# Market Survey

## for a

# Midwest Coating Shop

1997

**SAMPLE FOR EVALUATION ONLY**

# EXECUTIVE SUMMARY

An analysis has been made of the overall market for a ??-based PVD coating shop. The catchment area for such a shop lies within about a four-hour drive, which incorporates most of Indiana and western regions of Ohio, while it is possible for it to reach as far northeast as Cleveland. Although this area is quite dependent on the automotive industry, the market is very diverse, with a broad range of industries in metals fabrication, plastics, machine tools, and electrical goods. The regions covered in this report are: central Indiana (including Indianapolis, Muncie, Richmond, Bloomington, Anderson, Kokomo, Terra Haute), Fort Wayne, much of Ohio (including Cincinnati, Springfield, Columbus, Cleveland, Akron, and Toledo) and Louisville, KY. Southern Michigan was not included in the catchment area for a ?? job shop due to the stiff competition from existing PVD shops in the Detroit area.

Applications for PVD coatings include both tools and components (or products). The latter can in turn be subdivided into functional coatings (primarily providing corrosion, wear, or abrasion resistance) and decorative coatings (primarily providing attractive color, but often with corrosion or wear/abrasion resistant properties). The market can therefore be broken down into three primary segments - tooling (the traditional purview of PVD coatings), decorative coatings, and functional coatings.

More than a quarter of the entire US industrial capacity for those sectors in which PVD tool coatings are traditionally used is accessible to a ??-based shop. (These are companies that use large numbers of metal cutting and forming tools.) These companies represent a ready source of rapid cash flow for a new coating operation. The total market size available to the company from these "traditional" tooling sources is estimated at $30 million. Of this, about $10 million is available in the Cleveland area, which is currently served only by two small local shops - IVAC and Surftech.

At the same time there are numerous large potential customers manufacturing items that could be PVD coated with either functional or decorative coatings (only a few of which are now PVD coated). These companies span a very broad range of industries from plumbing and door hardware (decorative) to pumps, valves, automotive fasteners, and medical equipment (functional). Such applications currently represent a small portion of the PVD market, but this segment of the PVD is market is growing, and these applications are expected to be sources of strong future growth in the industry. Cincinnati, Dayton, Indianapolis, and Cleveland have strong bases in the Industrial Machinery sector (totaling $11 billion in sales), which is a primary source of functional PVD applications. Cincinnati and Dayton are both major centers for the aerospace industry, which is one of the main users of functional PVD coatings.

There are two primary competitors for tool coating, Gold Star Coatings in Richmond, IN, and Multi-Arc in Indianapolis. Both are experienced in the tool coating area, but neither is heavily involved in product coating at these locations. Gold Star is one of two shops owned by Star Cutter Corp of MI, while Multi-Arc is one of a worldwide network of shops owned by Multi-Arc of NJ. Other competitors include Praxair in Indianapolis, which (although it is a very large company) concentrates almost exclusively on aerospace applications, and Hohman Plating in Dayton, OH (which is also mostly involved in aerospace work). Both of these companies would be serious competitors in the aerospace industry, but would not compete strongly in the tooling and decorative industries. There are several small shops at the periphery of the catchment area - IVAC and Surf Tech in Cleveland and a small Multi-Arc shop in Warsaw, IN. The numerous shops serving Detroit and Chicago do not pose a strong competitive threat since they concentrate primarily on the large tool-using industries in their local catchment areas.

Because of the breadth of industry in the catchment area, there is sufficient potential business available for a ??-based shop to start out in the well-established tooling area that service (or toll) coaters traditionally serve in order to generate cash flow, and then to branch out into higher value functional and decorative coating of machine tool components and consumer items.

# TABLE OF CONTENTS

# 1 Introduction

Although most people rarely think about them, coatings are an integral part of our lives, used on a wide variety of industrial and consumer items.

The four most common types of coatings (in order of area coated per year) are

- Paints and powder coatings
- Electroplates and electroless plates (galvanizing, chrome, decorative electroplates, etc.)
- Physical Vapor Deposited (PVD) coatings: electronic (computer chips, LCD screens, portable computer LCD screens, disk drives); optical (architectural glass, lenses, filters, headlamp reflectors); tool coatings (cutters, punches, dies); decorative finishes (hardware, plumbing, watches, jewelry), etc.
- Enamels (stoves, refrigerators, etc.)
- Thermal sprays (aircraft engine parts, industrial rolls, etc.)

Over the past 20 years PVD coatings have become widely accepted as an important (and in some cases essential) component of industrial tools such as drills, cutters, punches, dies, and molds. They coat the surface 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) |

It so happens that these coatings are not just 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.

This survey covers the use of PVD coatings to reduce tool wear and to coat products for wear, abrasion and corrosion resistance, and for decoration. Everyone sees paints, enamels, and PVD coatings (on office windows) every day. However, most other PVD coatings are hidden from general view, since they are used to reduce wear of industrial production tooling, or are used to simulate soft materials such as gold and brass while providing a combination of decoration and abrasion resistance. Ceramic hard coatings (primarily TiN) are now widely used throughout the world on industrial production tools to provide wear resistance and increase production efficiency.

In general, local coating job shops supply coating services to toolmakers and manufacturers of commercial and consumer products, just as plating shops have traditionally done. Some manufacturers (primarily cutting tool makers such as Star Cutter, Pfauter-Maag, NY Twist Drill, Greenfield) have installed their own equipment, and over the last two or three years other high volume manufacturers have installed PVD coating equipment for coating their products.

