A MARKET ANALYSIS FOR PVD COATING SYSTEM OF AURORA NORTH AMERICA

by

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Abstract

Aurora North America, a venture founded by Dr. Da-Yung Wang, endeavours to offer its coating products while providing low-cost, quality solutions to North American manufacturers who apply thin-films to their goods. The objective of this proposed research is to provide a comprehensive analysis of the market opportunities for Aurora. This paper seeks to identify markets that have yet to fully adopt Physical Vapor Deposition (PVD) technology, as well as their potential customers. Market trend of past years will be analyzed, and future market values will be estimated based on these numbers. In addition, this analysis identifies suitable target areas in which Aurora is likely to achieve competitive advantage. Detailed analysis of market opportunity of modern PVD technology application and entrance strategies will be highlighted. This report is preliminary research of the large-scale PVD application market – further research should be conducted for more in-depth information.

Executive Summary

Over the past twenty years, Physical Vacuum Deposition (PVD) technology has developed from an idea in a laboratory to the second most popular method of coating component services. With its distinguished features of precision coating and environmentally friendly technology, PVD was quick to capture the attention of various manufacturing industries. From traditional hand tools to the exponentially growing microelectronics industry, products treated by PVD are everywhere.

Aurora Science Group (Aurora or Aurora North America) was formed as a joint venture between SurfTech Corporation – an incumbent of the PVD coating industry in the Asia-Pacific region – and Surface Engineering Research Centre (SERC) of MingDao University, a research centre that has focused on PVD material, process, technology and control system. Aurora is aiming to introduce its products and services to the North American market, and is ready to offer local manufacturers a low-cost yet quality turn-key solution.

However, Aurora is contending with global and local competitors who have rooted themselves in the market for decades; it would be inefficient for Aurora to compete with these companies through conventional industries where PVD technology is already broadly applied. Instead, after evaluating the potential of PVD technology and its ongoing development, Aurora decided to penetrate the North American market through industries that have a steady rate of growth and value, and not yet fully adopt PVD technology in their manufacturing process.

The overall market conditions of the PVD industry in relation to other manufacturing industries are analyzed in this report. In addition, this report discusses PVD's application and benefits to specific industries, includes evaluation of market potential, and presents market entry strategies.

Dedication

To my lovely wife, Shirley – this report could not have been completed without your support. Having had most of my time occupied by research and writing, your unconditional support allowed me to dedicate all of my energy to this paper. Your optimism and encouragement helped me make it this far.

Acknowledgement

The completion of this research could not have been achieved without the help of certain individuals. Dr. Dai-Yung Wang and James Hung from Aurora North America have offered great insight and knowledge about this industry. Dr. Wang shared with me the technical perspectives and potential applications he has in mind. Mr. Hung, my main contact in Aurora, exchanged all of his marketing research with me and shared the knowledge he obtained from various conferences he attended. Miss Vivienne Harwood Mattox from the Society of Vacuum Coaters also took time out of her busy schedule to aid me in my research. The most challenging part of the research was obtaining marketing information, as these professional figures are not easily accessible. Miss Ann Jacoby from BCC Marketing lent me her support in obtaining these numbers. Miss Chenoa Liu's help in editing my report is also greatly appreciated. I would like to extend my warmest thanks to my project supervisors, Dr. Gupta and Dr. Soh.

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Glossary

PVD	Physical Vapor Deposition A variety of vacuum deposition and is a general term used to describe any of a variety of methods to deposit thin films by the condensation of a vaporized form of the desired film material onto various work-piece surfaces.
CVD	Chemical Vapor Deposition A chemical process used to produce high-purity, high-performance solid materials.
SERC	Surface Engineering Research Centre Research facility in MingDao University, Taiwan
MEVVA	Metal Vapor Vacuum Arc The arc produces fully ionized plasma contains multiply charged ions.
HRRS	High Rate Reactive Sputtering The sputtering deposition procedure with improved deposit rate.
UBM	Unbalanced Magnetron A PVD process possesses stronger magnets on the outside resulting in the expansion of the plasma away from the surface of the target towards the substrate.
OEM	Original Equipment Manufacturer A manufacturer manufactures products or components that are purchased by another company and retailed under that purchasing company's brand name.
CAGR	Compound Annual Growth Rate The year-over-year growth rate of an investment over a specified period of time.
ECG	Electrocardiography A transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body.

EMI/RFI	Electro-Magnetic Interference/Radio Frequency Interference The disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. When happens in high frequency or radio frequency, it is called RFI.
DLC	Diamond-Liked Carbon Existing in seven different forms of amorphous carbon materials that display some of the typical properties of diamond. They are usually applied as coatings to other materials that could benefit from some of those properties.
PECVD	Plasma Enhanced Chemical Vapor Deposition A process used to deposit thin films from a gas state (vapor) to a solid state on a substrate. Chemical reactions are involved in the process, which occur after creation of a plasma of the reacting gases.
GDP	Gross Domestic Product The market value of all officially recognized final goods and services produced within a country in a given period.
SGMA	Sport Good Manufacturer Association The trade association of leading industry sports and fitness brands.

1 Introduction

Although the average person rarely thinks about it, thin-film coatings, used on a wide variety of industrial and consumer items, are an important part of one's daily life. The wide range of applications and the variety of coating technologies lead to high demand and market value, especially in an industrially developed region such as North America. Companies in the region are facing unique industrial market characteristics and tougher competition. Hence, the objective of this project is to conduct an investigation of the North American region in order to formulate a sustainable competitive strategy for Aurora Science Group, an established Taiwanese firm that has entered the North American market for almost three years. Among the variation of thin-film coating processes, the focus of this report will be discussing Physical Vapor Deposition (PVD), the second most highly adopted coating technology, and its application market.

The five most common types of thin-film coatings (in order of area coated per year) are as follows:[1]

i. Paints and powder coatings
ii. Electroplating and electro-less plating (galvanizing, chrome, decorative electro coating, etc.)
iii. Physical Vapour Deposited (PVD) coatings: electronic (e.g. computer chips, LCD screens, portable computer LCD screens, disk drives); optical (e.g. architectural glass, lenses, filters, headlamp reflectors); tool coatings (e.g. cutters, punches, dies); decorative finishes (e.g. hardware, plumbing, watches, jewelry), etc.

[1] pvd-coatings.co.uk

iv. Enamels (stoves, refrigerators, etc.)

v. Thermal sprays (aircraft engine parts, industrial rolls, etc.)

Over the last twenty years, PVD coating has become widely accepted as an essential component of industrial tools such as drills, cutters, punches, dies, and molds. Products with paints, enamels, and PVD coatings are used every day. However, many types of PVD coatings – those used to reduce wear of industrial tooling and those used to simulate soft materials such as gold and brass while providing a combination of decoration and abrasion resistance – are hidden from plain sight. The hard ceramic coating materials, primarily titanium nitride (TiN), are now extensively used on industrial tools of production to provide wear resistance and increase production efficiency.

In general, local coating shops supply coating services to toolmakers and manufacturers of commercial and consumer products as plating shops have traditionally done. Some manufacturers, primarily cutting tool makers such as Star Cutter, Pfauter-Maag, NY Twist Drill, and Greenfield, have installed their own equipment. High volume manufacturers have also begun to install their own PVD coating equipment over the last couple of years.

Due to the fragmented nature of the market, it can be difficult to estimate the size of the North American PVD coating market. There are approximately fifty PVD coating shops in the US (Society of Vacuum Coaters, 2012), and the value of the tool coating market has been estimated at around \$150 to \$250 million; the worldwide market is perhaps triple this amount. Increased industrial quality requirements, reduced manufacturing cost, and environmental concerns over cutting coolants have been driving factors in expansion of the tool coating industry. Furthermore, although decorative applications still account for only a small portion of the PVD business, it has more than doubled over the past five years.

1.1 Background of Market Research

Aurora North America, established in 2009 by Dr. Da-Yung Wang, is attempting to bring its products and services to the North American manufactures. As a new entrant in the North America PVD coating market, Aurora is facing heavy competition from the domestic small/medium-sized service providers, the multinational coating companies, as well as the foreign original equipment manufacturers.

This market research is essential to the assessment of potential market opportunities other than the existing ones, such as metal hard-coating, that have already been exploited by incumbents. Drawing from the information and data collected from other research sources, this report will analyze the global trends in PVD coating, determine the need for this technology, and reveal its potential. Market segments and the feasibility of a strategic market entry point for Aurora will be discussed in later chapters. This research is sponsored and supported by Aurora North America, SurfTech, and Surface Engineering Research Centre (SERC) of MingDao University.

1.2 Objective and Scope of the Market Research

PVD coating technology is still relatively new, as it was only broadly introduced to the metalworking industry in the early 1990s[2]. Research scientists and industrial engineers believe that there are still various potential markets where this technology can be applied, and are currently exploring these options. In comparison with the mainstream technology, electroplating, PVD process is relatively more costly. That results in electroplating being more popular among manufacturers producing low-cost items. However, the PVD process provides a more uniform deposit, improved adhesion up to six times greater in some cases, wider choice of materials to be deposited and contains no harmful chemicals to dispose of. Because PVD coating is more environmentally friendly and chemical disposal costs are minimal, the gap of PVD coating and electroplating costs is very marginal on some products.

