology in nano related developments from labscale to industrial dimensions. Further it is interesting to note that most entrepreneurial activity in nanotechnology tends to cluster in regions with experience in related sciences, with top-level universities or research institutes, or with R&D laboratories of major companies.

- Nanotechnology mainly affects the R&D and production activities of the case study companies. Many of the smaller companies focus exclusively on nanotechnology, while the larger ones
typically blend nanotechnology with a range of other technologies. In the larger companies it is thus difficult to single out the share of nanotechnology in total labour costs, R&D expenditure, production costs, capital spending and sales.

• The larger companies in the sample have typically been involved in nanotechnology for many years and seem well placed to assimilate nanotechnology due to their established critical mass in R&D and production, their ability to acquire and operate expensive instrumentation and to access and use external knowledge. The relative strength of larger companies in the early phases of nanotechnology developments runs counter to what the traditional model of company dynamics and technology lifecycles would predict where smaller, younger companies are generally considered more innovative.

• The case studies illustrate that nanotechnology is a complex field owing to its dependency on various scientific disciplines, research/engineering approaches and advanced instrumentation. Further, many nanotechnology sub-areas are in an early, immature, phase of development. These features of nanotechnology can often create barriers to entry especially for smaller companies which have limited human and other resources. They also contribute to the poor process scalability of nanoscale engineering during the transition from R&D to pilot and industrial scale production.

• Difficulties arise for recruiting human resources, especially for R&D and production activities. The need for employees, or so-called gatekeepers, who combine specialist and general knowledge (knowledge integration) and can manage interdisciplinary teams is also a challenge.

One of the concerns in various companies that have got involved in nanotechnology and/or nano-enabled products and processes is the need for new competences that may even lead to the disruption of the existing competence base of companies. It would be important to learn the art of managing uncertainties in discontinuous radical technologies, human capital, and other resources in a dynamic mode.

• Challenges to funding R&D and related activities are often mentioned, especially by business start-ups. The poor process scalability of R&D, which raises costs and prolongs new product development times, can make nanotechnology less attractive to investors. Uncertain regulatory environments and public perceptions of nanotechnology’s environmental, health and safety (EHS) risks can also influence R&D funding.

• The novelty of nanotechnology, the established interests of stakeholders, and difficulties that companies can have in communicating the value proposition of applications to potential customers (e.g. other companies), makes their entry and positioning in value chains harder. The challenge is even greater for smaller companies that experiment with multiple applications and have to monitor many different industries and business environments.

• Intellectual property rights (IPR) may become an issue as commercialisation progresses and nanotechnology matures as there is already a very wide range of patent claims, and the possible formation of patent thickets (interrelated and overlapping patents), which could contribute to barriers to entry for companies.
• The potential for overreaction to both actual and perceived Environment Health and Safety (EHS) uncertainties and risks, combined with regulatory uncertainties, complicates the business environment for companies. Global harmonisation of future EHS regulations is considered important.

4.1 Traditional models of R&D and technology commercialization

In the days gone by, R&D activities in nanotechnology were carried out in two sequential phases, namely upstream (basic) general in academic institutions and downstream (applied) in industry (Figures 7 and 8).

Figure 7: Traditional R&D modes

Figure 8: The traditional nanotechnology commercialisation value chain

Knowledge transfer from academics to industry has traditionally occurred through consultancy arrangements in which industrial problems were addressed by academics through contracts in which industry posed its problems to the academics for solutions. The consulting academic institution (more appropriately the scientist / technologist) was expected to respond these problems with solutions which were then taken up by the industry for implementation. In some cases, research contracts were offered to academics by industry to develop specific or even platform technologies which were then adopted by industry as per its need. Any intellectual property that resulted from such contracts generally became the property of the contracting industry and in return the academicians benefited from the consultancy fees, research grants, resources bought under the consulting contract, grants for their masters and PhD degrees, post-doctoral fellowships, etc.

In some traditional modes, academics especially involving the engineering disciplines conceived of industrial problems mostly independent of their stake holders and offered solutions to such problems through their R&D. In such cases most technology transfer processes remained partially fulfilled and did not find industrial acceptability as the technical problems were either not realistically conceived, and/or the solutions including their scale ups were not cost effectively implementable in existing manufacturing systems. Such working modes that were adopted in the early days of nanotechnology too met with very low success.

A study by Palmberg in 2008 on Finish Universities brought forth some of the perceptive differences between the university researchers and the industry workers (Figure 9).

![Figure 9: Responses to diverse issues by companies and universities in Finland](http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1176863&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F17%2F26421%2F01176863.pdf%3Farnumber%3D1176863)

Based on their survey of 72 micro-electro-mechanical-systems (MEMS) manufacturing firms they show that established firms rarely commercialize disruptive technologies and then prefer to use market-pull strategies to accomplish this. New firms select primarily disruptive technologies and choose either market-pull or technology-push strategies for commercialization. Further their study suggests that the time to market for new firms have two advantages in commercialization of disruptive technologies namely flexibility in marketing strategy and much shorter times to market which is generally one-fourth that for established firms. Their model is represented below:

In a publication titled ‘Commercialization of Nanotechnology in Developing Countries’ by Roya Naseri and Reza Davoodi in the 3rd International Conference on Information and Financial Engineering IPEDR, Vol.12 (2011), the authors discuss the Walsh model as applicable in developing countries and conclude that in developing countries (http://www.ipedr.com/vol12/70-c162.pdf):

- Most activities for commercialization of nanotechnology projects are performed by start-ups;
- Due to lack effective laws and regulations for supporting right of intellectual properties and absence of an appropriate framework for patent registration in developing countries, granting the ownership of intellectual properties is not an appropriate way of founding new companies;
- Independent entrepreneurship is not a common method for complexity and considerable costs for nanotechnology development and patent registration;
- Challenges in commercialization of nanotechnology can be classified into the following four groups namely, Infrastructural issues, Managerial issues, Sociocultural issues and Economic issues;
- Commercialization of fundamental technologies in developing countries is much riskier than evolutionary technologies; and
Most of the nanotech firms in these countries are start-ups that adopt technology push strategies for commercialization of their nano products.

A study titled ‘The Global Technology Revolution 2020, In-Depth Analyses ……….Bio/Nano/Materials/Information Trends, Drivers, Barriers, and Social Implications’ published by RAND Corporation in 2006, reports the technology acquisition and implementation capabilities of various countries including the drivers and barriers to such processes (http://www.rand.org/content/dam/rand/pubs/technicalreports/2006/RAND_TR303.pdf). In countries such as USA, Canada, Western Europe, Republic of Korea, Japan, Australia and Israel, technology acquisition (TA) is strongly driven by a high level of S&T capacity with the presence of many drivers but few barriers. Countries such as China, India, Poland and Russia have been reported as countries for which implementation of technology acquisition is strongly driven by a high level of S&T capacity and the presence of many drivers but for which many barriers are simultaneously present. Countries such as Brazil, Chile, Mexico, Turkey, South Africa, Indonesia, Colombia represents countries for which implementation of technology acquisition is not supported by a high level of S&T capacity and for which the number of both drivers and barriers is small. Further, countries such as Cameroon, Chad, Dominican Republic, Egypt, Fiji, Georgia, Islamic Republic of Iran, Jordan, Kenya, Nepal, Pakistan represents countries for which implementation of TAs is not supported by a high level of S&T capacity and for which the number of barriers exceeds the number of drivers. Commercialization of nanotechnology in these countries will be accordingly impacted.

Nanotechnology is now on a non-linear development trajectory with some of the traditional fields of material science, metallurgy, chemistry and physics of condensed matter, polymer science, electrical engineering, instrumentation, and biology now interfacing with plasmonics, metamaterials, spintronics, graphene, synthetic biology, neuromorphic engineering, quantum information systems, etc. Such hybridisation is leading to new convergence technologies with concurrent applications in fields hitherto unthought-of and unforeseen creating a pan-industry framework that not only include the adoption of materials, devices, systems and components but also demands their interoperability. Technologies resulting from such convergence are those with nano as a prefix, e.g. nanomaterials, nanochemistry or nanoelectronics, nanobiotechnologies, nano-energy, nano-engines, and new diagnostic tools from a merger of nanoelectronics and biotechnologies.

All these require speedier advance in knowledge related to nanoscience, with almost simultaneous targeted synthesis of technologies for an array of applications ideally moving into commercialisation with minimal time-lag.

Traditional modes of R&D and technology transfer do not meet such aggressive needs especially as ownership of knowledge and transaction of “owned knowledge” begins to play a dominant role in present day and future knowledge dynamics in nanotechnology. The key limitations of the traditional modes to service the special needs of nanotechnology stem from the segregated modes of working of the academic community and the commercial enterprises, both in physical locations and in acceptable time scales of operation, diversity in culture between them, preparedness of commercial enterprises to absorb new
scientific developments into their system, ability of the academic community to accelerate comprehensive knowledge transfer and provide timely and adequate cover through strategic intellectual property rights portfolio to the inventions as also providing to confidence that developments made are non-infringing with regard to prior patents and design registrations, fuzziness in knowledge ownerships, etc.

