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Technology management and innovation strategies in the development of smart textiles

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Abstract: This chapter presents an overview of smart-textile market economics. It discusses fundamentals of technology and innovation management in relation to the smart-textile community, especially in the environment of small and medium enterprises (SMEs). A few smart-textile market-related business models are discussed, showing the structure of the market (definitions, products, applications) and its dynamics (growth, trends, perspectives). Furthermore, a short overview of key challenges in the smart-textile business is presented.

Key words: smart-textile markets, technology and innovation management, smart-textile vertical and horizontal business models.

13.1 Introduction

This chapter presents an overview of the economics of the smart-textile market. It discusses fundamentals of technology and innovation management in relation to the smart-textile community, especially in the small and medium enterprise (SME) environment. A few smart-textile market-related business models are discussed, showing the structure of the market (definitions, products, applications) and its dynamics (growth, trends, perspectives). Furthermore, a short overview of key challenges in the smart-textile business is presented.

In Section 13.2, the fundamentals of technology management and marketing are reviewed, focusing on strategies and methods for new technologies in the SME environment of early markets. Furthermore, various innovation management approaches are discussed. Practical tips, based on the experience of innovation managers, as well as the authors themselves, are also presented. In Section 13.3, an overview of the market and its structure, as well as key trends and perspectives, are described. Then key challenges in smart-textile business are presented. In the last section, the authors outline the market structure and characterize the current smart-textile industry business models and provide closing conclusions.

The authors believe that the industrial structure combining electronics and textile worlds and the early market conditions create a very challenging non-mature competitive landscape, where companies are looking for strategic positioning in the technology and application segment. The understanding of the

drivers, challenges and market requirements for the specific segments should lead to clear value propositions in the delivery of both the competitive horizontal technologies and vertical applications. Different levels of maturity in both technology and solution segments should be taken into account while defining strategy and market approach. Strategic cooperations and alliances for solutions in specific segments will speed up the market innovation process and availability of market-ready products.

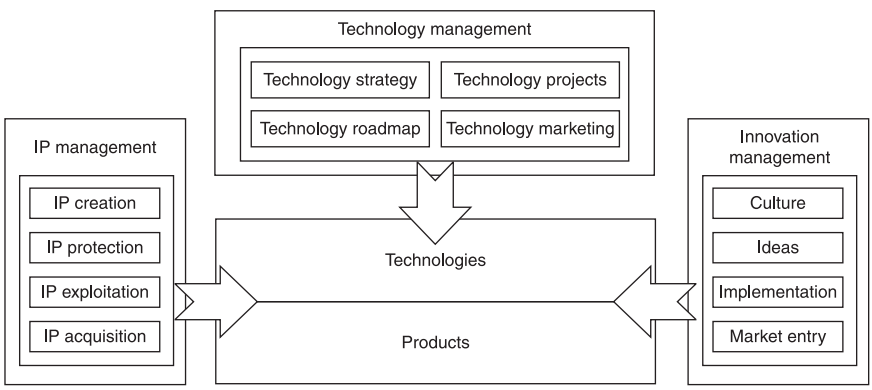
13.2 Fundamentals of innovation, technology and intellectual property management

We have found many different definitions and approaches to technology management, marketing and innovation management but no clear, unique and commonly-accepted views on the scope, boundaries and interfaces in the scientific literature (Fig. 13.1). As those of us working in SMEs have probably no time to read thousands of pages on different theories and views, we propose to concentrate on commonly understood pragmatic and clear definitions and strategies.

For us, these definitions are:

- Innovation management turns inventions into new products and commercial successes.
- Technology management builds the base for product development and maintenance and exploits the technological assets.
- Intellectual Property (IP) management protects the company's valuable assets.

In general, management means planning, organizing, implementing and controlling activities and in this manner can be applied to any discipline.



13.1 Major tasks of technology, innovation and IP management. (Source: Interactive Wear AG.)

13.2.1 Technology management

The major goal and task of technology management is to ensure that the company has the right technology base to provide competitive products. Technologies themselves can also represent a significant source of revenues. Having the right technology at the right time is the major competitive advantage for companies. However, the greater the progress of the new technology, the larger the gap for companies who have missed providing the appropriate technology base.

In many cases, a combination of technologies (e.g. smart phone = cell phone + PDA + wireless internet access + app market or YouTube = internet + cheap digital camera and camcorder) has made a real change in the business world and in our lives.

The smart-textile community is looking for answers on how the marriage between electronics and textile can deliver value to the products and how to design and market these products successfully. In addition to control and computation, electronics add actuating and sensing features to textile products; however, new organic materials are providing new possibilities for design and production of electronic components and products. There is a large potential on functions and possibilities on the one hand, but also some serious technological challenges on the other.

In this chapter, we will discuss the tasks of technology management and provide some ideas on strategies for SMEs.

Terms and definitions

In 1972, Rosenberg defined technology as tools, devices and knowledge that mediate between inputs and outputs and/or that create new products or services (Tushmann and Anderson, 1986). In 1987, the US National Research Council defined technology management as: 'Management of technology links engineering, science, and management disciplines to plan, develop, and implement *technological* capabilities to shape and accomplish the strategic and operational objectives of an organization.' Furthermore, the council listed the following key elements of industrial practice of technology management:

- the identification and evaluation of technological options;
- management of R&D itself, including determining project feasibility;
- integration of technology into the company's overall operations;
- implementation of new technologies in a product and/or process; and
- obsolescence and replacement.

In simple terms, technology management means to create and utilize the technological advantage for the company. The importance of appropriate technology management can especially be seen when, during technological changes, new companies grow very quickly and some already well-established

companies get in trouble. 'In high wage countries, both the competivity of firms and more general welfare depend critically on the ability to keep up in innovative products and processes and in the underlying technologies' (Pavitt, 1990).

Technology management key tasks

Key deliveries of technology management to the organization are evaluation and protection of the value of the technology portfolio, definition of future needs (roadmap), roadmap implementation projects, and technology marketing programs. The technology management activities can be structured as follows:

Technology strategy

The goal of technology strategy is to define the role and value of technology in the company. How essential this understanding can be for the future of the company can be shown in many examples of strategic failures in judging new technologies. As a major producer of radios underestimated the advantages of the new transistor technology in comparison to vacuum tubes, Sony was able to gain world leadership in only eight years. At the beginning of the current century, a company called VIZIO, Inc. founded in 2002 by William Wang, with the idea that everyone deserves to own the latest technology, achieved first position in US sales of LCD-HDTVs in the first quarter of 2012, beating companies such as Samsung, LG Electronics and Sony.