Aurora wants to bring PVD technology closer to the end user in North America. Aurora's STAR series of PVD vacuum systems[3] provide a budget solution of thin-film coating that meets the requirements of numerous industries. Having Aurora's own PVD system integrated in the production process allows manufacturers to maintain closer control of their product quality, and reduce cost of outsourcing the manufacturing procedure. In addition, PVD technology is a much greener coating process in comparison to traditional electroplating. As an increasing amount of attention is placed on environmentally friendly technology and sustainability, Aurora is devoted to

[2] http://www.pvd-coatings.co.uk/history-pvd-coatings/
[3] http://www.aurorascientificcorp.com

advancing PVD system development and providing eco-friendly manufacturing alternatives.

This market research was conducted to analyze the overall application of Aurora's turn-key system and coating services. By factoring in competitors and potential customers, a better understanding of Aurora's position in the North American market is achieved. This paper also points out where Aurora can enter the market without encountering heavy resistance from existing competitors. However, further analysis of market strategy – including a detailed account of the relationship between vacuum coating and other industries, as well as a business plan – would be recommended for a better understanding.

Chapter 3 includes an internal analysis of Aurora. The structure and history of the company will be described. The advantages and disadvantages Aurora possesses will be analyzed using SWOT analysis. In Chapter 4, a thorough view of the global market of PVD coating will be evaluated in order to portrait the trend of the market. It also helps to define the market segments that indicate the prospect of growth with profitability. Chapter 5 further analyzes the market by focusing on the North America region. The chapter also features two promising industries in which PVD technology has yet to be introduced.

2 The Technology and Application

In this chapter, the principle behind PVD technology will be discussed. A brief history of the technology, followed by a description of the basic process of PVD coating will be presented. Later, the three most popular PVD technologies will be introduced, and their key differences, advantages and disadvantages are compared. Deposition temperature and the materials deposited on substrate surfaces are key factors in PVD technology's rising popularity – these elements will also be reviewed. Being able to control the temperature and materials to meet customers' requirements is a fundamental skill of PVD coating service providers.

2.1 Introduction of PVD technology

When it comes to coating technology, Electroplating, first applied to metal jewellery in 1857, is often the first type that comes to mind. Electroplating was widely used in the metal goods industry throughout its 150 years of development, until vacuum coating started to be facilitated in industries in the late 1980s[4].

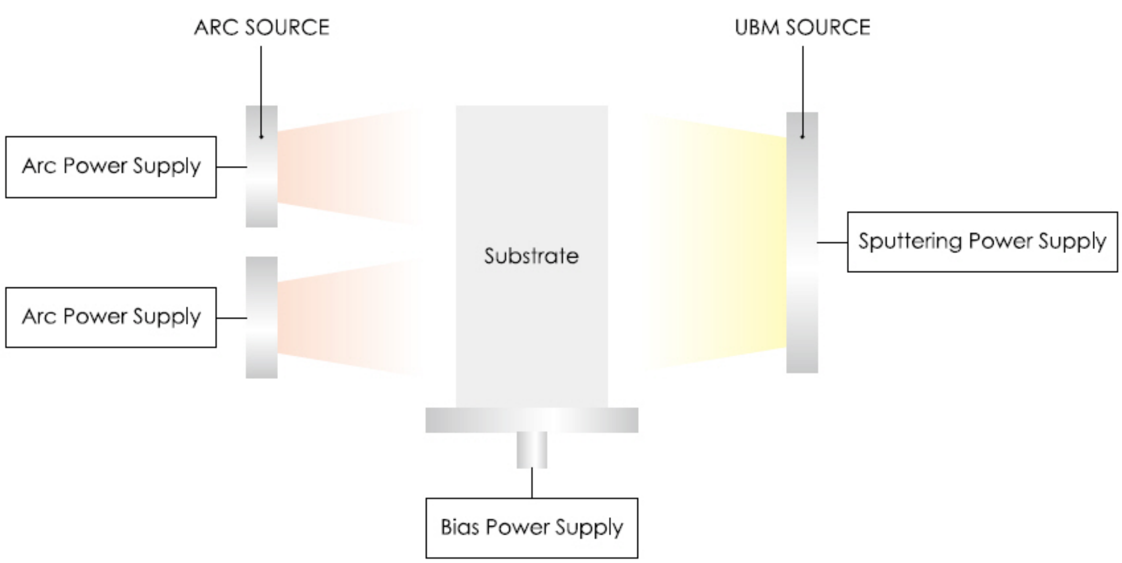
Vacuum coating is a general name for coating processes that occur in a vacuum environment. Of these, PVD is the most well-known and used in the industry. The most common PVD processes are evaporation and magnetron sputtering. The procedure is hosted in a vacuum chamber at low working pressure (typically 10^{-2} to 10^{-4} mBar), and generally involves bombardment of the substrate with positively charged ions to promote desirable adhesion. Coatings can be deposited in environments from room temperature to

[4] http://www.pvd-coatings.co.uk/history-pvd-coatings/

as high as 500°C depending on the substrate and the application. In addition, reactive gases required in the reaction may be introduced into the vacuum chamber to create compound coating. The strong bonds formed between the tool substrate and the coating are thus tailored with physical, structural and tribological properties (About Aurora, n.d.).

The PVD process provides a more uniform deposit and improved adhesion, up to six times greater, than electroplating. There is a wider range of materials able to be deposited, and there are also no harmful chemicals to dispose of. As PVD coating is more environmentally friendly and chemical disposal costs are minimal, the general cost of PVD coating is very close to, if not rivals, those of electroplating – while at the same time be of better quality.

Figure 2.1
Illustration of Vacuum Deposit Process
(Aurora, n.d.)



Considering PVD's features of precision control in coating thickness and consistency, flexible coating temperature and large selection of coating material, the possible applications of PVD are unlimited. In the early years of PVD treatment, it was mostly used in metalworking to provide endurance and lifespan to various cutting tools. In recent years, however, the procedure has expanded its range to include decorative coating and the precision manufacturing industry.

2.2 Available PVD Technologies

There are three main types of PVD coatings used commercially for hard coatings, and each has detailed modifications. The variations and descriptions of different coating methods are summarized in ***Table 2.1***. Each coating solution has its own advantages and disadvantages, and has selectively been applied to manufacturing processes in different markets. However, they all share one overarching feature – bombardment of the growing coating with ions. The bombarding ion coating procedure has two characteristics as follows:

i. It provides sufficient mobility to form a good crystalline structure and
ii. It increases density of the coating by "re-sputtering" material from the surface into voids that form beneath it.

The three major commercial hard coating technologies all draw their ions from plasma formed in the gas in the vacuum chamber. Most hard coatings are compounds that are deposited reactively by combining the metal with active gas (N or C) on the surface of the growing coating. Aurora accommodates evaporation and sputtering technology in its STAR series of PVD systems. These two process methods have always been used by SurfTech's services.

Table 2.1
Commercially Available PVD Technologies

Technology	Advantages	Disadvantages	Applications
Evaporation – ion plating, e-beam PVD, hollow cathode	Highest quality Low material cost Fast deposition	High temperature Limited coating materials	Cutters, molds, dies Small optical
Sputtering – balanced magnetron, unbalanced magnetron (UBM)	High quality Almost any material	Slow deposition High material cost High level of control needed	Cutters, molds, dies Decor Large optical
Arc – catholic, anodic, random, steered, confined, ducted	Good adhesion Wide process window	Macro-particles Limited alloys	Cutters, molds, dies, Aircraft parts
Ion-assisted – sputtering, evaporation, ion sputtering, meta-mode	Wide process window No bias	Unproven track record Line-of-sight beam	Molds, tools Optics

2.2.1 Evaporative Deposition (Ion Plating)

The highest quality coatings are produced by electron beam evaporation methods. There are two common approaches – the first method is to use an electron beam down the middle of the vacuum chamber[5] . In this approach, material is evaporated from a "boat" or crucible, usually using an electron beam that also supplies electrons for ionization of

[5] http://www.oerlikon.com/balzers/en/products-services/coating-systems/

the chamber gas. The major advantages of this method are its high quality results and low cost of evaporation materials. However, this method lacks in that the low ionization of the gas requires a relatively high deposition temperature (frequently 450 °C), in addition to the difficulty of alloy deposition. The chamber design of this approach also limits the size of the products being processed, as the center of the chamber must be kept clear for the electron beam. The second approach[6] is identical to the first, except that the electron beam comes from below, which frees the center of the chamber. Thus, this process can be used for molds and dies up to 35" diameter and 500 lbs weight.

2.2.2 Arc Deposition

Arc Deposition is the most commonly used method of tool coating. Recently, arc coatings are also being applied in the aircraft industry for auxiliary power unit wobblers and jet engine bearings. The major advantage of arc deposition is the minimized requirement of process control, especially for coating adhesion. Its main disadvantage is that it produces small "spits" or macro-particles several microns across, which give the coating a rough surface and a matte finish. This makes it unsuitable for decorative coatings and some precision tooling applications, such as mirror-finish molds for CDs. There are now some solutions for this, such as the ducted arc, in which the arc plasma is directed along a curved channel or around an obstacle to trap the particles. However, the lack of efficiency stops this solution from being standardized. Another recent innovation is MEVVA (Metal Vapour Vacuum Arc) deposition (Vacuum Arc Ion Source, n.d.), in which the material comes from a high

[6] http://www.tecvac.co.uk/coatingequipment.php

intensity metal ion source. This method is still under observation by the market for its productivity.

2.2.3 Sputtering

Although sputtered coatings sometimes also contain trapped particles similar to macro-particles, it generally produces very high quality coatings, and can be done over relatively large areas. It is used for architectural glass, electronics, and more recently, tools and decorative finishes (e.g. watch straps, bezels, automotive lights, pens, etc.). With close process control and good maintenance, sputtering can be successfully executed at low temperatures. Almost any material, including complex structured materials, can be sputtered.