4.2 Recent models of nanotechnology R&D and commercialization

As the level of understanding in nanoscience matured and promising applications as mentioned above started emerging especially using government grants in publicly funded institutions such as national research centres and universities, venture capital organisations, angel investors, and industry in general began indulging in nano-related activities by “proximating” with such centres of excellence in academic institutions via linkages and collaborations, partial funding of R&D and setting up channels for facilitated knowledge transfer and development (Figure 11). On the other hand several academic institutions initiated processes for the sprouting of first generation entrepreneurs evolving into “start-ups” and large companies nucleating “spin-offs” and further developing them as “nanobators” (nano-incubators) till they see the light of the day in commercial terms in the market place. With this mixed bag of technology centric “nanovities” (nanoactivities), the upstream and downstream mixed in diverse proportions resulting in what may be termed as a transiting “turbulent mode” for a relatively “rapid” transformation of the results of R&D to commercialization.

**Figure 11: R&D modes of the recent past**

The recent modes in R&D in nanotechnology for faster commercialization are initiatives from industry in which there is significant shift in evolving methods for Co-Production of Upstream Knowledge and Concurrent Transfer between industry and centres of excellence in publicly funded / industrial R&D.
centres, thereby blurring of boundaries and collapsing of timelines for knowledge bridging and integration.

There is also a gradual shift to establishing pre-competitive collaborative R&D operating as consortia, bringing together tributary streams of knowledge and skills to speedily supply the critical resources and expertise to build or fill the targeted gaps in the nano-knowledge domain. The partners in the consortia have agreements in which the conditions for the use of the generated pre-competitive knowledge in their respective commercialisation activities (Figure 12). Such consortia can work successfully only with cooperation among its members along the value chain. The challenge before consortia therefore lies in framing a pragmatic approach, including the publication of best practice including intellectual property rights (IPR) requirements that take into consideration foreground and background knowledge.

There is also a set of working models in which science and technology developers either working independent of each other or networking in clusters work closely with “commercialisation distributaries” through appropriate cost and benefit sharing arrangements.

A distinct contrasting feature in nanoscience and technology as compared to the developments in other knowledge led areas is the concurrent co-production of upstream and downstream knowledge is what I term as “Tailored Cavitation” mode (Figure 13). This term is borrowed from the field of “Cavitation” wherein a flowing liquid obstructed by a mechanical/physical barrier leads to the formation of “bubbles” (i.e., cavities) which lock and concentrate quanta of diffused energy depending on the nature of the liquid, characteristics of the bubble / cavity, such as size and contents which adiabatically implode downstream of the above said obstruction in the liquid flow to locally release the energy in a single event (termed as...
Transient cavitation) or multiple events (termed as stable or oscillatory cavitation). Thus if such cavitation is tailored, the formation of the bubbles (energy packets) can be controlled for release in quanta at desired location and in desired form in the flowing liquid for its targeted utilization (physical, chemical or biological conversions requiring energy supply).

The knowledge streams in nanoscience and technology which are in a diffused form now needs to be “cavitated” in a tailored manner so that the learning from the diverse contributing fields (tributaries) confluence to create a main knowledge stream that is “quantized” in a targeted manner with clear demarcation of their “ownerships” (Intellectual Property Rights, IPR) for effective release at desired points and in desired form of the main knowledge stream to ensure the effective utilization of the generated knowledge at the desired “application gates” with “appropriate acknowledgement and benefit sharing” including commercialization through distributaries that derive their feed from the main knowledge streams. It is imperative for the knowledge distributaries to create complementarities by smoothening interfaces that may act as barriers to learning, promote inter institutional collaboration with the creation of shared cultural spaces, norms and practices.

Most start-up or small company innovators have major limitations of resource and hence partnership linkages with academic institutions and researchers provide a very effective path to extended R&D activities. Such partnerships typically lead to the creation of appropriate and timely intellectual property, licensing, and technology transfer simultaneously helping to merge cultures of academic researchers and small businesses alike, both in providing new perspectives for each into the innovation cycle, as well as accelerating the time and path to commercialization.

![Figure 13: Present day and near future R&D modes](image-url)
Such an example of a productive partnership is between Rolith Corporation and Professor Jay Guo’s Research Group at the University of Michigan (USA) which has resulted in the licensing of a method to pattern nanoscale features in a surface over very large areas using a continuous optical lithography, using masks formed from a cylindrical polymer, the technique being termed as Rolling Mask Lithography (RML). The approach is inherently scalable with the process being limited only by the width of the cylindrical mask, and optimization of the photoresist and light source. RML is a “platform” technology, which can be applied to a wide variety of applications and markets. This nanopatterning, with its extraordinary flexibility and scalability, could open vast possibilities for advance products in commercial electronics, energy generation and storage, biotechnology, defense and others that include AR surfaces, self-cleaning, anti-fog, anti-icing, anti-drag, anti-bacterial surfaces, transparent electrodes for displays, solar cells and LEDs, dye less color filters, absorption enhancement layers for solar cells, extraction enhancement layers for LEDs, 3D solar cells, and wire-grid polarizers. Such a platform technology provides an excellent example of nanomanufacturing technologies transitioning from academic research groups providing a platform to effective scaling the process for numerous high impact applications and markets.

Drivers and barriers to technology transfer, acquisition and implementation have to be balanced to ensure speedy transition of an idea to the market place. An institution’s ability to acquire such technologies through their R&D efforts, through technology transfer, through R&D collaboration, or through purchasing / importing commercial off-the-shelf systems would only reflect the S&T capacity of that institution, particularly its ability to conduct R&D activities or import know-how. For successful commercialization, the institution ought to have the capacity to successfully implement the acquired technologies. The institution should be able to match a technology application to a targeted problem, translate the technology application from the development phase into the market at affordable cost to the consumer, and the market must be able to sustain that use over time. The entire process needs the support for financing the access to the technology application, infrastructure to support its use, skilled workers to maintain it with continual technology improvements developed by technology generating workers, feeding into the market. Finally, individual users and the society as a whole must be able to benefit from the use of the technology application and be willing to support its implementation.

All such modes require reengineering of organizational frameworks for agile Intellectual Property Rights (IPR) Management that would facilitate the facile creation and transaction of IP.

Another area that is an emerging challenge in nanotechnology commercialisation is the compliance with evolving stringent regulatory platforms addressing environmental and health concerns, and in the market place overseeing possible anticompetitive practices.

5 Integration of IPR Management in R&D

IPR has become an integral component in any competitive pursuit, especially in technology centric fields such as nanotechnology. It is therefore imperative that IPR be concurrently managed with R&D and not be considered as a post “R&D” activity.
Technology transfer processes in nanotechnology including sustenance of product pipelines, foresees a very special role of inventors due to high content of “know how” which does not form a part of patent disclosures. Access to the tacit knowledge of inventors and their technical expertise is crucial to the successful translation of R&D findings into innovations. Documentation of the tacit knowledge is therefore of immense significance in the integration of IPR Management in the R&D process.

Similarly innovation administrators with new sets of technical competencies and skills are beginning to play knowledge-bridging pivotal roles in the development of collaboration architectures to minimise organisational inertia in the process of technology transfer.

The rapidly growing “prior art” both in terms of publications in journals & diverse media, and densification of patents with overlapping claimed knowledge domains (growing patent thickets), poses challenges to the R&D scientists and businesses to craft patent non-infringing paths and also creating innovations that are novel and non-obvious with respect to the existing prior art (existing in open freely usable domain and in patents / design registered domains). Early identification and analysis of relevant prior art is of immense significance and therefore “nanalytics” (nano-analytics) including timely generation of “Freedom to operate (FTO)” reports ought to form essential modules of nano R&D, technology transfer documentation and business strategy.

Structured technology transfer documentation with clear status of prior art vis-à-vis the technology that has been developed and being transferred including its “freedom to operate” in specific jurisdictions is of immense value as such transparency would facilitate timely disclosure of the developed knowledge, identification of closely related patents, spot potential collaborators, assist in legitimate IP transactions (such as acquisition / licensing), minimize litigations related to patent infringement, thereby paving the way for speedier, synergized and cost effective transformation of developed knowledge into innovations and profitable businesses. Only then would affordable genuine products and processes be made available to people in the market place.

There is an urgent need for the formulation, endorsement and implementation of R&D and innovation policy at the institutional level for purposeful preparedness directing good practices for R&D and innovation with synchronised management of IPR.
The author’s model termed as “IPRinternalise®” that seamlessly integrates IPR in the innovation process in a structured manner that involves the inventors and innovation administrations in appropriate proportions drawn into the innovation stream by a natural tide of the innovation process, originating from one’s immediate requirements to play their respective and combined roles in the creative, technology evolution, technology transfer and business development phases (Figure 14). “IPRinternalise®” starts at the problem definition phase where a researcher explores and ethically exploits the prior art to contextually build on and provide creative solutions to the identified and assessed problem, get the explicit and tacit knowledge documented and have his solutions appropriately IPR protected and building of a strategic IPR portfolio by the innovation administrators for further processing to commercialisation. “IPRinternalise®” also provides a “stress and burden free” but “relevant and need based” gateway for early stage assessment of inventions, have them checked for possible infringement of others’ IPR, introduce mid-course corrections to then design the inventions to ensure that the solutions with the built-in IPR ethics satisfy all conditions for its “freedom to operate” in diverse jurisdictions thereby facilitating smooth technology transfer and commercialisation.

