Micro and nanotechnology commercialization: balance between exploration and exploitation

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ABSTRACT

Innovative materials, components, and systems based on micro and nanotechnologies are recognized as promising growth innovators. The coming years the commercialization of micro and nanotechnology will be extended, but in order to commercialize micro and nanotechnology successfully, besides exploration a parallel focus should be aimed at exploitation. This paper presents in a brief and non-exhaustive manor a theoretical introduction and two company introductions related to exploitation and exploration focus embedded in the innovation development process to commercialize customer-oriented applications. A balanced approach between exploration and exploitation within organizations business, technological, and scientific domain could sharpen micro and nanotechnology companies into sustainable competitive market-driven enterprises.

1. INTRODUCTION

Innovative materials, components, and systems based on micro and nanotechnologies are recognized as promising growth innovators for the years to come. A variety of industries, for instance aerospace, electronics, fashion, instrumentation or life sciences, (will) adopt and embed micro and nanotechnology-based materials, components, and systems. Examples are airbag accelerometers in automobiles, programmable DNA-array for the biotech industry, or organic light-emitting diode technology for portable electronic displays. These technologies have the ability to stimulate innovation processes concerning new or enhanced market-driven products and/or services. Nanotechnology compared with microtechnology is for a substantial part in the research and development phase. Eventually, micro and nanotechnologies will merge to a technology cluster offering complete range of functionalities in information, energy, construction, surfaces, biomedical, and catalysis domains.

From a macro economic growth perspective it is important to facilitate the ability to exploit the innovative and added value of micro and nanotechnology into applications. This means that micro and nanotechnology knowledge generated in knowledge intensive organizations needs to be transformed and/or transferred in order to design, produce, sell, adopt and

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implement customer-oriented applications. This trajectory should be an interactive process of value creation and realization, including serious attention for the societal theme of responsible innovation. A complete palette of competencies and actor interactions between knowledge institutions, companies, and others (e.g. interest groups, industry organizations, and governmental organizations) are necessary to fully walk through this value adding process.

This paper discusses in a brief and non-exhaustive manor from theoretical and practical perspectives the exploitation and exploration aspects related to the innovation development process of micro and nanotechnology-based applications. First, the paper describes the innovation development process. Next, exploitation and exploration with respect to several domains are introduced. Finally, exploitation and exploration are linked to two companies. The conclusion focuses on the outline presented.

2. INNOVATION DEVELOPMENT PROCESS

The innovation development process on (inter)organizational level from research & development to (high-tech) invention to market-ready applications is not linear, but a cyclic process with parallel and iterative loops (e.g. Tidd et al., 2001). With respect to enabling technologies like micro and nanotechnology, Walsh (2004) presents an innovation process related infrastructure model that points out the dynamics between technology-push side and market-pull side. Micro and nanotechnology as enabling technologies can lead to next generation (enhanced or new) applications, but also has the characteristics to create and facilitate next generation (initially unknown) markets. Referring to Christensen (1997), this gives additional dimensions and challenges to innovation processes concerning development and commercialization of micro and nanotechnology. From technological point of view, the up-scaling from laboratory production to full production is a fundamental challenge. Example is the purity level of specific single wall carbon nanotubes production.

In successful technology commercialization knowledge plays a key role; the innovation development process needs to incorporate knowledge from a variety of disciplines and sources. The commercialization process starts off with the seizure or creation of the needed scientific, technological, and market knowledge. Next, this knowledge is integrated, combined and applied to generate commercially viable micro or nanotechnology-based applications. Nowadays, due to intense market dynamics and complex engineering trajectories related to micro and nanotechnology, this process needs to be an open process in order to be flexible and adaptable to interact with (knowledge oriented) processes of external actors like customers, partners, suppliers and knowledge institutions. Jolly (1997) identifies five key subprocesses in the technology commercialization process: imagining, incubating, demonstrating, promoting, and sustaining. Each of the subprocesses involves solving problems and taking challenges of scientific, technological and/or business nature and requires a multifunctional approach.

3. BALANCE BETWEEN EXPLORATION AND EXPLOITATION

In terms of March (1991), maintaining an appropriate balance between exploration and exploitation is a primary factor in organization survival and prosperity. March links exploration to terms like search, variation, risk taking, experimentation, flexibility, discovery; exploitation includes things such as refinement, production, efficiency, selection, implementation, execution. The essence of exploitation is the refinement and extension of existing competencies, technologies and paradigms. Its returns are positive, proximate, and predictable. Experimentation of new alternatives is the essence of exploration and its returns are uncertain, distant, and often negative. In order to commercialize innovative materials,

components, and systems based on micro and nanotechnologies successfully in time, besides exploration, a parallel focus should be aimed at exploitation.