Because of the fractured nature of the market, market size estimates are quite difficult to obtain. However, in the US there are about 50 PVD coating shops and the tool coating market has been estimated at about $150 - 250 million, with the worldwide market probably about three times this. Increasing industrial requirements for quality, reduced manufacturing cost, and environmental concerns over cutting coolants have been driving expansion in the tool coating industry over the past few years. The industry is growing further with its expansion to decorative applications, which (although still a small portion of the PVD business) have more than doubled over the past 5 years.

# 2 Markets

## 2.1 PVD Applications and Current Usage

Because PVD coatings have an established market in tool coating the ideal location for a general coating job shop (toll coater) is the Midwest, where most of the U.S.' industrial production takes place. In fact, 25% of the country's manufacturing capacity in many of the industrial sectors traditionally served by PVD coaters is within a 6 hour drive of ??.

A shop based in ?? would have access to a very diverse group of industries, encompassing far more than just the automotive industry, which is the primary user of tool coatings in the Midwest. Applications for PVD coatings are divided into two broad categories: tool users and components manufacturers.

### 2.1.1 Tool users

The primary customers in the tool market are high production users of metal cutting, forming, diecasting, and punching tools, and of plastics molds, pins, etc. The types of tools that are commonly coated include

| **Tool** | **Industry** | **SIC codes** | **Margins** |
|---|---|---|---|
| gear cutting hobs | Gearmaking (automotive, etc) | 3495, 37 | Med |
| drills, milling cutters | Machining (all types) | 34, 37 | Low |
| inserts (including indexable inserts) | Machining (all types) | 34, 37 | Low |
| broaches | Machining (all types) | 34, 37 | Med |
| molds, especially for filled plastics (wear, corrosion, release) | Plastics | 30, 37 | High |

| | | | |
|---|---|---|---|
| pierce punches | Sheet metal fabrication | 34, 3444, 36 | Med |
| stamping dies | Sheet metal fabrication, auto. | 34, 37 | High |
| coining dies | Precision sheet metal fabrication | 34, 37 | High |
| can making tools | Cans | 3411, 3466 | High |
| deep drawing dies | Cans, automotive | 3411, 37 | High |
| zinc and aluminum diecasting dies | Automotive, hardware | 3363, 3364 | Med |
| push out pins for diecasting and plastic molding | Diecasting, plastics | 30, 3363, 3364 | Low |
| paper and rubber slitting blades | Pulp and paper, rubber, plastics | 26 | Low |

These types of tools are found in a wide variety of manufacturing industries, primarily located in the Midwest. PVD hard coatings are now used, according to industry sources, on about 5% of cutting tools, leaving a great deal of room for growth in this area. However, tools such as drills, milling cutters, and inserts tend to be simple, high-competition items with tight profit margins. Historically, the most profitable items are those that only a few vendors can coat, such as dies and molds (especially the fine surface finish dies and molds of moderate size - a foot or so across).

Most of these tools are coated with TiN, which is the most commonly used coating (partly because of its attractive gold color and its simplicity of application). However, CrN has now emerged as a premium coating for a large number of applications where the coating is subjected to higher temperatures or to abrasion. There are a great many other tool coatings, including TiAlN, TiC, ZrN, diamond-like carbon (DLC) and various multilayer coatings. The choice of coating depends on the application - for example coatings such as DLC cannot be used for ferrous machining because they dissolve in the workpiece.

### 2.1.2 Customer requirements and customer service

One would expect that in general customers would be prepared to pay coating prices commensurate with the degree of improvement in tool life. To some extent this is true for very expensive tools such as molds and stamping and coining dies. However, simpler tools such as drills and cutters rarely command more than about a 20% premium unless they are used for special applications.

Tool coating customers usually demand

< consistent (predictable) performance

< high quality (wear resistance), which is a complex function of hardness, fracture strength, thermal conductivity, and diffusion barrier properties

< uniform color, since non-uniformity suggests unpredictability

< rapid turnaround (sometimes 24 hrs) to minimize tool inventory and production downtime

< pick-up and delivery (many companies keep two or three vans for this)

< ability to strip and recoat (to correct errors and to permit large numbers of recoats on hobs, for example)

### 2.1.3 Component manufacturers

Components that can be coated using PVD processes are divided into two major categories: decorative and functional. Decorative applications are those in which the primary reason for using a coating is aesthetic even though the decorative coating may also serve an important function such as corrosion and abrasion resistance. Functional applications are those using PVD coatings for primarily functional or industrial uses such as improved wear resistance, improved corrosion resistance, specific optical properties and so on.

**Decorative** applications for PVD coatings include:

< door hardware, locksets (corrosion resistant, decorative, abrasion resistant)

< faucets and other plumbing parts (stainless steel, plated brass)

< knives and other cutlery

< automotive trim

< high quality pens

< watch bands and bezels

< class rings and other jewelry

< lighting products

**Functional** applications for PVD coatings include:

< gate and ball valves (stainless steel, aluminum, titanium)

< pump parts

< ultrasonic welding horns

< dental and medical (surgical) equipment and tools (stainless steel)

< automotive fasteners (high volume, low unit cost)

< plastic reflectors for automobile headlights

< titanium alloy race car components (low volume, high unit cost)

< aircraft engine turbine blades and accessories (requires aerospace qualification)

< auxiliary power unit wobblers (requires aerospace qualification)

Some PVD coatings can only be deposited by specialized equipment and are not generally available to the toll coater:

< architectural glass (special, large-scale equipment) - dual decorative and functional use

< eyeglasses and other optical components, such as lenses, filters and mirrors (simple, modified evaporative or sputtering equipment) - decorative use

< electronic chips - functional use.

The same hard nitrides used for tools happen to have the sorts of attractive colors required for decorative coatings - TiN for gold, ZrN for brass, TiAlN for a range of colors.

