

BIOSENSOR COMMERCIALIZATION STRATEGY – A THEORETICAL APPROACH

Chin-Tsai Lin¹, and Su-Man Wang^{1,2}

¹ Graduate Institute of Management Science, Ming Chuan University, 250, Chung Shan North Road, Section 5, Taipei 111, Taiwan, R.O.C. ² St. John's & St. Mary's Institute of Technology, 499, Tam King Road, Section 4, Tamsui, Taipei, Taiwan, R.O.C.

TABLE OF CONTENTS

1. Abstract
2. Introduction
3. Biosensor market and biosensor entrepreneurs
 - 3.1. Biosensor market
 - 3.2. Biosensor entrepreneurs
4. Commercialization and technology commercialization
 - 4.1. Commercialization
 - 4.2. Technology Commercialization
5. Commercialization environment impact on commercialization strategy and competitive dynamic
 - 5.1. The drivers of star-up commercialization strategy
 - 5.2. Excludability and
 - 5.3. Complementary asset
 - 5.4. The Attacker's Advantage
 - 5.5. Ideas Factories
 - 5.6. Reputation-based Ideas Trading
 - 5.7. Greenfield Competition
6. Implications for biosensor entrepreneurs
 - 6.1. Case Background
 - 6.2. Case Study
7. Conclusion
8. Acknowledgment
9. References

1. ABSTRACT

Biosensors are analytical devices, which use biological interactions to provide either qualitative or quantitative results. They are extensively employed in many fields such as clinical diagnosis and biomedicine, military applications, anti-terrorism, farm, garden and veterinary analysis, process control, fermentation control and analysis, pharmaceutical and drug analysis, food and drink production and analysis, pollution control and monitoring, microbiology, bacterial and viral analysis, mining, and industrial and toxic gases. The biosensor market has significantly increased and will be mushrooming in the next decade. The total biosensor market is estimated to be \$10.8 billion by 2007. The emerging biosensor market presents both opportunities and obstacles to start-up biosensor entrepreneurs. The major challenge and threat for these entrepreneurs is how to predict the biosensor market and how to convert promising biosensor technology into commercialized biosensors. By adopting a simple commercialization strategy framework, we identify two key elements of biosensor commercialization strategy: excludability and complementary asset. We further divide biosensor commercialization environments into four distinct sub-environments: the Attacker's Advantage, Reputation-Based Idea Trading, Greenfield Competition and Ideas Factories. This paper explains how the interaction between these two key elements shapes biosensor commercialization strategy and biosensor industry dynamics. This paper also discusses

alternative commercialization strategies for each specific commercialization environment and how to choose from these alternatives. The analysis of this study further provides a good reference for start-up biosensor entrepreneurs to formulate effective biosensor commercialization strategy.

2. INTRODUCTION

Biosensors are analytical devices, which use biological interactions to provide either qualitative or quantitative results. They are extensively employed in many fields, such as clinical diagnosis and biomedicine, military applications (e.g., anti-terrorism), agricultural and veterinary analysis. Other areas of application include but not limited to process control, fermentation control and analysis, pharmaceutical and drug analysis, food and beverage production and analysis, pollution control and monitoring, microbiology, bacterial and viral analysis, mining, and industrial and toxic gases. The biosensor market has significantly increased and will be mushrooming in the next decade. In fact, the total biosensor market is estimated to be over \$10.8 billion by 2007.

With advantages of highly target specific, sensitivity, selectivity and real-time output, biosensor had gained its ground in glucose monitoring market. By 2005, sales of biosensor based glucose monitor will reach 4

Table 1. Total Biosensor Sales in Worldwide 1997-2005(in \$000)

	1997		2000		2005	
	Total	%mkt	Total	%mkt	Total	%mkt
Clinical Diagnostics	580	89	2000	93	8500	96
Industrial Biotechnology	40	6	60	3	100	1
Environmental/Waste Water	20	3	50	2	100	1
Food and Beverages	10	2	50	2	150	2
Total	650	100	2160	100	8850	100

Source: Theta report, 1998 (1)

billion US\$ and will capture at least of 50% market share (1). Combining advances in technology of microchip, microfluidics, micro-fabrication and telecommunication, future biosensor will offer enormous diversity of applications.