6 Business development and planning and implementation of R&D commercialization / technology transfer projects

The N2M booklet CSA-SA 233476 NANO2MARKET, titled ‘Towards Good Practices for IPR and Technology Transfer in Nanotechnology Developments’ under the 7th framework programme in Europe
(accessible at http://www.nanofutures.info/sites/default/files/N2M_Booklet.pdf) presents the Iterative Nano2Market-Approach observing that individual IPR and Technology Transfer are often heavily influenced by the size of the market the respective technology is planned to be commercialised within, as well as the level to which the technology would disrupt that market (Figure 15).

Accordingly specific technology maps are required to be generated to provide (a) a generic market vision of the technology, (b) a list of key-players of the technology, (c) a description of company segmentation, and (d) an introduction to the regulations governing the technology.

As illustrated in the report, Nano2Market Technology Maps were generated based on a search strategy, composed of accurate combinations of key-words, enabling the collation of information related to a specific nanotechnology application. Innovative data-mining techniques were subsequently applied to combine the technology map with an analysis of sector-dependent IP cultures, with a view to identifying underlying clustering and other market conditions influencing intellectual property and technology transfer.

The analysis resulted in an illustration of the evolution in patents and scientific publications, as well as an overview and brief introduction to the top companies in the respective technology capability in patents and publications, on both (a) the global level, and (b) the European level.

The N2M Report further observed that even for a specific sector, it is difficult to assert that only one optimal strategy for technology transfer is appropriate. Aspects such as the regulatory framework, standardization, cost vs. benefit, converging with bio/IT technologies and its feasibility, etc., can vary greatly from one application to the next, and have to be carefully reviewed and covered. One single breakthrough scientific advance can lead to a manifold of products, each of them to be sold to different markets and consumers, with different barriers to overcome.
In terms of patenting and licensing, the report further observed that each sector has its own nuances and that there is no standard patenting / licensing mode cutting across all the sectors. Hence the complexity of patenting / licensing is sector specific and all associated characteristic to that sector must be taken into consideration in drafting patents and striking licensing deals and accordingly structuring an appropriate business model. The case studies presented later in this chapter clearly illustrates these aspects.
The N2M Report shows that there is an ascending order in the value chain involving nanotools, nanomaterials, nano-intermediates and nano-enabled products. The patentting / licensing complexity also follows the same order as in the value chain (Figure 16).

![Diagram of Complexities of Patenting/Licensing vs. Technology Maturity](source: CSA-SA 233476 NANO2MARKET)

The report further presented the investors’ perspective (Figure 17) on the equity lifecycle that has an influence on technology transfer and the business model to be adopted.

![Diagram of Equity Lifecycle](source: CSA-SA 233476 NANO2MARKET)
All these factors are of significance and have to be taken into consideration before working on the N2M Iterative Approach presented in Figure 15. The case studies presented in this chapter also illustrate these features.

7 Role of technology transfer / licensing offices of Universities and R&D institutes

Technology Transfer Offices (TTOs) in Universities and R&D Institutions are the main gateways to technology transfer across the institutional walls (Figure 18). The role of TTOs is multifarious that ranges from managing the innovation cycle in the institution from concept to periodic progress review, ensuring appropriate documentation, confidentiality, evaluating commercial potential, conducting periodic due diligence, filing of appropriate intellectual property applications for the creation and management of strategic IPR portfolios, establishing Freedom to Operate Reports on institutional innovations, developing commercialization strategies, marketing, negotiating IP transactions such as assignments and licenses, facilitating the formation of start-up companies, encouraging entrepreneurs, validating new practices to minimise market, technology, financial, managerial and legal barriers, maintain beneficial partnerships with public and private sectors in research and technology, actively pursue commercialization opportunities for nanotechnology-based inventions and promote controlled diffusion of institutional knowledge with a pragmatic revenue model say in nanotechnology to the commercial world.

Figure 18: Technology Transfer Gateway
8 Due diligence for technology transfer

Technologies may be developed to provide solutions to existing problems and to fulfill the unmet needs. On the other hand, one may have developed new understanding in nanotechnology or developed new materials with new properties or have found new properties of known materials for which innovative applications in diverse fields are explored and found.

The diverse motives to acquire technologies range from expansion of markets with territorial coverage & exportability, getting access to strategic and targeted resources, establishing a manufacturing platform for the region and minimizing the learning curve in adapting technologies, complying with specific requirements of certain governments that require operating companies to transfer technologies and know-how for the development of the region and to ensure accessibility and affordability of IPR protected products meeting global standards within their jurisdictions thereby meeting domestic content requirements, preempting competition, avoiding tariffs, etc.

Technology transfer is considered a special case of knowledge transfer because in many cases what is transferred is not the technology itself, but the knowledge that can result in the technology. It ought to be appreciated that technology transfer requires continual interaction between the transferor and the transferee through multi step processes leading to a range of activities that should ideally strengthen their inter-relationships for mutual benefits.

In all such cases technologies may be transferred between interested parties which not only involve the dynamic translation of knowledge by way of knowhow and / or right to use the intellectual property rights (e.g. patents) of the technology/knowledge owner through negotiated agreements. During such technology transfer processes, one conducts due diligence on the developed technology, legal aspects such as intellectual property rights ownerships and freedom to operate in markets of interest (diverse jurisdictions), marketability of the technology, regulatory issues, etc. The collaborative partners may differ in their working culture, role and competence during different phases of the technology transfer process, and management of this multifaceted often conflicting interface is the real challenge.

One needs to prepare well in advance for any technology transfer exercise. Several searching questions need to be addressed prior to detailed negotiations between the parties. Some basic questions are: What is the background and history of the party interested in transferring the technology and why? What is the background and history of the party interested in acquiring the technology and why?

8.1 Broad aspects of due diligence

Any technology transfer process is preceded by a due diligence on various aspects linked to the technology being transferred. The main broad categories of the due diligence may be classified as:

- Scientific / technical strength and weakness
- IP ownership and rights
- Validity and infringement of the associated IPR
8.2 Checklist for scientific /technology related due diligence

- What is the field of invention? What is the problem being addressed? How comprehensive is the solution to the problem? Is it a platform technology that can be adapted to provide solutions to other related problems?
- What is the relevant background information available in the literature and in the open domain including the market place?
- Has a feasibility report and market opportunities on the technologies developed been prepared by the party intending to transfer the technology / technologies? If no such report is available it would be advisable to get such a report prepared by a competent party / technology broker.
- What are the competing technologies and what is the gap between existing technologies in prior art and the developed technologies? What is the probable life cycle of the technology to be transferred?
- Does the party intending to transfer the technology have sufficient know-how and know-why to make the technology work? What is the nature and structure of documentation available with the party intending to transfer the technology? Have they made a proper listing of the appropriate documentation, computer packages including source codes, oral communications, e mails, minutes of meetings, project reports, certified laboratory note books recording the work done both in terms of successful and unsuccessful experiments, drawings including clarity on the ownership to the copyright to such drawings, prior art search including data bases searched, analysis, search strategy adopted, etc to aid in the transfer of technology?
- What is the level of expertise with the party intending to transfer of technology in the field of the technology developed? Can they do a hand-holding exercise during and after the technology transfer exercise? Can they provide support in setting up plants, establishing production processes, quality control procedures, etc?
- Can the party intending to transfer the technology have resources to undertake Contract Research and Development?
- Does the party intending to acquire the technology have the technical capability in terms of equipment and skilled human resource to absorb the technology and convert it into a commercial reality?
- Does the party intending to acquire the technology have a feasible business plan to market the technology?
- Does the party intending to acquire the technology have adequate financial resource to complete the technology transfer and diffuse it into the business plan of the company?
- Does the party intending to acquire the technology have the capability of developing the technology in terms of applications, etc after the acquisition?
- Does the party intending to acquire the technology have the intention to continue the linkages after acquiring the technology?
8.3 Checklist for IPR related (patents, trademarks, industrial design registrations, copyrights, trade secrets, domain names) due diligence