Some of these components are high volume (such as automotive fasteners and watch bands), and others are large (such as ball valves, which are often a foot or more in diameter). Some substrates - primarily brass, zinc, and plastic - are not suitable for most coating methods (brass usually has to be nickel plated for corrosion resistance and to be compatible with vacuum processing).

### 2.1.4 Customer requirements and customer service

Because of the high volumes, some customers require in-house equipment (faucets often fall into this category). In most cases, however, companies prefer to farm out the coatings because they do not want to invest in the specialized equipment and staff. Companies frequently demand just-in-time delivery.

In many cases, the market for component coating is not as local as that for tooling, making it possible to target companies in specific industries that are well outside the tool coating catchment area (even overseas in some cases). These customers can be served by regular or overnight shippers rather than van pick-up and delivery.

Decorative coatings are a growing area, with a special set of requirements. Decorative coatings can often be made very thin (less than 1 micron, versus the 3 microns typical of wear coatings). However, they cannot be as thin if corrosion or abrasion resistance is needed. The softer substrates on which such coatings are typically deposited also offer very limited support, and this sometimes makes it necessary to deposit the coatings quite thickly to provide abrasion resistance. The primary critical issue with decorative coatings is uniformity of color within a (coating) run as well as from run to run, day to day, and even year to year. This necessitates good process control. Because of their high volumes and generally low unit value, unit pricing on decorative items tends to be low, and profitability is critically dependent on throughput and process efficiency.

## 2.2 Market Analysis of the ?? job shop catchment area

The potential markets are split between

- Wear resistant tooling applications that are the traditional markets for PVD coatings (cutters, molds, hobs, inserts, etc.). These are to be found in any industry that involves metal fabrication or plastics.
- Functional and decorative coatings on components. These include door hardware, faucets, knives, pens, watch straps, automotive racing parts, etc.

?? is central to a large number of very diverse companies in the automotive and other manufacturing sectors. The catchment area for this location is the area within about a four hour drive, and stretches from Evansville and Louisville in the south to Fort Wayne and Toledo in the north, and from Indianapolis to the west to Columbus to the east (see **Figure 1**). Industries in Chicago and Cleveland are on the edge of the area that is easily accessible. The major close-in manufacturing cities are Indianapolis and Cincinnati, both of which have a broad industrial base. The types of business available in this market include traditional high speed steel and carbide tooling, as well as functional components such as Moyno pump drives (Springfield, OH) and turbine engine bearing races (Cincinnati, OH).

While a ?? shop should be able to compete with the other coating companies in Indianapolis and Richmond, it will do very poorly in tool coating at the periphery of the catchment area that are already well-served by competitors, such as Chicago and Detroit. This is because tool coating tends to be a localized industry with fast turn-around. However, the shop will be able to compete with competitors in Cleveland, since the competitors are small, and appear to be not very aggressive and poorly equipped.

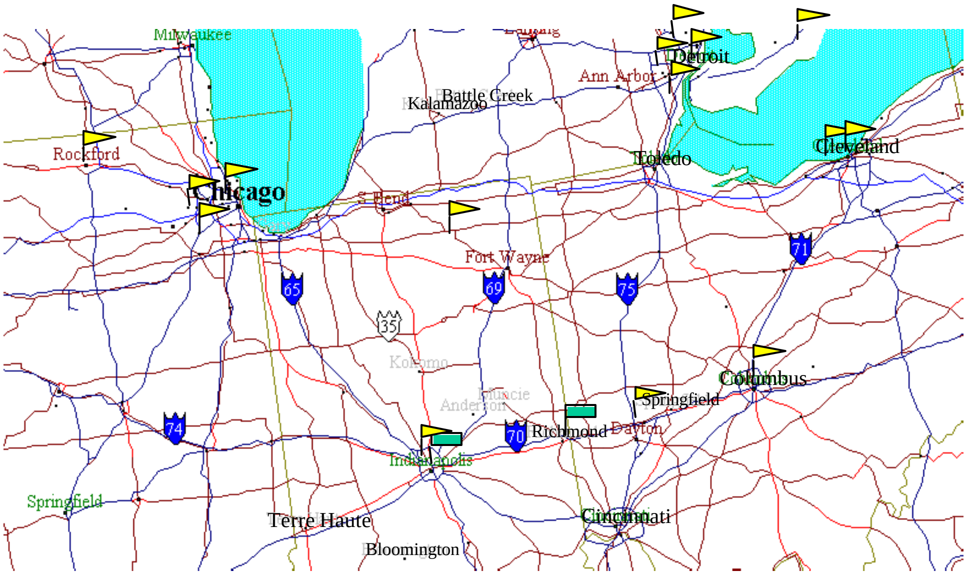


**Figure 1**. Catchment area for a job shop located in ??. Major competitors are shown as rectangular flags, minor competitors as triangular flags.

### **2.2.1** Industry sectors within the catchment area

In order to evaluate the market for the ?? shop, we have considered only those industries that either use tooling that is often coated or that make items that can be coated with PVD coatings. The same industries tend to use coatings both on tools and on products - i.e. metal and plastic products, and the tools used to produce them. Potential customers are therefore found almost exclusively in the following industries (and their SIC codes):

| | |
|---|---|
| 30 | Rubber and plastics |
| 34 | Fabricated metal products |
| 35 | Industrial machinery and equipment |
| 36 | Electronic and electric equipment |
| 37 | Transportation equipment |
| 38 | Instruments and related products |
| 39 | Miscellaneous manufacturing industries |

The only part of the automotive sector of SIC 37 that is generally relevant is SIC 3714, Motor vehicle parts and accessories. In a heavily automotive manufacturing area such as the Midwest, SIC 3711, Motor vehicles and car bodies, is dominant, but is primarily vehicle assembly, which does not employ PVD coatings. Therefore, it is important to leave this sector out of the statistical analysis to avoid gaining a false impression of the market. In our analysis we have therefore eliminated SIC 3711 from the evaluation.