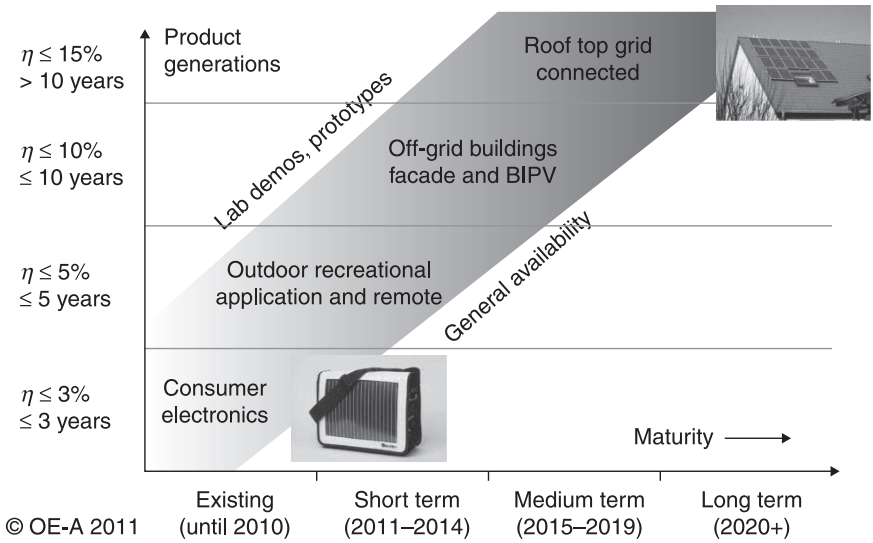
The major goal is to understand how well your technology strategy supports the business strategy of your company. Technology strategy should provide a sound base for innovations. Major tasks are technology assessment, technology evaluation, IP management and the organizational set-up.

Helpful questions:

- *Strategic match*: How well does my current Technology Portfolio support the business strategy (are critical technological requirements clear)?
- *Competitive value*: Is the technology state-of-the-art or better? Is it unique and protected? How can we profit; protect, share or sell?
- *Organizational set-up and management quality*: Do we have a strategic technology plan? Who takes care of it?

Technology forecasting and road mapping

A technology roadmap is a forecasting and planning tool for the strategic development and application of new technologies. The major goal of the technology roadmap is to identify critical technologies and to provide a framework for coordination of future developments. In the smart-textile environment, there are some very helpful general roadmaps, such as 'A roadmap on smart textiles' (Schwarz *et al*., 2010), a valuable general input for the smart-textiles community.



13.2 Organic photovoltaics roadmap.

Another good example of a smart-textile roadmap can be found in the overall roadmap for organic and printed electronics from the Organic Electronics Association OE-A (Hecker, 2011).

You will find many frameworks and examples available on the internet. The technology roadmap does not need to be complicated – it should visualize the plans. The easier it is to understand why and when we plan to implement our technology programs, the better is the basis for the next steps. The technology roadmap is usually more driven by need than by solution. For example, in our current roadmap, we address the major technology gaps in the process of development of smart-textile products. The major requirements are in the area of connectivity, housing and textile actuators technologies.

We find it very helpful to include the market and application focus in the technology roadmap. You can find an example above in the Roadmap for Organic Photovoltaics (Fig. 13.2). There are technology parameters on the left (efficiency and durability of photovoltaic modules), the time schedule on the right, and the applications in the middle.

Helpful questions:

- *Requirements match*: How well does the technology roadmap build the base to satisfy the market requirements? Does it address the needs of my organization to provide innovative products? How well does it support my product or solution roadmap?
- *Value check*: If we succeed with the implementation, how will it influence our market position?

- *Feasibility check*: Are resources available for implementation? What are the major risks and challenges?

Technology projects implementation

Implementing the defined roadmap means to plan and implement actions in technology development and/or acquisition. It has to be decided how the projects have to be implemented on our own, within a community, or by purchasing the development services or technology.

Technology projects are usually both exciting and risky. In comparison to projects for product development, they often include a higher level of uncertainty and new options. This can lead to more failures, especially if the risks and possible obstacles have been underestimated in the planning phase. We have gained valuable experience working with short feasibility studies before we started the implementation. We have focused on one side on major features to be delivered and, on the other, on key challenges to be addressed. We generally use feasibility studies to test possible options. As a result, within a short time we are able to exclude unattractive options (materials, methods, etc.) via testing prototypes or simulating the desired behavior. For example, domestic washing machines are sufficient tools as a first step to prove the feasibility of mechanical robustness of wearable electronics and conductive textile components.

Helpful questions:

- *Complexity level*: Are multiple organizations involved? Is my role and outcome clear?
- *Risk level*: What if the project task is not delivering the expected results? Is there a critical part of the development to be addressed separately?
- *Industrialization check*: Is the result stable, and ready to be implemented (produced) within the expected price range?
- *Project set-up*: Is the project properly prepared? Is a controlling schedule in place?

Technology marketing

There are some regional differences in defining and addressing technology marketing. The definition and understanding of the role of technology marketing has a major impact on the approach and the methods. Let us have a brief look at the differences.

Technology marketing in Europe is often related to marketing strategies of ‘high-tech’ products, while some American technology marketing centers focus on transferring the investment in research into commercial products and others emphasize the early-stage marketing strategies. According to the chapter on ‘Technology Marketing’ on the web pages of the Asian and Pacific Center for

Transfer of Technology (APCTT, 2012), technology marketing is 'a process involving the planning and executing of conceptualizing, pricing, distribution, and promotion of technology so that exchange activity can take place.' In technology marketing, process of the technology is seen as a product to be sold.

Behind all the disparities there are major common targets: how to efficiently transfer and transact technology, how to successfully transfer the technology into commercial products, how to market new high-tech products and how to address early markets.

For companies dealing with new technologies in early markets, it is very helpful to understand and implement marketing strategies in the difficult 'crossing the chasm' situation. Crossing the chasm means to overcome the gap between the early adopters of any new technology and the mainstream customers. In his famous book, Geoffrey A. Moore analyzes the specifics of marketing high tech products during the early phase of innovation (Moore, 1991). He has extended Everett Rogers' 'diffusion of innovation model' from 1962. His findings in this book and in his sequel, *Inside the Tornado* (Moore, 1995), has had a significant and lasting impact on high tech entrepreneurship.

13.2.2 Intellectual property management

Intellectual property (IP) is not easy to understand. Very helpful, especially to SMEs, is the World Intellectual Property Organization (WIPO, 2012), one of the 17 specialized agencies of the United Nations. To many, IP is a rather obscure legal concept that can only be properly understood and applied by those who are specially trained. You may be asking yourself why any SME and, more so, your SME, should pay attention to IP, or what benefits your SME could possibly draw from its use (WIPO, 2012).

According to WIPO, IP refers to creations of the mind: inventions, literary and artistic works, and symbols, names, images, and designs used in commerce. IP management comprises all methods and tools for protection and marketing of the company's proprietary know-how.

In comparison to large companies, many SMEs under-utilize the IP system. The reasons are mainly lack of awareness of the usefulness of the IP system combined with perceived high costs and complexity, as well as lack of easily accessible training and fast entry support. Sometimes IP management is limited in perception to patents, and the opportunities working with trade secrets are not evaluated. In some other cases, there is the question of how to start IP activities. To summarize, there is often uncertainty whether the investment in IP management will really pay-off. This question can be answered only case by case. Above all, however, this question must be asked and there must be enough knowledge about IP management to enable a qualified answer.