- What is/are the sources of funding used for the development of the technology or technologies? Are there any terms and conditions of the funding agency / agencies on the ownership of the IPR / rights to use the technologies? If so, what are they?
- If the party intending to transfer the technology is an institution, then does it have an Institutional IPR policy? If so, what are the boundary conditions set in the Institutional IPR Policy on matters related to confidentiality, publications, permitted disclosures, pirating, reverse-engineering, creation of start-ups, spin-offs, knowledge purchase or lease mechanisms, transfer of technology and IPR?
- What is the chain of title associated with the IPR?
- Has an evaluation been done on the patentability of various facets of the technologies developed? Would any aspect of the said technologies fall within the ambit of exceptions to patentability in selected jurisdiction [an example of such an exception to patentability would be Section 3(d) together with its explanation of the Indian Patents Act 1970 (as amended in 2005)]?
- Have all aspects of the developed technology been covered by appropriate IPR applications before public disclosure?
- Would one have to file additional IPR applications?
- Have all the documentation related to correspondences and office actions with the patent offices been examined for completeness of all office actions including pending office actions? Are all priorities claimed in the patent applications valid?
- Has an assessment been done on how well have the trade secrets and confidentiality been protected?
- Have appropriate assignments been taken from the inventors / collaborators? Further does the party intending to transfer the technology have the rights to those technologies by way of assignments, and are they the legitimate owners of the IPRs/ IPR applications? Do the collaborating institutions have joint rights to the said IPR? If so, are there any agreements controlling the rights to negotiate, assign, benefit sharing between the collaborating parties? Does anyone have the first right to refusal? Does anyone else have an option over the IP?
- Are there other contracts with carried forward interests, options for rights, or for shares? Are there any breaches of existing contracts? What are the terms and conditions of such contracts? Are there any performance obligations and/ or are there any termination rights that may have accrued?
- Have the employee contracts been examined for the confidentiality clauses, assignment and transmission of rights, warranties, non-compete clauses, etc?
- Are there any preconditions on the rights to further develop the technology? If so, who would own the IPR on such further developments?
- Are appropriate materials transfer agreements in place with rights to use the materials for further work, investigations, etc?
- What are the search reports and opinion on patentability of the various PCT applications?
• What is the strength of the claims of the granted patents and would they survive if validity is challenged?
• Have the patent claims been appropriately constructed to enforce them against alleged infringers?
• Is any party already infringing the claims of the granted patents and/or of the claims of the patent applications? If so, what actions have been taken or contemplated?
• Have all the renewal fees to the IPR offices in the appropriate jurisdictions been paid? Has the term of each IPR in the IPR portfolio been assessed and recorded? Have any of the IPRs lapsed in any of the jurisdictions?
• Have any of the IPRs been mortgaged? If so what are the details? Are there any lock-in clauses?
• Has “Freedom to Operate (FTO)” in jurisdiction of interest been assessed? Do other parties have the right to operate within the given field of technology?
• Are there any regulatory issues that may come on the way of exploiting the IPR/IPR applications? If so, what actions have been taken or need to be taken?
• Have any related aspects of the technology been in-licensed by the party intending to transfer the technology? Have those licensing agreements been examined for all the terms and conditions including rights to sue and claim damages for infringements? Are these licenses related to the core area and / or peripheral area of the technology being transferred? Are the licenses exclusive or non-exclusive?
• Have any of the aspects of the technologies developed been out-licensed by the party intending to transfer the technology? If so, have the agreements been examined? Are these related to the core area and / or peripheral area of the technology? Are the licenses exclusive or non-exclusive?
• Have any of the aspects of the technologies developed been cross-licensed by the party intending to transfer the technology? If so, have the agreements been examined? Are these related to the core area and / or peripheral area of the technology? Are the licenses exclusive or non-exclusive?
• Have any of the IPRs / IPR applications been assigned to other parties? If so have those agreements been examined? What has been assigned? Who has the rights to the knowhow related to the assigned applications or granted patents? Who would have the rights to the knowhow related to the assigned applications to file further patent applications? Is the assignment of the patents linked to physical assets of the patent holder?
• Are the licenses and assignments free of conflicts?
• Are there any ongoing litigations and / or proceedings with regard to any of the IPRs in the IPR portfolio? If so, what is the status?
• What is the market value of the IPR Portfolio?
• Are there any liabilities associated with the IPR Portfolio?
• Do any of the transactions associated with the IPR portfolio (e.g. grantback provisions, tie-in provisions, front-end lump-sum fees, royalties, technical assistance fees, payment in equity, payment for supplies, value of grantbacks, etc.) fall within the ambit of the provisions of competition law / anti-trust law in jurisdictions of interest?
• Are there any tax liabilities / benefits associated with the transfer of technologies / IPR in the jurisdiction of interest including issues related to cross-border transactions?
• Who would bear what costs?
9 Case studies on technology transfer and commercialization


The authors have reported their study on university–industry collaboration related to nanotechnology and the impact of the technological diversity and value chain complementarity in multiple partner collaborative public nanotechnology research projects. They their findings are:

- A non-significant effect of technological diversity on application development.
- Value chain complementarity has a positive effect on both application development and commercial performance of the collaboration projects. These findings also hold for public nanotechnology R&D projects.
- A U-shaped effect of technological diversity on commercial performance of the projects. In the nanotechnology projects, the effect of technological diversity first shows a decrease followed by an increase of application development and commercial performance.
- The participants’ commitment has an overall positive impact on the outcomes of nanotechnology research projects.


The authors investigated the model of technology transfer in nanotechnology, focusing on the position of smaller and larger firms in that model. They created a database of nanotechnology firms and conducted a network analysis of R&D collaborations between the partners in the sector. Their findings suggest that nanotech SMEs do not play a key role in bridging the gap between public research institutes and large companies but rather perform as providers of specialized services/technologies. In contrast, their results indicate that large firms play a key central role in knowledge co-production processes in nanotechnology.


This article reports on the research and development of a cutting-edge biomedical device for continuous in-vivo glucose monitoring. This entirely public-funded process of technological innovation has been conducted at the University of Barcelona within a context of converging technologies involving the fields of medicine, physics, chemistry, biology, telecommunications, electronics and energy. The authors examine the value chain and the market challenges faced by in-vivo implantable biomedical devices based on nanotechnologies.
Using a case-study approach, the authors have examined the high-tech activities involved in the development of this nano-enabled device and describes the technology and innovation management process within the value chain conducted in of a public-funded R&D&I environment involving a University typified by the convergence of technologies and disciplines –Hospital–Industry–Administration–Citizens framework.

The Department of Electronics at the University of Barcelona, in collaboration with the Institute for Bioengineering of Catalonia (IBEC), the Biomedical Research Networking Centre in Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN) and the Biomedical Research Network in Diabetes and Metabolic Diseases (CIBER-DEM), promoted an alliance with the aim of developing a cutting edge multidisciplinary research and commercial team covering the entire range from applied research to clinical diagnostic. In this way, research centers, hospitals, firms, health policies and citizens shared the same goal: launching onto the market safe, reliable and affordable biomedical devices for the diagnostic and therapy of diabetes, improving the quality of life of those who have to control their blood sugar level by on-line monitoring and keeping the requested glucose level constant (by using a Radio Frequency activated clock-alarm or with exact doses administered directly from an insulin reservoir).

The overview provides the value chain of research and technology transfer processes and highlights the importance of a common framework in which multidisciplinary teams and organizations can work together directed by determined scientific leadership. In this specific case, the Department of Electronics at the University of Barcelona has had overall charge of the research and commercialization activities. The resulting biomedical device is nano-enabled in a dual sense: when miniaturizing the system (fluidics, electronic, energy autonomy) and when new functional structures are included (nanobiosensors developed by the IBEC). The CIBER-DEM joins the value chain when clinical research and commercialization are considered.

The process described offers an efficient method for performing experiments at large test and clinical facilities, within an innovative framework that takes advantage of new scientific tools and discoveries. Biomedical devices represent a strategic gamble for the future of Spain’s scientific and technological policy areas as they seek accelerated economic growth within the knowledge-based society. In this way, the country’s regions can strengthen the network links between their R&D agents – science and technology parks, institutes and research centres, hospitals, technology platforms and incubators – as they explore and confront the new scientific and market challenges.

9.4 Nanotechnology entering into the Danish glass window market

A paper presented at the DRUID 2011 on ‘Innovation, Strategy, and Structure - Organizations, Institutions, Systems and Regions’ at Copenhagen Business School, Denmark, June 15-17, 2011 titled ‘Silent innovation - Corporate Strategizing in early Nanotech Evolution’ by Maj Munch Andersen, Technical University of Management, Denmark analysed how firms organize innovation in the early embryonic stages of a technology and how the market as a selective device undergoes qualitative change as part of economic evolution. The traditional Danish window chain is used as a case study.
A model of nanotechnology evolution has been proposed which suggests that nanotechnology commercialization is significantly driven by small and medium-sized firms based on their internal know-how, with larger firms as important suppliers of knowledge. These smaller firms are adept at addressing social needs which appear to be key factors in the nano-commercialization process. A qualitative study was undertaken to understand how nanotechnologies entered into the window supply chain in the Danish market.

This case study typically represents the urge of technology development, transfer and commercialization based on “market pull” to satisfy an unfulfilled need or what may be considered as a “continuous demand for enhanced performance by way of innovative coatings to meet an unmet meet” through nanotechnology strategies and innovation activities of core actors in the Danish window chain market.

The Danish window chain comprises those firms active in Denmark in the market for windows, as well as their suppliers and customers. Interestingly, the Danish window chain comprises of “start-ups”, “multinational companies”, and small to medium sized enterprises, with the producers of glass and windows generally headquartered in Denmark. These firms network with relevant (nano-active) suppliers and with customers in wholesale and retail trades fully commercializing nano-enabled products. They are also involved in a variety of development projects and emerging new nanotechnology applications with the multinational glass companies taking lead in developing advanced nanocoatings.

Pilkington for example spends around £33 million a year on R&D, organized within their two business lines of building products and automotive products. Additionally, Pilkington cooperates with the R&D labs of the parent Japanese NSG Group. Pilkington marketed the first selfcleaning glass in 2001. This has garnered international recognition as one of the first commercially-available nano-consumer products.

