THE ART (AND SCIENCE) OF PROPELLING GROWTH IN TEXTILES

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Abstract
The Twentieth Century gave us an abundance of "miracle" fibers and polymers of every description. Textile scientists did not just imitate the products of nature, but improved on them. This success was derived through the imaginative and innovative use of low-cost petroleum-based feed-stocks and efficient manufacturing schemes to achieve consumer-driven functional characteristics of comfort, performance and aesthetics.
In the past 20 years, the textile industry has undergone enormous changes and its influence on the society as a whole has eroded enormously. From its once lofty perch in the global economy, the industry is stalled. Furthermore, it has been forced to adapt to a plethora of changes in recent years. The global elimination of quotas at the end of 2004 has led to greater competition. At the same time, companies are faced with rising and fluctuating raw material costs, being subjected to ever greater demands by retailers in terms of product quality, deliveries times and reduced product life cycles. This has made sustainable growth, critical for the survival, very challenging indeed.
What does the future hold, how can we reverse the trend and what must we achieve to sustain the impressive credentials of the past? The paper will deal with requirements for propelling growth in the textile industry. The concept of disruptive innovation as a route to future growth and success is discussed. A combination of tactical remedies, long-term business strategies, influence of globalization, and knowledge intensity will be the key business drivers. The future product and process discoveries will be built upon multi-disciplinary/synergistic technology platforms. As borders between material, biological and information sciences erode and become seamless, the areas where they interact or overlap will catalyze the re-conceptualization of tomorrow's textiles with disruptive technologies as the hallmark.

Keywords: Excellence, Disruptive Innovation, Technology Management, New Product Development

1. INTRODUCTION

We live in a world in which technology is advancing at such an astonishing rate that it is often difficult to comprehend its impact on our lives. The application of modern biotechnology for the cloning of adult mammals, the development of disease and pest resistant crops and miracle pharmaceuticals/nutraceuticals that promise hope for the management of selected cancers, heart disease and infectious diseases continue to dazzle us on a daily basis. The textile industry has likewise kept pace and today's technology can provide fibers that go well beyond the best that nature can offer. It is indeed narrow to consider textile technology as a rigid discipline concerned with making fiber, yarn and fabric. It is certainly more diverse and is in a continual state of flux in response to technical innovations and the changing needs of society. The challenge for the industry is to improve short-term financial performance in a way that accomplishes the long-term transformation necessary for sustained growth. A way to achieve this is thru disruptive innovation. The inherent characteristics of new textiles underpin the functional and aesthetic qualities in varied applications beginning with apparel and extending to medicine, aerospace, construction, agriculture and home furnishings. There has been rapid growth in the polymer, material, information and biological sciences.

Advances in these divergent sciences (and particularly at their interfaces) has begun to allow a new view of future textile systems.

History has shown that the earliest fiber technologies originated mainly in Asia. Cotton and silk are native to India and China, while wool was first put to practical use in Central Asia. It is widely known that the "Silk Road" arose from the strong desire of western civilization to acquire silk products originating in China. Centuries later, the era of man-made fibers began with the invention of rayon in the late 19th century. Discovery of nylon in 1935 by Wallace Carothers at DuPont was closely followed by the development of acrylic and polyester fibers(1). This led to increased research to develop a variety of new materials comprised mainly of these three polymer platforms. New fiber processes suitable for these polymers were invented. High-performance fibers including, among others, carbon and aramid fibers were invented in the 1960's. Forty years after the invention of nylon, worldwide synthetic fiber production surpassed that of man-made cellulosics. Today, synthetic fibers comprise more than half of the total fibers consumed worldwide and is expected to grow to 64% of the total by 2010.