IP management can deliver a significant value to your SME. Properly done, IP management is the key to success of any innovation strategy. It can increase the

value of your IP, support avoidance of unnecessary R&D spending, generate income through licensing, and reduce the risk associated with third-party IP. IP rights can enhance the value of your enterprise for financial reasons or in the event of a sale or a merger. In September 2008, adidas International, Inc. acquired Textronics, Inc. for a purchase price of US$ 35 million. Textronics, Inc. was a specialist in the development of wearable sensors for use in fitness and health monitoring. The net assets of Textronics, according to adidas publications (adidas Group Annual Report 2009), were solely trademarks and other intangible assets valued at US $9 million. In addition, adidas paid US$ 26 million goodwill arising on acquisition; a very high valuation of the trademarks, patents and know-how of the small smart-textile company.

The importance and choice of the IP system depends on the sector of the company's operations; for example, for science-based companies (e.g. electronics), a formal IP rights system is important. Many SMEs may choose informal IP protection methods, such as contracts, confidentiality agreements, circulation of tasks, etc. The formal and informal protection can be used in a complementary fashion during the lifecycle of a product or service.

How to start: first, after creating awareness for IP management within the company, it is essential to evaluate the strengths and weaknesses of the existing IP implementation. There are good introductions on IP management, both on WIPO and EU web pages. There are also helpful studies, tools and methods that every SME can use to understand how to get started and how to implement or improve the IP management within the company's strategy.

13.2.3 Innovation management

'Nothing is so embarrassing as watching someone do something that you said could not be done'. – Sam Ewing. Is there a magic formula to create and implement innovative ideas? In other words, is there an innovation management strategy that, regardless of the manufacturing organization size, market, and business cycle orientation, provides an innovative portfolio and process landscape? Although we have not found a silver bullet, at least our search for the answer has provided a number of useful strategies and techniques for managing innovation for SMEs.

SMEs rarely direct large research departments and central offices to execute significant innovation management tasks. Some are new businesses and just an innovative idea is the basis of their existence. The others have a more or less stable business and want to invest in new applications, products or processes. Examples are narrow-weaving companies, as well as embroidery companies who integrate metallic or carbon threads into their products. For example, Forster Rohner AG, a Swiss-based company with traditional embroidery products for more than 100 years, began in 2009 with activities in technical embroideries. In 2010, a first spinout, the Bionic Composite Technologies AG, was founded. While this

company is ramping up first industrial productions with optimized processes for small- and medium-sized composite products, Forster Rohner, in 2012 created the business unit 'Textile Innovations'. The multi-disciplinary R&D innovation team identifies potential applications and together with partners in research and commercialization works on processes and solutions for volume production. Dr Jan Zimmermann, Project Manager of Technical Textiles, stated that 'Innovation should be part of the genetic code of an enterprise and has to be in line with the corporate strategy and management to be successful'. However, all SMEs want to take advantage of their best ideas and succeed in business with the changing market conditions and customer requirements.

In our search to find the best pragmatic and actionable strategies, we have studied the innovation management books and articles, analyzed innovation portals, listened to interesting lectures on innovation (Garry Kasparov, Matthias Horx) and have discussed the strategies with colleagues from research institutes and SMEs.

Innovation management terms and definitions

There are many definitions and views of innovation in science. Starting with French sociologist Gabriel Tarde in the 1890s, generations of scientists and managers have contributed to the picture of innovation that we have today. We have chosen the definition quoted by Paul Trott in his comprehensive work, *Innovation Management and New Product Development*: 'Invention, then, is the conception of the idea, whereas innovation is the subsequent translation of the invention into the economy' (US Dept of Commerce, 1967; Trott, 1998). The following simple equation helps to show the relationship between the two terms:

> Innovation = theoretical conception + technical invention + commercial exploitation (Trott, 1998).

We can simply say that invention is a new idea and innovation is the commercialization of the invention itself. Or, as Theodore Levitt said, 'Creativity is thinking up new things. Innovation is doing new things'. Innovation management is a set of tools and processes to ensure the ability of the organization to create and market innovative products and services. Furthermore, you have probably had some ideas about the differences between innovation management, new product development and technology management.

Innovation management supports both technology and product management in their abilities to develop and deliver to the market an innovative and accepted portfolio of products and technologies to build a sustainable value proposition in the marketplace. In this chapter, we describe how innovation management fulfills this task. We focus on pragmatic methods and models to help us set 'the conditions to be in place to ensure that the organization as a whole is given the opportunity to develop new products' (Trott, 1998).

Innovation management key tasks

There are thousands of pages written on innovation management theories, approaches, tools and methods. Despite the large amount of books, articles and portals, we have the impression that innovation management is still under development and there is no dominant method or approach. On the other hand, there are some common elements that we can rely on to support us in our innovation work.

In general, we propose to ask ourselves two essential questions about the innovation culture:

- Does our company's culture support new ideas and concepts?
- Do we have the right habits in place to make them successful?

If your company's culture is both open to new ideas and disciplined enough to implement them successfully, you are in the best starting position. If you are more creative than disciplined (and probably some projects were not successful), you will concentrate on finding a solution and work on realization methods. If you are very process-orientated and controlled, but may not be happy to find more innovative solutions in the market, you will probably be willing to think about open innovation or creativity techniques. As in sports, we should concentrate on our strengths and try to find a solution for our weaknesses.

Thomas Alva Edison (1876–1881) was one of the key personalities for an innovative culture. He managed to create a favorable space and climate for innovation. He was not only first in creating professional R&D labs in Menlo Park, he also managed to establish an informal environment with no rules for work but with easy communication between team members, great infrastructure and lots of fun. His team worked long hours (despite or because of the lack of a working hour clock) and produced substantial results. Thomas Edison said, 'I never did a day's work in my life, it was all fun'.

Creativity

Creativity is the source for future success. There are methods and tools supporting the organization in generating and collecting new ideas. Examples are very many creativity techniques such as brainstorming, associations, creative problem solving, improvisation, etc., which boost the generation of ideas. Very often companies concentrate on brainstorming and do not try to find new approaches. As the majority of techniques are not complicated to implement, we encourage trying some new ones, especially if brainstorming does not bring the expected results.

There is a huge potential in interaction with universities, communities, freelancers and others to access new sources of ideas. 'Not invented here' mentality is still very often an obstacle to creativity.

One of the most promising areas to generate innovations is the investment into a deep understanding of the requirements of the targeted customers:

> Innovation is fostered by information gathered from new connections; from insights gained by journeys into other disciplines or places; from active, collegial networks and fluid, open boundaries. Innovation arises from ongoing circles of exchange, where information is not just accumulated or stored, but created. Knowledge is generated anew from connections that weren't there before. – Margaret J Wheatley

How can smart-textile companies understand the requirements of their targeted customers? It is often not even clear who the potential customers are and what kind of applications can be targeted. We believe that these questions need to be discussed and to be tackled from the very beginning. We think it is worth looking for innovative customers early-adopters – who are willing to take risks in implementing new technologies. It is important to understand the advantages of smart-textile components in their solutions and applications. We work a lot with prototypes to visualize the application to the customer and create the basis for evaluation. We look at the smart-textile blogs and also follow discussions of user groups for end-users of our systems to anticipate feedback.