Within a year, PPG Industries, Cardinal Glass Industries and Saint Gobain also launched their selfcleaning glass products. Self-cleaning glass is now widely available in glass wholesalers’ product portfolios, although it still awaits a major breakthrough in market demand.

Another entrant in nano-enabled glass is Sunarc, a small Danish up-start company, specializing in the production of nano-structured anti-reflective surfaces on large glass sheets was established in 2000. The capabilities underlying Sunarc’s production are mainly tacit and rest with core employees. The critical elements lie in the fine adjustment of the production process, which is essential to achieve a uniform high product quality. The company has chosen not to patent its technology. Others have tried to copy what they are doing, including the larger glass companies. However, although laboratory-scale production is easy, scaling-up to commercial levels is difficult, and Sunarc is still the leading full-scale global producer with this technology.

VELUX is the dominant company within the VKR Group, with a well-known international brand and specializations in roof windows and skylights. Nanotechnology has long been of interest to VELUX because it plays an important role among a number of their suppliers and in the components of their products. VELUX has its own R&D department, which is divided into two sections, one for the frame and one for glass. Both sections are involved in nanotechnology R&D.
Dovista, also part of VKR, is the holding group of the main two Danish producers of vertical windows, Velfac and Rationel. Dovista undertakes R&D for these two affiliates. In the past, Dovista was not focused on nanotechnology and did not undertake targeted searches into nanotechnology innovations. However, interest is now growing. In 2009, Dovista began their first nanotechnology R&D project, with a Danish university, aimed at reducing condensation problems of windows (which, as noted, is a major issue in increasingly energy efficient buildings). There is also cooperation between VELUX & and Dovista: they draw heavily on each other’s R&D and engage in common product developments and marketing.

According to VELUX, their main sources of knowhow are not research institutes but their varied major international suppliers who VELUX sees as being at the forefront of technological development, including for nanotechnology.

The VKR Group has recently become engaged in nano-enabled product development for wood impregnation. VKR has long been looking for more environmentally-friendly wood preservation methods. In 2006, VKR bought Superwood, a Danish start-up company, which offers a nanotechnology-based and environmentally-friendly wood impregnation method using supercritical carbon dioxide (CO). The method is based on a 2001 patent. Superwood was started in 2002 as a buy out from FL Schmidt – a Danish-based global supplier to the cement and minerals industries. Superwood struggled with scaling up, and went bankrupt in 2003.

Following VKR’s purchase of the company in 2006, VELUX, Dovista and Superwood are jointly engaged in further development of Superwood’s technology, targeted specifically to window products.

A further nanotechnology entrant in the window chain is Photocat A/S, a Danish startup company. Photocat produces nano-structured materials and coatings with photocatalytic properties, e.g. self-cleaning functions. Photocat has a product directed at the glass market, ShineOn® Pro, which is an aftermarket treatment to make window glass self-cleaning. The company is a spin-out from SCF Technologies A/S, a dedicated Danish nanotechnology company that from 2003 also specialized in supercritical technology, similar to Superwood. SCF initially experimented with a range of applications for supercritical technology. SCF focused relatively quickly on bio-oil from organic waste, which is now the core focus of the company. In the advanced materials area, SCF focused on self-cleaning glass. For this product SCF initially relied on imported nano-materials from China, but after encountering technical challenges the company began work to design its own nanoparticles of the patented ShineOn® product in 2005.

Additionally, working with a Swedish floor company, Välinge Innovation, in 2007, a new patented composite flooring material was developed (ActiFloor). Photocatalytic nanoparticles are integrated in the floor material matrix, the first of its kind. These floors are depolluting, improving the indoor climate (formaldehyde release is eliminated from the floor itself, while the floor also removes formaldehyde from other sources). With SCF seeking to focus on products other than self-cleaning materials, Photocat was spun-out in 2009, with plans to start industrial production of the floors in 2010. Meanwhile, ShineOn has been licensed by Photocat to wholesale companies in the UK and US, with moderate success. The users are professional glaziers and renovation companies. In Denmark marketing activities have been limited and no license partner has been found.
Key learnings from the Danish experience

The Danish experience over the last three decades indicates that medium-size players in the Danish window industry (both in size and chain position) play a key role as integrators of a variety of nanotechnologies. Internal R&D combined with input from their large suppliers form the basis of their internal nano-capabilities. The recent observed strategic shift among mid-chain window producers from window to green building providers strengthens their roles as system integrators, indicating that they may become even more important carriers of nanotechnology commercialization in the future.

Nanotechnology has already affected the organization and operation of the window sector. Large companies play a central role, through the provision of nano-based coatings (by the large glass companies) and chemicals and metal materials. A small number of these large integrated organizations placed upstream have substantial nanotechnology capabilities which function as a source for firms further downstream. They are complemented by nano-dedicated start-up companies who, in the Danish window case, have developed several promising new nano niche products.

While there seems to be a distributed set of nano-capabilities in the window chain, this case study also highlights the widespread disinterest and lack of awareness among many of the smaller and medium-sized companies who dominate the construction sector. Even companies that are innovative in other domains (such as Fiberline) are not very engaged with nanotechnology.

The Danish market may be categorized into various types of enterprises based on their involvement in the nanotechnology sector, namely:

Category 1: the makers of instruments, equipment, facilities and software for nanotechnology production;
Category 2: producers of generic nano-materials; and
Category 3: producers of nano-services, e.g. specialized consultants who advise on aspects related to nanotechnology.

Firms in these three categories enable other firms to develop and apply nanotechnology.

The next set of firms is downstream, moving towards nanotechnology used.

Category 4 comprises dedicated nanotechnology firms (such as Superwood, Sunarc and Photocat) where nanotechnology makes up a fundamental part of the firms capabilities and innovative activities and it is applied to develop innovative (nano) products.

Category 5 consists of nanospecialized firms where nanotechnology forms a serious but not central part of their capabilities. The multinational glass producers are leading nanotechnology developers within the construction area, but they also possess other important capabilities and lines of business.

Category 6 comprises nano-active firms, where nano R&D play a modest but not very central role for their innovative activities and capability development. An example is VELUX, whose nanotechnology innovation is mainly centered on applying and integrating nanotechnology developed by others.
Category 7 consists of *nano-explorative firms*, with no development activities in nanotechnology but with interest and some level of research into nanotechnology opportunities (as for Pro-Tec and Velfac/Dovista).

Category 8 encompasses *nano-tacit users* with no R&D in nanotechnology themselves but applying nano-enabled products (e.g. many construction companies and architects). They may be more or less knowledgeable about the nano-content of their products.

Category 9 contains what can be termed *nano-shadow companies*. Nanoscience forms part of their underlying technology base and is applied in niche products by others in the sector. However, companies in this category have limited or nil efforts themselves in developing or applying nanotechnology. These companies are typically relatively high tech and are potentially nano-dedicated companies. An example of such a firm is Fiberline.

Technology transfer takes place at various points in the value chain between the collaborating and business partners who are mainly integrators through business deals, contracts and diverse types of agreements.

### 9.5 Nantero


Nantero is a nanoelectronics company based in Massachusetts, with around 400 patents relating to carbon nanotubes and “next-generation semiconductor devices” for mass memory storage, such as NRAM. Nantero also specializes in logic switches, sensors, carbon nanotube antennas, and liquid solutions. Further experimentation and explorations in nanotechnology is still a major priority of the company, as well, and it is supported through the company’s strong relationships with corporations, the United States government and academic institutions. Nantero has always explored for true partners who will give as much as they get. Nantero is the licensor of technologies, and its intellectual property portfolio allows the company to choose under which terms and conditions its IP will be shared with its licensees. Nantero has already built up an impressive portfolio of 200 US patents filed of which 120 have already been granted and many more around the world, including valuable manufacturing know-how that could be licensed to others who want use their technologies for diverse applications.

In 2001, Greg Schmergel a Harvard M.B.A. and former management consultant and Thomas Rueckes a researcher at Harvard University along with Brent M. Segal, another former Harvard chemistry doctoral student, formed Nantero, a name whose genesis again combined the small (“nano”) and the large (“tero,” a corruption of “tera,” or trillions, as in trillions of bits). The immediate mandate for Nantero was to move beyond an advanced graduate project to create a device that could be manufactured in a working semiconductor facility. The company set up shop in a Woburn, Mass., industrial park populated largely by biotechnology firms.
When Nantero started, no good options existed for forming a nanotube on the surface of a wafer (the round silicon disk from which chips are carved) without interfering with adjoining electrical circuitry. Deposition of nanotubes onto the wafer using a gas vapor required temperatures so high that the circuitry already in place would be ruined. Nantero devised a proprietary solvent suitable other than the banned excessively toxic chlorobenzene for spin coating. The thin film of nanotubes left after the solvent is removed can be subjected to lithography and etching that leaves the surface of the wafer with evenly spaced groupings of nanotubes that resembles a helter-skelter unwoven fabric. An electric field applied to one of the fabric elements bends it downward until it contacts an electrode, a position that represents a digital 1. ASML, a major semiconductor tool manufacturer, helped to refine this process with Nantero.