In the past, sputtering has always been the slowest deposition method. The more recent development of High Rate Reactive Sputtering (HRRS) has improved deposition rate (Boling, Wood & Morand, 2002). In order to perform reactive sputtering at high rates, one must maintain control of the partial pressure of the active gas to prevent it from poisoning the cathode, otherwise the deposition rate would be greatly reduced. The process can be managed by partial pressure monitoring with closed loop feedback control; however this in itself is an additional complication. A recent advancement is Unbalanced Magnetron (UBM) (Unbalanced Magnetron, n.d.) sputtering, which increases ion bombardment by spilling the magnetic field of the magnetron out into the working volume of the vacuum chamber (hauzertechnocoating.com). ***Table 2.2*** below provides a list of PVD process technologies and their application in various industries. As mentioned in the previous paragraph, Aurora's STAR series coating system are adopting the evaporation and sputtering method based on clients' requirement. In another words, Aurora's coating systems are capable of handling a great range of application purposes. In later chapters, PVD applications and corresponding products in various industries will be described accordingly.

Table 2.2
Most Commonly Used Approaches for Different Markets

Market/application	Most Common Method
Tools	Arc Evaporation UBM sputtering
Decorative	Sputtering
Functional (wear)	Arc Evaporation UBM sputtering PECVD
Functional (corrosion)	PECVD
Small plastic moldings	Sputtering
Architectural glass	Sputtering

2.3 Deposition Temperature

In principle, one can trade off ion bombardment rate, whether from an ion beam or plasma, for temperature – the more bombardment, the lower the temperature needed (Pranevicius, 2006). However, there are practical limitations:

- Raising the bombardment raises the deposited energy, therefore the temperature.
- The lower the temperature, the more difficult it is to obtain good adhesion and structure, thus process control needs to be even more stringent.

Consequently, the best results are generally obtained when the temperature is as high as the material can withstand.

2.4 Available Coating Materials

There is a large collection of coating material available for various purposes, and can be applied in different industries. The surface is coated with a hard, lubricious ceramic layer that reduces wear and increases tool life three to ten times. These coatings are mostly metal nitrides and carbides, such as:

TiN (Titanium nitride)	TiAlN (Titanium Aluminum Nitride)	CrN (Chromium Nitride)
TiC (Titanium carbide)	TiCN (Titanium Carbo-Nitride)	ZrN (Zirconium Nitride)
Cr_3C_2 (Chromium Carbide)	DLC (Diamond-like Carbon)	AlN (Aluminum Nitride)

Conveniently, these coatings are not only wear resistant, but decorative as well - e.g. TiN looks like gold, while ZrN looks like brass. As a result, PVD coatings are gaining new markets for decorative or combined functional/decorative uses. An extended list of commonly used materials and their application in various industries is available in ***Appendix I***.

In summary, the research and development of PVD processes and materials is an on-going race between companies. Most of the technologies developed are evolved from the three main methods described above. In the beginning, due to the limitation of temperature, vacuum environment and materials, PVD coating was only applicable to metal substrates. It has since advanced to being able to coat non-metal substrates at a lower temperature, without the risk of substrate damaged. This broadens the applications and markets of PVD coating, and benefits manufacturers and users in various industries. Aurora's R&D team also works closely with SERC to fine tune their products, improving the performance and efficiency of evaporation and sputtering methods. On top of that, SERC is continuously experimenting new coating materials and methods, aiming for more variety and better quality for its clients.

3 Industry and Market Overview

It is crucial to obtain information of the ecosystem of the market, and become familiar with the value and growing potential of the market. As mentioned before, current PVD technology allows for a large selection of materials that can be applied to almost any kind of substrate. This means there is unlimited potential for PVD coating waiting to be evaluated and applied for commercial use. Analyzing the existing market allows one to understand the current trend of industries that have already adopted PVD process, such as cutting tools and microelectronics, and segments that still have potential, such as medical equipment.

According to a BCC Research report published in August 2008, the market size of the metal surface processing industry was at US$42.3 billion dollars (Industry & Technology Intelligence Services, 2009). This steadily grew to US$44.4 billion dollars in 2008, and is estimated to rise to US$61.1 billion dollars in 2013. From 2008 to 2013, the compound annual growth rate (CAGR) will be 6.6%.

When analyzed in comparison to other technologies, electroplating and vapour deposition are the most commonly used. To this day, electroplating is still an essential component of metal surface processes. The value of the electroplating market was US$11.5 billion dollars in 2007, which was approximately 40% of the market. It reached US$12 billion dollars in 2008, and is predicted to approach US$16.4 billion dollars in 2013, with a CAGR of 6.4%. In second place, due to its ability to apply thinner layers of coating with equivalent effectiveness as electroplating, is Vapour Deposition. This technology is widely applied in the precision industry and has been rapidly growing its application in various industries since 1990. Vapour deposition can be further broken down to Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD). The value of the vapour deposition market in 2007 was US$8 billion dollars, which has since grown to US$8.1 billion dollars. It is anticipated that the market will increase to US$11.1 billion dollars with a 6.4% CAGR.

3.1 Market Segmentation for PVD

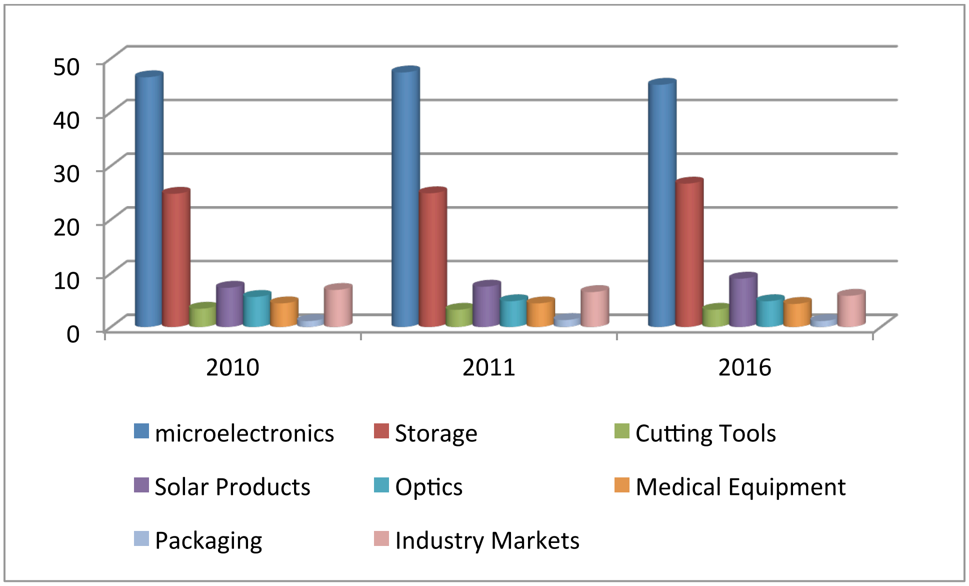
In order to further analyze the PVD coating market, the market has been broken down into eight different segments according to industry. This is a closer look at the recent changes in market trend and anticipation of market growth towards year 2016. The following table is a list of PVD equipment revenue in each industry, and its proportion to the overall market (Moran, 2012). Figure 4.1 shows the graph of the Global PVC equipment market share.

Table 3.1
Global PVD Equipment Revenue and Market Share
2010 – 2016 ($Millions, %)
(Moran, 2012)

	2010		2011		2016 (Forecast)	
	Revenue	Percentage	Revenue	Percentage	Revenue	Percentage
Microelectronics	3065.0	46.5	3355.5	47.4	4681.5	45.1
Storage	1636.2	24.8	1764.8	24.9	2773.6	26.7
Cutting Tools	216.1	3.4	225.2	3.2	329.6	3.2
Solar Products	478.9	7.3	528.4	7.5	938.7	9.0
Optics	364.2	5.6	340.1	4.8	486.4	4.8
Medical Equipment	290.9	4.4	315.1	4.4	448.0	4.3
Packaging	90.7	1.1	92.0	1.3	121.9	1.1
Industry Market	448.2	6.9	464.0	6.5	590.9	5.8

Total	6590.2	100.0	7085.1	100.0	10370.6	100.0

Figure 3.1
Global PVD Equipment Market Share
2010 – 2016 (%)
(Moran, 2012)



Key points about PVD coating equipment market can be drawn from the analysis of the revenue and market share data. Firstly, based on the existing data for 2010 and 2011, one can observe a 6.9% growth rate of the overall value of PVD shipments. Secondly, in comparison to the previous years of recession, the market has resumed rapid growth as prior economic situation between 2008 and 2009.

The microelectronics market still remains at its all-time high due to the demand of precision manufacturing processes, as well as high quantity and high quality requirements of production. Following the drastic growth of development and demand of microelectronic devices at consumer and industrial levels, the interest in PVD is expected to grow at an exponential rate.

The cutting tool industry, the first to adopt PVD technology, continues steady application of PVD technology to replace the traditional electroplating methods. However, as PVD technology has been used on cutting tools for a while now, the market opportunity is saturated. The share of the cutting tool industry is likely to decrease slightly approaching year 2016.

The data storage device industry was discussed separately in the analysis due to greater involvement of PVD technology in its processes; the majority of storage device components require PVD coating in order to achieve desired performance. Their market share grew by 7.8% through 2010 and 2011, and is expected to rise to 10.6%. This is also due to the high demand of storage devices in the computer and business worlds. Storage is ranked second, behind microelectronics, amongst all industries.