Sometimes ideas come and then go if we do not collect and keep them. We find it very important and helpful to have a 'treasure chest', where we can save our ideas and have them ready for later evaluation and decisions.

Feasibility

Right or wrong choices define the future value of our work. When we have an idea, it is time to challenge it and consider whether it is valuable enough and whether its implementation is practicable. This is depending on the level of innovation, sometimes a tricky task. You all know the different assumptions of the past that have lead companies not to follow the development:

- 'What use could the company make of an electric toy?' – Western Union, when it turned down rights to the telephone in 1878.
- 'Who the hell wants to hear actors talk?' – Harry M Warner, Warner Bros Pictures, 1927.
- 'Video won't be able to hold on to any market it captures after the first six months. People will soon get tired of staring at a plywood box every night.' – Daryl F Zanuck, 20th Century Fox, commenting on television in 1946.

As Einstein (*On Science*) said 'Imagination is more important than knowledge'. The majority of innovative ideas are not so difficult to imagine and evaluate, as the above-mentioned disruptive technologies. We can usually improve the quality of our choice by answering key questions on the innovation potential and practicability of a particular innovation:

- Is the idea desirable for the users? Why and what kind of product/technology will be replaced?
- Is it possible to implement? What are the major risks in the implementation?
- Is it viable in the marketplace? Can the product be delivered at a reasonable price? Are sales channels in place?

In this early phase, we used to working with feasibility frameworks, focusing on understanding the product advantages, potential and industrialization effort, as well as innovation level. We have gained valuable experiences working with demonstrators and looking at the product from the overall application perspective. We evaluate technological feasibility as well as economic aspects. For example, if you are working on an innovative heating material, but do not consider how to handle interconnects in a large-scale production, you will probably face delivery problems.

There are many tools – for example, Decision Memo, Pros and Cons or Nominal Group Technique – supporting the decision process; no one will guarantee success but almost all will give you valuable support for the evaluation and help you to limit the risks.

Implementation

The implementation phase is the basis for the future success of the innovation. Most of us tend to be very optimistic at the beginning of any project. However, as the project progresses, we realize that there are new issues to solve with no time left to do so.

How does the realization process of innovations differ from the standard development? What are the critical factors to be taken into account for the implementation? The focus of the development process depends on the innovation level:

- product development process for incremental and routine innovation;
- new product development + technology management + IP management for radical and improvement innovation.

Innovation level, incremental or routine innovation, does not usually generate big challenges and surprises. For example, we have continuously improved the method of integrating small electronics components such as LEDs or sensors, by using standard circuit boards for textile – cable interconnections combined with snap buttons and molds. This has optimized the robustness as well as the industrial look and feel of the components. The higher the innovation level the larger the uncertainty about the unknown challenges we may face during development. In some more advanced cases, we experienced that our supplier did not succeed in scaling up new production techniques for mass production, but even so, the prototypes and pre-series worked perfectly.

In the e-textiles world, you need to consider not only a (conductive) textile component but also the connectivity, integration, power supply and, last but not least, the complete system approach. Most of these issues are unknown to textile engineers, while traditional electronics engineers have no experience with the special requirements of the textile world:

- *Maturity of technologies*: which technology used in the realization process is new? Can I replace it if necessary?
- *Industrialization effort*: building a robust component (compound) ready for production;
- *Production aspects*: reproducibility, scalability;
- *Risk management*: 'what if' scenarios, if the realization process faces severe hurdles.

In the smart-textile environment, we face technical challenges in connectivity, isolation, mechanical and chemical stress. In addition, we are dealing with compound products containing multiple technologies. As SMEs usually have few resources for research and development, we may engage in cooperative projects, resulting in faster execution of the project and supporting the knowledge sharing.

Market introduction and dissemination

The success and payback will depend not only on the potential and quality of the innovation but also on market entry and implementation of market strategies. We will not describe the general theory in this chapter, but recommend reading Geoffrey Moore's exciting books about the challenges of marketing new technologies (Moore, 1991) and how evolving markets should be managed (Moore, 1995).

Strategies of innovation management

When we look at the history and classical strategies through the lessons that we have been taught from the famous innovation thinkers, we realize how valid their thoughts still are. In recent times, new approaches have become popular: Open Innovation and Distributed Innovation.

Open Innovation means that we open the development process of our products or technologies to external sources of ideas and solutions. Of course there is a broad spectrum of approaches to the project definition. We can be closer to the fully controlled innovation project by hiring an outside specialist or we can – be optimistic – putting the problem to be solved out in one of the portals and wait for suitable responses.

Openness starts in our minds. As Edison said, 'I readily absorb ideas from every source, frequently starting where the last person left off'. There is a big potential in building up on our common knowledge and not limiting ourselves to

internal sources. Distributed Innovation is defined as a process of linking together numerous people with disparate expertise working in different institutions and countries, but united under a single project focused on rapid product development and deployment (Morey, 2009). Distributed Innovation is used by many cutting edge companies. European- or national-sponsored projects are often based on this principle.

For us, the most valuable aspect of Open and Distributed Innovation is to be part of a community and to have access to a broad knowledge base and to speed up the implementation process by task distribution. The communities and blogs are also an interesting source of feedback on our products and systems.

Strategies for small and medium enterprises (SMEs)

We believe that every company has to create its own way; it should match the culture, situation and way of operating. The former world chess champion Garry Kasparov said, 'You must also become intimately aware of the methods you use to reach your decisions' (Kasparov, 2007). We suggest the following guidelines:

- Be open for new ideas, encourage your organization to create and collect its own ideas and ideas from the 'outside'.
- Challenge your ideas – is it feasible, doable (possible to produce with reliability and market price)? Are there advantages that the customer is willing to pay for? Is the business model appropriate?
- Be clear about the strengths and weaknesses of your approach; focus on the strengths but be prepared to find a solution for the weaknesses.
- Create a link between the formal and informal, avoid bureaucracy, manage to incorporate informal results into your processes; e.g. all different forms of customer requirements (e.g. drawings are included in our certified process).
- Use networks – interact, compete and cooperate (e.g. in joint research projects), but care about your IP.
- Do not forget the industrialization and commercialization efforts – a prototype is not a product! You will find some of our showcase prototypes not on the market but in a museum. It is great if this happens as an exception, but it should not become a rule.

13.3 Business models for smart textiles

13.3.1 Business models

In the previous chapter, we looked at technology management and marketing, innovation and IP management. While technology in general is a common source for innovations, we need a market, for innovations should become real products. A market is defined as a network between sellers and buyers to exchange products

and services for money. Sellers are normally established as companies or businesses. A business model is a description of the operation of a business including all components of the business, the functions of the business, the participants and the revenues and expenses that the business generates. The phrase 'business model' appeared for the first time in the late 1950s.

