# CARBON NANOTUBES

*Carbon Nanotechnologies Incorporated*

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## EXECUTIVE SUMMARY

**Introduction** The field of nanotechnology jumped forward in 1985 when Dr. Richard Smalley (Rice University) and Harry Kroto co-discovered a new form of carbon ($C_{60}$) which they termed "buckyballs." "Buckytubes" (which is a term used interchangeably with the term “nanotubes”), produced by Carbon Nanotechnologies Incorporated (CNI) under exclusive license from Rice University, bridge the gap between nano and micron sizes. Buckytubes have "exceptionally high material properties such as electrical and thermal conductivity, strength, stiffness, and toughness."[1] These characteristics make many potential applications possible. One technology that is close to production is in the area of low-power, high-quality display solutions, namely, advanced flat panel displays.

**Business Model** CNI has positioned itself as "the preeminent producer of buckytubes." As such, they have a differentiated product to service their customers, which currently include over 700 leading academic research centers and a wide variety of small and large companies whose businesses depend on advanced materials. The ultimate end users are the consumers of the products manufactured with buckytube components, such as the flat panel displays. To accomplish this task, CNI maintains a delicate balance with their coopetitors to advance the research and development of products to drive the need for their buckytubes.

**Market** The sale of buckytubes seems to be in the growth phase. Since the discovery of them, and the subsequent theoretical application of their properties, more technological firms are seeing a potential future use for them. However, some firms are abandoning buckytube research for nanowire research, given the apparent impossibility of a practical and cost-effective purpose for buckytubes in their industries. The nanotube market is expected to grow to $540 million by 2007.[2]

**Competition** Currently, there are between 50 and 100 nanotube producers worldwide.[3] Producers can be divided into two categories (captive and open producers). Captive producers produce for internal use only and open producers sell to the general market.

**Summary** The business model CNI is following has great potential to produce positive financial results. CNI certainly faces challenges such as future competition in the nanotube industry and pressures from substitute products for commercial applications. However, it is also possible for CNI to overcome these challenges through effectively and efficiently capitalizing on its cutting-edge research and intellectual property rights.

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[1] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Buckytube Properties, accessed 7/30/2005.
[2] http://www.fuelcellsworks.com/Supppage1285.html, accessed 8/4/2005
[3] http://www.aip.org/tip/INPHFA/vol-8/iss-6/p18.html, accessed 7/25/2005.

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## Introduction

Nanotechnology is the science of particles of approximately 1/75,000th the size of a human hair (one-billionth of a meter).[4]

The field of nanotechnology jumped forward in 1985 when Dr. Richard Smalley of Rice University in Texas and Harry Kroto of the University of Sussex co-discovered a new form of carbon ($C_{60}$) which they termed "buckyballs."[5] "Buckytubes," (used interchangeably with the term nanotubes) produced by Carbon Nanotechnologies Incorporated (CNI) by exclusive license from Rice University/Dr. Smalley, have nanometer-scale diameters and micron scale lengths that bridge the gap between nano and micron sizes. Buckytubes can be either single or multi-walled carbon tubes endowing them with "exceptionally high material properties such as electrical and thermal conductivity, strength, stiffness, and toughness."[6] Possessing these characteristics creates the opportunity for many potential applications. One technology that is close to production is in the area of low-power, high-quality display solutions, namely, advanced flat panel displays.

## Overview of the Business Model

Buckytubes serve the basic and applied research markets, as well as numerous other markets of end-stage industrial and consumer goods. For example[7]:

- Textiles/Materials: The textile industry could use nanotubes in applications from bullet-proof vests to building materials for a "space elevator." Other advancements could be made with aerospace materials, electron beam lithography, fuel cells, and possibly even nano-sized needles that can inject substances into, or sample substances from, individual cells.

- Electronics: The electronics industry could forge large advancements in integrated circuits and memory storage capacity. Other advancements can be made in X-ray technology, lighting, and flat panel displays (with possible near-term commercialization).

The main products that CNI produces are application-specific buckytubes and research-grade buckytubes tailored for specific industrial applications based on purity, morphology, chemical functionality, thermal stability, electrical connectivity, and other application specific features/needs.[8]

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[4] http://www.ellipse.ch/Produit.aspx?Produit=118386, ellipse libraire, Nanotechnology for Dummies, accessed 7/30/2005.
[5] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, About CNI, accessed 7/30/2005.
[6] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Buckytube Properties, accessed 7/30/2005.
[7] CMP cientifica, Nanotubes, Applications, page 11, January 2003.
[8] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Online Store, accessed 7/30/2005.

CNI offers three application types of buckytubes (Conductive Polymer XD, Conductive Polymer XM, and Field Emission XC). CNI offers five research types of buckytubes (HiPco, Purified HiPco, Super Purified HiPco, BuckyPlus Fluorinated HiPco, and Purified Double-Wall).[9]

CNI has positioned itself as "the preeminent producer of buckytubes." As such, they have positioned themselves as having a differentiated product to service their customers. That customer base, according to CNI, currently includes over 700 leading academic research centers and "a wide variety of small and large companies whose businesses depend on advanced materials."[10]

*Activities*

CNI's current major activities include mass producing buckytubes for other researchers and manufacturers requiring advanced materials while continuing to develop new buckytube designs.

CNI conducts its own in-house research using intellectual property licensed exclusively from Rice University. It furthers this research by participating in several government-funded research projects. CNI is able to fund these activities by seeking many private investors and government grants, and selling buckytubes via menu pricing through industry/academic networks and online.[11]

*Resources*

CNI's major resource is its intellectual property. As discussed above, CNI has obtained exclusive licenses from Rice University. Additionally, it has licensed technology from other universities as well as developed technology in its own labs. Currently, CNI has obtained over 100 patents related to nanotube technology. Financial resources are derived through selling nanotube materials, private funding, and government research grants.[12]

## Value System/Value Chain

The focus of CNI is mainly on the R&D side of carbon nanotubes. They do produce, but that is not their main focus. The company develops and advances its nanotube know-how through experimentation and selling the resulting products to outside companies who, in turn, manufacture end products such as display screen. Currently, there are between 50 and 100 producers worldwide, but most are academic institutions for research purposes.[13]

[9] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Online Store, accessed 7/30/2005.
[10] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Online Store, accessed 7/30/2005.
[11] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Online Store, accessed 7/30/2005.
[12] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, About CNI, accessed 7/30/2005.
[13] http://www.aip.org/tip/INPHFA/vol-8/iss-6/p18.html, accessed 7/25/2005.