The medical equipment and packaging industries are considered very small in comparison to microelectronics and data storage device industries. Despite this, both industries show large potential, especially in the North American market. The medical equipment industry is unique in that its products are mostly manufactured in North America, unlike many other industries that have a large portion of their production done in China and the Asia-Pacific. The medical equipment market will be further discussed in later chapters as a candidate market entry point for Aurora.

3.2 Porter's Five Forces Analysis

Michael Porter argued that there are five forces that determine the profitability of an industry (Porter, 2008). These five forces are illustrated in ***Figure 4.2***. Porter's Five Force model consists of those forces surrounding an average company in the industry that affect its ability to serve customers and make profit. Ideally, a change in any of the forces requires a company to re-assess the market place. In order to achieve a profit above the industry average, a firm needs to strategically apply their resources, business model and/or network based on a thorough analysis of the competitive environment. The later analysis is using Porter's five forces to evaluate the PVD coating service and product market. By reviewing the market situation from different aspects can provide a better understanding of Aurora's current competitive position.

Figure 3.2
Porter's Five Forces
(Porter, 2008)

3.2.1 Threat of New Entrants

A growing, profitable market that yields high returns will attract new firms. However, an increase of new firms dilutes the profitability for all firms in the industry. Thus, new firms often face entry barriers; certain industries require new firms to meet specific conditions before entering the market, and some incumbents deter new entrants by claiming patent of essential technology.

As this market is considered a heavy capital and technology oriented industry, barriers to entry are fairly high. The preliminary barriers of PVD coating equipment industry are:

- Protection of intellectual property of certain core PVD process technology
- Ability to obtain sales and service channels for the market while building brand name
- Recruitment of personnel with experience and skills in consolidating vacuum chambers and electro-systems
- Establishment of supply chains for components and reliable technical support
- Period of trial and error to develop satisfactory recipes
- The consistently growing requirement for capital investment
- The economic of scale established by incumbents that gain advantages in pricing or profits

3.2.2 Bargaining Power of Customers

The bargaining power of customers, or buyers, can put pressure on goods/service providers. Buyers with strong bargaining power also have the opportunity to request lower prices; this is highly dependent on the availability of substitutes and switching costs.

Customers are normally bound to a single PVD coating service provider, and have minimal bargaining power for prices. Due to the difficulty of finding the right recipe to meet customer standards in quality and functionality, the cost will affect price. In other words, the switching cost for customers to turn to alternative providers is high, especially for clients who require precision coating or high unit cost products.

PVD coating used to be a complicated process that required discrete control in order to achieve desired quality; in other words, integrating the system in one's production line was a large capital investment. For industries such as microelectronics and auto/aviation manufacturers, they have invested a large sunk cost in building the coating system in their production line, which results in high switching cost for other solutions, thus minimizing room for price bargaining. Although small/medium-sized manufacturers often contract out the coating procedure to local workshops and overseas vendors in order to reduce cost, their options are still limited.

3.2.3 Competitive Rivalry within the Industry

Competition over customers, market demands and resources is inevitable for companies working in the same industry. The intensity of competition within an industry is usually defined by the number of companies in the region, the size and the value of the market.

Instead of competing with each other, some companies use merger or strategic cooperation in order to gain a competitive edge.

As there are limited options for PVD coating technology, existing companies occupy the majority share of the market, the top 12 companies occupy approximately 70% of the global market. These major players have more than 20 coating shops in North America and 88 shops around the world by year 2008 (Golombek, Pakula, Mikula & Kwasny, 2012). The competitors are facing rapid growth of market demand, high short-term profit and large investments in R&D; the PVD technology used by the competitors are not highly differentiated, mainly within the three categories mentioned in Chapter 2. As previously mentioned, each company has their fixed group of clients; in order to break this status quo, new applications of known and newly discovered materials in various industries are necessary.

Strong incumbents have been in the market for decades – many have invented popular PVD technologies. The rivalry between these companies such as Platit, Balzers, Ionbond (former Multi-Arc) is intense. Their sustainable competitive advantages are in sales and service channels; technology patent leadership and customer lock-in, which make it harder for newer and smaller firms or new entrants to obtain significant profits. However, these incumbents lack in the variety of their industrial focus; they mostly target selected industries with similar characteristics. Platit, for example, has focused most of its PVD development on cutting/drilling tools, and precision mechanical components. In order to establish a foothold in the market, smaller competitors need to conduct research into novel applications of PVD technology and specialize in niche areas that have not yet been fully explored.

3.2.4 Threat of Substitute Products

The existence of products outside of the realm of the common product boundaries increases the propensity of customers to switch to alternatives. It also determines the price caps of such products or industries, and consequently affects the level of profitability. There is currently no applicable substitute for vacuum coating equipment. The biggest threat is traditional electroplating, as it is of a lower cost. However, the development in more advanced technology, cost reduction, superior quality and environmentally friendly nature of vacuum coating leads to a higher opportunity of advancement over electroplating.

3.2.5 Bargaining Power of Suppliers

The bargaining power of suppliers is also described as the market of inputs. Suppliers of raw materials, components, labor, services and expertise can often have power over the firm when there are few substitutions. Suppliers provide technical support and assembly of components; their prices directly influence the compatibility of the company. When facing strong suppliers, new entrants and small-scale companies cannot compensate the increased cost by increasing price. This results in diminished revenue and the profit being forwarded to the suppliers. Suppliers have more bargaining power towards companies that require smaller quantities, as these components are of value to them.

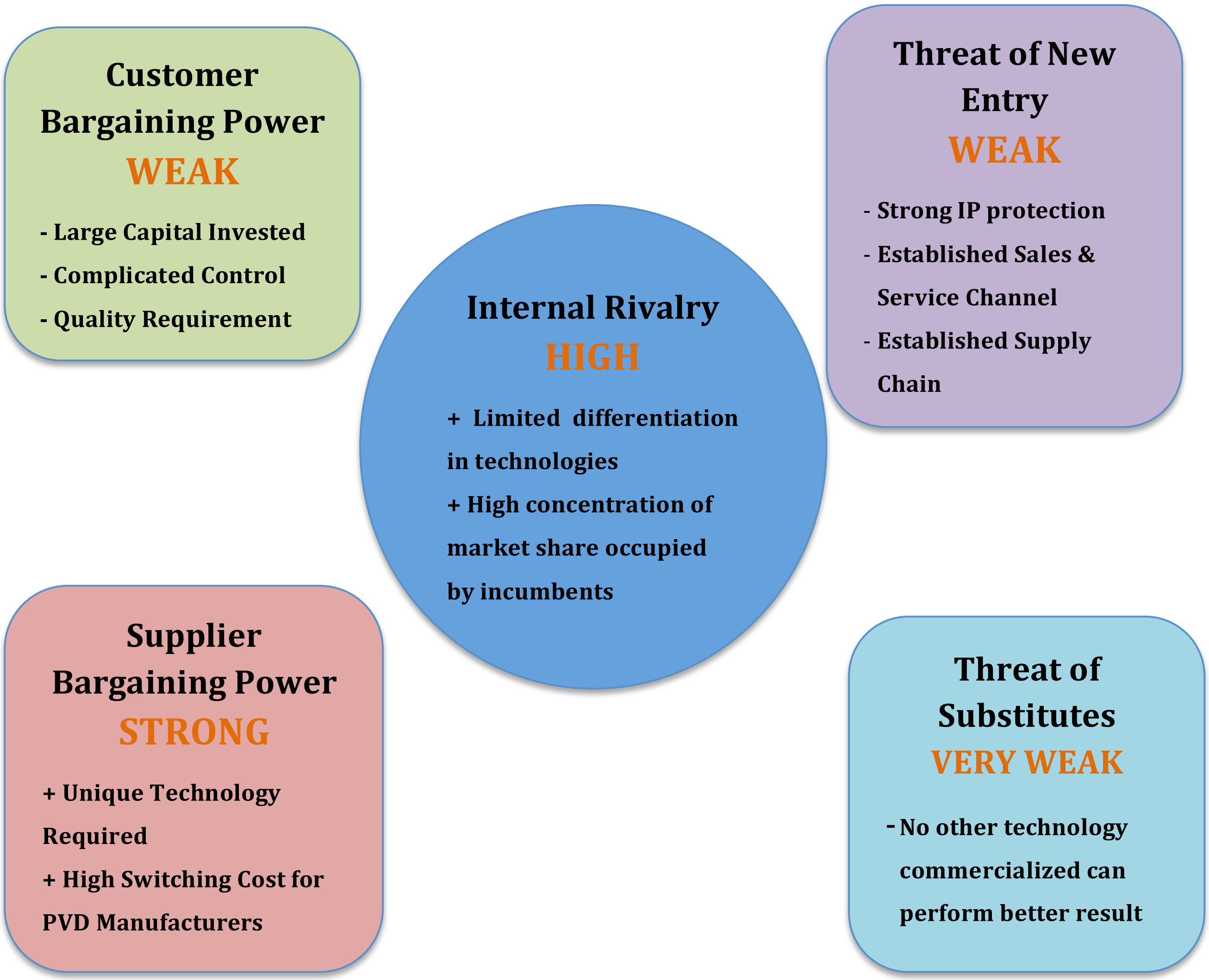
The supply chain of PVD turn-key system can be classified into following categories.