Nantero in 2003 in collaboration with LSI Logic, a leading maker of customized chips for the telecommunications, storage and consumer electronics industries, initiated a project to bring the process for making what Nantero calls nanotube random-access memory (NRAM) into its factory in Gresham, Oregon and within nine months, the collaborators had a working prototype. The project was quickly put on an early-development track, and brought it into first commercial production memories by 2006 using the process in a standard CMOS facility. LSI and Nantero then worked together to increase “yield,” the ability to scale up to make millions of nanotube memories with near-perfect repeatability.

Nantero also set up collaboration with BAE Systems, to work on defence and aerospace applications for the radiation-resistant NRAMs. It also set up a partnership with the American global aerospace, defence security and advanced technology company, Lockheed Martin. In 2008, this partnership culminated in Lockheed Martin purchasing Nantero’s government business unit and creating Lockheed NanoSystems. The federal government also plays a large role in nanoelectronics, and companies can benefit from government involvement, as Nantero did with an opportunity to test their memory chip’s durability by sending it up on the space shuttle Atlantis in partnership with National Aeronautics and Space Administration (NASA).

When looking for manufacturers with which to partner, Nantero considers sophistication, experience and credibility of the potential partner such that the potential could provide Nantero the greatest possible market penetration. Nantero also looks to areas where they can manufacture while also limiting possible competition and infringement. Once a product is manufactured, the partner identifies the location of the user market and begins to commercialize the product. Above all else, Nantero focuses on making sure that their inventions are fully employable in a current and modern infrastructure.

A large research and development team, and the steps Nantero takes before it approaches manufacturers and marketers, helps Nantero leverage its company’s IP. Nantero is at the forefront of their field of industry, and plans stay this way.

Lessons on technology transfer

Nantero develops the core technology and then partners with high tech companies who are actively involved in applying the core technology with active participation between the technical teams of the partners to convert the developed technology into successful commercial opportunities. Technology
transfer therefore takes place through licensing of the patents, sharing of knowhow and targeted working to achieve set objectives by the partners.

In nanotechnology development, large firms hybridize their existing knowledge base with the newly emerging technologies, and strategically invest in pre-adaptation so as to speed up the development of new technologies and to be ready as markets emerge. Large firms play a prominent role in the process of coproduction and transfer of knowledge in nanotechnology by acting as a node of high centrality directly linking the industry’s co-patenting network with research in small organisations / institutions.

9.6 Invitrogen (presently Life Technologies Corporation)


Invitrogen is a typical example of a company which was initiated as a start-up in 1987 with an impressive growth to a robust, successful and profitable sustainable enterprise in the field of “bio-molecular labeling” offering the world's largest line of products for gene expression. The company’s pragmatic business model ensured targeted technology development, technology transfer, commercialisation, procurement of funds from diverse sources, planned mergers and acquisitions, timely exit from unprofitable activities, enforcing its intellectual property rights when necessary, and effective networking with stakeholders and clients. The company was seeded as a biotech enterprise essentially to develop and supply kits but over time expanded it to provide some of the most sophisticated products based on novel specially coated fluorescent nanocrystals and metal alloys for applications in multicolor labeling, sorting and imaging of cells, lateral flow immunoassays, and fluorescent inks for automated assays of complex biological samples.

Invitrogen was founded in 1987 by three scientist/entrepreneurs to make and sell kits to help molecular biology scientists make cDNA libraries. Libraries, or collections, of cDNA are important for identifying new genes. As a startup with limited resources, but with some experience in the venture capital industry, Invitrogen focused on short-term product development ideas that could rapidly generate revenues with a minimum development cost. Some of these products failed, but the investment in the failures was low enough so as not to have a significant financial impact on the company.

During 1992 and early 1993, the company went through a challenging phase as there were mounting back orders caused by products failing quality control. High scrap rates drove production costs up and slowed sales growth to single digits for the first time in the company's history. The founders of the company - typically scientists/entrepreneurs, had no manufacturing experience. However, with concentrated efforts the company completely reorganized the manufacturing process by adopting a focused six-month Manufacturing Excellence program. By the end of 1993, the manufacturing issues were sorted.

In 1997, based on a market survey, the company explored the expansion of its custom cloning service business, based on its proprietary “topoisomerase (TOPO) mediated cloning” specifically targeting the pharmaceutical companies as a value added proposition to significantly reduce drug development...
timelines and expenses. The positive response was so overwhelming that Invitrogen pulled the project back to rethink the objective.

Realizing that the company was getting into an area outside of their core competencies of kits and services, the company brought in experts in pharmaceutical drug development to help develop a business plan that could be used to sell the service to large pharmaceutical companies based on its value. To further test the value of the service, they performed some initial work for Merck and Co.

This is a good example of knowledge development, acquisition and transfer during the business development phase.

In June 1998 of a new division, Invitrogenomics was created as the functional genomics services division of Invitrogen to provide high-throughput cloning and gene expression services to genomics companies and large pharmaceutical and agricultural chemical companies.

From 1998 onwards, Invitrogen adopted an aggressive mode of technology acquisition and consolidation through periodic mergers and acquisitions including venturing into the nanotechnology area to ensure speedy business response in a growing market (Table 2). These moves provided Invitrogen timely technology, market base coupled with strategic and invincible IP protection to ward off competition.

Some of the key milestones of Invitrogen are listed below:

<table>
<thead>
<tr>
<th>Dates</th>
<th>Transactions by Invitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 1999</td>
<td>Merger with San-Diego based NOVEX a developer of products used for gene and protein analysis, in a $52 million deal</td>
</tr>
<tr>
<td>December 1999</td>
<td>Research Genetics Inc, Huntsville, Ala, for $139.2 million in stock</td>
</tr>
<tr>
<td>June 2000</td>
<td>$15.1 million acquisition of Ethrog Biotechnologies Ltd. Of Israel which had developed and patented a system for the electrophoretic separation of macromolecules. This was followed by a cash and stock merger valued at $1.9 billion</td>
</tr>
<tr>
<td>July 2000</td>
<td>Dexter Corp, a chemical maker, and Life Technologies Inc, which makes biological material for genetic research, for $1.9 billion in cash and stock Dexter has 75 percent stake in Life Technologies</td>
</tr>
<tr>
<td>September 2000</td>
<td>completes its takeover of chemical maker Dexter</td>
</tr>
<tr>
<td>March 2001</td>
<td>Invitrogen agrees to sell division housed on 240,000-square-foot site to Human Genome Sciences Inc for $55 million</td>
</tr>
<tr>
<td>October 2002</td>
<td>$42 million agreement to acquire Informax, which developed software that helped to design, manage, and interpret research kits for gene identification and cloning</td>
</tr>
<tr>
<td>July 2003</td>
<td>Acquires Molecular Probes Inc for about $325 million to add drug-discovery products</td>
</tr>
</tbody>
</table>
December 2003   | Acquires BioReliance Corp for $430 million to expand its production ability for biotechnology customers
---|---
February 2005  | Agrees to acquire closely held Dynal Biotech for $381.6 million to gain technology for cell research to speed development of products
July 2005      | US$ 130 acquisition of BioSource International with expertise in functional proteomics. This deal augmented Invitrogen’s growing collection of protein and primary antibody products gained through its earlier acquisitions of Zymed Laboratories and Caltag Laboratories
October 2005   | Announced the acquisitions of Quantum Dot Corporation and the BioPixels(R) business unit of BioCrystal, Ltd. and the early closing of the Biosource International, Inc
June 2008      | Agrees to $6.7 billion in cash and stock to buy Applied Biosystems company that provided most of the equipment for Human Genome Project and created a supplier of machines and materials for university, academic, pharma industry, R&D laboratories, with about $3.5 bn annual sales. The overall company is called Life Technologies.
October 28, 2008 | Buys VisiGen for $20 million to Bolster Its Third-Gen Platform using the expertise and IP of the budding developer of a real-time, single-molecule sequencing-by-synthesis technology to become the leader in a new genomics era
Mid 2010       | Acquisition of computer chip DNA sequencing company Ion Torrent Systems

The acquisition of Quantum Dot Corporation and BioPixel® by Invitrogen Corporation (IVGN) was done in October 2005. Invitrogen Corporation (IVGN), with its Molecular Probes was then a leading life science company providing innovative labeling and detection technologies to support disease research. Quantum Dot Corporation offered novel solutions for biomolecular labeling and detection that employ Quantum Dot (Qdot(R)) semi-conductor nanocrystals. The company also held the broadest intellectual property portfolio in the life science industry for semi-conductor nanocrystals with more than 160 patents and applications, and had built a significant customer base that was using this latest labeling and detection technology. BioPixels(R) provided novel specially coated fluorescent nanocrystals and metal alloys for applications in multicolor labeling, sorting and imaging of cells, lateral flow immunoassays, and fluorescent inks and represented a promising technology for the development of automated assays of complex biological samples. The combination the three companies allowed the creation of smaller, brighter, lower toxicity particles that do not blink.

At around the same time Invitrogen also announced an agreement with Georgia Tech Research Corporation to exclusively license novel "nanocluster" technology. Taken together, the combination of these acquisitions and licenses provided Invitrogen with a significant intellectual property position and robust platform for cutting edge product development. Further the added capability enabled Invitrogen to create new innovative products based on advanced inorganic materials science for molecular detection that enable life science researchers to better visualize and understand cellular processes, molecular
interactions in proteomics, genomics, gene expression, and imaging and other factors essential to diagnosing and treating disease. Terms of the acquisitions and license were not disclosed.