2. TRENDS AND CURRENT CONCERNS

Over the last sixty years the textile business has enjoyed rapid growth in synthetic fibers, which has been fueled largely by seminal discoveries in polymer and fiber science. Fiber and textile manufacturing facilities have also undergone enormous improvements in automation and simplification wherein large volume fiber production facilities today may require only tens (instead of hundreds) of personnel for their operation. Fibers, which have ease of care and natural-like aesthetics, have been major themes in recent decades with high performance and specialty fibers taking on particular significance. Fiber and fabric tests, critical to product quality, have relied largely on destructive, off-line methods. Advances in online testing and quality control promise to have a major impact on first pass product yields and quality.The textile industry today stands in stark contrast to its preeminent position of just 20 years ago. Many of the synthetic fiber products that once fueled the rapid growth of the industry (Figure 2) have become mature commodity products now characterized by low growth and lower profit margins. Intense global cost pressure, higher consumer expectations, a highly diverse customer base, shorter fashion cycles and reduced R&D spending have all contributed to sluggish growth in the current business climate. The challenge for the future is to revitalize the industry through disruptive technological innovations in products and processes and to reevaluate business practices in a global context.

Polyester remains the bright star in the textile portfolio. The global polyester outlook for 2006 thru 2010 is as follows:

• Global polyester market is projected to reach 46 million tons by 2010 and grow at a rate of 6.39%, compounded annually.

• Polyester filament yarn is anticipated to register higher growth rates than polyester staple fiber, and projected to burgeon at a compounded annual rate of 7.18%.

• Asia-Pacific is projected to be the fastest growing market, with a compounded annual growth rate of 8.15%.

• Asian polyester manufacturers are expected to continue dominating the global polyester marketplace.

• Low-cost and easy-care characteristics of polyester continue to drive the demand for polyester in apparel market.

Factors influencing the polyester market are:

• Supply/demand outlook for polyester, polyester raw materials, and cotton, are among the major factors influencing the polyester market.

• A major portion of polyester costs is influenced by the volatile prices of raw materials such as para-xylene, PTA, and ethylene glycol. In terms of cost, PTA represents the single largest raw material for polyester manufacture.
• Problems faced by the polyester industry are driven by supply. Polyester supply-demand scenario is expected to be poor owing to the excess capacity in the industry. This is expected to lead to a prolonged pricing weakness, which can only be countered by serious cotton shortage.
• CAGR for capacity expansions approximate to 9.8%, while demand growth is expected to range between 5%-6% by 2006. Most of these expansions are not likely to be stalled as Asian companies are expanding to meet domestic demand, and economies of scale. The situation is magnified in case of polyester raw materials, with manufacturers adopting backward integration, and traditional companies, expanding.
• Factors influencing demand for textiles are income levels, demographics, and fashion. Fashion plays a pivotal role in the mature markets. However, demographics and income levels fuel the demand in emerging markets such as Asia Pacific and Latin America.
• The textile manufacturing industry worldwide is expected to fare better in the next few years. The stockpiles of the industry, in almost all the segments, are reducing. The costs of the feedstock are also more balanced. Production facilities used by the industry are technologically more advanced and efficient. Demand for polyester textiles has increased, especially from the younger generation, who prefer stretch fabrics that retain their shape.
• Polyester is the fastest growing fiber, and due to high Eastern demand, it is expected that polyester would account for over 50% of the total demand for textiles worldwide.

3. ECOLOGICAL FACTORS

The delicate ecological balance of our planet is now comparatively well understood and grass roots organizations exist in most countries for its preservation. Heightened awareness of the harmful environmental effects of some manufacturing processes mandate that if the textile industry is to survive, it too must play a leading role in environmental conservation. Indeed, companies researching new textiles are making ecology a primary concern. In fact some will defer on attractive new products unless they can be made safely and without deleterious impact to the environment. The textile industry is keenly aware that world resources are not limitless and recognizes that major changes must be implemented in manufacturing systems to assure their long term availability. Key problems on which the industry is focusing:

- **Waste elimination**
  - Reduce
  - Reuse
  - Redesign
- **Energy conservation**
- **Product reclamation**
- **Product recycle**

All steps of the textile processing value chain from raw material conversion to fabric disposal must be environmentally friendly. For the industry to be sustainable long term it must strive to achieve a 100% recycle loop for all polymers to eliminate materials entering the landfill. Furthermore, global efforts to curb illegal labor including child labor and sweatshop labor have gained impetus with adoption of the Worker Readjustment Program (WRAP). Moves to prohibit imports from countries with illegal labor practices are constantly being reviewed at global trade talks.