These opportunities come along with obstacles. Since the first biosensor designed by L.C. Clark and C.L. Lyons in the 1960s, governments and private companies in developed countries had been heavily invested in biosensor development. Hundreds of scientists around the world had concentrated on biosensor research. In US alone, more than 2,500 new inventions had been patented. However, only few biosensors were commercialized successfully other than that of biosensor based glucose monitor. Why didn't biosensors achieve a satisfactorily successful commercialization rate? The answer is lacking effective, systematic commercialization strategies.

This paper will address this problem with a theoretical approach. Section 2 gives an insight to the biosensor market and biosensor entrepreneurs. Section 3 reviews commercialization theories and presents a simple commercialization strategy framework (2). Section 4 presents and discusses in details the two key elements of biosensor commercialization strategy: excludability and complementary asset, and the four distinct sub-environments: the Attacker's Advantage, Reputation-Based Idea Trading, Greenfield Competition and Ideas Factories. In section 5, we illustrate strategic implications of this framework for a biosensor entrepreneur through a case study.

3. BIOSENSOR MARKET AND BIOSENSOR ENTREPRENEURS

3.1. Biosensor market

The Theta Report (1998) predicted a strong future of biosensor industry even though it has been relatively flat in terms of real market penetration since their initial market appearance in the 1960s. This projected market growth for diagnostic biosensor testing can be attributed to several factors including significant market growth in two major IVD segments served by biosensors – diabetes and POC testing for critical care analytics.

Market growth in biosensors will ride the coat tails of diabetes testing that is expected to grow to \$4.8 billion in 2000 and \$8.5 billion by 2005 (1). The world total sales of biosensor are shown in table 1.

This research also estimates that the market size for worldwide biosensors at yearend of 2003 was about \$7.3 billion. Even with scary geopolitical events unfolding

and a stubborn weak global economy, the market is projected to improve and grow to about \$10.8 billion in 2007 with a growth rate of about 10.4% (3).

F&S report, entitled World Biosensor Markets, examines the market in four segments and states that 90% of sales come from medical applications. For the other segments - environmental, industrial and military - the F&S authors observe, "Scientists have been conceptualizing biosensor products almost as long as those in the medical market, but these markets were slower to emerge." Reasons for this include unacceptably high risk and uncertain returns.

Regarding technology trends, the F&S authors contend, "The most challenging issue biosensor producers face is transferring research efforts to commercialization, while medical applications will continue to dominate, "advancements into the environmental market, and into market segments such as food and beverage, and industrial health and hygiene, are expected to yield substantial returns" (4). This also initiates the motivation of this paper to study how the biosensor entrepreneur can enter the market and successfully commercialize biosensors.

Based on the indication of summary table 2, U.S. Market for Biosensors and Bioelectronics through 2006, and the current trend of population aging speed slowing down, and the attention on food quality and environment, the future of biosensor has great potential. There is value in further research on biosensor commercialization.

3.2. Biosensor entrepreneurs

There are many start-up biosensor entrepreneurs initiated by the universities. Professors and graduate students engaged in basic science research and have their invention patented. When some of these patents start showing potential market value, these professors and graduate students may team up and become the key persons of a start up biosensor company (5). Once the company starts running and establishes its commercial foundation based on its patented technology, a patent portfolio can be set up around its key patents. Also, biosensor industry exhibits a mix of established players and biotechnology start-up companies traditionally seen in most high technology business. Smaller research focused companies develop products that are marketed by large multinational organizations. As the diagnostics industry continues to consolidate and increasing emphasis is placed on globalization and manufacturing efficiencies, it can be expected that this trend in development/marketing collaborations will be intensified (1).