In 2008, Invitrogen virtually doubled its size with the purchase of biotech instrumentation company Applied Biosystems, maker of DNA sequencing and PCR machines and reagents. The company then renamed the overall organization as Life Technologies. The Invitrogen brand and most of the brands acquired still exist on product packaging, although the overall company is called Life Technologies.

In summer 2010, the company acquired the computer chip DNA sequencing company Ion Torrent Systems. In June 2010, Evident Technologies Inc. admitted infringing three patents and agreed to an injunction as part of a settlement in a case brought by Invitrogen Corporation (now known as Life Technologies Corp) over quantum dot semiconductors. The parties stipulated that Evident had infringed and induced infringement of the patent-in-suit, and that the patents' claims were valid in all... Judge Leonard Davis of the U.S. District Court for the Eastern District of Texas signed off on a consent order and permanent injunction in the case. This is an example of strategic enforcement of one’s patent portfolio in business.

Through this history of acquisitions and continued product research and development, Invitrogen / Life Technologies now have over 50,000 products.

Lessons on technology transfer

This case-study provides the following lessons:

- Essential to develop a pragmatic business model with effective networking with stakeholders and client;
- Ensure targeted technology development;
- Strategise technology transfer and commercialisation;
- Organise procurement of funds from diverse sources;
- Explore technology acquisition and consolidation through mergers and acquisitions;
- Make provisions for timely exit from unprofitable activities; and
- Enforcing its intellectual property rights when necessary.

9.7 'Transfer of nanotechnologies from R&D institutions to SMEs in India'


9.7.1 Nano silver suspensions for anti-bacterial textiles

M/s. Resil Chemicals Pvt. Ltd. (Resil), Bangalore, a company that supplies chemical finishes to the textile industry sensed the business opportunity in the use of nanosilver suspensions to manufacture odor-free antibacterial textiles that find applications in hospitals, innerwear, sportswear, socks, active wear,
baby care products, etc. The company collaborated with ARCI to develop a highly stable nano silver suspension for such antibacterial textile applications.

ARCI developed the technology for the lab scale preparation of nano silver suspensions having particle size of 20–50 nm by a chemical route. These suspensions were tested by Resil for anti-bacterial activities and appropriateness for applications in textiles. ARCI scaled up the process to a 15 liters batch size. The process parameters were optimized to obtain consistent quality and physico-chemical properties of the nano suspension, including stability after dilution, packaging and transport. These suspensions demonstrated wash-durable anti-bacterial activity up to 100 washes, at concentrations of 1wt% nano silver suspension in the treatment bath. The nano suspension produced at the ARCI pilot plant was tested by Resil, which demonstrated reproducible results and met all the industry requirements.

ARCI has transferred this technology to M/s Resil Chemicals, on an exclusive license. The pilot plant facility of ARCI was used to demonstrate the process to the company personnel who then prepared one tonne of nano silver suspension in the same facility. The technology development and transfer has been completed by ARCI over a period of two years. Resil has successfully commercialized this technology by establishing an in-house facility to manufacture nano silver suspensions in batches sizes of about 60,000 kgs. The product is marketed by N9 World Technologies (a marketing arm of Resil) under the brand name of “N9 Pure Silver”. Since then the company has been supplying these finishes in India and abroad to several textile/garment manufacturers.

9.7.2 Nanosilver incorporated ceramic candle filters for water disinfection

ARCI developed a technology, incorporating nano silver into ceramic water filter candles to provide safe drinking water in rural areas, where the main sources of water (ponds and canals) are contaminated and existing water purification systems are expensive and unaffordable.

Considering the social need and huge market opportunity, ARCI developed a simple and inexpensive method to synthesize nano silver coated ceramic candle filters. The pores of the candle filters were coated with nano silver. These nano silver coated candle filters were extensively tested for their anti-bacterial activity at two accredited laboratories and a hospital which demonstrated reduction of bacterial concentration from $10^5$ cfu/ml to 0 cfu/ml after filtration. ARCI conducted a life cycle analysis of the candle filters to evaluate silver leaching into the filtered water as a function of usage time and long-term anti-bacterial activity. The amount of silver leaching out of freshly prepared candle filters was carefully monitored and the values for five successive filtrations were noted. The results were found to be well within the WHO limits of 0.1 mg/L for silver in ionic form in drinking water and US EPA limits for colloidal silver intake by humans.

Extensive field trials of these nano silver incorporated candle filters were conducted in 40 villages in collaboration with a Non-Governmental Organization (NGO). The filtered water was tested daily by H$_2$S vial test to ascertain the absence of bacteria after filtration. The data obtained using canal and pond water from one village over a seven month period revealed the total absence of bacteria in the filtered water.
even after storage of 72 hours. Similar data was obtained for tap and tank water.

The candle filters used in the field trials were tested for silver leaching by Inductively Coupled Plasma Optical Emission Spectrometer (ICPOES) analysis. The tests showed that silver leaching out of the used filter met the WHO limits even after one year of usage. Accelerated tests, carried out on fresh candle filters by immersing them in boiled water for 30 minutes, showed release of less than 0.08 ppm of silver (below the WHO prescribed limit) into the water.

As the in-house developed technology has major societal implications, ARCI took a policy decision to transfer the technology on a non-exclusive license basis to entrepreneurs / industry. Technology Development Board (TDB) of the Government of India also decided to extend financial assistance to the companies for commercializing the technology.

The technology was successfully transferred to M/s SBP Aquatech Pvt. Ltd., Hyderabad. The company had set up a plant in Hyderabad with production capacity of 1000 filters per day and the product was marketed under the brand name of PURITECH®.

Although the technology was successfully transferred and the product was commercially launched in the market, the company could not sustain its growth in the market due to several financial, management and marketing problems.

ARCI is continuing to explore opportunities with other entrepreneurs to transfer this technology who would possibly have appropriate financial backup and marketing skills to enable wider accessibility of the innovative product in the country.

**Lessons on technology transfer**

- Publicly funded institutions can meaningfully collaborate with private sector on to develop technologies for unmet needs identified by entrepreneurs / companies.
- Technologies developed for needs identified by the Publicly funded institutions may be transferred to entrepreneurs/ private sector, but care needs to be exercised in the selection of the partners who would commercialise the technology based on their financial back up, technology skills, adaptability, marketing acumen, etc.
- Socially relevant technologies developed by publicly funded institutions need to be transferred on a non-exclusive basis to ensure wide and affordable availability of the developed technology to the society at large.

### 9.8 Bilcare Research, Pune India

Developing technology in house, coupling with knowledge tributaries and commercialization through knowledge distributaries, Bilcare Research is an innovation-led company which started as a solution provider for packaging of sensitive pharmaceutical products with its own R&D and production centre in Pune, India. Over the years it has expanded into diverse operations including intense R&D to provide anti-counterfeit solutions based on nano-tags and associated technologies. It has also created a strategic portfolio of patents around its technologies.
The research model adopted is one of in-house research on identified targeted problems, selectively draw upon external knowledge tributaries (selected commercial vendors working in partnership or even contract to provide targeted solutions, devices developments, etc) for knowledge in-flow, create IP protected solutions to the targeted problems, and strategically combine with a range of knowledge distributaries to commercialise the IP protected technologies in the global market (Figure 19).

Close working with the vendors and other collaborators ensure that technology transfer is complete at the early stage of development to create technology convergence around Nanotag which becomes a knowledge centre for the authentication, registration and compliance technologies with the unique “nano tags” as products, miniaturised devices, relevant software, etc. This in-house knowledge centre which is IP protected then interacts with diverse knowledge distributaries to provide distinct and integrated solutions for diverse identification, authentication, track-n-trace and anti-counterfeit solutions.

Figure 19: Business model of Bilcare Research, Pune, India on technology development and transfer (Figure adapted from Prabuddha Ganguli and Siddharth Jabade, “Nanotechnology Intellectual Property Rights, Research, Design, and Commercialization”, CRC Press USA, July 2012)

An example of this focused working, in January 2008, Bilcare Singapore Pte Ltd a wholly owned subsidiary of Bilcare Limited bought 100% of Singular ID a SME in Singapore engaged in research, development and creation of micro and nanotechnology based novel products and the provider of integrated high technology enterprise brand security system, for a consideration of Singapore $ 19.58 million. Singular ID had in-licensed two patent applications PCT/SG2004/000216 (titled “A method of identifying an object and a tag carrying identification information”) and PCT/SG2005/000012 (titled “Identification tag, object adapted to be identified, and related methods, devices and systems”), from the
Agency for Science Technology and Research (A*STAR), Singapore. Singular ID was quickly integrated into Bilcare Technologies — a division of Bilcare Research which works closely with its knowledge distributors (clients) to tailor its technology to meet specific customer requirements. This is a good example of a university created knowledge that was IP protected found application and became the basis for a development which could not have been done in the university system. It is interesting to note that the present form of the technology that is actually in use in the market place is very different from the technology licensed from A*STAR.