4. PROCESSES OF THE FUTURE

Commodity PET fiber technology is generally mature and broadly available to investors (capital orientation), hence competitive advantages in process technology worldwide are shrinking fast. Next generation technology will be driven by many factors, primarily to retain or regain a competitive position. Creation of knowledge (product, process, and business) will be the deciding factor for survival and sustainable growth (2).

The global portfolio of PET technologies available varies from conventional to next generation disruptive technologies. These are :

- Conventional process of CP and SSP: Offered by Invista-Chemtex-Sinco, Zimmer, and CTIEI-Buhler.
- Melt to Resin (MTR) process: Offered by Inventa-Uhde-Fischer.
- Direct High IV (DHI) process: Offered by Zimmer.
- IntegRex (direct PX to PET) process: Offered by Eastman.

Of the conventional processes, Invista and CTIEI are financially attractive due to lower CAPEX and OPEX. Invista has marginally superior OPEX and is a proven process on a commercial scale. The world’s largest single line CP of 1050 TPD is currently operational.

MTR technology offers advantageous CAPEX and OPEX over conventional technology. The SSP stage is eliminated and a high viscosity melt is produced directly. The technology, however, is not proven commercially. The first plant based on this technology is under construction at DAK America’s Cape Fear site and is expected to go on-stream in Q1-Q2 ’07.

DHI technology is similar in concept to MTR technology with production of high viscosity melt directly at the CP with elimination of SSP. The OPEX is superior than Zimmer’s conventional process, though not as good as MTR process. The technology is not proven commercially but has only been demonstrated on a pilot scale of 1 TPD.

Zimmer (Direct-to-Preform) as well as Uhde-Inventa-Fischer (Melt-to-Perform) have also developed a direct melt to preform technology which is not available commercially. Sufficient information is not available on these processes. Both claim superior CAPEX and OPEX in addition to improved characteristics and quality of performs, lower emissions, no intermediate chips handling stage, lower IV variations, brighter and better colour, lower cost recipe, heavy metal free catalyst, chips with lower heat of fusion etc. However, the technology has the potential drawbacks like higher levels of Acetaldehyde, degradation and high b colour.

M & G has developed technology based on a horizontal SSP reactor (rotary kiln type). The melt production is based on Invist’a conventional CP technology. The process has reduced CAPEX (claimed to be 40%) and OPEX. A 1200 TPD plant is under construction in Brazil. This technology is not currently for sale.

IntegRex technology integrates PX-PTA-PET processes through elimination of a number of intermediate steps including purification process for PTA. Eastman have patented a large number of intermediate processes under this technology. Information available on this process is extremely limited. Eastman claims a 15-20% reduction in CAPEX and a substantial reduction in OPEX. The first plant of 350 KTA capacity based on this technology has recently been commissioned at Eastman’s Columbia site in South Carolina, USA.

The textile sector has enjoyed the benefits of cost reductions and productivity improvements in the last decade. This has been due to processing improvements, including greater automation, increased spinning speeds, production capacity enhancements and process simplification. The production cost variance of fiber manufacturers is governed by both the investment per ton of fiber as dictated by economies of scale and the cost of basic feedstock. The investment cost for new plants is determined by raw material conversion costs and all downstream processes which include spinning, drawing and texturing.

Future fiber manufacturing technology must also accommodate mass customization in the market place. Specifically, a system of specialized product variants for small-lot production can provide high value-added products to the consumer. The challenge for the future will be the development of efficient small-scale production technology for such products.

6. NEW EMERGING TECHNOLOGIES (INTEGRATED SCIENCE)

The new emerging technologies are characterized by three salient features:

- Highly synergistic
- At the frontiers of the small, and
- In a "feeding frenzy" of each other

These technologies are:

- IT (communication, computing, sensors, electronics, machine intelligence).
- Bio (genomics, molecular biology, designer life forms).
- Nano (coatings, barriers, computers, sensors, materials).
- Energetics (solar, biomass, explosives, propellants, storage).
- Societal Technological Systems (distance learning, virtual presence, tele-everything, robotic everything, digital earth/digital airspace).