## Market Analysis

*Target Market*

In 2002, the global market for nanotubes reached almost $12 million.[14] The global market size is estimated to reach $540 million by 2007.[15] Frost & Sullivan, a firm that provides market consulting on emerging high-technology and industrial markets, reported in 2004 that the carbon nanotube market was growing at an annual rate of 98% and projected that the market size would reach $540 million by 2007.[16] In 2004, CNI had $1.6 million in revenues.[17] CNI's target market includes leading academic research centers and many small and large businesses that use advanced materials in their manufacturing processes.[18] The ultimate end users are the consumers of the products built using buckytubes. One technology that is close to production is in the area of low-power, high-quality display solutions. For example, the dramatic expansion of the mobile phone and hand-held electronics market uncovered a larger market for new display technologies. An even larger market may be in the area of Field Emission Displays (FEDs). These would be the replacements of computer monitors but without the problems of burn-in and poor viewing angles seen with the current flat-panel units, televisions taking up less space than the current advanced technologies, and large advertising displays (billboards) that can be easily and frequently updated/changed.[19]

Currently, the display market consists of various firms that make display screens, but do not have the capacity to manufacture their own buckytubes. Those firms, at present, use CNI's buckytubes for experimenting with creating new types of displays.

The potential market could be much greater, should one of those firms, or CNI itself, find an affordable way to mass produce buckytubes for use in displays. In that case, more companies would be interested in licensing the ability to make their own nanotubes from CNI. The size of the market in terms of annual sales at maturity for the nano-display market is expected to grow to $1.6 billion in 2007 and reach $7.5 billion by 2011.[20] It is not currently known what percentage of total nanotube sales will be concentrated in nano-displays.

At present, Digital Light Processing (DLP) screens offer the highest level of technology in reliable display screens, and with them the highest price tag. Plasma screens, due to their lack of reliability, are phasing out of the market. As such, Texas Instruments, the company that has patented the DLP chip, experienced $750 million in sales of DLP for 2004.[21] This is significant because the DLP market would likely be the same as the plastic display market, and serves as a benchmark.

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[14] http://www.fuji-keizai.com/e/report/carbon_nano_e.html, Carbon Nanotubes, Worldwide Status and Outlook, September 2002.
[15] http://www.fuelcellsworks.com/Supppage1285.html, accessed 8/4/2005.
[16] http://www.fuelcellsworks.com/Supppage1285.html, accessed 8/4/2005.
[17] http://www.zapdata.com/cl/view_report.jsp, zapdata.com, Company Lookup Reports, Carbon Nanotechnologies Inc, accessed 8/3/2005.
[18] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, About CNI, accessed 7/30/2005.
[19] Wireless News, NanoMarkets Research: Next Generation Plastic and Nanotube-Based Displays to Hit $3.4 Billion by 2009, posted 4/21/2005.
[20] www.tekrati.com/T2/Analyst_Research/ResearchAnnouncementsDetails.asp?Newsid=3932, accessed 7/25/2005.
[21] http://www.business2.com/b2/web/articles/0,17863,1019460,00.html, accessed 7/23/2005.

*Market Growth Rate*

The sale of buckytubes, for all uses, is in the growth phase. Since the discovery of them, and the subsequent theoretical application of their properties, more technological firms are seeing a potential future use for them. However, buckytubes' future is nebulous. They could prove to be a tremendous success, should profitable uses of them be discovered. Alternatively, they could prove minimally useable in commercial markets. Given the current trends in this growth phase, as reported in the "Target Market" section, cautious optimism is warranted.

Speaking specifically of nanotube displays, potential sales could be very robust. The growth in the digital television market is particularly noteworthy. The growth rate for this year is expected to be 70%.[22] Home theaters are a very hot seller, and as more channels begin broadcasting in High Definition, or HD format, more people are upgrading their televisions to digital models. As such, if nanotube displays can overcome the cost-effectiveness barrier, they could become tremendously profitable. For CNI, this would mean increased sales, increased interest in new forms of buckytubes, and increased interest from other industries in using buckytubes in their own technologies.

*Marketplace Characteristics*

Since the buckytube is a highly specialized product with a very narrow target market (researchers in chemistry and physics), there is no need for an outside sales force. CNI is known in professional circles via word of mouth and professional interactions. Additionally, they are accessible through the internet. Richard Smalley, being the pioneer of fullerenes, is very high profile in that community. Therefore, the company with which he is affiliated is also high profile to those people who are interested in the field. Given the prominent nature of Smalley and Rice University, people looking for nanotubes will naturally be cognizant of CNI.

*Demand-Related Risk*

The risk in the income variability for CNI for our analysis will likely come from the overall economic cycle when we discuss the specific application of nanotubes to televisions. Televisions are replaced at a faster pace when the economy is good and less so when the economy is slow. One way to mitigate this risk is to reach global markets for televisions. However, as more economies become tied together, most economies show strong correlations as shown by the comparison of market indices for major countries. Another way to mitigate this risk is to reach into non-cyclical markets such as household goods market. If carbon nanotubes could be used for toothbrushes, razors, or watch belts, the ups and downs in the electronics market could be moderated. If CNI can generate enough revenue in the stable markets to cover its R&D expenses and other fixed costs, it would only help it to advance in the nanotube market despite the inevitable economic cycle.

Another type of risk that must be considered is whether nanotubes can be applied in a commercially viable manner to make nanodisplays work. Currently, CNI supplies high-purity nanotubes to cutting-edge research and academic institutions. However, the purity and quality required for commercial applications could be lower and the amount to be supplied will likely be

[22] http://www.business2.com/b2/web/articles/0,17863,1019460,00.html, accessed 7/23/2005.

greater. Given this situation, if CNI pursues its strategy of producing only high-end nanotubes, there is a risk of not having a manufacturing technique that could mass produce a commercially viable quantity.

Further, the current business model entails the risk of being overtaken by other firms that also produce multi-walled nanotubes. As it is later discussed, multi-walled nanotubes have a lower price. If the multi-walled nanotubes are a viable substitute to single-walled nanotubes in commercial applications, the market may favor manufacturers that pursued the strategy of making cheaper nanotubes.