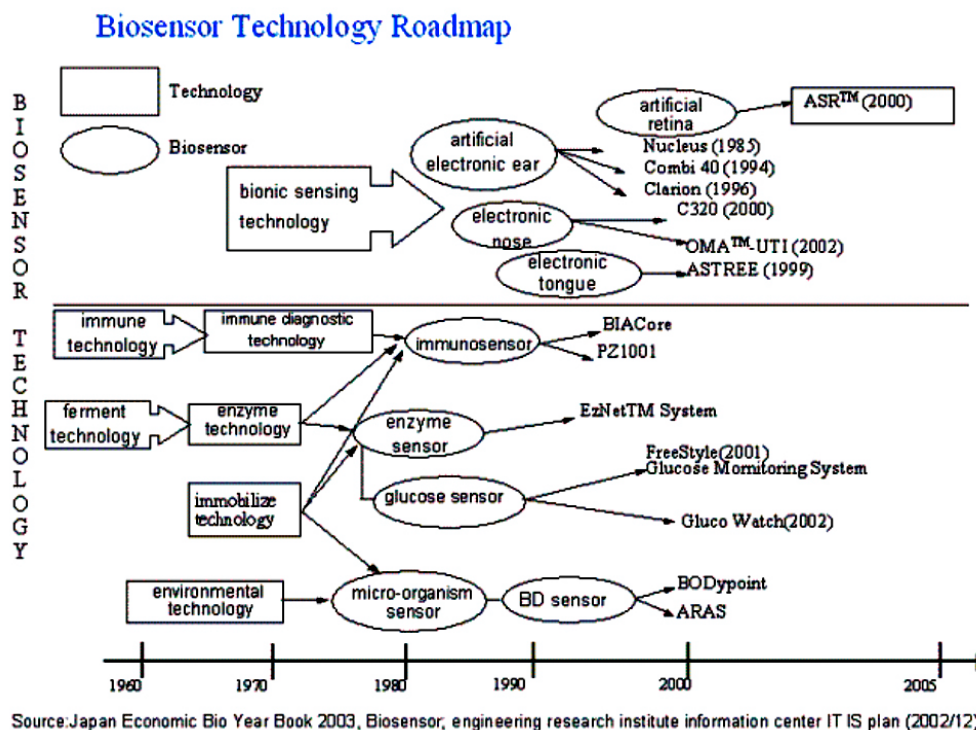


Figure 1. Biosensor Technology Roadmap.

After Clark and Lyon brought up the concept of enzyme electrode in 1962, YSI Company aggressively put into biosensor commercialization development and production in the 1970's. In 1979, YSI successfully entered the medical diagnostic market, and its glucose diagnostic enzyme electrode became the first successfully commercialized biosensor. The recent acquisition of Medisense and I-STAR by Abbott Labs, the marketing of Selfcare's biosensor by Lifescan, the numerous alliances forged by Affymetrix and pharmaceutical companies, Gen-Probe's alliance with BioMerieux Vitek, the co-marketing agreement between AVL and Roche as well as many other collaborations are being negotiated. In the diabetes industry, the biosensor portion of monitor sales received a healthy boost when Abbott Labs acquired Medisense, marketer of the ExacTech, the first glucose biosensor to be developed. In 1997 the major portion of biosensor sales belonged to Medisense with \$200 million of the \$500 million total market for glucose biosensors. Of the other major players in the diabetes industry, Roche Diagnostics (BMC) and Bayer were the first to introduce biosensor glucose monitors, but they also carry an extensive line of reflectance monitors that still occupy a significant market share. In addition, in the early 1990's, LifeScan's reflectance monitors captured at least 50% of the glucose self-testing market worldwide, leaving little room for biosensor-based meters (1).

During the year 2000, several acquisitions and mergers took place. Roche acquired Scientific, Bayer acquired Chiron Diagnostic, and BioMerieux merged with Pierre Fabre after acquiring Biotrol Diagnostic. From here, we understand that biosensor companies have to widen

their product line to gain competitiveness. Besides improving their key technology and the trend of internal vertical integrity, customer service driven integrity is also the main consideration of biosensor companies when acquisition or merger takes place. Transnational companies continue acquiring and merging to enlarge their territory, and small companies use new technology to gain profits.

From the development of market and entrepreneur of biosensors, only glucose biosensor market shows its maturity. The commercialization of other products still appears large gap to work on. Therefore, we need to value the biosensor technology commercialization seriously. Due to biosensor industry differs from other industry, almost every biosensor company enter the market after owning specific technology before they start running. Besides, independent research by a company itself is not the only way to survive. Merger, acquisition, technology authorization, and strategy alliance become a strategy consideration due to environment change when biosensor companies initiate commercialization of technology inventions.