New polymer platforms may emerge from the biological synthesis of polymeric materials, an approach which offers in some cases the precise specification and synthesis of modular building blocks for polymeric materials. The need for architectural specificity and uniform macromolecular structure has never been greater. It is expected that biosynthesis will become increasingly important for traditional chemicals. It is no longer necessary to start with a barrel of oil to produce chemicals but rather crop plants may become attractive feedstock sources. Fermentation can be used to make a fine quality ale, or for that matter synthetic polymers. Comfortable, easy-care apparel may soon be made with fibers derived from feedstocks that have been fermented from sugar.

Using microbes or biocatalysts, a number of biological processes to make monomers or polymers can be developed. Three general approaches may be used: (1) inserting genes into seeds, growing the plants, and then isolating the monomer or polymer. (2) inserting genes into microbes which then process a feed source producing the desired polymer intermediate, and (3) using recombinant DNA technology to prepare protein-based polymers via bacteria.

Companies are now developing technology that uses genetically altered microorganisms to produce basic chemicals including some that are not readily made from petroleum. Starting with glucose it is possible to produce intermediates that can be used to make nylon and polyester. The process is expected to be less expensive and more environmentally benign than traditional chemical methods. Progress has been faster than expected in this area and if the pilot production is successful, the process could be commercialized in the near future.

With the advent of genetic engineering, it is now possible to create molecules that are difficult to synthesize by traditional methods. Today, there are two classes of manmade fibers: regenerated cellulosics from wood and cotton, and wholly synthetic fibers made from petrochemical sources. The future may offer new classes of fibers—including synthetic biopolymers derived from green plants, microorganisms or enzymatic processes. Thus, bioprocessing offers vast and emerging opportunities. Fermentation processes using genetically modified microorganisms will give rise to new routes to polymer intermediates or to directly synthesized polymers. The predominant driving force for this transformation is for products with new and improved properties. These are based on abundant, cost effective and domestically renewable feedstocks, delivering sustainable growth.

Biotechnology also offers a route to protein-based polymers with enhanced structural properties. Fibers and biocomposites in nature have attained remarkable levels of sophistication through evolutionary selection. The biosynthetic process is uniquely adapted to making such materials because it allows precise specification of hierarchical order at four levels.
Primary: based on sequence and composition
Secondary: based on conformation
Tertiary: based on supermolecular helices and sheets
Quarternary: based on folding patterns and relative placement to other components in a composite structure.
The current processes by which common engineering polymers are prepared generally allow good control of only primary and secondary structure. The precision with which living systems manage all levels of materials organization accounts for the extraordinary diverse functions of protein polymers which in structural and chemical terms can be thought of as nature's nylons. This diversity is even more striking when it is considered that proteins are constructed from a comparatively small set of monomers – the twenty naturally occurring amino acids.

As an example, effort is underway to create synthetic analogs to silk. By using recombinant DNA and learning exactly how a spider makes its silk, we have created synthetic spider silk as a model for a new generation of fibrous materials. Our approach includes the use of advanced computer simulation techniques that integrate all the information available about the structure of the evolutionary materials. Synthetic genes are then designed to encode information-matching aspects of the material. These genes can be cloned into an expression host to produce the silk proteins, which can subsequently be dissolved and spun into silk-like fibers.Spider silk is but one example of a sizable family of biopolymers possessing a combination of properties that synthetic materials cannot yet approach. With its unusual elastic properties, learnings from silk may impact other existing materials such as spandex and nylon. The new generation of advanced materials from biotechnology research has the potential to create textile materials which can only be imagined.

These technology introductions into society are not without impact. All aspects of our daily lives will feel the change consisting of how we:

- Work (at home telecommuting, reduced travel).
- Shopping (at home web-based, delivery).
- Entertainment/Leisure (at home immersive 3-D interactive/multi-sensory via holographic projection).
- Travel (3-D/interactive/multi-sensory tele-travel).
- Education (at home low cost, web-based on-demand, highly motivational, life-long distance learning, .edu).
- Health (at home interactive tele-medicine).
- Politics (increased real-time virtual involvement of the body politic).
- Commerce (tele-commerce already ubiquitous).