*Customer Needs Satisfied*

CNI satisfies over 700 leading academic research centers by providing research-grade buckytubes and participating in government research projects. They satisfy companies whose businesses depend on advanced materials by providing application-grade buckytubes.[23]

As mentioned above, the proliferation of industrial/medical/consumer handheld electronics has driven a need for low-power, high-quality display solutions (plastic displays). According to Wireless News, "Plastic electronic displays based on organic LEDs and circuitry will meet this challenge and also enable flexible, paper-like displays that can be rolled and connected to handhelds when needed, thus enhancing the visual output for smart phones, portable video devices and industrial/medical handhelds."[24]

*Customers' Alternatives*

Nanotube customers could choose to vertically integrate backwards and begin production of their own buckytubes. Additionally, other technologies, not based on organic carbon nanotubes, could be developed that would negate the value of buckytubes altogether. Silicon nanowires are also emerging as a potential substitute for buckytubes.[25] Thus, CNI faces the risk that its customers would produce their own nanotubes rather than buy from CNI, or choose to work with other emerging technologies rather than nanotubes.

Of course, a customer in need of buckytubes could choose to turn to another nanotube manufacturer. Particular companies are discussed in the Direct Competitor's section. Other manufacturers of buckytubes do tend to offer lower prices.

*Superior Value*

CNI works very closely with its 700-plus customers and research partners across the globe to help generate value for its product. The delicate balance is to work with coopetitors to advance the research and development of products who will then drive more need for CNI's buckytubes. For example, many firms such as Motorola are working to perfect the plastic display technology. However, the first firm to develop a workable method will patent the technology and hold first mover status in the market. CNI wants to help move the research

[23] http://www.cnanotech.com, Carbon Nanotechnologies Incorporated, Online Store, accessed 7/30/2005.
[24] Wireless News, NanoMarkets Research: Next Generation Plastic and Nanotube-Based Displays to Hit $3.4 Billion by 2009, posted 4/21/2005.
[25] *The Skinny on Nanotubes*, Helm, Burt, Business Week Online, posted 10/28/2004.

along, while at the same time try to lead the pack so they can be the lead supplier for applications such as plastic displays. CNI believes that its buckytubes offer superior value in terms of reliability. By CNI's calculations, its own production process yields 100% useable buckytubes, while competitors' processes only yield a 30% usability rate. CNI's ties with Rice University and the large number of patents it holds also hold promise for superior value.

## Competitive/Cooperative Forces

*Dependence on Complementary Products*

A complementary product for the nanotube, given this application, would be television itself, or other forms of display screens. Should those products' popularity and usefulness wane, the nanotubes themselves would be in less demand. The advent of HDTV has encouraged and continues to encourage people to upgrade their televisions to HD-ready models, which have caused a huge boost in digital television sales. As content and software (i.e., games) advances are made, improved graphics capabilities will be required.

*Bargaining Power Relative to Buyers and Suppliers*

Menu pricing is listed on the website, with no mention of bulk discounts. The bargaining power of the buckytube maker is relatively high. If a firm believes that buckytubes might be the next big innovation in their industry, early research is important. Because of the complexity of producing Buckytubes, manufacturers are dependent on producers such as CNI for buckytubes. However, there is always the risk that a firm could backwardly integrate and research a way to manufacture its own buckytubes. Should that happen, CNI would lose the opportunity to provide either buckytubes themselves or licensing for the production of them.

The raw materials used by CNI are widely available carbon materials. The primary value of the buckytubes is as a result of the proprietary processes CNI performs to develop the buckytubes.

*Direct Competitors*

Currently, there are between 50 and 100 nanotube producers worldwide.[26] Producers can be divided into two categories (captive and open producers). Captive producers produce for internal use only. Examples of captive producers include government, academic, or corporate laboratories. Examples of open producers include Carbolex, NanoLab, Carbon Nanotechnologies, MER, and Dynamic Labs, Helix Material Solutions, Nanocyl S.A., and Rosseter Holdings Limited. Finally, some companies are a mix of captive and open producers (i.e., Motorola Labs and IBM).

Three of these companies stand out as major producers that directly compete with CNI: Helix Material Solutions, Nanocyl S.A., and Rosseter Holdings Limited. Helix Material Solutions, interestingly, pays to advertise with Google.[27] Nanocyl S.A. is the leading manufacturer and developer of carbon nanotubes in Europe.[28] Rosseter Holdings Ltd. is a firm

[26] http://www.aip.org/tip/INPHFA/vol-8/iss-6/p18.html, accessed 7/25/2005.
[27] http://www.helixmaterial.com/Ordering.html, accessed 7/17/2005.
[28] http://www.nanodynamics.com/Home/NDcorporateInfo/NDpressreleases/March32005, accessed 7/17/2005.

in Cyprus that manufactures nanotubes for sale. Because the nanotube market is in an accelerating growth mode, the market is large enough to minimize rivalry.

Helix Material Solutions, Incorporated (www.helixmaterial.com) is located in Richardson, Texas. It was founded in 2003 by a group of experts in nanotechnology. Their value proposition is to "bring the best nanoscale materials to the market at affordable prices." According to Helix, they use proprietary chemical vapor deposition and arc processes to produce nanotubes with controlled diameter distributions that can be tailored for various applications.

Nanocyl S.A. (www.nanocyl.com), founded in 2002, is located in Sambreville, Belgium and, according to their web site, is the leading producer of carbon nanotubes in Europe. According to Business Wire, Nanocyl "specializes in the production and functionalization of nanotubes, enabling the company to integrate carbon nanotubes into metals, biomaterials and polymers." Nanocyl recently invested 2 million euros in a planned 5 million euro investment to develop a new technology nanotube reactor. According to Business Wire, this reactor is expected to substantially raise Nanocyl's nanotube production capability to 15 kg per day, making Nanocyl one of the world's main producers of nanotubes. As of September 2004, Nanocyl had twelve employees.

Rosseter Holdings Limited (www.e-nanoscience.com), founded in 1998, is located in Limassol, Cyprus. Their value proposition is to specialize in the large-scale production of carbon nanotubes and related materials. Rosseter claims to have developed a new low-energy, easy to use, environmentally friendly technique of mass producing nanotubes at the rate of 60 kg per week. According to Rosseter, "We have finally put into production what we call our Nanotube Generator. We are already in talks to supply US and Japanese companies that make mobile phone, flat panel displays, computers and fuel cells."

*Threat of Potential Entrants*

The biggest threat for CNI in terms of potential entrants is the potential of display manufacturers funding their own labs to begin production of their own nanotubes. The threat of large-scale manufacturers, such as Samsung, Sony, Toshiba, and Hitachi, is relatively moderate. This is because of the high costs of setting up a research and development laboratory, installing cutting-edge scientists to work in the lab, and the lack of intellectual capital in the area of nanotube manufacture that the company would have.