With the beginning and after the dotcom bubble, the interests in, and discussions on, business models were very strong. In our opinion, this was related to the new options of de-construction and re-construction of value chains through the new information and communication techniques (web 1.0). The stunning growth and availability of cheap information and communication technology enabled companies to work in networks, because coordination and transaction costs decreased substantially. This led to industrial boundaries becoming more and more open. A good overview can be found in the thesis of Alexander Osterwalder (2004). Henry Chesbrough mentioned that usually companies struggle hard to manage innovations that do not match their experience (Chesbrough and Rosenbloom, 2002). This is especially true for the textile companies dealing with electronics components.

A good model to work with is described by Andrews (1971):

- value proposition, i.e. the value created for customers by the product;
- value chain, i.e. the structure of creation and distribution of the product;
- value network, i.e. suppliers and complementors, customers and competitors;
- market segment, i.e. customers and applications;
- competitive strategy;
- cost structure and profit potential.

The value chain describes the value added from raw materials until end consumer products. If a company controls all the steps – or at least most of the steps – it is called 'vertically integrated'. A company that sells one product to different market segments is utilizing a 'horizontal' business model.

Horizontal market players focus on high-volume products or (patented) technologies and/or processes. For example, fabric manufacturers try to leverage cost advantages in mass production due to roll-to-roll processes. The drawback for the horizontal market players: there is no end product. And if they do not find a vertical end product where the new technology will fit, there will be no pull for the technology.

13.3.2 E-textile business models

Of course, we cannot define a general business model for smart-textile vendors. Looking at the value proposition, e-textiles could enhance or improve basic functions of textiles as there is climate regulation (i.e. heating, cooling, and moisture management) or create new functionalities (i.e. sensing and energy harvesting).

From our experience, smart-textile companies should carefully review their business model. Helpful questions are:

- What kind of USP do you offer?
- Is it know-how, a component, a system, a product?
- To which segments do your customers belong?
- Which complementary products and or partners do you need, to offer the right level of product or service to your customer?

The material provider offers common or specific material such as printed circuits, roll-to-roll, highly flexible wires for weaving and knitting, flexible printed circuit boards, etc. The material providers need a pull from the next level of the value chain, the component manufacturer. When we analyze the value chain of a system with incorporated conductive textile, we will find:

- *Base material*: e.g. conductive yarns, polymers or inks.
- *Textile material*: e.g. the woven smart fabric heating fabric on roll.
- *System components*: e.g. a heat-pad, cut and provided with interconnects.
- *Integrated sub systems*: e.g. a heating system including a heat pad, controller, interconnection and batteries.
- *Products*: e.g. heated gloves or LED jackets.

Of course, it is relatively easy to design a value proposition for a niche market or even for a single customer. However, most of the textile companies looking into the smart-textile markets are targeting mass markets.

Forming alliances is an interesting and appropriate way to work on innovations such as smart textiles. Alliances are usually installed to market systems with the potential to address several market segments. Ideally, the partners of an alliance contribute not only components or technologies that build a complete product but also provide complementary roots to markets.

Vertical model supplier

There are some companies that offer a vertical product based on a core of smart-textile components. In most cases, a lack of customers for the base technology forces the companies to develop the full vertical product and sell it. The possibilities of offering goods via the internet help these companies to establish a sales channel without large investments.

WarmX® is a subsidiary of a German knitwear company that offers heated underwear with elastic silver-coated yarns (Fig. 13.3). They developed their own control electronics and offer the products to distributors and end users. After two years of development and one year of field tests, in 2006 WarmX® introduced its first products. Since then, it has had more than five years of slight but constantly growing business, using the internet as the main sales channel. WarmX® has established itself as a commercial vendor of elastic heated underwear products

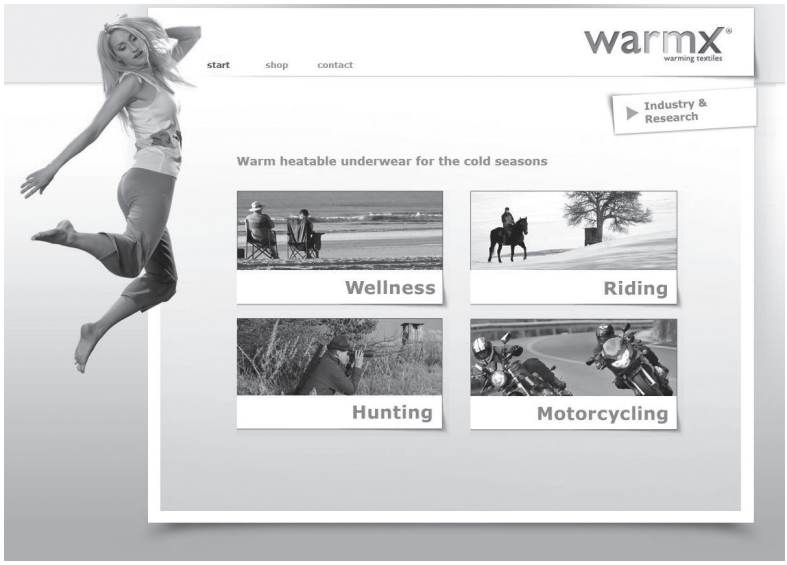
(a) (b)

13.3 WarmX®: Heated underwear shirt/detail knitted heating wires: (a) front; (b) back. (Reproduced with permission from WarmX®.)

(Fig. 13.4). Christoph Müller, CEO of WarmX®, recognizes that the main barrier for the sale of his products is the need to explain the benefits and properties of the products, due to the fact that this kind of product is not widely known to potential consumers.

Future-Shape, with its roots in the Infineon Research Labs, has developed special bonding techniques to build large-area capacitive sensor systems, which could be integrated into any floor covering. The SensFloor® is based on a smart-textile underlay with built-in microelectronic components and capacitive proximity sensors (Fig. 13.5). Future-Shape has developed a radio module on a flexible substrate, which is specially designed for integration into textile surfaces and can be connected to as many as eight sensor areas. Products like the SensFloor® mats are offered to senior residences and hospitals, shops and architects, as well as to the end user.