- Vacuum System Component (vacuum chambers, suction motors)
- Heat Sources (laser, plasma, catholic ion gun)
- Control System (controlling interface, terminals, database)
- Mechanical Components (robotic arm, transfer belt)
- Electrical Components (power supply, printed circuit board, integrate circuits)

As the environmental requirements for PVD coating are rigid, a precision vacuum system is required to ensure coating quality. In the past, only a handful of manufacturers had the ability to produce industrial level vacuum components that matched PVD coating needs. Most suppliers are located in Europe and America, including Applied Materials (US), Lam Research (US), Balzers & Leybold (German), ULVAC Japan, Novellus (US). Suppliers in China and Taiwan were not capable of producing PVD graded vacuum system components until late 1990s. Limited number of suppliers allows for strong bargaining power - especially for manufacturers like Balzer, who not only manufacture vacuum systems but also provide complete PVD solutions.

When SurfTech first entered the market in Asia twenty years ago, all systems were purchased from manufacturers in Europe, such as Platit. Certain proprietary technology and components such as vacuum chambers and its control systems were not available from local suppliers. Twenty years of experience and development of manufacturing technology have subsequently reduced the dependence of Aurora on European suppliers and allowed Aurora to gain an advantage on pricing.

Figure 3.3
Porter's Five Forces Analysis for PVD Coating Industry



3.3 Competitor Analysis

Although large numbers of local companies are beginning to contract out parts of their manufacturing processes and components to OEM factories in Asia, manufacturing-related industries have always aggressively fought over the North American market. Competition is particularly high for PVD coating applications, as they can be widely applied on all levels of manufacturing segments. Furthermore, North American manufacturers prefer to keep precision or delicate products and components made in

North America to ensure quality control. With the numerous features and advantages of PVD coating, manufacturing industries will increasingly demand its services and machines. Prominent competitors will be discussed in this section, along with analysis of their background, strengths, and weaknesses.

3.3.1 International Competitors

PLATIT

Platit[7] is a Swiss company that manufactures and markets coating equipment for the cutting tool industry. It is considered the world leader of PVD coating technology. The company was founded in 1992, and within years, it spread its service around the world – there now have nineteen sales offices in thirty-four countries. The conglomerate behind Platit is the BCI Group, which has its focus on a Swiss watch industry, and offers a wide perspective on coating, decorative and precision manufacturing.

Although its services reach all around the world, Platit is now focusing on cutting, drilling tools and precision mechanical components. It is undoubtedly the pioneer of these industries; it would be very difficult for newcomers to compete with its research and development team that has worked on PVD technology and material for decades.

Despite being the strongest competitor, Platit plays a significant role in Aurora's development in PVD technology. Prior to SurfTech's collaborating with SERC, Platit was already a trusted supplier in providing coating devices and technical support. In

[7] www.platit.com

recent years, SurfTech has also formed technical alliances[8] with Platit (Swiss), Ionbond (US) and Teer (UK). These companies share their technologies, experiences and development in order to stay ahead of other competitors. Later sections of this report will reveal strategies that help avoid direct competition with Platit while still allowing Aurora to benefit from this technical alliance.

Oerlikon Balzers (Balzers)

Balzers[9] is another large international competitor who has been in the North American market for a significant amount of time. Founded in 1946 (oerlikon.com), it is part of the Oerlikon group, another scaled Swiss technology conglomerate, and consists of companies in textiles, drive systems, vacuum technologies, solar, coating and advanced technologies. Balzers may not have as many offices and service centres as Platit, but it has built strong foundations in industrial and manufacturing oriented countries such as the US, Germany, Italy, France, UK, Japan, Brazil and India.

Balzers is often considered "the one to beat" among the competitors. Its long history of vacuum and coating technology has secured Oerlikon Balzers' place in the vacuum coating industry. The core competencies of Balzers are also in tools for various industries, especially in automotive and precision components. The principles of Balzers' technical services are also commendable. The company has very high standards of coating quality; they carefully evaluate each client's request and only take on jobs if they are confident of success. In other words, if the company does not have applicable

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8 http://www.surftech.com.tw/p1.htm
9 http://www.oerlikon.com/balzers/

technology to ensure the quality of the product, or prior experience with the service, they would not accept the contract.

3.3.2 Domestic Competitors

Ionbond

Prior to 1997, Ionbond[10] was known as Multi-Arc Scientific Coating (Multi-Arc) (ionbond.com). Multi-Arc entered the coating industry three decades ago, and as one of the local leaders of PVD in the US, is now owned by Swiss-based technical group Bernex Surface Metallurgy. Over the years, Ionbond had various breakthroughs in PVD technology, such as Cathodic Arc coating and the TetraBond process.

The company is experiencing rapid expansion after the changeover in 1997. It currently has over thirty coating centres spread around the US, Europe and Asia. In the US locally, Ionbond is on par with Balzers in terms of number of servicing locations. However, in contrast with Balzer, Ionbond is a risk taker. Although its standards of quality are not as high as those of Balzer, it aggressively pursues advances in coating applications and materials.

Ionbond depends solely on arc technology, which is one of the reasons that coating quality is not its strength. Nevertheless, this is also an advantage, as it allows them to widely apply coating in more industries. Other than the traditional tools and mechanical components, Ionbond's services can also be seen in sports goods, medical goods,

[10] http://www.ionbond.com

automotive, aviation, packaging, and construction industry. Thus, Ionbond is one of Aurora's head-on competitors – it is difficult to differentiate between the target market and customers of these two companies.

3.4 Summary

The application of PVD coating is growing at promising rate. All competitors focus their endeavours on developing new process methods and materials in order to meet the increasing demand from various manufacturing industries. The microelectronics and storage industries are the best options for PVD service providers who are looking for large portions of market share, as there is a high demand for PVD coating on production systems and product components. Traditional industries, such as cutting tools, are considered saturated because the incumbents have already established solid foundations. It would be unwise for newcomers and small companies to compete with incumbents in industries where customers have already been locked-in by incumbents. As Porter's Five Forces summarized in ***Figure4.3***, the weak threats of new entrants, customer bargaining power, substitutions, strong supplier bargaining power and medium inter-industry rivalry makes the global PVD coating industry relatively attractive. Despite this, good strategy is required to stay competitive and maximize profit. Not only can PVD coating provide supreme performance and protection, it also takes the environment into consideration – an aspect that has gradually become an important factor that defines the success of an industry. Strict government regulations and public awareness for environment can be considered as the sixth force that directly influences the growth of an industry and its market demand.

In the next chapter, industries that have yet to fully adopt the PVD process and show growing patterns will be discussed. These will be potential market penetration points for Aurora without head-on confrontation from existing competitors.

4 Company Analysis

AURORA Scientific Corp. is a preeminent Canadian surface coating company. Established in 2009, Aurora is based in Richmond, BC, and provides turn-key solutions for precision coating to North American manufacturers. Aurora is a joint venture between SurfTech Corp, an incumbent of PVD coating in the Asia Pacific market, and SERC, the Surface Engineering Research Centre of MingDao University in Taiwan.

The products provided by Aurora include pre-coating surface treatment equipment, eco-friendly cleaning line, post-coating surface finishing equipment, and state of the art QC laboratory. Aurora's quality policy is the framework for establishing quality objectives with the customers before and after the implementation of the PVD system. Based on the cutting-edge coating technology supported by the Surface Engineering Research Center of MingDao University and the professional craftsmanship of Surftech Corp., Aurora is bringing the best turn-key solution to the ever-challenging manufacturing industries with high level of customer satisfaction (About Aurora, n.d.).

4.1 History and Mission of Aurora

Dr. Da-Yung Wang, a prominent researcher of materials engineering, and his technical team founded Aurora in 2009. As senior advisor of SERC and a member of the board of SurfTech, Dr. Wang combined his various resources to help establish Aurora North America. Aurora's North American office is located in Richmond, BC, Canada, and all products and systems are manufactured in Taiwan and China.

SurfTech's twenty years of experience in PVD coating services, supported by SERC's advanced research, allowed for the creation of Aurora's STAR series of PVD coater. The preliminary business strategy of Aurora is to explore the potential manufacturers in North America that produce either large quantities of products or core products with relatively high costs. In other words, it is more economical for these manufacturers to invest in a PVD coating machine in their manufacturing process instead of contracting them out. According to Dr. Wang, Aurora's short-term goal is to implement Aurora's STAR series coating system in the production lines of manufacturers in North America, instead of establishing a servicing centre. Aurora is focusing on selling their PVD coating machines, coating recipes and technical support. Aurora's mission is to bring North American manufacturers a low-cost, high quality and eco-friendly solution.

Figure 4.1
Structure of Aurora North America
(Aurora, 2009)

4.2 S.W.O.T Analysis

A SWOT Analysis looks at Aurora's strengths, weaknesses, opportunities and threats, and aims to reveal the competitive advantages of Aurora in North American market as well as analyze its prospects for sales and profitability (Humphrey, 2005). Strengths and weaknesses are internal factors of Aurora that determine its ability to compete in the industry, whereas opportunities and threats are external or environmental factors, including the economic or social trends, changes of behaviors of other competitors, over which the company has no control. The following SWOT analysis is based on an assessment of facts and assumptions about the company and on market research findings.