*Pressures from Substitute Products*

Silicon nanowires are emerging as a potential substitute for buckytubes. As noted above, nanowires are showing more potential at this point in research.[29] "Like tubes, nanowires can form super small transistors and wires. While they lack tubes' spectacular strength, they can still be counted on to produce complicated configurations."[30] Additionally, other forms of display technologies are also substitute products, such as LCD, DLP, and CRT.

As the popularity of digital televisions continues to grow at a tremendous pace, DLP displays are nibbling away at market share from year to year. As the prices of DLP continue to

[29] *The Skinny on Nanotubes*, Helm, Burt, Business Week Online, posted 10/28/2004.
[30] *The Skinny on Nanotubes*, Helm, Burt, Business Week Online, posted 10/28/2004.

drop, due to increased sales and thus economies of scale, the market share continues to expand. Should nanotubes prove to be financially viable in display screens, a similar phenomenon would likely occur: There would be huge potential to capture market share, as the newest technology. The tiny size of nanotubes could shrink the unit size drastically, which would be a great competitive advantage in the television market, as units continue to be weighty and sizeable. As the nanotube display gained market share, it would enjoy increasing returns due to economies of scale, just as DLPs currently are. With lower costs of nanotube displays, lower-tech products like LCD and CRT would fail to compete. Thus, the challenge and the key are to make nanotube displays price competitive with other television types. There is little doubt that nanotube displays can be made, from a technological standpoint. However, there is a tremendous amount of uncertainty regarding whether or not such technology could ever be made affordable to produce and sell.

Overall, the market is attractive due to good bargaining power relative to buyers and suppliers, and low rivalry among direct competitors and threat of potential entrants. Although dependence on complementary products is high, those complements are in a high growth, sustainable market. The only unattractive element is that many substitutes will be available. However, this one element does not overshadow the other factors.

| *ATTRACTIVENESS:* | |
|---|---|
| Dependence on complementary products | High. The market for display screens directly affects the success and profitability of the use of nanotubes in displays. |
| Bargaining power relative to buyers | Good |
| Bargaining power relative to suppliers | Good due to readily available carbon material. |
| Rivalry among direct competitors | Low |
| Threat of Potential Entrants | Moderate. High cost of laboratory setup, high cost of appropriately experienced researchers, the need to "reinvent the wheel" in terms of production methods for a newcomer firm. |
| Pressures from Substitute Products | There will be substitutes available, so pricing of the finished product will be crucial. |

## Macro Environmental Forces

Current indications of the macro environment indicate an attractive yet risky market for CNI. As a result of the government's interest in the continued development of nanotechnology the industry is ripe with opportunity and funding, but lurking in the background is the uncertainty of the general safety of consumers exposed to carbon nanotubes.

Outside of intellectual property rights there are no current regulations or industry standards issued on how to handle carbon nanotubes. There has been a slight indication as to the safety of this product due to the microscopic size of the carbon particles allowing it to easily become airborne. The reaction to inhalation, contact with the eyes, nose, mouth or skin, and ease of entrance into the bloodstream is not yet known to its fullest extent at this time.

According to Anthony Seaton, a professor at the University of Aberdeen, research indicated that in a small percentage of small animals exposed to large quantities of carbon nanotubes for long periods of time, there have been unfavorable results. Petia Simwonova, of the National Institute of Occupational Safety and Health in Morgantown, WV, indicated that mice exposed to airborne particles for at least six months showed substantial DNA damage. This denotes that protective measures will need to be taken during the research and development stage through the production process. In addition to handling precautions, exposure levels should be further studied for in-home applications. Once an acceptable exposure rate has been established multiple federal agencies, including the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), the National Institution of Occupational Safety and Health would need to monitor the research and development industry and production facilities for quality assurance. [31]

With the U.S. dollar at a significant disadvantage in the global economy, purchasing licensing rights from CNI, an American based firm, would prove to be an attractive opportunity for companies such as South Korea's Samsung and Japan's Ise Electronics. Seeking buyers outside the United States would increase its market share, create additional revenue, and increase industry competitiveness.

Pricing for carbon nanotubes technology rights vary greatly due to several factors: quality, purity, exact form, and the techniques used in manufacturing. Currently potential royalties are vast due to the innovative nature of the knowledge base. Much like other research and development industries, CNI will be able to benefit from economies of scale (royalties acquired through high demand of this knowledge) and eventually economies of scope (several slight modifications to the nanotube to produce significantly different application possibilities) once nanotube technology has penetrated the mainstream of consumers. Capitalizing on these two factors will decrease the financial risks associated with this form of technology and act as a buffer to the ill effects of the product lifecycle.

In recent years the American Government has taken interest in the nanotechnology market. As a result, it has spawned a research and development movement with approximately $422 million dollars in funds being distributed to firms in 2001 alone and the promise of more to come.[32] In May of 2003, The House of Representatives passed a bill authorizing more than $700 million for nanotechnology research in fiscal 2004. These additional fund are to support the National Nano-Technology Initiative (NNI) legislation initiated by the Clinton administration and implemented by the Bush administration.

Educating the public will create opportunities to implement new technologies into the realm of commercialization. Just as television entertainment overtook radio shows, nanotube technology will also revolutionize the communication and entertainment industries creating opportunities not yet discovered in the current R&D industry.

[31] PRIMEDIA. Business Magazines & Media Inc. 2004.
[32] Fortune Magazine, The Soot That Could Change the World, posted 6/25/2001.

## Summary of Opportunities and Threats

Currently, CNI is a technology driven business with a first mover advantage. Through this strength, it has been able to meet the performance and demands of the fast paced industry through its many nanotechnology advancements. CNI currently has over 700 direct buyers capturing a large portion of the carbon nanotube market while patenting all of its additional advances. CNI has also created financial security through its partnerships with Rice University, the sale of its products and its continuing R&D efforts. Although CNI appears to have security and stability, CNI also has the potential threat of competitors within its market. Companies such as Samsung, Sony, Toshiba and Hitachi are currently researching the buckytube flat screen implementation and may chose to develop their own R&D facilities should buckytube technology become the preeminent technology. Motorola has already entered the market by establishing its own R&D of carbon nanotubes for the potential production of flat panel screens. Carbon nanotube technology is in the premature stage of development and many of the environmental factors are still unidentified. Should health issues arise, carbon nanotubes may be deemed hazardous for public use and CNI would no longer have a viable business plan. CNI also has to factor in the threat of emerging technologies. Advances in battery power could downplay the need for a low-power display device. Also, nanowire research could result in buckytubes being a useless factor in the industry. Firms in the nanotube industry will need to plan for such disruptive factors in order to continue to survive.