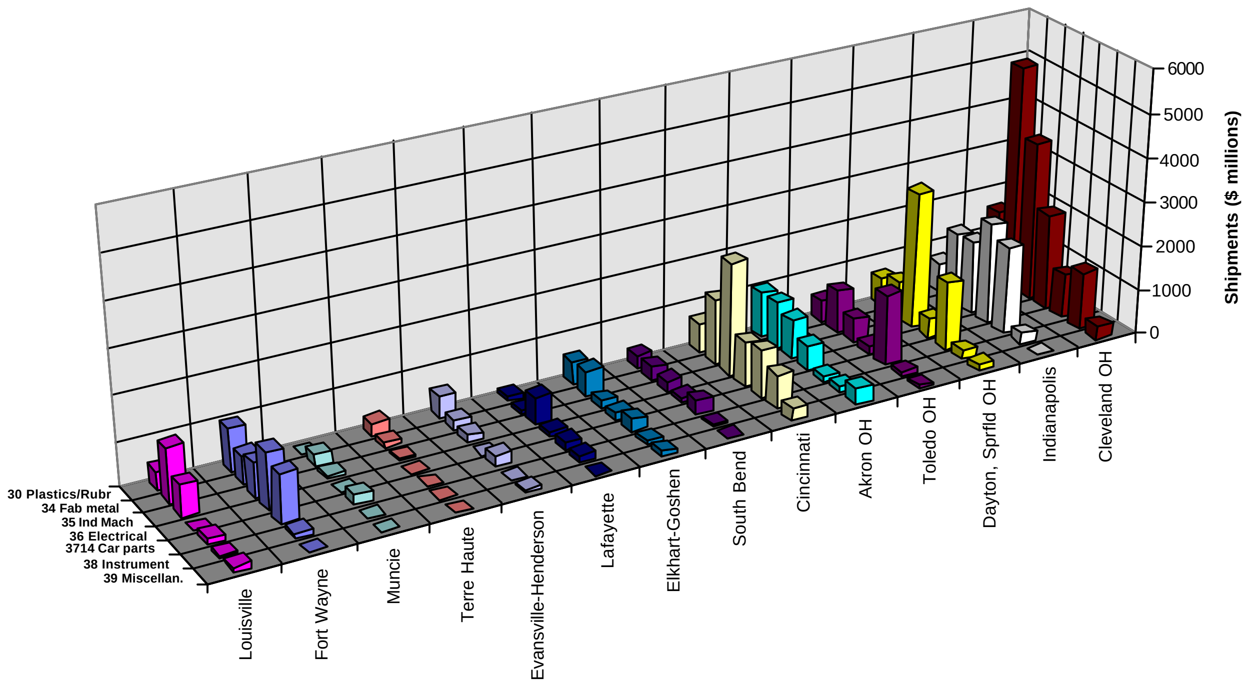


**Figure 2**. Shipments by industrial sector (SIC Code) and geographical area for the ?? job shop.

Most of the data for industry size by SIC and geographic area are gleaned from government statistics (the Census of Manufactures and County Business Patterns). Unfortunately, in some cases data is omitted from these statistics to prevent disclosure of sensitive business data from major manufacturers. In cases where the data was critical we have estimated the numbers by using average sales per company for that SIC and region from other manufacturing directories and multiplying this number by the number of companies in the government statistics. Where we have done this, we have indicated it with asterisks in the accompanying data sheets (**Appendix 1**).

For ease of understanding, we have used market breakdowns by metropolitan statistical area (MSA), which includes all the manufacturers in and around each of the major cities (spanning state lines in some cases), but excludes any companies far away from large metropolitan areas. A chart of shipments by SIC for the MSA's in and near the ?? catchment area are shown in **Figure 2** and summarized in **Table 1**.

It is clear from the data that, while ?? itself is relatively small, other cities within the catchment area have a very large manufacturing base. In fact, **more than a quarter of the entire U.S. industrial capacity for the industrial sectors in which PVD coatings are most commonly used is accessible to a ??-based job shop**. The largest industrial concentration lacking a strong local job shop is Cleveland, which is just outside the area, although it could be accessible for tool coating with the proper marketing approach. It would also be a market for product coatings, which tend to be accessible over much larger distances.

One cannot, from industry size data alone, make an estimate of the market size for tool or component coating, since there is no obvious direct correlation between industry shipments and number of tools used, for example. (Market size is calculated below.) Thus the fact that one industry is bigger than another does not necessarily mean that it will represent a bigger coating market. What these data show is the **concentration** of industries in the target sectors, and the breadth of the industrial base in the catchment area.

The largest markets for tools are generally in the metals fabrication industry, which uses cutters, punches, and dies (of which the latter two are the most profitable). The largest concentration of this industry is in Cleveland, suggesting that access to the Cleveland market will be important if the shop concentrates on the tooling market. However, there are sizable metals fabrication markets in Indianapolis, Cincinnati, and Louisville, which are all closer to ??.

The major centers for manufacturing of automotive parts (involving stamping, machining, and plastic molding) are in Fort Wayne, Dayton, Indianapolis, and Cleveland. At this point, few (if any) U.S. automotive products are PVD coated, except such items as headlight reflectors (Al coatings), some decorative trim, and diesel fuel injectors on a pilot basis.

The best markets for functional coatings on industrial components are in the industrial machinery market, which is concentrated in Cincinnati (Cincinnati Milacron, etc.), Dayton, and Cleveland.