AiQ Smart Clothing Inc. is an example of building a vertical company within a textile group, with subsidiaries in different steps of the value chain (Fig. 13.6). AiQ is a subsidiary of TexRay Industrial Co. Ltd., a publicly listed global fabric and apparel company based in Taiwan, with global operations across North America, Asia and Africa. AiQ offers a complete vertical integration of wearable technologies to its customers, by combining and installing multiple key components from its upstream affiliate, King's Metal Fiber Technologies. AiQ

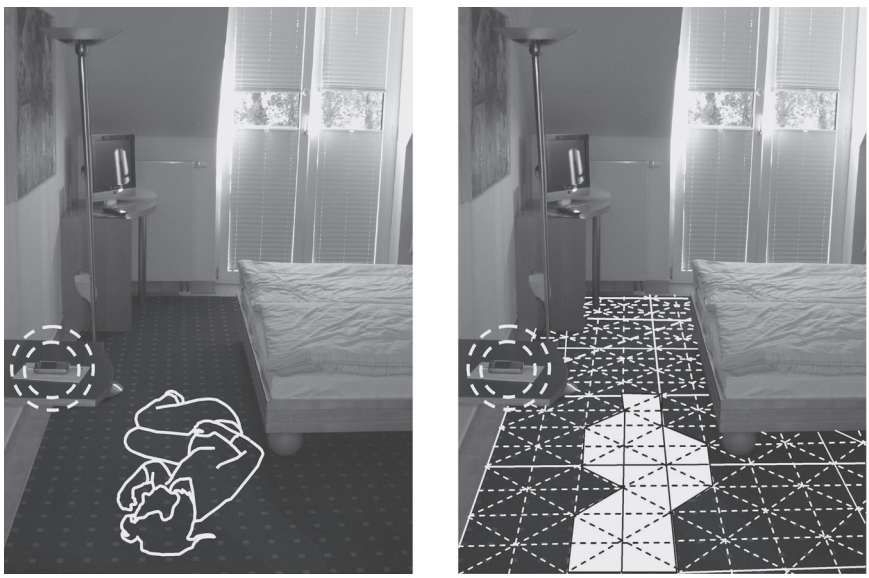


(a)

(b)

13.4 Typical for a vertical product supplier: (a) WarmX® is proposing a value added product for special target segments: (b) the niche customers can order the products in the online shop.

(a)



(b)

13.5 Future-Shape's Sensfloor®: underlay with: (a) textile sensors; and (b) bonded electronics, downfall pattern.

13.6 AIQ LED buttons and other components from the group.

specializes in developing wearable systems that are fully compatible with its downstream manufacturer and parent company, Tex-Ray. The company has developed a range of e-textile systems: the AIQ Biker Jacket with LEDs to indicate turns, and LED safety garments, heated garments, bio-monitoring shirts and touch screen compatible gloves.

Other examples of vertical approaches have been seen from Cute Circuit, famous for their 'hug-shirt', designing and marketing LED-garments, and also Textronics Inc., which launched the Numetrex sports bra when sports clothing companies were reluctant to build products with their sensors. After being acquired by adidas in 2008, products of Textronics Inc. submerged in the adidas universe.

13.4 Opportunities and challenges in the e-textiles business

13.4.1 Smart textiles terms and definitions

A definition of the smart-textile market is very challenging. An exact and clear definition does not exist. An often quoted definition is 'smart textiles are materials and structures that sense and react to environmental conditions or stimuli, such as those from mechanical, thermal, chemical, electrical, magnetic or other sources'. In the e-book, *Smart Fabric Technologies and Applications* (Intertech Pira, 2011(a)), smart textiles are defined to:

> . . . provide feedback to the wearer, improve safety and supply power. It covers a wide range of fibres and raw materials, as well as the connection methods necessary to integrate transistors, circuits and, ultimately, components such as sensors, LEDs and power supplies.

'Smart' is a buzzword that describes somehow unexpected and useful properties of well-known materials or products. In some research studies, the phrase 'smart fabrics and interactive textiles' (SFIT) is used. However, the expression of 'wearable electronics systems', 'wearable electronics' or even 'wearable' is used for electronic components or systems integrated into textiles. But from the exact meaning, also a mobile phone or a torch could be categorized as 'wearable'.

In this chapter, we would like to define the scope of smart textile as 'conductive textiles' or 'e-textiles', which has the capability to transport an electrical current. In our opinion, this term is even more general and descriptive than the phrase of 'electro-active fabrics'. There is also the huge number of innovative fabrics that, for example, improve the fabrics' moisture or temperature control in a very smart way but without electrical control or stimulus. E-textile systems are built with conductive textile components such as electrodes for monitoring, resistive or capacitive sensors, or resistors for heating elements.

Instead of using the broad term 'wearable electronics', we will focus on the system aspect of an electronic solution integrated into textile. Within the scope of smart-textile solutions, we would also like to point out that one of the main differences to simple mobile – hence wearable – devices like mp3-players, is the usage of a distributed architecture, flexible material and special textile compliant integration methods and techniques.

The e-textile market is strongly fragmented and unclear. While a variety of ongoing research results foster high expectations in the mid- and long-term future, the technology maturity level of most of the advanced applications is still very low.

13.4.2 E-textiles market

The textile industry itself, generally used to producing high quantities, expects to produce conductive material in a roll-to-roll process. Their customers, like the garment brands or automotive industry, aim to integrate sub-systems and treat them as trims or dashboards. In between, we find the assembly lines and integrators who need knowledge of all related technologies.

We will not conduct a complete market analysis, instead referring the reader to Section 13.6. Most of the studies expect strong growth for the smart-textile market. They are looking at the textile part of the value chain or at vertical products such as automotive seat heating systems or sensing and monitoring products. In the smart-textile business, we know of only one segment that shows sustainable growth and a noticeable market size, the segment of automotive seat heaters that use heat pads built of stainless steel or copper wires, or carbon fibers. This

segment is constantly growing, as seat heating as a comfort function is in demand for all car classes, from luxury to compact.

13.4.3 E-textiles business drivers

What are the business drivers to invest in conductive textiles? The textile and clothing industry in Europe and North America has been an important part of the overall economy in the last century. Like in other industry segments, value added products and services are still growing, especially in the area of technical textile production. Mass production is moving from north to south, and from west to east. This is one of the major reasons why the European Community (EC) is allocating significant amounts of money for research projects in the field of smart textiles and especially e-textiles.

In 2006 there were 220 000 companies in the textile industry in the EC. These companies employed 2.5 million people and generated a turnover of €190 billion, which accounted for 3% of the total manufacturing value added in Europe (EC's Directorate General for Enterprise and Industry website).

Technical textiles find their way into more and more application fields, from innovative materials for traditional markets of garments and home textiles into automotive, architecture and other industrial applications. The European electronics industry exported €124 billion while importing €224 billion. A strong segment is measuring devices, which had a positive trade balance (Sectore Fiche: EU Trade in Electronics, 2011).

In the electronics industry, the market of embedded systems is increasing steadily. Driven by automotive and consumer electronics, components such as microprocessors and micro-electromechanical systems (MEMS) are becoming increasingly powerful and are available in mass production. Sensing and monitoring networks are becoming a state-of-the-art application in several industries. IDC analysts expect market growth of intelligent connected embedded systems from US$800 million in 2011 to US$2.3 billion in 2015 (IDC, 2011). Reynette Au, executive partner for GTIA L.L.C, said:

> Today's smart embedded technologies do more than just control and contribute features to a system. These technologies enable systems to connect, offer security and manageability, and open the door to new applications and innovation that are fundamentally changing the way we work, live, create and consume. How products in the Intelligent Systems category evolve and get to market will be an extremely dynamic process. It will require new levels of cross-industry collaboration with new business models emerging. This will make the ecosystem critical and it will be an exciting and value rich environment.' (IDC, 2011)

Furthermore, we see two major trends that will foster special application segments of smart textiles:

1. Increasing interest in electric vehicles lead to a growing demand for pure electrical heating systems beyond seat heaters in the automotive industry.
2. The replacement of traditional light bulbs with LEDs will allow the design and construction of completely new lighting systems, especially in conjunction with textile constructions (interior and exterior architecture).