**Opportunities:**

- Technology Driven
- First Mover Advantage
- Sustainable Financial Backing
- Current Customer Base
- Intellectual Assets

**Threats:**

- Competitors
- Environmental Issues
- Emerging Technologies

## Key Success Factors

The capabilities needed for a company to be successful in the nanotube industry include a technological vision, financial resources, intellectual and human capital, production capability, and strategic partners. Technological vision is important because it helps to focus a firm on what it does well and should continue doing. Financial resources give a company the financial investment and revenue growth that are needed to succeed in this fast-paced environment. Patent ownership and well-educated, competent employees are important to keep on the cutting edge of rapid advancement. The production capability and capacity of a firm is imperative for continuation of any leading edge. Strategic partners are necessary for success in all the aforementioned categories in which a company does not have its own capabilities. Our analysis of CNI's capabilities (discussed below) focuses on these key success factors.

*CNI's Capabilities*

*Technological vision.* CNI has a very broad and generic technical vision, which is an area for improvement due to its generality. The company's basic technical vision is to produce a high quality and highly reproducible product, which will result in the competition not being able to

compete, and thus, leave the market. The problem with this vision is that it doesn't answer how the company is going to accomplish this or when. The flaw of most companies in the industry, including CNI, is a lack of business focus. It is for this reason that most of the business aspects utilize strategic partners to fulfill this need.

*Financial resources.* In looking at financial statements, average annual growth of individual companies in the industry is between 30 and 50%. CNI is one of these growing players in the market. CNI works closely with over 700 customers around the world, resulting in extreme economies of scale, giving them more for less. The company secures funding through private investors, venture capitalists, and works closely with the government to secure additional funding. The environment for funding is competitive and the more parties that enter diminishes the funds available per company. For this reason, CNI needs to focus on becoming self-sufficient, which will come in time with increased function of buckytubes.

*Intellectual and human capital.* CNI has over 100 patents and continues to acquire more to secure its current hold in the market. The company also has one of the most experienced teams of scientists in the industry. This allows CNI to supply a large amount of high quality buckytubes and other product developments. Knowledgeable scientists also enable the company to adapt to changes in the environment and make appropriate adjustments.

*Production capability.* The company's capability lies in its knowledge of producing carbon nanotubes. The problem with CNI's capability is that the company only produces single-wall nanotubes. Unless the double-wall nanotubes succeed while single-wall nanotubes are forced to exit the market, CNI will continue to grow and expand. If single-wall nanotubes continue with historic growth, CNI will have to double its production capacity every 2-3 years. Otherwise, there will not be enough capacity at existing facilities. If funding to have its own facility becomes an issue, the company may be forced to partner with someone and outsource capacity.

Having these key strategic factors would further allow a firm to have a first mover advantage in the nanotube industry. Being a first mover in this industry is important to securing market share and establish brand name with consumers. Followers will not be as much of a force or threat unless they can make their product stand out in some other way.

*Technological Core Competencies*

CNI's core competency is the research and development of single-walled nanotubes. In the course of this endeavor they seek some of the best scientists (intellectual capital) in the industry to help them develop and secure methodology for a high quality product. It is this intellectual capital that keeps the company ahead of the competition. Additionally, patent protection adds customer value due to its securing of ideas. CNI currently holds over 100 patents.

*Complementary Assets*

Complementary assets are important for CNI because they help the company offer and appropriate customer value. The complementary assets of CNI's nanotubes include marketing and operational capabilities. The superior operational capabilities help make up for its lack of marketing capabilities.

Partnering enables CNI to capitalize and focus on its core competencies. CNI partners with companies for R&D purposes, marketing and distribution, and patent attainment. Marketing capabilities are easy to imitate and are freely available, and therefore, holds no edge over competition. The marketing and distribution activities are done through partnering with Sumitomo Corporation. Rice University is used for R&D partnering and Winstead Sechrest and Minick P.C. for intellectual property protection. These partnerships allow CNI to focus on developing nanotubes.

Operational capabilities, on the other hand, are hard to imitate and innovate. The scientists that CNI hires are important in using this very important asset to the company's advantage. The importance of operational capabilities has been mentioned and will continue to be mentioned throughout the paper due to its immense importance to the firm's livelihood.

## Comparison to Similar Business Systems

Six publicly traded companies with similar business system activities to CNI are Lam Research, Lifecell, PortalPlayer, SigmaTel, Strategene, and Volterra. Lifecell and Strategene are in the biotechnology industry, and the other companies are in the semiconductor industry. The following paragraph will point out the similarities of the companies to CNI, and possibly the future business model for CNI. Further details of the operations of these companies are described in Appendix I. The appendix also includes a discussion of the benchmarking methodology for arriving at a cost structure for CNI's business model.

Lam Research engages in the design, manufacture, marketing, and servicing of equipment used in the fabrication of integrated circuits, making its activities a critical component of other companies' manufacturing processes.[33] LifeCell engages in the development and marketing of human-derived tissue-based products for use in surgical procedures, making it a necessary corporation for both the doctors (buyers) and patients (end users). The company has strategic sales and marketing partnership for its products.[34] PortalPlayer engages in the design, development, and marketing of platform solutions, but has no production facilities. Their buyers are manufacturers of personal media players.[35] SigmaTel engages in the design, development, and marketing of integrated circuits for various products in the consumer electronics and computing markets, but has no manufacturing plants. They focus on providing system-level solutions to let their customers rapidly introduce new products.[36] Stratagene Corporation engages in the development, marketing, and manufacture of specialized life science research and diagnostic products. Its products are used throughout the academic, industrial, and government

[33] http://finance.yahoo.com/q/pr?s=LRCX, accessed 7/25/2005.
[34] http://finance.yahoo.com/q/pr?s=LIFC, accessed 7/25/2005.
[35] http://finance.yahoo.com/q/pr?s=PLAY, accessed 7/25/2005.
[36] http://finance.yahoo.com/q/pr?s=SGTL, accessed 7/25/2005.

research sectors.[37] Volterra engages in the design, development, and marketing of proprietary semiconductors for the commercial and consumer markets. Its products are used in electronics equipment over a wide spectrum.[38]

## Financial Analysis

Frost & Sullivan, a firm that provides market consulting on emerging high-technology and industrial markets, reported in 2004 that the carbon nanotube market was growing at an annual rate of 98% and projected that the market size would reach $540 million by 2007.[39] In 2004, CNI had $1.6 million in revenues.[40] Assuming that the competition is low at this stage and CNI will maintain its market share, the near-term future revenue of CNI can be projected as shown below.