4. COMMERCIALIZATION AND TECHNOLOGY COMMERCIALIZATION

Commercialization is the utilization of intelligence property and technology assets to create commercial profit. Due to the specific property of biosensor industry, this paper will further research the application of technology commercialization and discuss the Procedure of Technology Commercialization proposed by Jolly in 1997 and the Relationship between

THE PROCESS OF TECHNOLOGY COMMERCIALIZATION

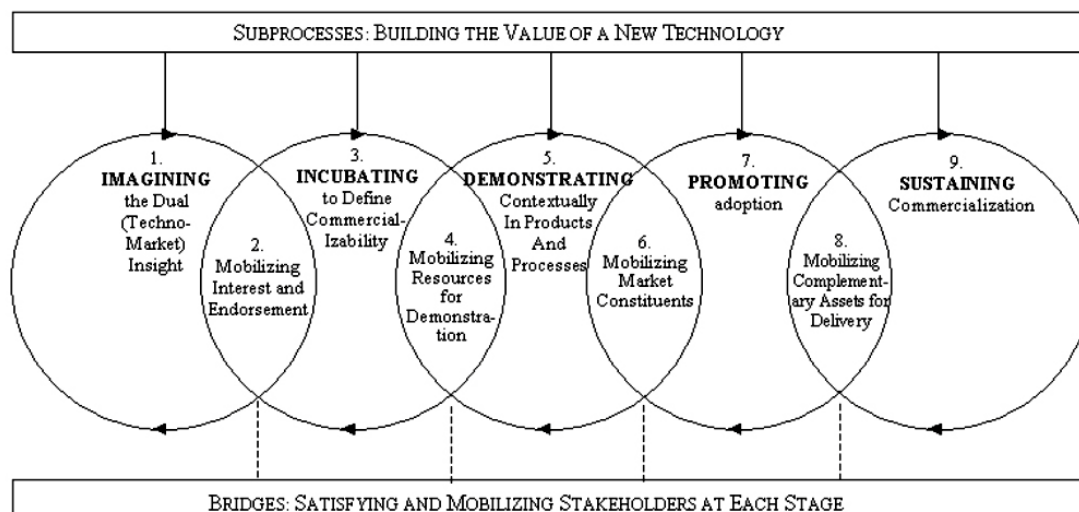


Figure 2. The process of technology commercialization.

Commercialization and Strategy Model submitted by Joshua and Scott in 2003.

4.1. Commercialization

Commercialization is to lead something that potentially possesses specific property to be sold, manufactured and displayed to produce revenue or gain capital (6). In other words, it is to promote newly developed products and market them to sell. Previous scholars suggested how to successfully commercialize new products. For example, Kotler (1998) indicated that during the development procedure of a new product, before commercialization, it should be ascertained if there is enough attraction in that particular product market before commercialization to attract the new product owner to enter that market (7). Olesen (1991) proposed that majority of the companies those succeeded new technology commercialization paid attention to the characteristics below: 1. They take risks. 2. They are market drive. 3. They focus on a product entire life cycle. 4. They are long-term thinking. 5. They are willing and able to acquire technology. 6. They seek cooperative efforts with other organizations (8).

From figure 1, we learn that biosensor commercialization can't separate from its technology development. For example, a Swedish company, Pharmacia Corporation promoted BIAcore and BIAlite biosensor products in 1991 because this company knew SPR key technology well. Therefore, it will be proper to start from technology commercialization when we study biosensor commercialization.

4.2. Technology Commercialization

Cooper (1990) pointed out in his research that the process of technology commercialization is the result of the interaction of technology push and market pull (9). A technology-based invention or discovery is initiated from an ideal and goes through research and development so the

fundamental ideal becomes a technology. When the technology integrates into a product, it can't succeed in market if the demand for the product is not concrete. Therefore, successful commercialization brings in both resource of growth and competitiveness. Emerging technology is the innovation of scientific base and has the potential to create a new industry or to change an existing industry (10). This process also can be applied to biosensor technology development. When the application of an existing technology expands to a new demand, a new technology will break out from the old technology and emerge to a new process of development and environment.

Yet there are many different theories of technology commercialization. Professor Jolly of Harvard University proposed the most significant theory in 1997 (11). He indicated that the process of new technology commercialization was divided into five stages: imagining, incubating, demonstrating, promoting, and sustaining. These five stages need four value creation activities: 1. Stimulate, support and believe the interest of new technology 2. Mobilize the assets that prove new technology commercialization 3. Provoke the element formation of demand market composition 4. Mobilize complementary assets that coordinate the promotion of commercialization for market entry (Figure 2). Within the five stages and four activities, the fourth activity is the most important step in the whole technology commercialization process. Joshua and Scott (2003) studied this most important step, market entry, in more details. In their proposed simple commercialization strategy framework, the two key elements of commercialization strategy, excludability and complementary assets, divide commercialization environment into four sub-environments. Their study provides a very clear direction for formulating market entry strategy. Hence, this paper will base on the model Joshua and Scott (2003) proposed to discuss the market entry strategy for biosensor entrepreneurs.