13.4.4 Technology push versus market pull

During the hype from the years 2005 to 2008, smart textiles were used as a marketing tool to gain brand attention. Successful examples are Infineon, O'Neill and Zegna. After dipping into the trough of disillusion in 2008 to 2010, we see a constant growth of interest in this technology reaching a plateau of productivity in the current decade. Although the wearable electronics products became very popular in the hype period, the real business was in the automotive industry: with a 25% growth from 61.7 million cars in 2009 to 77.6 million cars in 2010, this market is still the most interesting for the smart-textile industry. Furthermore, due to growing demand, the number of heated seats per car is also increasing. As the e-mobility gets more and more focus, the automotive industry is looking for purely electrically driven alternative heating concepts as the engine heat waste used to warm up the car will not be available any more. Therefore, we expect that in the short term the automotive heating applications will be the largest business segment in the e-textile market.

13.4.5 Two worlds apart – textile and electronics businesses

Developing, manufacturing and marketing of products in the textile and the electronics industries are completely different. We will compare the garment industry and the consumer electronics industry at a high level. The main difference in the product characteristics is the analog, continuous and flexible world of textiles versus the digital, discrete and precise world of electronics. Garment makers address their customers each season with new styles, whilst the product itself stays more or less the same – a jacket with pockets, sleeves and maybe a hood. But it comes to the market in a variety of styles, fabrics and sizes. In the electronics industry, product innovation is driven by integrating new technologies, adding functionalities and increasing performance. A smart phone of today is a mobile phone, a pocket computer, a camera and an internet network device, more powerful than a mainframe computer of 25 years ago.

The product properties influence the development processes. The garment development process is clearly defined by schedule. A product manager of a garment brand is responsible for dozens to even hundreds of products, to be launched each season (twice a year, sometimes even every quarter). Product changes seem to be simple; no matter how the button is designed, from which

company, material or size, a garment designer does not need to care about the integration. However, in the electronics industry, the integration of new components is always complicated; building a prototype, testing and measuring the electrical values, power consumption, etc. In the next step, the developer will program the microcontroller, integrate the components and peripherals and perform the integration testing. After successful implementation and integration, certification tests are necessary before the product can be produced.

Looking at the production processes, tailoring is still a labor-intensive job. Textile productions, fabrics and trims are automated bulk production comparable with mass production of semiconductors. But putting the electronic parts together is an automated and very precise process. The lead time to do all this correctly is much longer than in the garment industry.

Last but not least, sales people at the point of sales are used to handling textile products, but not electronic devices. In addition, the service processes are not designed and organized to handle electronic component returns. The bottom line for these differences is that today we do not have appropriate sales channels for e-textile products.

13.4.6 Economics from production to retail

We also find major differences between the garment and consumer electronics industries in the area of sales. A typical margin structure in the garment industry shows a ratio of four to seven from the cost of manufacturing to the retail prices. A brand company sells the garment to a distributor and takes a margin of 25 to 50%. A distributor and a dealer each take a margin of around 50 to 100%. Compare this with the electronics industry, where the ratio from production to retail in consumer electronics varies typically between 50 and 150%.

Now imagine that an electronic product manufactured for €20 is available in a store for €49. A garment brand produces a jacket for €20 and sells it for €99 in the store. If this brand integrates that electronic system into the jacket, it would be offered in the store for €199 and the customer would pay twice as much for the integrated electronic than just for the device in the electronics store.

13.4.7 Regulations, certifications and markings

Beside the differences in the commercial price calculations in the garment and electronics industries, there are also significant differences in the effort required to market e-textile products.

Legal issues also have to be taken into account. Textile and electronic products need to comply with different norms. Garment manufacturers know about the region- or country-specific norms of material properties required for products with skin contact. There are especially restrictions for use of chemicals, like the European Union (EU) regulation REACH (Registration, Evaluation, Authorization

and Restriction of Chemicals). Some garment brands define their own criteria for suppliers of fabrics and trims. Usage of voluntary marks, such as the Oekotex 100 or the EUR Eco-label, are well-known. Markings are commonly in use for material compounds and care procedures.

Electronics products have to be compliant with safety norms and regulations for electro-magnetic compatibility (EMC) and several standards, depending on their usage. Although standardization of these norms is ongoing, most of them have specific national or regional versions. Look at all the marks of a power supply (e.g. from a laptop) to gain an impression. Fortunately, most of the wearable devices do not need to comply with these safety norms, as voltages below 25 or 60V DC are rated as safe, even to children.

On the material level, compliance with the EU Directive on Restriction of Hazardous Substances (RoHS) is mandatory within the EU and part of the CE declaration. REACH is of course, also applied as to textiles, but the importance is not so high.

Standardization on the interfaces, communication, as well as power supplies, is widespread. Some of the standard interfaces that are used within wearable systems are Bluetooth and USB. Some vendors offer compliance marks with their products (e.g. made for iPod™).

13.5 Conclusion

We see ongoing development in the technological areas, as well in materials and (textile) production, electronics hardware and software, which will foster the development of new smart-textile applications. However, there will be ongoing increasing demand to develop portable, connected devices, which will educate users to handle electronics devices as self-evident as clothes. A breakthrough of wearable electronics or smart textiles, as predicted by numerous market studies in the past, will depend on overcoming the following multiple obstacles in the mid-term:
Technological challenges are:

- textile look and feel for electronics (robust, lightweight, flexible, elastic);
- connectivity and textile integration;
- lack of standards and inter-operability.

Business challenges are:

- complexity of products;
- channels (know-how in point-of-sales, service processes, margin systems);
- compliance and certifications.

Acceptance challenges are:

- use of batteries (bulky, limited performance and lifetime);
- fear of health impacts (burning batteries, radiation);
- care (lifecycle compliance, demand of green products).

Product managers, designers and developers of smart-textile solution should keep in mind that they are dealing with an electronic system and partner up with companies that complete their own experiences. The conditions to do so are very good, as the smart-textile community is dominated by SMEs, working in flexible networks and alliances.

Short term, we are expecting a combination of market driven projects and offerings from vertical organized alliances and segment specialists. Long term, there is a need to develop horizontal product vendors, in order to offer components and products at lower prices, supplying stable mass production.

13.6 Sources of further information and advice

Fundamentals of innovation, technology and IP management. Enterprise Europe Network: develop your business in new markets, source or license new technologies, access EU finance and EU funding: http://portal.enterprise-europe-network.ec.europa.eu/

European Commission on Innovation and SMEs: http://ec.europa.eu/research/sme/leaflets/en/

Transnational funding opportunities for European SMEs: http://www.innovation-for-sme.eu/

Online Knowledge Center for creating value with innovation management: http://www.innovationmanagement.se/

Paul Trott (1998) was building links between innovation management, new product development, technology marketing and IP management. His work has created a consistent base for the understanding of how to execute innovation as a management process.

Robert Burgelman, Clayton Christensen, Steven Wheelwright: *Strategic Management of Technology and Innovation*, a book with concepts and case studies.