Table 1: Projection of market size and revenue growth

| Year | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|
| Market Size ($M) | 69.6 | 137.7 | 272.7 | 540.0 |
| Revenue ($M) | 1.6 | 3.2 | 6.3 | 12.4 |

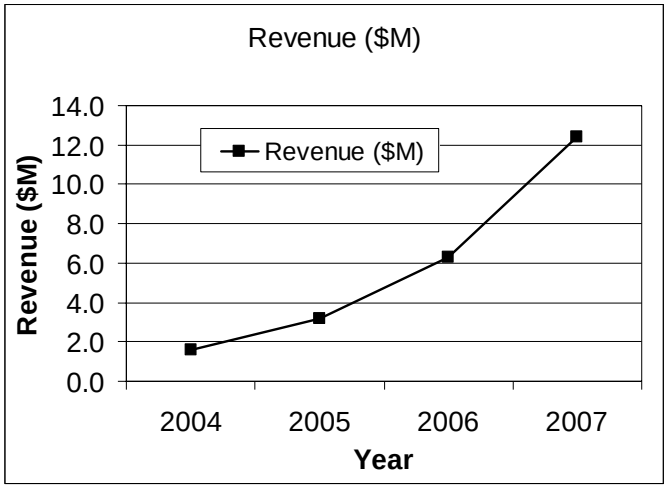


Figure 1: Revenue projection for CNI

The cost structure of the CNI model is estimated by using the financial data of companies with similar business system activities as benchmarks. The data suggest that CNI may have a cost structure that will give it a gross margin of 50%, an EBIT that is 11% of the revenue, and R&D spending that is 16% of revenue. However, the income statement for LifeCell suggests that the initial R&D spending could have a higher percentage of the revenue.

[37] http://finance.yahoo.com/q/pr?s=STGN, accessed 7/25/2005.
[38] http://finance.yahoo.com/q/pr?s=VLTR, accessed 7/25/2005.
[39] http://www.fuelcellsworks.com/Supppage1285.html, accessed 8/4/2005.
[40] http://www.zapdata.com/cl/view_report.jsp, zapdata.com, Company Lookup Reports, Carbon Nanotechnologies Inc, accessed 8/3/2005.

Fluctuations in income levels may have an impact on CNI's R&D. If the company does not generate enough revenue to support its capital expenditure necessary to conduct sufficient R&D activities to maintain its position in the market, it must seek additional funding through grants or venture capital firms.

This report has assumed that CNI will continue to pursue its strategy of differentiation through R&D and making high-quality single-walled carbon nanotubes. The financial analysis in this report assumed that the revenue of CNI would grow at the same pace of the industry.

Depending on the future use of nanotubes, there are two ways the market focus could evolve—quality and quantity. If the practical applications require high-purity carbon nanotubes, CNI is well positioned to capitalize on the market trend. However, if the market requires quantity instead of quality, competitor companies that produce carbon nanotubes by the ton may come to hold the majority of the market share.[41] However, there seems to be a large price difference between single-walled (SWNTs) and multi-walled nanotubes (MWNTs).[42] Table 2 shows that SWNTs are more expensive than MWNTs. Because the price discount based on weight is less for SWNTs, it can be assumed that the mass production techniques for SWNTs are behind that of MWNTs. A company looking into competing in the mass production of nanotubes may have to decide how much of which type of nanotubes to manufacture and choose the appropriate business strategy.

Table 2: Sample prices of single-walled and multi-walled nanotubes

| Grams | SWNT 90wt% | MWNT >95wt%, 20-30nm |
|---|---|---|
| 1 | $175 | $20 |
| 10 | $1,500 | $140 |
| 25 | $3,300 | $230 |
| 100 | $10,750 | $600 |

## Strategic Analysis and Recommendations

CNI has the opportunity of taking the role of first mover in the nanotube industry. The fact that it holds over 100 patents already is a great strength for the company. The firm also has taken advantage of networking alliances, using them to enhance their own core competencies. Additionally, CNI has benefited from the National Nanotechnology Initiative legislation that has created an environment for sustainable financial backing.

Of course, not everything in CNI's outlook is rosy. The company is not an assured success by any means. Motorola currently funds its own R&D of carbon nanotubes for electronics purposes, particularly for developing flat panel displays. As such, the threat of competition definitely exists. If other companies were to invest the vast amounts of money required to backwardly integrate as Motorola has, CNI would have a shrinking potential customer base. The fact that carbon nanotubes have shown some preliminary possibilities for adverse health effects could be tremendously detrimental to the company. They could be forced

[41] Guangzhou Heji Trade Co., http://www.gaopoint.co.uk/us/english, accessed 8/4/2005.
[42] http://www.cheaptubesinc.com/pricelist.htm, accessed 8/5/2005.

to either isolate and eliminate the deleterious conditions, or cease producing the buckytubes. Finally, technology is a fast-moving industry that can leave a firm in ruins when an alternative, superior technology is discovered. It is always possible that the "next big thing" could make the buckytube obsolete before it even becomes mainstream.

Three potential strategies for CNI are blocking, running, and teaming up. Blocking would prevent competition by keeping potential entrants at bay with barriers to entry. Without the ability to enter the market, those potential entrants would not be able to offer substitutable products, and CNI's nanotubes would be more inimitable. Running would allow continual improvement and innovation to drive the firm forward, with the goal of staying ahead of competitors. Teaming up would allow CNI to outsource work that is not in its own core competency, thus taking advantage of the competencies of partners.

Because CNI does have the opportunity for first mover status, the strategy of blocking is recommended. Preserving the inimitability of the product by preventing other potential entrants from arriving at the marketplace could be a winning strategy in the nanotube field. The run strategy is already in place at CNI, as it continues to improve the variety and types of buckytubes it offers its customers. As the potential first mover, it is important for CNI to stay at the height of innovation, so that competitors don't get the opportunity to trump CNI. Like running, CNI also already employs the teaming up strategy, which allows it to outsource its marketing department so that CNI can remain focused on its core competency, which is R&D.