Table 2. U.S. Market for Biosensors and Bioelectronics through 2006 (\$ Millions)

Category	2001	2006	2001-2006 (AAGR%)
Agriculture	76.2	94.0	4.3
Medical analysis	172.3	195.5	2.6
Food monitoring	34.3	38.0	2.1
High throughput screening	1010.7	1451.1	7.5
Nan biotechnology	25.9	38.4	8.2
Total	1319.4	1817.0	6.6

Source: Business Communication Company, Inc.2002 (19)

Table 3. Commercialization strategy environments

		Do incumbent's complementary assets contribute to the value proposition from the new technology?	
		No	Yes
Can innovation by the start-up preclude effective development by the incumbent?	No	The Attacker's Advantage	Reputation-Based Ideas Trading
	Yes	Greenfield Competition	Ideas Factories

Source: Joshua and Scott,2003 (2)

5. COMMERCIALIZATION ENVIRONMENT IMPACT ON COMMERCIALIZATION STRATEGY AND COMPETITIVE DYNAMIC

From laboratory to commercial mass production, the execution is different than scientific research. It has to integrate the entrepreneur's internal technology resources and external resources to achieve the goal of commercialization. This is what current biosensor field is missing. Strategic Analysis (2002) pointed out six environmental factors: 1. Demographics—aging population. 2. Healthcare cost containment governmental policies. 3. Reimbursement issues. 4.shortfall of skilled personnel/laboratory technicians. 5.outcomes-based medicine. 6.stricter regulatory environment from Market Assessment of Global Biomaterials and Diagnostics Industries (12). In addition, Levesque *et al.*, 2004 proposed a model to indicate the complexity of the entry strategy decision and offers guidance on when to enter the market and how to enter the market, taking into consideration the current environment (13). This also supports the importance of the two elements of Excludability and Complementary asset. This paper will further explain the two key elements of biosensor commercialization strategy: Excludability and Complementary asset and the four distinct sub-environments: the Attacker's Advantage, Reputation-Based Idea Trading, Greenfield Competition and Ideas Factories proposed by Joshua and Scott (2003).

5.1. The drivers of star-up commercialization strategy - Excludability and Complementary asset

Base on Joshua and Scott (2003), our analysis focuses on two subtle yet crucial elements of the commercialization environment:

5.2. Excludability

Excludability: the extent of difficulty or easiness to obtain a product, manufacturing process, and its related technology. If the product, manufacturing process and its related technology are well protected, it will be impossible to be imitated. In general, they can be protected by patent, copyright, and business secret methods and means. This

way, imitators will be very difficult to enter this market (14). The easier the technology can be copied, the less value of the technology is. Hence, the technology-based company often has to use the patent protection to avoid competitor's imitation to ensure its competitive advantage gained through technology development. If it is foreseen that the technology may be replaced by a new technology, the company should buy out the new technology to maintain its competitive advantage. Kurokawa (1997) found that patent protection would improve a company's performance on technology development (15). Therefore, if the protection of patent is strong, company will prefer to obtain technology through internal research and development. In biotech field, patents can be classified into material-structure patent, manufacturing-process patent, and manufacturing machine patent, etc. (5).

5.3. Complementary asset

There are two types of complementary assets. One type of the complementary assets is the technology the company needed for product development. This company doesn't own this technology but need this complementary asset to develop product for commercialization. For example, Sony's Mini-Compact Disc uses the patented laser technology owned by Philips. The other type of complementary assets is the technology needed for commercialization made up by basic distribution channel facilities which includes manufacturing, marketing, distribution channel, service, reputation, brand, as well as regulations, economic and political environments, etc. which the company needed to enter its target market successfully.

The major consideration of utilizing complementary assets is to quickly form manufacturing and marketing cooperation relationships and to apply the owned complementary assets with proper adjustments to meet the needs of different stages of technology innovation when this new technology germinates at the beginning of entering market (16).

Teece (1986), who first introduced the concept of complementary asset, strongly emphasized manufacturing

and distribution related ability and believed that EMI lost its market leader position on cat scanning technology to Magic Medical due to lack of distribution channel complementary asset (17). In biotech pharmaceutical industry, Rothaermel (2001) pointed out that the complementary assets of technology development process, e.g. product experiment, testing & inspecting, FDA auditing related administrative management, marketing and distribution, etc. are the main factors of the innovation successfully transformed into best selling products (18).