Rubber and plastics manufacturing are most heavily represented in Cleveland, Fort Wayne, and Akron (tires). Note that this market sector presently offers the best opportunities in plastics rather than rubber, which is dominant in Akron.

**Table 1**. Shipments by industry and MSA (millions). Based on 1992 Census of Manufactures (last available full census data)

| | 30<br>Rubber and misc. plastics products | 34<br>Fabricated metal products | 35<br>industrial machinery and equipment | 36<br>Electronic and other electric equipment | 3714<br>Motor vehicle parts and accessories | 38<br>Instruments and related products | 39<br>Misc. manuf. industries |
|---|---|---|---|---|---|---|---|
| Ft Wayne | $960 | $631 | $758 | $1,276 | $1,085 | $112 | |
| Indianapolis | $678 | $1,602 | $1,639 | $2,291 | $2,002 | $238 | |
| Cincinnati | $678 | $1,459 | $2,548 | $991 | $1,073 | $782 | $294 |
| Muncie | | $250 | $87 | | $217 | | |
| South Bend | $297 | $286 | $228 | $127 | $304 | $51 | $21 |
| Terre Haute | $289 | $120 | $35 | | | | |
| Elkhart/Goshen | $530 | $576 | $160 | $153 | $287 | $86 | $108 |
| Evansville | $497 | $215 | $167 | | $260 | | $80 |
| Lafayette | $124 | $71 | $627 | $125 | $174 | $136 | |
| Louisville | $415 | $1,216 | $680 | | $131 | $39 | $121 |
| Dayton | $667 | $826 | $3,118 | $450 | $1,536 | $220 | $147 |
| Akron | $1,031 | $1,041 | $891 | $553 | $126 | $148 | $356 |
| Toledo | $474 | $952 | $562 | $181 | $1,601 | $99 | $40 |
| Cleveland | $1,566 | $5,150 | $3,622 | $2,193 | $1,012 | $1,315 | $311 |
| **Total** | **$8,206** | **$14,395** | **$15,122** | **$8,339** | **$9,808** | **$3,226** | **$1,478** |

## 2.3 Market size

We can estimate the market size for the proposed ?? coating shop by comparison with a more established region that is well-served by PVD coating shops, namely Detroit. The Detroit area is served by four mid-size companies and one small company with total sales of about $26 million (see Section 3.1, below). In contrast, the ?? shop catchment area is served by only two major competitors and several small companies, with total sales of about $9.5 million. We exclude Hohman Plating, and Praxair since they mainly operate in the aerospace industry, and only a small part of their business is PVD coating, of which very little is in competition with the traditional job shops.

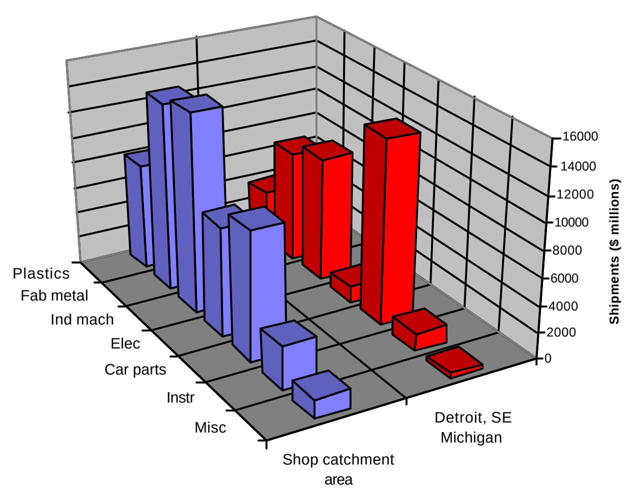


**Figure 3**. Comparative sizes of industrial sectors in the ?? and Detroit/Southern MI catchment areas.

However, the relative sizes of industrial shipments for the ?? catchment area and for the Detroit/southern Michigan area served by the Detroit shops are \$61 billion for ?? (of which \$15 billion is in Cleveland), vs \$39 billion for Detroit. Furthermore, as shown in **Figure 3**, the breakdown of industry across industrial sectors is not much different between the two areas (leaving out car assembly, which is not relevant to the coatings industry). Therefore, we would expect that the catchment area of the ?? shop should have a market large enough to support a coating market of about

**\$26 million x (61/39) = \$40 million**

This suggests that in the ?? catchment area there is about \$30 million of unserved coating business (\$40 million minus the business of the existing shops).

Even excluding Cleveland, which is on the edge of the catchment area, there should be about \$20 million of available business (i.e. one third of the available business would come from the Cleveland area). Of course, some of this business is doubtless already being served by Detroit area companies. Nevertheless, the available business does appear to be enough to support a large coating facility, even assuming that no new business areas are generated in the coming years - i.e. assuming that most of the business will be in tool coating.

## 2.4 Specific potential customers

There are a great many potential customers in the ?? catchment area. A listing of some of the most prominent of these is given in **Appendix 2**, broken down by their four-digit SIC code. These include major tool users in all categories, most of whom are major existing or potential users of coated tools. Some of them are also potential users of coatings on products, such as

| | |
|---|---|
| Best Lock | Door hardware |
| US Tap | Plumbing hardware |
| Cummins Engine | Injectors |
| Cincinnati Milacron | Bearings, gears and slides |
| Moyno Industrial Products | Pump internals |
| Maytag and GE | Refrigerator compressor parts |
| Lucas and others | Headlight reflectors, small automotive wear parts |
| GE Aircraft Engines | Bearing races, actuators |

Even in this limited listing there are dozens of potential customers with over \$60 billion in annual sales. Therefore there is a very substantial industrial base to support the ?? shop branching out from tool coating to functional and decorative coating of components. This will increase the coating market well beyond the \$40 million size estimated above.