Strengths

- Aurora's greatest resources are SurfTech's technical support and experience along with a strong R&D team from SERC of MingDao University. SurfTech has twenty years of experience in the industry, and is familiar with PVD technology and its application. The database and technical personnel are also great assets. As an OEM manufacturer, SurfTech has also built networks of loyal clients around the world, such as manufacturers from USA, Canada, the UK, Australia and Brazil over the years. Reliable technical support and steady business with global clients are strengths provided by SurfTech.
- The Surface Engineering Research Center (SERC) is made up of professional teachers and researchers of materials, energy, optoelectronics, information, and design fields from MingDao University. The director, Dr. Da-Yung Wang, a well-known researcher in the field of surface engineering, is also the CEO of Aurora North America. SERC has dedicated the past fifteen years to the

development and process control of PVD coating turn-key systems. SERC provides continuous support for Aurora North America's products, and works to ensure that customer satisfaction standards and ongoing R&D meet clients' needs. There will be engineer assisting clients implementing the coating system and test compatibility and quality to meet clients' requirements. A reliable open channel communication is in place with Aurora's technical support team and SERC to respond to customers' questions and issues.

- All of Aurora's products are developed and manufactured in Asia. Project specialists from Aurora will work with clients to determine their need and work out solutions for the clients. It could take two to six months to have the equipment fully implemented and tested. The lower manufacturing cost allows the products of Aurora to be more price-competitive, and the continuous support from Aurora ensures customer satisfaction.

Weaknesses

- Entering the coating industry, a mature market, puts Aurora at a disadvantage. Most incumbents have been in the North American market for decades; a number of them are also global leaders in the coating industry. They have claimed a majority of the market in conventional applications of PVD coating, such as cutting or drilling tools. These older corporations have built strong relationships with large manufacturing industries such as automobile and aviation companies. Aurora also lacks experience in manufacturing coating machinery when compared to existing global competitors.

Opportunities

- The environmental regulations in North American countries continue to set more limitations, especially within the manufacturing industry. An increasing number of manufactures in various industries will start considering PVD processes for replacements of their existing methods in order to align with new standards.
- Rapidly rising costs of transportation will increase the cost of shipment. Contracting out manufacturing processes to OEM factories in China or other lower labor cost countries may no longer be economical. Integrating the coating process in the existing production systems may perhaps be a more reasonable investment.
- Continuous developments in PVD technology, along with the increasing range of available materials and industrial needs, give PVD coated products more value. The demand for PVD technology and service is growing exponentially.

Threats

- Large capital investments in R&D made by existing deep-pocket competitors in Europe and America put additional pressure on Aurora to narrow the technology gap in coating speed, quality, quantity and energy consumption. The barriers to entry will be difficult to overcome.
- Cheap labour in Asia still presents a threat. Many North American manufacturers generate revenue from exporting; these local manufacturers could consequently move the complete production system to Asia instead of integrating a PVD equipment nor stay outsourcing to further reduce cost.

4.3 Summary

Dr. Wang spent five years researching and planning before he launched Aurora North America. Although heavy competition within a matured PVD process and service market was expected, Aurora had great potential. The company's strategy is to avoid direct confrontation with incumbents in industries that they already established themselves in. Instead, Aurora will utilize SurfTech's connections and SERC's R&D resources and approach industries that have not fully adopted PVD technology, as well as North American manufacturers who are searching for quality, low-cost alternatives. The next chapter focusses on PVD market. The structure, values and potential of the PVD coating industry will be discussed in order to determine the preliminary marketing strategy of Aurora in North America.

5 Market Targeting

As discussed in previous sections, the competition of PVD coating services and products is relatively heavy. The market for traditional applications has been occupied by incumbents mentioned in the previous chapter – it may prove to be difficult for Aurora to compete with these corporations that possess large market shares. This section features a couple industries that have great potential where applying PVD technology on their end products or components can lead to significant profit, while improving product quality and customer satisfaction.

Each industrial sub-section will explain how PVD technology can be applied, the benefits of integrating this technology, as well as include an analysis of the market situation and potential success.

5.1 Medical Equipment/Tool Market

A variety of medical industry products are coated by PVD process with different materials. These devices, instruments and appliances support the growth of the medical equipment industry. Medical instruments and devices are made with a number of substrates including metals, polymers and ceramics. PVD technology can be facilitated to coat these materials, which results in properties of adhesion, bonding, lubricity, and infection prevention.

Devices that are used for medical treatment and diagnostic purposes include prostheses, catheters, tubing, heart valves, digital thermometers, laboratory equipment, and endoscopes. Equipment in this category is made from a wide range of substrates, and the thin film material deposited on them requires properties such as protection from corrosion, increased adhesion or lubricity, and EMI/RFI shielding. Common medical products can be classified into groups based on their functionality and features, as presented in ***Table 5.1***.

Table 5.1
Basic Types of Medical Devices

Surgical and medical instruments
Orthopedic devices and surgical supplies
Diagnostic reagents
Electromedical equipment
X-ray equipment
Dental equipment

5.1.1 Technology, Requirements and Benefit

PVD technology was initially considered for coating surgical instruments when the technology was first introduced commercially in the 1980s. However, due to the limitations of materials and vacuum technology back then, the growth of PVD coating application in this field did not increase as anticipated. Maturing of PVD technology in recent years has allowed it to be used to deposit thin-film, wear-resistant coatings on a variety of medical devices, including orthopaedic implants, pacemakers, surgical instruments, orthodontic appliances and dental instruments. The value of PVD technology rests in its ability to modify the surface properties of a device without changing the original properties and biomechanical functionality of the underlying materials.

Another factor that hinders the advancement of PVD-coated medical equipment is that all potentially applicable materials not only need to possess certain characteristics, but also need to meet the biocompatibility requirements. As per regulation ISO10993-1 guidelines for materials that come in short-term contact with the body, coating processes undergo a series of tests conducted by an independent biological testing laboratory before being introduced to the market (International Organization of Standard, 2010). Currently, it is known that TiN, ZrN, CrN, TiAlN, AlTiN and two Multi-Arc (Ionbond) proprietary coatings (Blackband and Tetrabond) are acceptable for medical devices that come in contact with bone, skin tissue and blood. However, the coating materials also have to be able to sustain sterilization procedures such as high temperature steam and UV light. From the list above, TiN and CrN are able to resist corrosion that can be caused by liquid, steam or chemical autoclaving.

Thin films are also deposited on electrocardiography (ECG) monitors to protect them from electronic interference (Electro-Magnetic Interference, EMI, and Radio Frequency Interference, RFI). This is a key application in the medical equipment industry, as it minimizes the chance of interruptions and false readings.

Lubricity and adhesion are other key factors to be considered for devices used internally, such as catheters, tubing, artificial joints and related items. Corrosion protection of the prosthetic device is another major application, and can be treated on a variety of metal and polymer substrates. Surgical tools, the first to apply PVD coating to prevent wear and corrosion, have now fully integrated the process into their manufacturing line.

Research and development of a new coating process in the past seven years, known as "biocompatible coating", has drawn the attention of many manufacturers. Silver is playing an increasingly significant role in this emerging technology of depositing thin layers of amorphous carbon to achieve diamond-like properties of hardness and sharpness. However, this application requires precise control and various gradients in the coating process, which makes it difficult to ensure consistency in quality. Thus, only a few manufacturers can offer this level of the service, especially on medical equipment.

The table below lists common materials that have been tested and broadly applied to medical equipment. Some substrate materials, such as polymer or non-metallic substrates, can be worked with at lower temperatures. Due to the needs and requirements of today's market, PVD materials and methods are constantly being developed.

Table 5.2
Major Thin Film Materials Used to Manufacture Medical Devices
(Pellman, 2007)

Material	Properties
Metals (Al, Cu)	Corrosion resistance, EMI/RFI shielding, environmental stability
Precious Metals (Ag, Au)	Biocompatibility, plaque control, anti-microbial properties
Nitrides (TiN, ZrN)	Wear and abrasion resistance
Carbides	Temperature control, wear and abrasion resistance
Amorphous Carbon	Improved wear and abrasion resistance

The benefits of PVD processes can be summarized as follows:

- Improved wear resistance
- Increased lubrication/reduced heat generated by friction
- Biocompatibility
- Anti-microbial coatings to prevent infection
- Decorative colours and aesthetic
- Prevention of corrosion and formation of chemical barriers
- Nickel sensitivity
- Higher levels sterilization
- EMI / RFI shielding
- Calibrate adhesion
- Water repellence

These benefits in turn reduce medical expenses of maintenance and replacements, as well as shorten patients' hospitalization period. Medical resources can be better allocated and medical services and treatment more affordable.

5.1.2 Medical Equipment Market Analysis

Global medical equipment market analysis

Recent market studies have indicated that about two fifths of medical instrument and device sales are to hospitals. The remaining fraction is distributed among physicians, dentists, nursing homes, clinics, home healthcare providers and related parties. The medical device industry manufactures products in every major geographic region –

however, North America has been recognized as a global leader for decades. ***Table 5.3*** summarizes the relative percentages of production by region.

Table 5.3
Global Production of Medical Equipment & Supplies by Region
2010 – 2016 (%)
(Moran, 2012)

Region	2010	2011	2016 (Forecast)
North America	27.1	27.2	28.2
China	26.0	26.1	27.5
Asia-Pacific	23.5	23.7	23.1
Europe	19.2	18.9	17.6
Other	4.2	4.1	3.6
Total	100.0	100.0	100.0

It is predicted that in 2016, the shares of each manufacturing country/region will mostly remain the same, though focus will shift slightly towards North America and China. This indicates that the North American market still has room to develop in the medical device industry, especially since PVD coating-related medical products only occupy 4.3% of the total share, as shown in the segmented market analysis.

Various market leaders in surface coating have also recognized the business potential of this industry, and have increased R&D investments in every region. Consecutive technological breakthroughs push the entire industry to collaborate with government agencies to improve regulations on universal market standards, which leads to further market expansion.