Looking at the research and development activities on micro and nanotechnology within organizations (e.g. universities and laboratories of companies), they are strongly related to exploration. An open culture of discovery and creativity is desirable to foster new fundamental insight via triggering experiments. On the other hand, explorative mentality is also desirable within organization's business domain, in order to let marketers define and tackle new and promising markets. Scenario method form an instrument to support organizations with a broader focus on micro and nanotechnology business opportunities (Knol, 2004). Exploitative scientific and technological activities focus substantially on the engineering and production up-scaling aspects of science-based customer-oriented materials, components, or systems. Exploitative business attitude of micro and nanotechnology oriented companies is essential to actually serve customers with value adding applications and to generate cash-flows.

4. EXPLORATION AND EXPLOITATION FOCUS WITHIN TWO COMPANIES

Two companies and their innovation approach in relation with exploration and exploitation are briefly discussed. On a general level DSM's venturing and business development approach is introduced. The nanotechnology company Mo6 is introduced on a more specific level.

DSM Venturing & Business Development

DSM - a multinational with approximately 25,000 employees world-wide and annual sales of approximately Euro 8 billion (www.dsm.com) - creates innovative products that help improve the quality of life. DSM transformed from a petro-chemicals bulk supplier to a supplier of specialized products in the field of industrial chemicals, performance materials and life sciences.

DSM's business unit Venturing & Business Development is specifically aimed at commercial oriented innovation development processes of DSM. This unit contributes the value creation process of DSM through innovative initiatives via license in, license out, spin in, spin out, acquire, and divest. Examples of innovative initiatives are projects on advanced coatings (e.g. anti-relflective coatings and hydrophobic coatings) and size-selective nanofiltration, start-ups like Micabs (laser marking technology), and grown-ups like is DSM Solutech (producer of the specialty film Solupor). The approach shows high-level flexibility to balance exploitation and exploration within DSM's scientific, technological, and business domains.

Mo6

Last decade, the Slovenian Jozef Stefan Institute performed breakthrough research in the field of transition metal chalcogenide nano-materials like MoS_2 and $MoS_2I_{1/3}$ nanotubes. These nano-materials show properties very similar to single wall carbon nanotubes (e.g. Baughman et al. 2002; Vrbanic et al., 2004), but from a production point of view they require - just like carbon nanotubes - delicate production processes. Lately, the institute discovered and patented the nano-material $Mo_6S_3I_6$; these transition metal chalcogenide nanotubes can be synthesised in a single step. It is composed of identical small-diameter nanowires, weakly bound in bundles, which can be handled in the same way as carbon nanotubes. The $Mo_6S_3I_6$ material exhibit excellent field emission properties, a large capacity for lithium storage, great mechanical strength, a low shear modulus implying good tribological properties, and large paramagnetic susceptibility characteristics.

The small and independent company Mo6 (www.mo6.com) closed a deal with the Slovenian institute to own the rights with respect to production and commercialization of the $Mo_6S_3I_6$ nano-material. The business model of Mo6 is focused on the commercialization of the patented $Mo_6S_3I_6$ technology via licenses and/or royalties. Typical customers are those who orient intensively on carbon nanotubes properties usage in specific applications and could use the nano-material as a value adding substitute for carbon nanotubes in their applications.

With respect to exploitation and exploration focus (explicit or implicit) within the business, technological, and scientific domains of the company, a qualitative interview-based overview is constructed (see table 1). Summarizing, the commercial character of Mo6 can be seen within all three domains: substantial part of the activities within all domains have an exploitative character to support business development actions to interact with and to close deals with specific targeted prospects. Additional explorative actions are less relevant for the moment: a scientific knowledge base is buildup, scientific research is naturally ongoing within the Slovenian institute and new business development activities on non carbon nanotubes-oriented segments are currently deliberately out-of-scope. Due to the current business stage of Mo6, it is clear that the balance between exploitation and exploration is for the moment in favor for exploitative activities.