## 2.5 Market penetration approaches

The different market segments and varying geographic locations will demand differences in approach.

### 2.5.1 Tooling

Hard PVD coatings are already well known in cutting tools, such as milling cutters, carbide inserts, taps, hobs, broaches, etc. Most of these applications are good for cash flow but margins are getting tighter as the markets mature. Some of these tools are sold already coated (drills, mills, inserts, hobs) and the service provider either contracts with the tool manufacturer or does recoating for the users. Recoating usually involves the adoption of good stripping methods for TiN, ZrN, and TiC. As the tooling markets for PVD coatings continue to mature, newer technologies, such as duplex and multilayer coatings are being introduced, partly to replace lubricants commonly used with the tooling.

Other tooling, such as punches, molds, and dies usually requires more demonstration of the effectiveness of the coatings. Because most of these specialized tools are not commodities, their price tends to be higher, they are often designed by the user, and the user therefore is usually more aware of their performance and their manufacturing costs. Users are often willing to investigate coatings as a way of reducing tooling costs and inventory. In general, the best approach is to the tooling engineer and, in smaller companies, the CEO.

The tooling market in Cleveland represents a third of the market in the catchment area. However, it is too far away from ?? to serve efficiently, since tooling customers generally seek rapid turnaround and therefore local service providers. This problem could be overcome by instituting a local Cleveland telephone number and a local pick-up delivery service, perhaps with a 48 hour rather than 24 hour minimum turnaround.

### 2.5.2 Components - functional coatings

At this point each component is an individual case. Design engineers are often looking for performance improvements or ways to overcome wear or corrosion problems without new materials or design changes. At the same time they tend to be skeptical of coating performance until it is well proven, and very concerned over price. These types of customers usually turn to coatings as a way of solving a problem (and often it is a problem that has always proved intractable), and working with them requires understanding of the problem and a willingness to adapt the process to their particular application. From the coater's point of view the best applications are those that solve a major problem that is costing a lot of money, such as extreme warranty claims.

Some companies are now looking for alternatives to chrome plating or other environmentally problematic processes. Among these is the Moyno Pump Division of Robbins, Myers. In these cases, one must bear in mind that chrome plating is still a very cheap process, despite its problems, and that replacing it with a vacuum process will require demonstration of truly superior performance (when it is truly needed) or higher marketability (such as a gold-colored component).

For many components, there are concerns that are often not addressed up-front but are critical to coating performance, such as allowable temperature, surface finish, corrosion resistance, and masking.

### 2.5.3 Components - decorative coatings

Decorative coatings are also mostly the province of the design engineers (and usually upper management, even in quite large firms). In this case the decorative coating is the most visible part of the product (and in some cases the most critical part of the product), and is therefore a matter of great sensitivity. Decorative coatings are usually put onto steel, brass, aluminum, or plastic. Color is always the most critical issue, and color must be reproducible around the chamber, around the object, from run to run, month to month, and even year to year. In many cases color must also match other objects and materials, such as brass or gold plated faucets.

One should note, however, that color is not the only factor of importance. Corrosion resistance and surface smoothness are almost always critical. Both corrosion resistance and smoothness are usually achieved with an electroplated nickel or nickel-palladium layer on the surface of the part to serve as a corrosion protector (since PVD coatings always have pin holes that permit corrosion) and leveler (since PVD coatings conform too closely to the surface with its polishing scratches and defects.) When using high temperature deposition methods, the electroplate also serves as a sealer to prevent outgassing of the zinc in brass. These electroplates are a frequent cause of rejects in PVD operations, since they often contain impurities, stains, or surface irregularities that show up as defects in the final surface.

In many cases, decorative coatings are needed on brass or plastic, which are low temperature materials that cannot be coated by most PVD methods. However, lower coating temperature, even when it can be achieved, is usually obtained at the expense of adhesion and film quality, which are either lower, or can only be maintained in a narrow range of process conditions. In these cases, tight process control is essential for reliable performance. In some cases, manufacturers are willing to change materials to accommodate a more reliable coating. This has happened, for example, with a major manufacturer of pens, who substituted steel for brass in order to avoid quality problems with a nickel electroplate.

### 2.5.4 Typical job shop

Obviously, job shops vary with their area and the industries they serve, but there are many common factors in job shop operations. A “typical” job shop is a $3-10 million operation with

- 2 - 10 coating machines,
- 1 process technician per machine per shift,
- 1 or 2 well-qualified repair technicians who can handle electronic and vacuum repairs,
- 2 or 3 salesmen,
- 1 or 2 secretarial/administrative staff, and
- 1 or 2 relatively low-paid general workers to help with cleaning, maintenance, and shipping.

It operates out of decent commercial/light industrial space (i.e. much better than the typical plating shop, but not expensive "high tech" space), often in an industrial park, near a major industrial center. The shop may be stand-alone, or it may be part of a chain of shops (e.g. Multi-Arc), or it may be owned by a tool-making company (e.g. Gold Star).

#### 2.5.4.1 Customer service

In the tool coating industry rapid turnaround is essential. Three days is usually sufficient, but customers often need coatings done and the tool returned to them in 24 hours. (24 hour service usually carries a 25-30% premium.) It is common practice for tool coaters to have a fleet of 3 or 4 vans running around the metropolitan area picking up and dropping off tools.

Customers for component coatings usually have reasonably steady and well-planned production schedules, and often require delivery on a just-in-time basis, which requires the highest reliability in equipment and personnel.