8. DISRUPTIVE INNOVATION – FUTURE DIRECTIONS

With some exceptions, most noticeably with the synthetic dyes replacing natural dyes in 1860 and the introduction of condensation/addition chemistry in 1935, textiles has fostered sustaining technologies. These technologies are incremental in nature and may also be discontinuous or radical. This form of innovation only provides incremental improvement in product performance. What all sustaining technologies have in common is that they improve the performance of established products along the dimensions of performance that mainstream customers in major markets have valued. Textile industry of the past has brilliantly provided novel product innovations over time, but of incremental nature where by sustaining existing businesses within the existing industry structure framework. The customers have been satisfied thru better, cheaper and faster mentality. In the final analysis, the strategy of the suppliers of textile products has been to satisfy the same and now declining customer base focused on their narrow vested interest. In the future these minds set will not succeed. For the textile industry to emerge once again as a dominant force in the global economy, what is required of us is disruptive innovation (7).

8.3 Disruption Innovation Characteristics

Disruptive technologies emerge occasionally, bringing with them innovations that, at least in the near term, result in worse product performance. However, they bring to the marketplace a very different value proposition than previously available. Generally, disruptive technologies underperform established products in mainstream markets. But they have other features that a few fringe (and generally new) customers value. Products based on disruptive technologies are typically cheaper, simpler, smaller, and, frequently, more convenient to use. Furthermore, disruptive technologies that may underperform today, relative to what users in the market demand, may be fully performance competitive in the same market in the future. However, established companies shy away from investing in disruptive technologies. First, disruptive products are simpler and cheaper; they generally promise lower margins, not greater profits. Second, disruptive technologies typically are first commercialized in emerging or insignificant markets. And third, leading firms' most profitable customers generally don't want, and indeed initially can't use, products based on disruptive technologies. By and large, a disruptive technology is initially embraced by the least profitable customers in a market. Hence, most companies with a practiced discipline of listening to their best customers and identifying new products that promise greater profitability and growth are rarely able to build a case for investing in disruptive technologies until it is too late.

As seen historically, for textiles to succeed, we must focus on disruptive innovations. Existing technical programs in both academic and industry today, in general, focus on understanding improvement of current technology. This will inevitably lead to sustaining innovation for incremental gain. Clearly, there is no substitute for good science. But we must change our mindset to elicit disruptions for the success of textiles.

9. CONCLUSION – THE EMERGING PARADIGM

Innovations in textiles and in fiber science during the last part of the 20th century followed a relatively narrow and perhaps limited route of development. Fibers have been largely made from condensation or addition-type polymer platforms. Fibers may have polymer modifications, contain additives or be altered on the surface. This has resulted in nylon and polyester textiles which may be cationically dyed, are flame retardant or bioactive and have whitener/delusterant features available in a variety of cross section and surface treatments. These enhancements have resulted in product evolution of incremental nature thus sustaining in character.

For textiles to reinvent itself it should and must chart a course which will lead to disruptive innovations. The seemingly unlimited power of the synergy of diverse disciplines as borders between material science, biological science and information science blur and erode is where the future lies. Today the breadth of complementary technologies is far greater. As has been seen over and over again, game changing innovations usually occur at the interfaces between often apparently disparate scientific disciplines. Analyses of the historical development of many breakthroughs such as xerography, the heart pacemaker, or oral contraception demonstrate this. The dramatic growth in polymer science and technology in fact was fueled by interdisciplinary developments using organic and analytical chemistry, material science, as well as engineering. Today exciting developments are taking place at the interface of biotechnology and polymer science. This will certainly be a lasting and growing relationship leading to disruptive innovations. Next generation molecules will be designed, engineered and produced more efficiently from advances in combinatorial chemistry, robotics, nanotechnology, bioinformatics, spectroscopy, and high throughput screening. We will continuously seek to express a desired property in a molecule or a material, whatever are the composition and the structure and develop strategies towards building precise molecules with desired properties and functions (8,9). This will finally result in smart textile materials with attributes of selectivity, sensitivity, shape ability, self-recovery, self-repair, self-diagnosis, self-tuning and switch ability.

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