With the knowledge that the North American region is responsible for one third of all medical equipment production, it is crucial to analyze the demand of medical equipment globally, as this indirectly reveals the need to integrate PVD coating into manufacturing processes in North America. ***Table 5.4*** depicts the variations of market value for medical equipment from 2005 to 2010.

Table 5.4
Global Demand for Medical Products
2005 – 2010 ($Billions)
(Moran, 2012)

Product	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**CAGR% 2005-2010**
Medical Equipment	207.0	225.8	240.7	230.4	242.3	244.9	3.4

As shown in ***Table 5.4***, the demand for medical equipment steadily increased despite the recession and economic crises of 2008. Several factors contribute to the industry's stability, including:

- Increase of aging population globally rapidly raising the demand of medical care
- Continuous research and development in medical and health industries bringing about new technology and products that aid in prolonging average lifespan
- Improved and inexpensive technology allowing developing countries to upgrade their existing systems and equipment. Private health care institutes, clinics and individuals can afford the equipment for personalized health care.

There are additional factors that stimulate the growth of the medical equipment market. At the end of the day, medical and health care exist to treat ailments and provide a better quality of life; the more sophisticated the treatment providers can offer, the better and more effective the care patients receive. Having quality equipment allows these institutions to reduce labour and human resource costs, which make up a large portion of medical system expenses.

Drivers of PVD Technology in Medical Equipment Market

Efforts made by PVD coating providers lead to improved deposition techniques and materials, which has the potential to positively influence the performance of medical products and further contribute to user (physician and patient) satisfaction. This can assist in lowering costs in the long run.

Another factor of the market is how much it costs patients to receive medical treatment. In countries like US and Canada, the health care system only covers basic medical treatment and diagnosis. If a patient requires specialist consultation and treatment such as surgery or chemotherapy, the fees are high and often unaffordable unless the patient is covered by insurance. These expensive fees are generated from the figures required in order to replenish equipment, cover labour and maintenance of the facilities and devices. When better PVD procedures and materials are applied to corresponding equipment and tools, it enhances the efficiency, effectiveness and lifespan of the devices. These technological improvements will result in shorter hospitalization periods and lower treatment fees, and pave the way for a more affordable medical system overall.

Global Medial Equipment Market Trends and Forecast

In order to further analyze the circumstances of PVD coating demand in the medical equipment market, it is necessary to revisit ***Table 5.4*** and analyze the market size in corresponding years. This will make visible the correlation between these two factors and reveal the trend. The correlation appears in the following table.

Table 5.5
Global Growth Trend of PVD and Medical Equipment Industry
2007 – 2011 ($, % Ratio)
(Moran, 2012)

Type	2007	2008	2009	CAGR% 2007-2009	2010	2011	CAGR% 2010-2011
Medical Equipment ($Billion)	240.7	230.4	242.3	0.3	244.9	256.4	4.7
PVD ($Million)	290.9	295.5	315.1	4.1	298.9	315.5	5.6
% Use Ratio	0.121	0.128	0.130		0.122	0.123	

The use ratio is obtained by dividing the PVD market size figures by medical equipment market value. It confirms a steady rate of development. Growth of this market is less susceptible to decrease, because of present global aging and health care problems, and continuing expansion of advanced health care around the world.

Based on the preceding analysis and calculations, one can anticipate that by year 2016, the growth rate will increase to 7.4%. The ratio between the medical equipment market and PVD market will most likely grow, albeit limitedly unless there is dramatic technical breakthrough or change in regulations. The growth pattern can be derived by plotting estimated numbers in the following table for year 2016 with the data collected from 2007 and 2011.

Table 5.6
Projected Growth Trend of PVD for Medical Equipment Market Through 2016
(Moran, 2012)

Type	2007	2011	CAGR% 2007-2011	2016	CAGR% 2011-2016
Medical Equipment ($Billion)	240.7	256.4	6.5	366.1	7.4
PVD ($Million)	290.9	315.1	8.3	448.0	7.3
% User Ratio	0.121	0.122		0.126	

In summary, the potential of PVD coating application in the medical equipment market is quite promising. The North American market in particular has the potential to increase in revenue by one third. In comparison to the cutting tool industry where incumbents have already established solid foundations, the medical equipment market is a more suitable breaking point to capture market share. As indicated in ***Table 5.3***, China is the second largest manufacturing region of medical equipment supply. Aurora's mother company, SurfTech has also played a role in the supply chain and established invaluable connections and experiences. Aurora should penetrate the market using this to their advantage.

5.2 Sports Equipment and Accessory Market

The global sports industry has gained more attention in recent years as consumers began to realize that it is an important approach to maintaining good health. It is anticipated that the global sports revenue will grow to $145.3 Billion, at an annual rate of 3.7% (Taiwan Trade, n.d.).

The purpose of this section is to discuss the market trend of sports equipment and its related industries. New PVD technology and materials will also be explored, along with their benefits. Analysis of potential applications of PVD coating in sports equipment in relation to driving factors of PVD coating will determine feasible market entry strategies for Aurora.

5.2.1 Technology and Benefits

Conventionally, only metal components of sports equipment receive treatment for protective coating done through electroplating, as it is low in cost. Despite the effectiveness of sports gear, they are often lacking in the visual aspect. With the introduction of PVD coating, a balance between the functionality and appearance of the gear can be achieved.

Functionality

In terms of functionality, most end users' concern is durability, especially of components that sustain continuous wear, such as skating blades, shafts of roller blade wheels, and bicycle gears. The PVD process allows a thin film to be applied to these components without changing their dimensions or weight, while at the same time greatly strengthening the components and reducing friction. Corrosion prevention is also a great concern of outdoor sports equipment. PVD film can apply various materials to accommodate the most extreme environmental conditions. The most common materials used on these components are TiN, generally applied on low-end cutting tools, and TiCN, used for components that involve high-speed movement and require hardness and lubrication. Components that will be exercised in extreme conditions also have a thin layer of CrN deposit.

Diamond-like carbon (DLC) film, a hybrid process of PVD and PECVD, is also appealing to sports equipment manufacturers (Robertson, 2002). For sports gear that need to withstand consistent direct impact, the solidity of the impact surface requires additional treatment. For example, a coating of only 2 μm thickness of DLC increases the resistance of common stainless steel against abrasive wear; changing its lifespan from one week to 85 years. The various forms of DLC can be applied to almost any material that is compatible in a vacuum environment. However, due to the complexity of DLC deposition, precision control, specific vacuum conditions and corresponding reaction agents are required; the cost of this process is relatively high. The hitting surface of high-end golf club heads is popular example of DLC application on sports equipment.

Decoration

Athletes and sports companies alike are now widely seeking personalized sports equipment. In other words, customized and decorated sports gear are becoming more popular in the market. The decorative presentation can vary from budget paint to metallic colours that can be deposited on metal or plastic substrates. PVD coating is commonly used in this industry because the materials being deposited to provide additional wear, corrosion resistance and performance enhancement can also be modified to various metallic finishes. Due to the long lasting features of PVD coating, the decoration does not suffer discolouring or tarnish.

PVD coatings can be deposited in a wide range of colours[11]. Targeted materials of decorative PVD processes are zirconium (Zr), titanium (Ti), chromium (Cr), titanium-aluminum (TiAl) alloys and niobium (Nb). For pure decorative purposes, coatings are even thinner than those used for function; a layer of ceramic coating can be deposited to increase the hardness of the coating when necessary. Depending on the metal-to-gas ratio and structure of the coating, decorative coatings are produced within a certain colour range. This is achieved by altering the control parameters in the coating process

The benefits of PVD processes on sports equipment are summarized as follows:

- Improved wear resistance
- Reduced friction
- Increased solidity
- Colour decoration and personalization
- Prevention of corrosion in extreme condition

[11] http://www.pvd-coatings.co.uk/applications/decorative/

PVD coatings cover a wide range of products – in addition to the previous examples mentioned, they are currently used in motor sports, water sports, knives, sunglasses frames, firearms etc.

5.2.2 Sports Equipment Market Analysis

The sports industry has gained significant economic value, especially in developed countries. The United States has the most developed sports industry – its annual market value is 2% of US's GDP (Lin, 2008). The market value of sports industries in other developed countries such as UK, France, Germany, Japan, Italy, Swiss, Spain and Australia are also within 1% to 3% of each country's annual GDP. Evaluation of these numbers shows a growing demand in sports activities, ranging from personal at-home exercise to professional sports. This leads to large investments in sports industry, and shows great potential for growth and globalization. Coupled with the growth of sports industries, the need for sports equipment also increases dramatically – leading to large business opportunities.

When focussing on sports equipment, there are a few trends that manufacturers need to evaluate:

- The steady growth of the population's need for regular exercise.

  Owing to the increased annual GDP in many industrial and developed countries, consumers start to pay more attention to leisure and personal health. It is estimated that within the next five years, sports equipment market will grow at a steady rate of 5% annually. The population's involvement in indoor exercise, rollerblading, ice skating, biking, group/family sports such as golf, baseball, soccer, ski and snow boarding will continue to grow.

- Increasing demand for personalized sports equipment.

  Consumers in the past have often passively accommodated to existing sports equipment. Consumers of today have started to request personalized sports equipment in order to meet their individual exercise needs, style and environment concern. Instead of shopping from a conventional brand with a limited selection of products, they would choose manufacturers that make customized products with specific materials or personalized designs. Consumers' enthusiasm gradually influences the manufacturing processes, designs and materials.

Sports equipment manufacturers will have to take action in respond to these trends. Research in their design and manufacturing processes must be done in order to capture the business opportunities.