#### 2.5.4.2 Pricing

Jobs are usually priced per batch, where a batch is defined as the items that are loaded into the machine at one time. How many items constitute a batch depends on their size and shape, the spacing required around each for adequate coating uniformity, and the dimensions of the coating volume in the vacuum chamber. For example, in a standard 1 meter cube machine, a batch is likely to be 600 1/4' drills, 50 gear-cutting hobs, 12 broaches, or 1 plastics mold. In each of these cases, the processing cost is the same, but the profitability varies with the value of the item and the amount of competition.

**Table 2**. Typical gross profits from different types of tools.

| Item | Coating cost | Coating price | Gross profit |
|---|---|---|---|
| 1/4" drill | $0.83 | $0.50-1.00 | Loss-$0.17 |
| Hob | $10 | $15-25 | $5-15 |
| Broach | $42 | $100 | $58 |
| Small mold | $500 | $1,500 | $1,000 |

Typically a batch has a direct cost ( materials and labor) of about $500 and a selling price of about $1,000 - $1,200, for a 100% gross margin. Indirect costs, including depreciation, cost of sales, down-time, repair and maintenance, etc. reduce the profit level to about 20-30% once the business is running well. When properly occupied, with two-shift operation, weekly maintenance, and minimal breakdowns, a coating machine generates about $500,000 to $2,000,000 million per year in sales.

While items such as drills and milling cutters often can be used to provide cash flow, they rarely provide more than minimal profit because they are commodities, customers will not pay more than about a 20% premium for a coated tool, and competition is fierce in many markets, since any coating company can coat them. The only reasonable way to make a profit on such tools is to process them for a tool manufacturer so as to minimize the cost of sales.

Items such as molds and dies provide much higher profit levels because only a few companies can coat them and their value is high (tens of thousands or even hundreds of thousands of dollars per tool). Volumes of these items are low, it takes more effort to convince companies to coat them (i.e. cost of sales is high), but the value to the customer is very high.

Some items, such as hobs, are frequently recoated up to six times in their lives. Some tool coaters provide a standard recoating service (which also entails stripping about every third coating). This kind of service is only profitable if volumes are high. While coating of new hobs can be done for either their manufacturer or their end users, recoating is typically provided only to end users - i.e. large gear manufacturers.

Prices for coating components rather than tools depend entirely on the component and on what the customer is willing to pay, since there are no “standard” rates. For example, automotive engine valve stems would command only a $0.10 or lower price, which is not achievable with any standard piece of coating equipment, and would require a specialized production chamber. On the other hand, dental and surgical instruments are quite high-priced and can be functionally and decoratively coated at a high profit margin.

# 3 Competitors

## 3.1 Existing PVD coating shops

In the PVD toll coating business it is a rule of thumb that the catchment area of any coating shop is about 4 hours drive, since this defines how far a delivery van can go and return in one day. On this basis there could be customer overlap from shops as much as 8 hours drive away. However, most shops only serve about a 2 to 3 hour radius, which allows time for multiple pick-ups and drop-offs. Most companies based in or near a large city tend to take most of their business from that city, with occasional customers well outside the area (or even across the country), depending on accidents of marketing or on unique capabilities. Therefore, although any PVD job shop within half a day’s drive of ?? can be considered a competitor, only those serving the same major manufacturing areas are direct competitors.

All figures given below are **estimates** - very often a range of sales is given to reflect different numbers from different sources. Companies currently offering PVD coatings within a ½ day’s drive of ?? (by state) are given in the tables below and shown in **Figure 1.**.

### 3.1.1 Indiana competitors

The Gold Star shop in Richmond, IN and the Multi-Arc shop in Indianapolis are the two major direct competitors. Gold Star tends to place its shops well outside its major markets (its Detroit shop, for example, is in West Branch, MI, about 2 hours north of Detroit), so the Richmond shop primarily serves the Indianapolis, Fort Wayne and Cincinnati areas (as well as ??). The Multi-Arc shop primarily serves Indianapolis and surrounding areas (including ??).

| **Company** | **Year establ** | **# emp** | **Estimated annual sales** | **Process offered** |
|---|---|---|---|---|
| Gold Star/Div. of Star Cutter Co. 1580 Progress Dr Richmond, IN 47374 (317) 935-7631 | 1989 | 40 | About $5 million | Sputter PVD<br>Arc PVD |
| Multi-Arc (Sub. Andal Corp, NY, NY) 7301 Georgetown Rd Indianapolis, IN 46268 (317) 876-1212 | 1986 | 20 | $1 to 5 million | Arc PVD |
| Praxair Surface Technologies (Div Union Carbide)1500 Polco St Indianapolis, IN 46222 (317) 240-2500 | | 300 | 45 | Arc PVD: Aircraft coatings only (3 or 4 PVD machines).<br>Thermal spray: Aircraft engine rebuilding, industrial rolls |
| Multi-Arc (Sub Andal Corp, NY, NY) 40 Ems Lane, C288 Warsaw, IN 46580 (219) 267-7677 | | 7 | $0.5 to 1 million | Arc PVD |

### 3.1.2 Ohio competitors

| Company | year establ | # employees | estimated annual sales | process offered |
|---|---|---|---|---|
| Beamalloy Corp 6360 Dublin Indust. Ln Dublin, OH 43016 (614) 766-3300 | 1982 | 5 - 10 | $500,000 to $1 million | Nitrogen ion implantation, diamond-like carbon coatings |
| Hohman Plating & Mfg 814 Hillrose Ave Dayton, OH 45404 (513) 228-2191 | 1917 | 125 | $15 million | Primarily Cr Plater; cathodic arc or sputtered TiN, dry film lubricants |
| Ion Vacuum Technologies Corp., 4500 Lee Rd, Cleveland, OH 44128 (216) 662-5158 also: 1-800 869-4962 | | 10 | $500,000 to 1 million | PVD coatings - TiN |
| Surf Tech (Div. Euclid Refinishing Co.) 2937 Industrial Park Dr Austinburg, OH 44010 (216) 275-3356 | 1996? | 3 | about $180,000 | PVD coatings using MESH system |