	Business domain	Technology domain	Science domain
Exploitation focus	Mo6 is primarily focused on prospects who are interested in the nano-material as a value adding substitute for carbon nanotubes in specific applications, due to the characteristics of the nano-material, the single step production method, the purity level and usage possibility of prospects' carbon nanotubes knowledge base. More specific, targeted prospects are primarily operating in the field of carbon nanotubes-based field emission devices (displays), semiconductors (chips), and sensors (water-based solutions). Competencies in the field of business development and business contracts are available within the company.	Based on specific prospect questions, Mo6 and/or the related Slovenian institute do perform minor technology analysis related to nano-material usage in certain applications and/or production up-scaling of the nano-material. Most of the technology aspects are researched by potential customers, due to the fact that they have (or should have) the key knowledge concerning the application, carbon nanotubes usage, and application production. Mo6 do want to perform independently minor exploitative technology research via their own laboratory facilities. Competencies in the field of exploitative technology research are to be extended within the company.	The Mo6 related Slovenian institute performs exploitative scientific research on the nano-material. New fundamental insights on characteristics are available for the company Mo6. Mo6, the institute and (temporary) involved Slovenian university departments do have the ability to make agreements on laboratory usage to perform prospect focused scientific research on specific characteristics of the nano-material. Mo6 do want to perform independently minor exploitative scientific research via their own laboratory facilities. Competencies in the field of commercial-oriented scientific research are available within the company.
Exploration focus	Mo6 is not focused on nano-material license exploitation in segments other than the specific defined carbon nanotubes-based applications segments (see above). Serving other segments requires huge investments in fundamental, application-oriented, and production-oriented research, with as-for-now relative unknown chances of commercial success.	Mo6 is primarily focused on license exploitation in specific segments. Due to this business model, the company and the related Slovenian institute are not specific focused on explorative technology aspects related to nano-material usage in a broad range of applications or production up-scaling processes. Therefore, competencies in the field of nanotubes-based application design, analysis and engineering are not needed and not (extensive) available within the company.	The Slovenian institute performs naturally ongoing explorative scientific research to further discover and understand characteristics of the nano-material. Mo6 and the institute do have the ability to make agreements on the publication level and timing with respect to commercial sensitive scientific information. Competencies in the field of explorative scientific research are available within the company.

Table 1: Qualitative overview of exploitation and exploration focus within Mo6

5. CONCLUSION

Commercialization of micro and nanotechnology-based materials, components, and systems puts pressure on the innovation development process in order to balance exploration and exploitation. From scientific and technological point of view an explorative focus is desirable to discover and understand new phenomena. On the other hand, an exploitation attitude linked to scientific and technological activities is crucial to funnel knowledge in order to define and develop applications. With respect to the organizations' business domain, exploitation is the key element to serve customers with micro and nanotechnology-based applications and to generate cash flows. An explorative business mindset is essential to trigger and tackle new markets. A business model and business stage related balanced approach between exploration and exploitation within organizations' business, technological, and scientific domain is important to sharpen micro and nanotechnology companies into sustainable competitive market-driven enterprises.

REFERENCES

Baughman, R.H., Zakhidov, A.A. and Heer, W.A. de (2002), Carbon nanotubes - The route toward applications, *Science*, Vol. 297, pp. 787 - 792.

Christensen, C.M. (1997), *The innovator's dilemma: When new technologies cause great firms to fail,* Harvard Business School Press, Boston, MA.

Jolly, V. (1997), *Commercializing new technologies: Getting from mind to market*, Harvard Business School Press, Boston, Massachusetts.

Knol, W.H.C. (2004), Nanotechnology and business opportunities: Scenarios as awareness instrument, presented paper published in the proceedings of the 12th international conference High Tech Small Firms, Enschede, 24 - 25 May, pp. 609 - 621.

March, J.G. (1991), Exploration and exploitation in organizational learning, *Organizational Science*, Vol. 2 (1), pp. 71 - 87.

Tidd, J., Bessant, J. and Pavitt, K. (2001), *Management innovation: Integrating technological, market and organizational change*, Second edition, John Wiley & Sons Ltd. Chichester.

Vrbanic, D., Remskar, M., Jesih, A. Mrzel, A., Umek, P., Ponikvar, M., Jancar, B., Meden, A., Novosel, B., Pejovnik, S., Venturini, P., Coleman, J. and Mihailovic, D. (2004), Air-stable monodispersed $Mo_6S_3I_6$ nanowires, *Nanotechnology*, Vol. 15, pp. 635 - 638.

Walsh, S.T. (2004), Roadmapping a disruptive technology: A case study; the emerging microsystems and top-down nanosystems industry, *Technological Forecasting & Social Change*, Vol. 71, pp. 161 - 185.