North American Market - US

In the US, sports industry is one of the most rapidly developing industries. The value of production was $213 Billion in year 2000 – twice the automobile industry and seven times the movie industry. By year 2009, this number almost doubled to $414 Billion. Of the entire sports industry, sports equipment occupies approximately 30% of the share (Lin, 2008).

US has the largest market in manufacturing and retail sales of sports equipment. Most of the population partake in sports for leisure and/or personal fitness. According to Sport Goods Manufacturer Association's (SGMA) report, ***Table 5.7***, the wholesale market is growing at an exponential rate. The retail sale of sports equipment was $40 Billion in 2007. According to statistical research, in 1998, US consumers spent an average of $81.6 on retail sports equipment. In 2005, this value increased to over $100 per person per year, and grew 10% to $114.7 the following year. The US will most likely still assume the leadership role in sports gear manufacturing in future years.

Table 5.7
US Sport Equipment Whole Sale Value
2000 – 2007 ($Billion)
(SGMA, 2008)

Type	**2000**	**2006**	**2007**
Annual Sales	46	66.5	68.4
Growth Rate		44%	2.9%

North American Market – Canada

According to Industry Canada's report (Industry Canada, n.d.), the annual production value of sports equipment is about $1.25 Billion. Due to the extended winter climate in Canada, sports products are more winter-oriented. The retail market value of sports equipment in 2003 was $6.61 Billion, which is a 5.4% increase from the previous year; the growth rate becomes steady in the following years. The growth figures are listed in ***Table 5.8***.

Table 5.8
Canada Sports Equipment Retail Sale Value
2000 – 2003 ($Billion)
(Lin, 2008)

Type	2000	2001	2002	2003
Annual Sales	2.8	3.1	3.4	3.6
Growth Rate		5.9%	5.2%	5.4%

The above table indicates that the market value of sports equipment in Canada is growing at a rate of 5% yearly. Although the overall market size is significantly smaller than the US market, there is still great potential of profit.

In general, the overall retail and manufacturing markets of sports equipment in North America is growing in a promising rate. Although there are no statistical numbers showing the direct correlation between the amount of PVD services that has been applied in sports equipment manufacturing and sport goods sold, the benefits offered by current PVD technology and materials, in addition to consumer trends, lead to a positive forecast. DLC technology could be successfully used as an entry point into this market for Aurora. SERC also has a team actively researching the control system of DLC coating. The level of support that Aurora will be able to provide its clients in the future is assuring.

5.3 Summary

Although PVD coating services is a relatively small part of the medical equipment business, it plays an important role. Many device and tool-makers prefer to coat their products in-house, especially devices that directly come in contact with patients. Aurora has great opportunities in North America, as it is the largest manufacturing region of medical components. Having survived economic crises through 2008 and 2009 without suffering dramatic decrease in value, the stability of this industry makes it an ideal market entry point of Aurora.

PVD coating services in sports market industry is also showing a rising trend in popularity. Personalization and performance – two features of PVD – have become top concerns of professional athletes and leisure exercisers. Although this industry is not as essential as the medical goods industry, and was affected significantly during the recession, it carries immense market value. North America, also the largest manufacturing region and largest market for sports goods, shows remarkable potential. High-end sports gear, such as premium golf clubs, are usually made in North America. Other sports-related industries such as sunglasses, firearms and accessories frequently manufacture their proprietary components locally; these companies match the profile of potential customers for Aurora, as they could greatly benefit from integrating Aurora's coating system in their production lines.

The industries discussed in this chapter show promising growing patterns. North America is the biggest manufacturing region of both industries. There is no specific order of industries in which Aurora should reach out to first – the company could approach either to quickly gain market share. Participating in exhibitions and conferences, such as the annual vacuum coater conference hosted by Society of Vacuum Coater (SVC), and getting in touch with manufacturers seeking potential application of PVD coating is a great way to gain exposure. Establishing a solid relationship with local educational institutes takes Aurora one step further than its competitors when it comes to finding potential applications and testing grounds. The existing relationship between SurfTech and its North American clients in medical and sports products can also be utilized. These existing customers are already loyal to SurfTech; it would be advantageous to migrate SurfTech's service to their own product line, as long as it is economically feasible.

6 Conclusion

PVD coating is gradually becoming an essential component of various industries as new technology and materials develop. Not only does it help manufacturers reduce cost, it also improves the performance of their products. End users, despite knowing little about PVD processes, still benefit from the long lifespan and reliability of their purchases.

Aurora North America, born from a vehemently competitive market in Asia and trying to capture markets in North America, is facing numerous challenges. SurfTech's past experience and established networks are definitely advantageous to Aurora; in addition, the strong technical support and continuous R&D of SERC ensures that Aurora is able to offer the best quality of service even if they are unfamiliar with the situation. As all of Aurora's products are designed and manufactured in Taiwan and China, the component supply chain and lower labour cost in comparison to US and Europe allows Aurora's STAR series to be very competitive in pricing. Rising shipment costs can also be eliminated if North American manufacturers, who have been contracting out their coating processes, integrate Aurora's products in their production process.

When it comes to research and development, Aurora should collaborate with local universities or material and surface engineering laboratories. Not only would the combination of industrial experiences and academic resources accelerate the development of new products, it would also be greatly beneficial to the business if new academic discoveries lead to technical patents. Instead of building local service centres, Aurora can focus solely on selling the devices. Working with local service shops, Aurora can provide high quality and reliable product and service at a lower price. These local service shops would benefit from reducing their cost and maximizing their profit.

According to the market analysis, the medical equipment industry appears to be a promising market in North America. This industry guarantees increasing demand of advanced medical care and equipment globally, and offers stability throughout economic crises. However, this industry is also under investigation by the incumbents and being targeted by new entrants with strong technological capability. Therefore, Aurora should take action sooner while leveraging its strong partnership with SurfTech. China occupies the second largest market in medical equipment manufacturing, and SurfTech has accumulated a considerable amount of experience while being an ongoing supplier to the manufacturers in North America. Having Aurora's devices integrated in these manufacturers' production lines is practically migrating SurfTech's services from China to North America. The same proposal can be applied to the sports equipment industry. The sports equipment industry may not be as economically stable, but it is one of the industries that have high market value and a growing potential in North America.

The marketing analysis in this report briefly discussed the market potential and the applications PVD technology can offer to various industries. Challenges from a technical perspective and variations of costs of service should be included in further research and analysis. In conclusion, Aurora, as a low-cost quality PVD equipment producer, is well positioned to take advantage of these growing markets under three conditions; a strong relationship with local manufacturers, end users and educational institutes, a patented PVD technology, and ongoing seamless customer support.

7 Appendix

7.1 Appendix I

Category	Material	Application
Electrode	Al, Al-Si, Al-S-Cu, $MoSi_2$, W, WSi_2	LSI, AMLCD, Solar Battery
	Ti, Au-Zn, Au-Sb	Magnetic Reading Head
	TiN, $TiSi_2$	LSI
	IrO_2, Ru, RuO_2	FeRAM
Transparent Electrode	ITO, SuO_2-Sb_2O_3, Zn-Al_2O_3	LCD, EL, Solar Battery
Superconductor	Nb-Sn, Nb-Al, YBCO, BSCO	Josephson Junction
Storage Unit	Co-Cr-Ta, Co-Cr-Pt, Co-Cr, ZrO_2, CoNi, Fe_3O_4	Soft Disk, Hard Disk
	Fe-Al-Si, Fe-Ta, Co-Zr-Nb, Fe-Ta-C, Fe-Si, Fe-Ms, Ni-Mn, NiO, Ni-Fe, Ru	Magnetic Reading Head
	Te, Se, BiTe, Te-Se, Sb-Se, Te-Sb-Ge, Se-Bi, Se-Sn	Optical Disc
	Fe-Tb-Co, Tb-Gd, Nd-Dy, Fe-Co-Cr, Tb, Gd, Dy	MO
Ferroelectric	PZT, PLT, PLZT	FeRAM, Pyroelectric Sensor
Dielectric	BCT, STO, Ta_2O_5	FeRAM, DRAM, Capacitor
Insulation / Protection	SiO_2, Al_2O_3, TiN	EL, PDP
	C, C-SiC, Cr-SiO_2, Al_2O_3, SiO_2, Ta_2O_5, TiO_2-SiO_2	Soft Disk, Hard Disk
	Ta_2O_5, Si-Al-O-N, SiC-SiO_2, SiO_2	Thermal Head
	SiO_2, MgO	Josephson Junction
Piezoelectric	ZnO, AlN	Surface Acoustic Wave Device component
Display / Lighting	ZnS-Mn, ZnS-TbF_3, ZnS-Ag, CaS-Re, GaCaS-$CeCl_3$	EL
	GaN	LED
	Y_2O_3-Eu, ZnS	Fluorescent Display
Optical Film	Al-Ti, Al-Cr, Al-Ta, Al-Zr, Al	DVD, MO
	BaF_2, CaF_2, MgF_2, GeO	Optical Component
Resistive Element	Ni-Cr, Ni-Cr-Si, Ni-Cr-Si-Al, Fe-Si, Fe-Pd	Thin Film Resistor
Heating Resistive Element	TaN, Ta-SiO_2, Cr-SiO_2, NiCr, Ni-Cr-Si, $BiRuO_2$	Thermal Head, Laser Printer
Others	TiN, TiC, TiCN, CrN, WC, SiC	Tools
	Ti-Al-N, Zn-Al, Cr, Al, Ag, Au, TiC	Decorative Items
	Cu-Al-Zn, Ni-Ti	Shape Memory Alloy

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