Furthermore, effective commercialization strategy results from the interaction between the excludability and complementary asset environment. These two elements defined commercialization environment into following four distinct sub-environments.

5.4. The Attacker's Advantage

Consider an environment with poor intellectual property protection and where incumbents do not control the complementary assets necessary for effective commercialization. In this environment, start-ups and established firms face off on a "level" playing field. Start-up investments in the product market need not be duplicative and are often modest in size. The star-up strategies are:

- I. Few opportunities for effective contracting
- II. Opportunity to exploit technical leadership to capture market leadership
- III. Performance depends on 'stealth' product market entry

5.5. Ideas Factories

Standing in complete contrast is an environment where successful invention precludes effective development by more established firms but those firms control the complementary assets required for effective commercialization. The star-up strategies are:

- I. Contracting with established firms
- I.I. Product market entry is very costly and perhaps impossible
- I.I.I.. Performance depends on securing bargaining power

5.6. Reputation-based Ideas Trading

The above environments have well-defined patterns of competitive interaction because both the disclosure and complementary asset environment reinforce the same strategy—either competition (when incumbent complementary assets are valuable and the disclosure problem is less severe). The star-up strategies are:

- I. May be few opportunities for contracting
- I.I. Product market entry risky due to high costs and imitation risk
- I.I.I. Performance depends on existence of incumbent commitment to ideas trading

5.7. Greenfield Competition

The patterns of commercialization are similarly subtle in the final environment, where incumbent complementary

assets are unimportant but star-up innovators can preclude effective imitation. While established firms set the terms for ideas trading when excludability is weak, the power to determine the most effective commercialization strategy lies with the star-up innovator under Greenfield competition.

Ideal opportunity to choose between contracting and product market entry

Opportunity to use temporary monopoly power to build future positioning

Performance depends on strength of technological competition

6. IMPLICATIONS FOR BIOSENSOR ENTREPRENEURS

Biosensor industry is an emerging industry. The strategy adopted by each firm will vary due to the entire environment. However, a successful strategy is built upon the consideration of both external environment—complementary assets, and internal condition—excludability. Due to the limitation on data availability, this paper analyzes in details the only biosensor producer in Taiwan, Apex Biotechnology Corp. (ApexBio). This paper will use this firm as an example to illustrate the model of Joshua and Scott (2003) of commercialization of strategy as a reference for biosensor entrepreneurs to formulate biosensor market entry strategy(2).

6.1. Case Background

The president and CEO of ApexBio, Dr. Yen-Shi Shen, after received his biochemistry doctoral degree in USA, he established the first molecular biology graduate school in Chin-Hwa University in Taiwan. He established Santai Medical Equipment Corp after 8 years teaching. This corporation focused on designing and manufacturing testing equipments for laboratory and hospital. At the beginning, this corporation had no technology to produce test strips so this corporation imported the test strips from Japan. After considering the fact that these test strips are consumable material and have higher margin than test equipments, Dr Shen decided to develop by himself. In 1996, ApexBio launched their first electric current sensor of Blood Glucose Monitoring System and received "National Elite Product" prize in a national exhibition under Santai brand. In 1997 December, Santai Blood Glucose Monitor and related key personnel officially spun off from Santai Medical Equipment Corp and established ApexBio. At the beginning, ApexBio outsourced the manufacturing of Blood Glucose Monitor but manufactured the higher margin test strips themselves. In 1998, the Blood Glucose Monitor acquired FDA approval and CE Mark and the manufacturing process of electrochemical test strips patented next year. This company applied high tech OTC in 2000 and became a public company from 2001 till today. From the percentage of sales among all products, we found that Blood Glucose Monitor and test strips are still ApexBio's key products. Its major markets are the advanced countries in America and Europe. Facing the competition of multi-national companies, the key strategies of ApexBio focused on product diversification and global

distribution channels. Since ApexBio became a public company, it kept high growth rate. The key factor of its success is that ApexBio patented its manufacturing process technology and acquired FDA approval and CE Mark. Its technology is synchronized with other international big companies. Since ApexBio's inception, it plunged relative impressive R&D manpower and funds. The quality of its products is compare favorably with the one of other three globe leading manufactures, J&J, Roche and Abbott. It competes head to head with its competitors in Europe and America markets. Even its current worldwide market share is less than 1%, the future potential growth is enormous. ApexBio's brand awareness is fermenting in the international market.

