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# 2K01 Technology Roadmapping for Nanotechnology Innovation

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**Abstract** - A promising strategy to stimulate learning and awareness of business opportunities in nanotechnology is the use of Technology Roadmapping. The paper presents technology roadmapping for nanotechnology innovation which provides a structured means for exploring and communicating the relationships between evolving and developing markets, products and related technologies over time. The intention of this paper is to explore the conceptual nanotech roadmapping framework as well as to increase overall innovativeness.

## INTRODUCTION

Technology Roadmapping links technology, products and markets for innovation. The key strength of TR approach is the time frame, adaptable structure (layers), integration with existing processes, tools and information sources [1]. TR has an anticipating value for businesses which are seen to suffer from frequent changes in product policy caused by lack of time perspective, late start up of long lead and diverging activities, missed market opportunities etc. without roadmapping activities [2].

TR enables plotting a future path, linking applications, technical challenges, and technology development which provides a shared insight and overview of the business in the future. For supporting technology management it helps in developing a consensus about a set of needs and the technologies, in identifying technology gaps that must be filled to meet product performance targets, provides a mechanism in forecasting technology developments in targeted areas, offers a framework in making a plan to visually integrate market, product, technology evolution and coordinate innovation [3, 4]. Innovation with roadmaps coordinate sharing of technologies and collaboration in developing and adopting new technologies. The goal of the TR is to develop innovation strategy. Roadmapping tools also provide a common language for innovation and building bridges between technologists and business managers within corporations, suppliers and customers [5].

A technology roadmap always has a specific theme and usually presents a multi-layered view of that theme consisting by

- a purpose layer (know-why), e.g. business or market objectives
- a delivery layer (know-what), e.g. a product or service deliverable
- a resources layer (know-how), e.g. technology or competency support

Clearly, roadmapping process is an ideal way to plan and to make in an innovation performance management initiative and an important way of improving the business performance. The particular feature is the use of a time-based structured framework. Figure1 provides a general schematic of a multilayered roadmapping process [1].

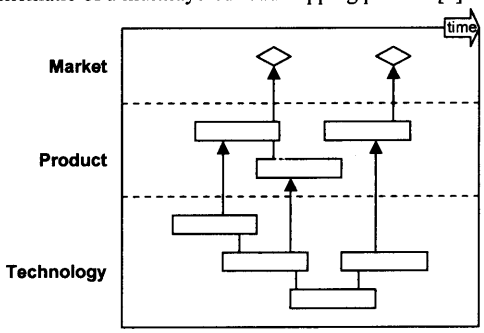


Fig 1. Schematic Technology Roadmap

Nanotechnology as a disruptive technology can lead to next generation (enhanced or new) applications, but it also has the characteristics to create and facilitate next generation (initially unknown) markets [6, 7]. This gives additional dimensions and challenges to innovation processes concerning development and commercialization of nanotechnology. This paper presents a TR strategy as a business opportunity awareness instrument for nanotechnology innovation from a theoretical perspective. TR is also introduced as an instrument of organizational learning to enhance and extend business senses in stimulating nanotechnology business awareness within technology management community.

## TR AS A DRIVER FOR NANOTECHNOLOGY INNOVATION

Nanotech has grasped the attention of government policy makers and corporate planners the world over, leading to a proliferation of industry conferences over the past few years [8]. Nanotechnology is a "cross-industrial" concept and a key area of inter-disciplinary research whose discoveries and inventions are likely to have strong commercial and societal impact. Electronics, materials and coatings, and catalysis are areas where the commercial impact is already very significant, and biotechnology, mechanical technologies, and other areas are likely to have significant growth in the coming years. The inter-disciplinary nature of nanotech and the broad application across industrial sectors presents a big challenge for the public and private sectors. It is hoped that long-term co-operation between the two will lead to breakthroughs in nanotech related research that will lead to the development of entirely new industries and markets in the future. Nanotech is already an enabling technology in the development of such products as cosmetics, sports, automotive, electronics, medical care etc. However, its potential as a truly disruptive technology may take some time to be realized.

In order for nanotech to grow and achieve its perceived potential, it is very important to develop a "TR" in order to attempt to measure the commercial feasibility of nanotech innovation developed in a laboratory. The inter-disciplinary and cross-industrial nature of nanotech, as previously mentioned, will make this task a challenge. Unlike most technologies, nanotech has no real front-end or back-end technology [7]. Rather, it has as many as different front-end technologies and these are mostly complementary. This translates into a challenge to devise key platform nanotechnologies. Therefore, a roadmap is crucial since it becomes important drivers of innovation, represent the co-evolution of technology and markets in regard to increase industry understanding and linkages to enhance cross-organizational communication.