## Execution Challenges

For a solid business plan to be successful it must first be implemented. Executing a business model well requires the right structure, system and processes, people and environment. CNI's functional structure should encourage continual communication and in-depth functional learning capabilities while creating a staff of experts. The business environment must be one that fosters innovation, creativity, and rewards for teamwork and collaboration. It is these key areas that will enable CNI to overcome technology-related and customer-related issues.

The technology-related issues are primarily centered on patents. Placing the emphasis on the success of the organization over the success of the individual will foster collaboration and teamwork within the culture of CNI and allow for the development of cutting edge technology. Rewarding the teams for their efforts will reaffirm CNI's dedication to continual innovation of the carbon nanotube in turn spurring additional creativity. Supporting confidentiality within the organization will also be essential to protecting the intellectual properties being discovered within CNI's structure. Until a patent becomes public knowledge, management must place an insurmountable amount of trust in each employee to ensure discretion. Because CNI's intellectual knowledge is proprietary it will be essential to protect this asset by block additional entrants into the industry and preserve the intellectual assets when deemed necessary.

Customer-related challenges will focus on gaining and maintaining market share. Because CNI's customer base will result in a long-term revenue stream, creating a culture that insures employee integrity and differentiated quality products will result in immense brand name recognition. Being known as the differentiated product supplier who has a staff whom

understands and supplies the customers' demands will structure CNI as the market leader and a benchmark for competitors. Brand recognition will commence customer loyalty while the ability to understand its customers will give CNI the direction needed for longevity and excellence.

## SUMMARY

The business model CNI is following has great potential to produce positive financial results. CNI certainly faces challenges such as future competition in the nanotube industry and pressures from substitute products for commercial applications. However, it is also possible for CNI to overcome these challenges through effectively and efficiently capitalizing on its cutting-edge research and intellectual property rights.

The nanotube industry is expected to grow at an annual rate of 98%, reaching $540 million in 2007. The growth rate of the market itself offers tremendous opportunity for CNI to increase its revenue. If CNI generates sufficient revenue and continues its investment in research and development and expands its intellectual property base, it would be well positioned to capitalize on the growth trend even more should commercial applications with nanotubes become widely accepted and demanded on the market.

## Appendix I (Company Info. from Yahoo! Finance and SEC Form 10-K)

This appendix will show the description of companies with similar business activities and an analysis of their cost structures.

1. Lam Research Corp, Semiconductor Equipment and Materials

Lam Research Corporation engages in the design, manufacture, marketing, and servicing of semiconductor processing equipment used in the fabrication of integrated circuits. It also supplies such equipment to the worldwide semiconductor industry. The company's product offerings include etch systems with a range of applications, chemical mechanical planarization (CMP), and post-CMP wafer cleaning systems, as well as post-sale services and support for these systems. The etch systems employ Lam's TCP® high density and Dual Frequency Confined™ medium density plasma sources to etch device features at current generation geometries and smaller than 100 nanometers in size. The CMP products are used to planarize the surface of the wafer to prepare it for further processing. The company sells its products primarily to companies involved in the production of semiconductors in the United States, Europe, Japan, and Asia Pacific. It competes with Applied Materials, Inc.; Tokyo Electron Limited; Ebara Corp.; and Novellus Systems, Inc.

2. Lifecell Corp, Biotechnology

LifeCell Corporation engages in the development and marketing of human-derived tissue-based products for use in reconstructive, urogynecologic, and orthopedic surgical procedures to repair soft tissue defects. It develops regenerative human tissue matrix, a three-dimensional structure that contains vascular channels, proteins, and growth factor binding sites, which provide a template for the regeneration of normal human tissue. The company offers AlloDerm for plastic reconstructive, general surgical, burn, and periodontal procedures; Repliform for urogynecologic surgical procedures; GraftJacket and GraftJacket Xpress for orthopedic applications and lower extremity wounds; AlloCraft DBM for bone grafting procedures; and Cymetra, a particulate form of AlloDerm suitable for injection. It also distributes cryopreserved allograft skin for use as a temporary wound dressing in the treatment of burns. The company has strategic sales and marketing partnership with Boston Scientific Corporation for Repliform; Wright Medical Group, Inc. for GraftJacket and GraftJacket Xpress; Stryker Corporation for AlloCraftDBM; and BioHorizons Implant Systems, Inc. for periodontal applications of AlloDerm. LifeCell was formed in 1986 and is based in Branchburg, New Jersey.

3. PortalPlayer Inc, Semiconductor - Broad Line

PortalPlayer, Inc., a semiconductor company, engages in the design, development, and marketing of platform solutions. These solutions include a system-on-chip, firmware, and software for manufacturers of hard disk drive-based and flash memory-based personal media players. Its system-on-chip platform is an integrated circuit that includes a central processing unit, memory interfaces, and other components. The company's firmware development kits include the embedded firmware code, tools, and documentation, which are necessary to develop personal media player products. Its software development kit helps customers to build applications for

managing audio and photo files stored on their personal media player. The company markets and sells its platforms through a combination of direct sales personnel, independent sales representatives, and distributors to original equipment manufacturers and original design manufacturers worldwide. PortalPlayer was founded in 1999 and is headquartered in Santa Clara, California.

4. SigmaTel, Semiconductor - Broad Line

SigmaTel, Inc., a semiconductor company, engages in the design, development, and marketing of analog-intensive and mixed-signal integrated circuits (ICs) for various products in the consumer electronics and computing markets. These products include portable compressed audio players, such as MP3 players, notebook, and desktop personal computers; consumer audio, including DVD players, digital televisions, and set-top boxes; universal serial bus; and infrared devices. The company provides system-level solutions that include integrated ICs, customizable firmware and software, software development tools, reference designs, and applications support. SigmaTel markets its products through independent sales representatives and distributors to direct and indirect customers, including original equipment manufacturers and original device manufacturers primarily in Asia, the United States of America, and Europe. It has a strategic partnership with Matsunichi Communication Holdings Limited for the use of SigmaTel MP3 audio technology within Matsunichi 2005 flash and hard disk portable audio player models. The company was founded in 1993 and is headquartered in Austin, Texas.

5. Stratagene Corp, Biotechnology

Stratagene Corporation engages in the development, marketing, and manufacture of specialized life science research and diagnostic products. Its products are used throughout the academic, industrial, and government research sectors in fields, such as molecular biology, genomics, proteomics, drug discovery, and toxicology. The company's Diagnostic division develops and manufactures products for urinalysis, and automated instrument and reagent systems that use blood samples to test for approximately 1,000 various allergies and autoimmune disorders. In addition, the company’s product portfolio includes molecular diagnostics kits and instrumentation. Stratagene is based in La Jolla, California.