In order to sustain its continuous growth by its high quality and best price, ApexBio must focuses on product diversification and differentiation and looks for niche market segment. On the other hand, as its capability of in-house glucose monitoring technology research and development becomes mature, ApexBio is going to develop other self-monitoring systems for home care and gene engineering technology for medicine, agriculture, environment and etc to diversify its products to expend its international market.

6.2. Case Study

This article discussed the timely changes of complementary assets and technology excludability environment faced by ApexBio since its inception in 1997. After his first electrochemical biosensor based blood glucose monitor successfully launched in 1996, Dr Shen separated this product and related key personnel and established ApexBio in 1997.

At the beginning, ApexBio outsourced the manufacturing of Blood Glucose Monitor and imported test strips. Then, ApexBio developed its own test strips manufacturing technology to manufacture the higher margin test strips themselves. At that time, its test strip manufacturing technology was not patented yet and the skill to manufacture Blood Glucose Monitor was still under germinating stage. Therefore, its complementary asset environment was not yet to mature in both branding and distribution channel. ApexBio's commercialization strategy is actively seeking cooperation with incumbent companies who committed to ideas trading and promoting itself as an excellent OEM manufacturer. ApexBio successfully gained a large outsourcing contract from Bayer. From commercialization strategy environments model analysis, ApexBio was in Reputation-Based Ideas Trading environment.

In 1998, the Blood Glucose Monitor acquired FDA approval and CE Mark and the manufacturing process of electrochemical test strips patented next year. These recognitions provided ApexBio a great protection of technology exclusive. ApexBio then applied OTC in 2000 and became a public company in 2001. Since then, ApexBio kept high sales growth rate. The main factor of these achievements resulted from the protection of product manufacturing process technology. A good product to be

sold in market successfully needs a better protection of the product related patent. Furthermore, another essential requirement to form branded image for competition advantage is to get patented, certified and approved. In order to sell through in a specific market, it is crucial to get approval from related government agencies. Hence, both approval of product and brand establishment are the key factors to promote technology exclusiveness. It is obvious that ApexBio was in the environment of Ideas Factories according to commercialization strategy environments model. However, during this time, the target market and complementary asset environment gradually appeared mature and ApexBio did not apply any strategy from Ideas Factories so that its worldwide market share is only 1% even though it has both advantage of R&D and cost efficiency.

Based on the experience of OBM (Ordinance Bench mark) the market of America and Europe in the previous year, ApexBio still adopted his OBM marketing strategy selling its Blood Glucose Monitor and test strips in the brand of Sensor, Seismic and Assure to American and European countries. Its strategy is to offer competitive prices to distributors, as Pguard (Medgenesis), Medline in USA and Imaco in Europe, so these distributors were willing to introduce these OBM products to their markets. From here, we can understand that ApexBio entered Ideas Factories environment of commercialization strategy environments model and cooperate with incumbent companies who own distribution channel complementary assets to improve its market share. Thus, ApexBio's Blood Glucose monitors attracted the attention of several big companies in America and Europe.

We understand from this case that Biosensor entrepreneurs' complementary assets and their exclusive technology ability will alter according to the change of environment. Joshua and Scott 2003 divided commercialization environment into four sub-environments discretely. This study suggests modify this model to continuous dynamic environment to present the complementary asset environment and the degree of protection of excludability. Biosensor entrepreneur could have better reference since their environment might falls into an area at the border of two sub-environments. However, the entrepreneur could also consider change current status of complementary assets environment. For example, American medical market is saturated and difficult to enter. If the entrepreneur chose another country as its target market, its complementary assets environment would turn into a new aspect, in addition to its exclusive technology ability and strength, to find the suitable commercialization strategy for the market.

7. CONCLUSION

Biosensor is a global industry. Its major characteristics that different from other industry are high capital intensive R&D and uncertainty of successful commercialization. In view of the fact that large international companies dominate the market as well as control the rapidly changing operation environment, a start-

up biosensor entrepreneur has to examine many commercialization strategy variables, especially the key drivers of commercialization strategy - excludability and complementary assets. There were many research papers discussed biosensor industry but very few of them discussed practical integration strategy analysis. This study reviewed many other literatures and used adequate industry analysis to examine internal technology excludability and change of external complementary asset environment to illustrate how these two elements shape commercialization strategy. At the same time, this paper also makes every effort to interview the only biosensor company in Taiwan in order to understand the process of R&D and commercialization.