TR represents a powerful technique for supporting technology management which addresses the processes need to maintain a stream of products and services to the market [5]. It deals with all aspects of integrating technological issues into business decision making, and is directly relevant to a number of business processes, including strategy development, innovation, and planning. Figure 2 presents a TR for nanotechnology innovation.

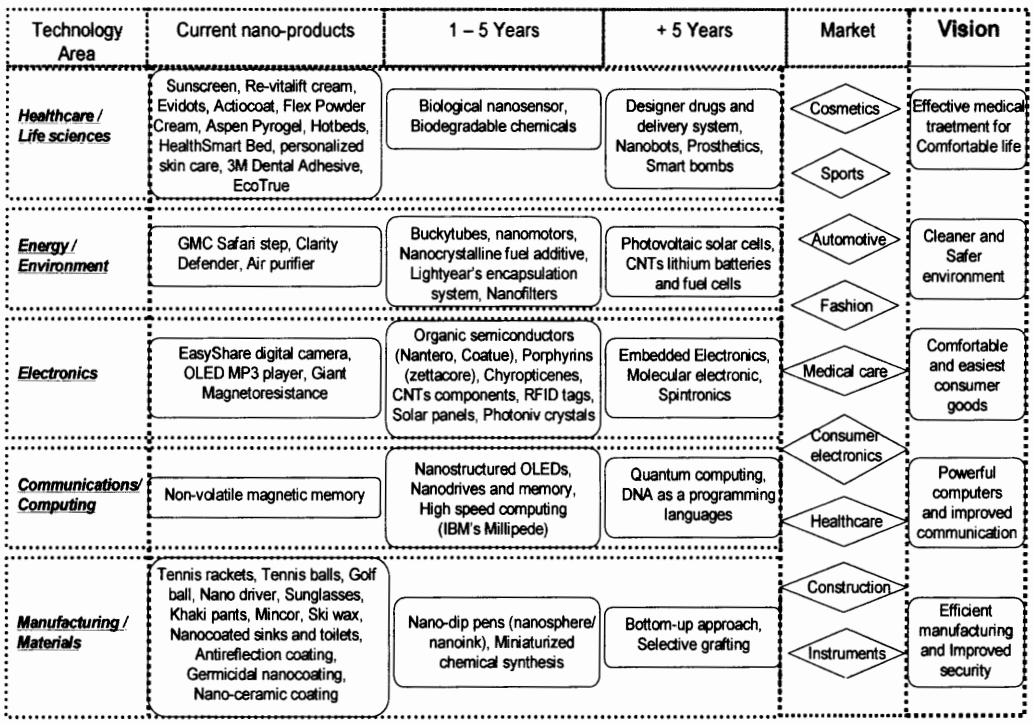


Fig 2. A TR for nanotechnology innovation

This roadmapping represents a visualization of the future integrating the business aspects, market, products and technology/resources, and revealing the time dimension of technological progress and also allows the evolution of each layer to be explored, together with the interlayer dependencies, facilitating the integration of technology into products, services and business system. It indicates that the market is a driver for the product, the technology, and the process. Vice versa, these processes and the technologies enable the products and support the needs of the market. Nanotechnology roadmapping can be seen as bridging two extremes, namely market and technology. Market pull is about the question how to reach a goal and involves planning with a market focus. It has a deterministic and convergent character and is customer driven. Technology push, on the other hand, obviously has a technology focus, is looking for opportunities and is open-ended and divergent. The elements of this roadmapping are also called the "know-why, know-what and know-how" factors.

Herein we developed three layers of technology roadmapping consisting of technologies, products and markets for nanotechnology [figure 2].

- Technologies are about the evolving technology areas linked to nano-products.
- Products come from the combination of technologies and the analysis of markets.
- Markets here means the world nano-market.

## NANOTECHNOLOGY ROADMAPPING FRAMEWORK

To fully take advantage of technology developments, there must have information about the timing of these developments, the resources needed to support the development effort. TR has been identified as a way to accomplish this information capture and presentation. Current technology roadmapping efforts heavily use computer-based graphical techniques to convey information to users and developers and link nano-manufacturing approaches to components, components to product charateristics. The focus here is on TR for nanotechnology innovation utilizing visual displays. A roadmap is not a prediction of future breakthroughs in science or technology, but rather an articulation of requirements to support future technical needs. Nanotechnology roadmapping is a visualization of the future integrating the business aspects based on the generic vision and mission in making the strategy much more specific in time as well as providing a framework toward realizing an immediate insight in the most relevant developments on the business aspects for approximately the near future. A conceptual framework for nanotechnology roadmapping is given in figure 3.