We have found a helpful framework focusing on SMEs in the technology management process (SME Innovation, 2012).

Guidelines on Technology Management for SMEs can be found on the website of Ten^3 (1000ventures.com), with focus on technology audit, business and technology strategy definition and a formulation of a technology strategy.

Centre for Technology Management of University of Cambridge: http://www.ifm.eng.cam.ac.uk/ctm/

A comprehensive information framework for SMEs is provided by the World Intellectual Property Organization (WIPO, 2012).

The EC Centre for Strategy and Evaluation Services has issued a study on working IPR for SMEs (EC IPR Enforcement Group).

There are many great thinkers, writers, inventors and entrepreneurs who created the base in terminology, models and methods. We can choose only a few of them.

We found interesting notes in a blog about the inventor and entrepreneur Thomas Alva Edison (Don Mangum, 2011).

From Tarde (1843–1904), we have learned the meaning and importance of imitation and the role of social networks in the innovation diffusion (Tarde, 1890).

Joseph Alois Schumpeter (1883–1950) was an Austrian-Hungarian-American economist and political scientist. He identified innovation as the critical dimension of economic change. He was one of the business cycle fathers and pioneer of innovation management. He analyzed the impact of organization size on innovation potential, evaluating the dilemma of large organizations (powerful but often bureaucratic) versus SMEs (flexible and fast but limited in resources) (Pol, 2006).

Peter Ferdinand Drucker (1909–2005) was an influential writer and management consultant. He created a base and many systematics in our management reality. His thoughts on innovation, simple, market-driven and built on our strengths, are still relevant today. We have learned from him that 'innovation is work' (Luebke, 2010).

Geoffrey Moore (Moore, *Crossing the Chasm*, 1991) has explained how and why technology companies succeed. He has enhanced the Rogers' diffusion of innovation (Moore, 1995).

Market studies on smart textiles

Several analysts and research organizations, as well as institutes, have worked on smart-textile studies. Their studies predict tremendous market growth and a bright future for the smart-textile market.

VDC stated in the first market study on SFIT (VDC, 2003) that 'the technologies and solutions reported here will be as ubiquitous as are cotton, polyester, computers and cell phones today'. At that time, VDC expected a common annual growth rate (CAGR) between 11% and nearly 30%, with a potential billion dollar business in 2008. Four years later, in the third update of the study in 2007, VDC's estimates showed a growth rate of less than 7% from 2003 to 2006 with even higher CAGRs of up to 50% for the segment of conductive textiles (VDC, 2007). In parallel to the SFIT study, VDC launched a wearable electronics study with emphasis on the electronic part, especially communication and computing, sensing and monitoring, and infotainment solutions (VDC, 2007).

It was reported in the BCC research study of 2007, that the US market for smart textiles was worth an estimated $70.9 million in 2006. BCC expected this market to reach $78.6 million in 2007 and $391.7 million in 2012, at a CAGR of 37.9% between 2007 and 2012 (BCC Research, 2007). Furthermore, the projected rapid growth of military, biomedical, and vehicle safety and comfort applications for smart textiles was expected to have a major impact on both the size and structure of the market. Sales of conductive fabric products were expected to more than double each year between 2007 and 2012.

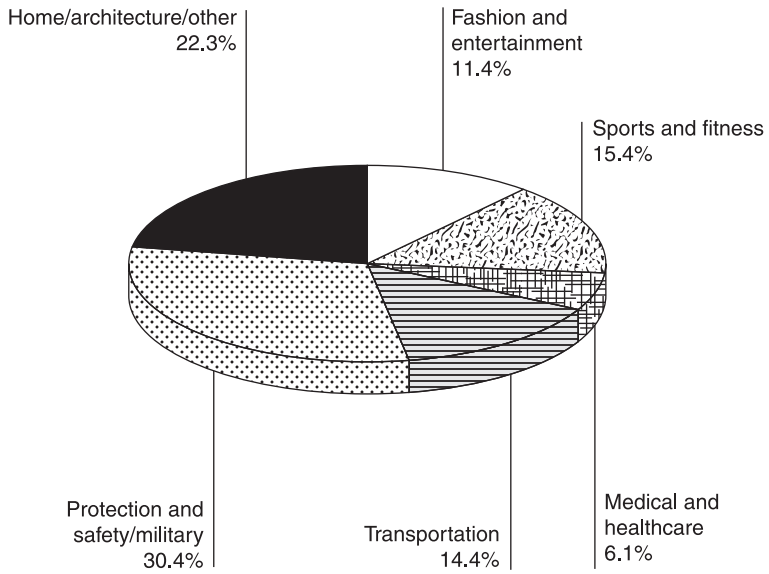
Frost and Sullivan (2010) stated that still:

> a wide gap exists between the end consumer and the product manufacturer's awareness. As a result, we do not see many big players into smart textiles. However, in the near future, the textile industry is expected to realize its true potential due to a recent surge in the demand for luxury and aesthetic products. This would open new avenues for smart textiles and a gradual growth in this sector will be seen.

In 2011, Global Industry Analysts forecasted the worldwide market of SFIT to reach US$1.8 billion by the year 2015 (Global Industry Analysts, Inc., 2011) (Fig. 13.7). They stated that:

> The market for smart fabric and interactive textile technologies, although in embryonic stages, is poised for tremendous growth. Despite slow adoption rates in several markets, demand for SFIT technology is expected to escalate, driven by emergence of advanced products and new application areas with significant potential. Years of refining technology innovation have helped smart fabrics progress steadily towards achieving successful commercialization in key end-use industries, such as biomedical and consumer electronics.

In the study *The Future of Smart Fabrics to 2021* (Intertech Pira, 2011b), Adrian Wilson evaluates smart fabrics as 'currently extremely fractured in their actual and potential end-use market applications, as well as the products that are being provided. There are few transparent supply chains and widely varying prices'.



13.7 Smart fabric end use markets 2011. (Reproduced with permission from Smithers Apex, formerly Intertech Pira.)

Intertech Pira, now established as Smithers Apex, estimated the market for smart fabrics at €188.15 million in 2011 and forecast a CAGR of almost 23% to 2016, and nearly 30% for 2016 to 2021.

According to the study, external drivers contributing to this growth include:

- Sensors and other electronics continue to get smaller in size and weight, as well as cheaper, even as their capabilities increase.
- The dramatic increase of the popularity and capabilities of smart phones will result in increased use of smart fabrics, for sensing and monitoring applications, but also in fashion and entertainment.
- By as early as 2016, there are expected to be around 300 million body-worn wireless sensor-based gadgets on the market, with Bluetooth Low Energy (BLE) technology having a major impact.
- Many emerging product packages, including smart fabrics and related products, are rapidly proving to have more value than the purpose for which they were originally intended, largely as a result of advances in software, apps and the internet.
- One key issue in the development of truly smart fabrics has been the lack of microconductors that exhibit the intrinsic qualities of textiles. This is now being successfully addressed.
- Smart fabrics continue to secure funding for new research and development projects.

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