6. Volterra Semiconductor Corporation, Semiconductor - Integrated Circuits

Volterra Semiconductor Corporation engages in the design, development, and marketing of proprietary, analog and mixed-signal power management semiconductors for the computing, storage, networking, and consumer markets. The company’s core products include integrated voltage regulator semiconductors and voltage regulator semiconductor chipsets that transform, regulate, deliver, and monitor the power consumed by digital semiconductors. Its products are used in data networking equipment, desktop and notebook computers, digital cameras, enterprise storage equipment, graphics cards, hard disk drives, mobile phones, optical drives, printers, servers, telecommunications equipment, wireless local area network cards, wireless personal digital assistants, and workstations. The company sells its products to original equipment, design, contract equipment, and power supply manufacturers, through its internal sales force, or through distributors and outsourced suppliers in North America, Europe, and Asia. The company was

formerly known as Berkeley Integrated Technologies, Inc. Volterra was founded in 1996 and is headquartered in Fremont, California.

The following table shows the basic income statement data for 2004 for the six companies described above.[43] All companies have high gross margins ranging between 41.9% and 71.0%. Except for SigmaTel, the EBIT is very similar among the companies, ranging between 11.3% and 11.9%. The companies spend between 12.7% and 29.8% of their revenue on research and development, and this percentage tends to become smaller as the company matures and generates more revenue. See Appendix II for historical income statement data.

Table 3: Basic income statement data for 2004 in $M

| Company | **Lam** | **Lifecell** | **PortalPlayer** | **SigmaTel** | **Stratagene** | **Volterra** |
|---|---|---|---|---|---|---|
| Revenue | 936.0 | 61.1 | 92.6 | 194.8 | 84.8 | 43.9 |
| COGS | 504.9 | 17.8 | 53.7 | 89.2 | 29.3 | 19.6 |
| Gross Profit | 431.1 | 43.4 | 38.8 | 105.6 | 55.5 | 24.3 |
| Gross Margin (%) | 46.1% | 71.0% | 41.9% | 54.2% | 65.4% | 55.4% |
| | | | | | | |
| SG&A | 146.1 | 28.5 | 7.6 | 18.1 | 34.5 | 5.6 |
| R&D | 170.5 | 7.9 | 14.8 | 32.3 | 10.8 | 13.1 |
| Other | 8.3 | 0.0 | 5.8 | 2.2 | 0.1 | 0.7 |
| Operating Income | 106.2 | 7.0 | 10.6 | 53.1 | 10.1 | 5.0 |
| EBIT/Revenue (%) | 11.3% | 11.5% | 11.4% | 27.3% | 11.9% | 11.4% |
| R&D/Revenue (%) | 18.2% | 12.9% | 16.0% | 16.6% | 12.7% | 29.8% |

[43] http://finance.yahoo.com and http://www.morningstar.com, accessed 7/25/2005.

## Appendix II (Financial Information)

Basic income statement information for Lam Research and Lifecell since 1997 is presented here. The rest of the companies have income statement information only for 2003 and 2004, so the data are not presented here.

| **Lam Research** | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | TTM |
|---|---|---|---|---|---|---|---|---|---|
| Revenue | 1002.4 | 1052.6 | 648 | 1230.8 | 1519.8 | 943.1 | 755.2 | 936 | 1478.3 |
| COGS | 689.5 | 678.4 | 414.6 | 688.9 | 866.3 | 677 | 451.4 | 504.9 | 730.8 |
| Gross Profit | 312.9 | 374.1 | 233.4 | 541.9 | 653.5 | 266.1 | 303.8 | 431.1 | 747.4 |
| Gross Margin (%) | 31.2% | 35.5% | 36.0% | 44.0% | 43.0% | 28.2% | 40.2% | 46.1% | 50.6% |
| | | | | | | | | | |
| SG&A | 197.1 | 201.9 | 145.7 | 161.4 | 218.9 | 161.9 | 132.8 | 146.1 | 161.6 |
| R&D | 170.6 | 206.5 | 142.5 | 176.9 | 227.3 | 179.2 | 160.5 | 170.5 | 194.6 |
| Other | 9 | 146.7 | 58.4 | -26.2 | 20.8 | 44.8 | 15.9 | 8.3 | 14.2 |
| Operating Income | -63.8 | -180.9 | -113.2 | 229.8 | 186.5 | -119.8 | -5.4 | 106.2 | 377 |
| EBIT/Revenue (%) | -6.4% | -17.2% | -17.5% | 18.7% | 12.3% | -12.7% | -0.7% | 11.3% | 25.5% |
| R&D/Revenue (%) | 17.0% | 19.6% | 22.0% | 14.4% | 15.0% | 19.0% | 21.3% | 18.2% | 13.2% |
| | | | | | | | | | |
| **Lifecell** | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | TTM |
| Revenue | 6 | 8 | 12.7 | 22.8 | 27.8 | 34.4 | 40.3 | 61.1 | 67.3 |
| COGS | 2.5 | 2.8 | 3.5 | 7 | 8.9 | 10.1 | 12.2 | 17.8 | 19.8 |
| Gross Profit | 3.4 | 5.2 | 9.2 | 15.8 | 18.9 | 24.3 | 28 | 43.4 | 47.4 |
| Gross Margin (%) | 56.7% | 65.0% | 72.4% | 69.3% | 68.0% | 70.6% | 69.5% | 71.0% | 70.4% |
| | | | | | | | | | |
| SG&A | 8 | 10 | 12.1 | 18 | 16.1 | 17.9 | 20.5 | 28.5 | 30 |
| R&D | 2 | 3.4 | 3.9 | 4.5 | 4.4 | 5 | 5.4 | 7.9 | 8.5 |
| Other | 0 | 0 | 2.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operating Income | -6.6 | -8.2 | -9.7 | -6.7 | -1.5 | 1.4 | 2.1 | 7 | 9 |
| EBIT/Revenue (%) | 110.0% | 102.5% | -76.4% | -29.4% | -5.4% | 4.1% | 5.2% | 11.5% | 13.4% |
| R&D/Revenue (%) | 33.3% | 42.5% | 30.7% | 19.7% | 15.8% | 14.5% | 13.4% | 12.9% | 12.6% |