In this conceptual approach towards building the framework successful implementation of nanotechnology innovation requires a strong focus on eight modules or components which provide the breakthroughs needed to extract the full benefits of nanotechnology. Therefore, research must focus on extending and applying Nanotechnology basic research and fundamental knowledge to the development of scaleable, cost-effective nanostructure synthesis; manufacturing processes (scale-up and scale-down); and the integration of nanostructures into final products. Toolkits based on fundamentals are needed for the design and synthesis with unique properties and for estimating the commercial merit in a target application. What material structures are required for a specific application must be developed concurrently with new processing capabilities. Infrastructure also needed to encourage knowledge sharing and implement technology transfer policies to foster commercialization. Greater public and industry awareness as well as education and trained workforce is necessary, because the public often lacks an understanding of emerging technologies and their potential benefits to society and the economy. And after all investing significantly and concurrently in the priority basis R & D of nanotechnology since nanotech infrastructure, enabling resources and cost-effective access to new capabilities at government-funded facilities is a cornerstone of the innovation strategy. Nano-manufacturing processes both top-down and bottom-up approaches are used to synthesize and assemble the nanostructures which are the basis for nano-products with unique characteristics of sophistication and diversification in function [9].

## CONCLUDING REMARKS

This roadmap presents the strategy and R&D priorities for realizing the vision for nanotechnology innovation. It introduces a new, goal-oriented approach to nanotechnology development—one that will provide the capability to design innovation as solutions in a broad range of applications. Navigating the course of research will require significant coordination and collaboration across scientific and technical disciplines. The required level of interdependent, multidisciplinary research constitutes a cultural shift in the way science and technology are presently pursued. To ensure success, a shared commitment is essential from key stakeholders who can provide strategic direction, technical knowledge, business acumen, and financial resources. We could say the roadmap is a strategic guide to investment in nanotechnology innovation with the goal of accelerating commercialization.

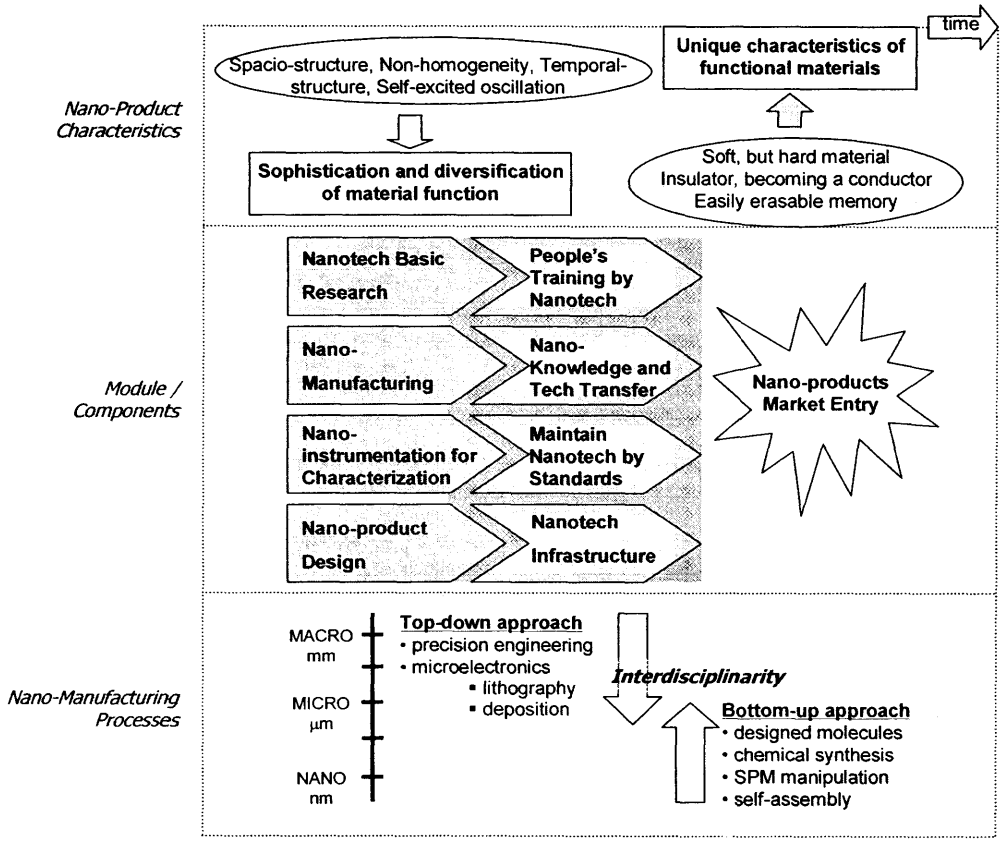


Fig 3. A conceptual framework for nanotechnology roadmapping

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