The major worldwide manufacturers of Blood Glucose Monitor and test strips include Johnson & Johnson, Abbott in USA, Roche in Germany, and Kyoto Daiich (OEM manufacture for Bayer). In total, these four companies control 96% of market share worldwide. Three of them entered this market by acquiring small companies who developed new biosensor technology. According to the commercialization strategy framework (Joshua and Scott 2003), this practice falls in ideas factory commercialization sub-environment (19). In their study, the incumbent strategies of "sustained market position required securing start-up partners" also explained this practice. Through distribution agents, ApexBio gained awareness of its brand and accessed to American & European biosensor markets. This is also an example of start-up commercialization strategy under ideas factories commercialization sub-environment.

In order to enter this industry successfully, the biosensor entrepreneur must analyze different commercialization environments encountered to formulate effective commercialization strategy. This study suggests start-up biosensor entrepreneurs need to understand complementary assets and to examine the strength and weakness of its technology excludability to improve its biosensor commercialization ability.

8. ACKNOWLEDGMENT

We would like to thank referees for their valuable comments and suggestions. We also would like to thank K.S. Chang, Associate Professor of Yuanpei University, and C.C. Feng, Senior Researcher of the Biotechnology and Pharmaceutical Industries Program Office, MOEA, Taiwan for their tremendous help of providing research resources.

9. REFERENCES

1. Theta Reports. 53. 59-61 (1998)
2. D.G. Joshua & Scott S.: The product market and the market for "ideas" commercialization strategies for technology entrepreneurs. *Research Policy* 32, 333-350 (2003)
3. W. Lauara: <http://www.researchandmarkets.com/reports/c1584> (2004)
4. Frost & Sullivan: The future of web access software market 8, 10-11 (2001)
5. A. Tom: Green genes: agricultural biotechnology. In:

- The biotech investor. Eds: A. Tom, Henry Holt and Company Press, NY (2003)
6. Webster's Third New International Dictionary. Encyclopedia Britannica press, Chicago (1986)
 7. P. Kotler, Ang, S.H., Leong, S. M. & Tan, C. T.: Developing new products. In: Marketing management. Eds: P. Kotler, Prentice Hall Press, Singapore (1999)
 8. D. E. Olesen: Six keys to commercialization. *EMR*, Summer, 59-62 (1991)
 9. R. G. Cooper: Stage-Gate System: A new tool for managing new products, *Business Horizons*, 44-54 (1990)
 10. G. S. Day: Assessing future markets for new technologies in managing emerging technologies, John Wiley & Sons Press (2002)
 11. V. K. Jolly: from mind to market: the process of technology commercialization. In: Commercializing new technology: Getting from mind to market. Harvard Business School Press, Boston, Massachusetts (1997)
 12. Report to chemical industries federation of Finland, Market assessment of Global biomaterials and diagnostics industries, Strategic Analysis Inc. Press (2002)
 13. M. Levesque, & Shepherd D.: A. Entrepreneurs' Choice of entry strategy in emerging and developed market. *J of Business Venturing* 19. 1, 29-54 (2004)
 14. B. B. Tyler: Evaluating Technological Collaborative Opportunities: A cognitive modeling perspective. *Strategic management J* 16, 43-70 (1995)
 15. S. Kurokawa: Make-or-Buy decisions in R&D: small technology based firms in the United States and Japan. *IEEE management*. EM-29.1, 28-45 (1997)
 16. E. B. Roberts & Liu, W. K.: Ally or Acquire? - How technology leaders decide. *MIT Sloan management Review* Fall (2001)
 17. D.J. Teece: Profiting from technological innovation: implications for integration, collaboration, licensing, and public policy. *Research Policy* 15, 285-305 (1986)
 18. F. T. Rothaermel: Complementary assets, strategic alliances, and the incumbent's advantage: an empirical study of industry and firm effects in the biopharmaceutical industry. *Research Policy* 30, 1235-1251 (2001)
 19. R. Malika: Biosensor and Bioelectronics. Business Communications Company (2002)

Key Words: Biosensor market, Biosensors commercialization, Commercialization strategy, Commercialization environment, Review

Send correspondence to: Dr Chin-Tsai Lin, President Office, Yuanpei Institute of Science and Technology, No. 306, Yuanpei St., Hsin Chu, Taiwan 300, R.O.C., Tel: 886-3-530-2588, Fax: 886-3-530-2588, E-mail: ctlin@mail.yust.edu.tw