Bilcare Technologies has now successfully developed novel proprietary nonclonable™ nano and micro structured materials based tags (randomly distributed micro and nano particles and cannot be reproduced or duplicated), and proprietary Bilcare specialty handheld/portable readers/scanners and proprietary associated software to authenticate the tags in real time in a fool proof integrated ICT system for security systems including anticounterfeit applications in brand protection and management. This unique technology has been protected by a portfolio of issued patents and patent applications in various countries. This technology significantly enhances security levels with an impregnable personal access control and identity management system that can be adapted for wide ranging applications spanning security, anticounterfeiting, etc. The heart of this system is the tamper-evident nonClonableID™ nanotag capable of seamless and secure integration with any ICT system wherein the proprietary reading device scans the fingerprint and instantly communicates the encrypted information with a secure server through mobility platforms such as GPRS, 3G or Broadband to generate an instant complete authentication report on a mobile or computer using robust web enterprise secured applications and data management at the back-end.

Commercialisation of this technology based on nano materials has involved close collaborative efforts of Bilcare with knowledge tributaries such as developers of the special reading devices and knowledge distributors such as technology integrators to incorporate communication systems into the reading devices and / or integrating the reading device with mobile telephony systems including developers of secured enterprise management systems. Another set of knowledge tributaries have been those having expertise in the incorporation of the nonClonableID™ nanotags into diverse substrates in a robust manner to withstand harsh operating ecosystems and platforms where the nonClonableID™ nanotag retains its unique signature and tamper evident characteristics.

An early large scale commercial application of Bilcare Technology’s nonClonableID™ nanotag was when they were incorporated in the high secure Identity cards adopted by the Delhi Police in India for real time authentication of the individual policeman and centralise the duty planning roster for planning and monitoring. Other commercial applications of this technology are being explored with governments for authentication and secured election systems, anti-counterfeit packaging including e-pedigree and secure track-and-trace increased visibility across the supply chain, patient compliance, clinicom solutions including tackling issues of diversion and theft in the supply chain in pharmaceutical industry, agrochemical industry and high value components & luxury goods.

**Lessons on technology transfer**

- Such a business model based on next generation technologies integrates the desired flexibility and cooperative network in real time with partners (knowledge tributaries and knowledge
distributaries) having diverse expertise to deliver targeted products, processes, and business solutions in the market place.

- Co-development of devices, software, ICT solutions for commercial implementation.
- Ensures phasewise holistic technology transfer with minimum knowledge transfer gaps.
- Continually hybridises strategic management of innovations with IPR protection, IP transactions, confidentiality, benefit sharing arrangement for profitable cash flows for the operating partners, regulatory compliance, including risks and liabilities.
- Ensures phase wise freedom to operate of the developed technologies and solutions thereby avoiding time and cost consuming legal battles in the market place.

9.9 Vista Therapeutics Inc.

Vista Therapeutics founded in 2007 by Spencer Farr and Charles Lieber, Professor of Chemistry at Harvard University got involved in the development of nanowires that would provide a means for continuous and real-time monitoring of multiple biomarkers in blood and urine using biosensors. Applications using functionalised nanowires to monitor and detect on a continuous and dynamic basis antibody-antigen interactions, enzyme substrate interactions and gene expression were also conceived.

Vista signed License Agreements with both Harvard University and Nanosys (a company that was a Harvard University spin out by Prof Charles Lieber in 2001) covering several patents and patent applications related to the use of nanowires for biosensors.

Under the terms of the agreements, Vista secured the exclusive, worldwide rights for the use of nanowires for detection of biomarkers associated with organ or tissue damage, and any form of treatment or therapeutics-associated adverse response(s). In consideration, Harvard and Nanosys received an equity position in Vista, as well as upfront license and downstream royalty payments. This arrangement allowed Vista to commercialise through manufacture and sale of nanowires that are formatted to provide real-time, continuous measurement of blood and urinary biomarkers of organ and tissue injury (Figure 20).
Figure 20: Business model of Vista Therapeutic Inc.

The company has strategic partnerships with MesoSystems/ICX and California-based TEL Venture Inc which is a subsidiary of Tokyo Electron Limited, the world’s second-largest semiconductor equipment maker will help manufacture and distribute the device.

ICx MesoSystems, an ICx company, is a leader in developing and commercializing innovative and practical solutions for bio-threat surveillance and incident response. Founded in 1997, ICx MesoSystems commitment to providing fast, effective, and affordable solutions has led to multiple product successes, including BioCapture®, the most widely used air sampler for bioterrorism response. The linkage of Vista Therapeutics Inc with ICx MesoSystems provides Vista the ready platform for the use of its devices in real working situations.

Vista Therapeutics Inc. received a $1 million investment in from TEL Venture Inc. to build out the technology, which Vista licensed from Harvard University. Vista has already developed a NanoBioSensor to provide real-time snapshots of protein changes in patients, allowing medical personnel to continuously assess an individual’s condition and measure responses to medication in trauma situations. As Tokyo Electron Ltd will manufacture the device, its investments in Vista Therapeutics will rise significantly.

Vista has created a model in which their team of world-class experts in medicine, biotechnology, nanotechnology, engineering, chemistry, and informatics develop cutting-edge technologies in their laboratory, continually collaborate in essential fields with Harvard University, and actively link up with pharmaceutical companies, doctors, and medical researchers for the development and deployment of its
Nano Biosensors. Interestingly such products do not need FDA approval and therefore the time to market reduces significantly. The technologies are protected with strategic patent portfolio.

The management of IPR is of immense significance to Vista Therapeutics as most of the assets are intellectual assets which can be effectively traded as part of business and technology transfer deals.

In June 2010 Active Care Inc and Vista created a strategic relationship to integrate Vista’s nanowire technology in Active Care’s products and services. The terms of the strategic agreement between Vista and Active Care is to make an equity investment in Vista Therapeutics and to pay a fee for the development of products utilizing Vista’s Nano Biosensor technology. As part of the strategic agreement, Active Care will have exclusive use of the Vista Therapeutic’s technology in the elderly market (excluding hospitals, for which Active Care will have the right to acquire an exclusive sublicense) [http://activecare.com/]

**Lessons on technology transfer**

- In breakthrough and disruptive technology related developments, the continual involvement of Star Scientists in the development of the products and supporting their manufacture is an imperative.
- Licensing agreements with the parent Institution has to be facilitating rather than restrictive. In this case Harvard University had well defined and yet a fairly facilitating licensing agreement with Nanosys and then with Vista Therapeutics which helped them to progress their business plans without much hindrance.
- Early linkage with manufacturing companies is also an imperative. In this case Tokyo Electron which is the world’s second-largest semiconductor equipment maker struck an early deal to manufacture and market the product.
- Early linkage with institutions that will provide the platform for large scale testing and use of the manufactured products is also an imperative.
- Creation and management of IP portfolio is of immense significance.

**10 Summary**

A range of business models have been applied in the field of nanotechnology. In the earlier days of nanotechnology, classical models have been used in which the science and concepts took roots in government funded academic institutions before applications were developed followed by independent groups creating markets, searching for commercialization and seeking transfer of technology from academic institutions. Nanotechnology however provided the opportunities for sprouting of start-ups within academic institutions in which evolution of concepts and applications under the same roof shortened the time scale for technology development and creation of possible markets for these developments. The early funding by venture capital and angel funding to such startups became significant. The involvement of large commercial enterprises was in the form of support to small enterprises, startups and spin-offs and in many cases backward / forward integrating / adapting the developed technologies with the existing businesses within the large enterprise and/or creating new
Public–private partnerships and consortia modes of operations in nanotechnology businesses also provide examples in which the time from concepts to commercialization has been significantly compressed due to the creation of facile conduits for transfer of technology. In recent times the funding of nanotechnology by the private sector has shown a sharp rise. Such developments have brought issues related to intellectual property rights to the centre stage. Technology transfer and commercialization in nanotechnology therefore provide challenges to institutions as they not only have to serve as centres of excellence, but also learn to work in complex international knowledge networks, manage transfer of technology with strategic handling of intellectual property rights in a holistic framework of knowledge management. The present chapter illustrates all these features with several institutional examples.

**Suggested readings**


2. Global Perspectives on Technology Transfer and Commercialization, edited by John Sibley Butler, David V. Gibson (2011), [http://books.google.co.in/books?id=VcAvVlSysesC&pg=PA255&lpg=PA255&dq=nanotechnology+technology+transfer&source=bl&ots=V1h5a16N-Y&sig=qdM8ItqtkwBE4h3_UNdjrkKxK9o&hl=en&sa=X&ei=FXqSBgGyL9CxrAfPjoCADQ&ved=0CFoQ6AEwBzgU#v=onepage&q=nanotechnology%20transfer&f=false](http://books.google.co.in/books?id=VcAvVlSysesC&pg=PA255&lpg=PA255&dq=nanotechnology+technology+transfer&source=bl&ots=V1h5a16N-Y&sig=qdM8ItqtkwBE4h3_UNdjrkKxK9o&hl=en&sa=X&ei=FXqSBgGyL9CxrAfPjoCADQ&ved=0CFoQ6AEwBzgU#v=onepage&q=nanotechnology%20transfer&f=false)


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