### 3.1.3 Michigan competitors

| Company | year establ | # employees | estimated annual sales | process offered |
|---|---|---|---|---|
| Balzers Tool Coating Inc 42728 Executive Dr Harrison Twp, MI 48045 (810) 465-0411 also: 1-800-435-5010 | 1984 | 40 | $3 million | electron beam PVD TiN and related coatings |
| Gold Star Coating (Div Star Cutter Co) 2234 Dam Rd, West Branch, MI 48661 (517) 345-7160 | | 50 | $10 million | sputter PVD TiN and related coatings; arc PVD TiN |
| Multi-Arc (Div Andal) 1064 Chicago Rd, Troy, MI 48083 (810) 585-8790 | 1979 | 50 | $4 million | arc PVD TiN |
| Ti-Coating, Inc 50500 Corporate Dr, Utica, MI 48315 (810) 726-1900 | 1975 | 60 | 8 million | Probably arc PVD and CVD TiN |
| Vactec Coating Inc 23900 Industrial Park Dr Farmington Hills, MI 48335 (810) 476-8185; new area code 248 > 5/10/97 | 1965 | 6 | $0.6 to 1 million | Cathodic or anodic arc coatings |

### 3.1.4 Illinois competitors

| Company | year establ | # employees | estimated annual sales | process offered |
|---|---|---|---|---|
| Balzers Tool Coating, Inc<br>1181 Jansen Farm Court<br>Elgin, IL 60123<br>(847)695-5200 | | 30 | $1 - 5 million | electron beam PVD |
| Multi-Arc Scientific Coatings, Inc<br>925 Atlantic Drive<br>West Chicago, IL 60185<br>(630) 231-9200 | 1982 | 50 | $ 5 to 10 million | arc PVD, CVD TiN possibly |
| National Coating Technology<br>3625 Woodhead Dr<br>Northbrook, IL 60062<br>(847) 205-5666 | | 15 - 20 | | Arc PVD TiN |
| Pfauter-Maag<br>Rockford, IL | | 250 | very small outside coating sales, probably less than 1 million | Hauzer PVD (mostly in-house bu some toll coating) |
| Empire Hard Chrome<br>1615 S Kostner Ave<br>Chicago, IL 60623<br>(312) 762-3156 | 1945 | 100-150 | $11 - 12 million PVD sales currently zero | Primarily Cr plater; PVD: Mesh system |

## 3.2 Competitor analysis

### 3.2.1 Balzers Tool Coatings (Chicago, Detroit, New York)

Although there are no Balzers shops in close competition in the area, we know that Balzers does sell quite far afield from its primary location in Tonawonda, upstate New York (including Indiana). Balzers is generally regarded as “the one to beat” in the coating industry, as they set the standard for high quality coatings. They use evaporation technology to produce very high quality coatings of TiN, CrN, $Cr_3C_2$, TiC, multilayers, and more recently TiAlN.

Their closest shop is in Elgin, just outside Chicago, and they have a Detroit shop. Their forays into distant markets are generally run out of their New York coatings headquarters. However, they have suffered from very slow turnaround when serving distant markets (often a week or more).

Balzers is very large and makes vacuum coating equipment and supplies as well as running coating centers across the world. It was recently merged with Leybold, the world's primary manufacturer of sputter coating equipment.

Balzers are proud of their position as high quality coaters, and are very careful not to take on jobs unless they are almost certain of success - i.e. unless they have some reasonable level of prior experience, usually in Europe. They have a large R&D activity at their center in Liechtenstein. They advertise heavily in trade magazines and at trade shows; they also write articles for the trade and scientific press.

### 3.2.2 Beamalloy (Dayton, OH)

Beamalloy is a very small company that has never done more than eke out an existence. It is run by Bob Partyka, an ion implantation specialist, and Arnie Deutchman, the business manager. They started out doing ion implantation of tools in the 1980's, and like most implantation companies, graduated to coatings. Their specialty is a DLC that is very thin but has never really caught on well.

We do not believe that they offer any serious competition. They have remained essentially a two-man operation for many years, and appear to have neither the money nor the technology for expansion. They do very little advertising.

### 3.2.3 Gold Star (Richmond, IN)

Gold Star is probably the most serious competitor for the ?? shop. The company is owned by Star Cutter, a manufacturer of cutting tools based in Michigan. Gold Star's coating operations are run by Bill Langendorfer, who is very experienced in running their job shops. Gold Star has a reputation for high quality work and good customer service. Their shops are equipped with arc machines, for tools, and Hauzer ABS (combined arc and sputter) machines for tools and decorative work. Some decorative work is being done at their Michigan shop, but their Indiana shop is primarily doing tools and other hard coatings.

They serve their customers by using vans to pick up and deliver. They offer the usual tool coatings, TiN, TiC, TiAlN, CrN, as well as some decorative ZrN, TiAlN, and TiN coatings.

Gold Star advertises in tooling magazines and at trade shows. Because they are owned by Star Cutter, the two companies sometimes share booths at trade shows devoted to the tooling industry. They also give presentations at meetings.

Gold Star has limited R&D capability - essentially a single Masters-level scientist, but they do join university development efforts.

### 3.2.4 Hohman Plating (Dayton, OH)

Hohman plating is an anodizing and electrolytic plating shop that primarily serves the aircraft industry. They do cadmium, chrome, tin, zinc, nickel, black oxide and other electrolytic coatings, and are aerospace (NADCAP) qualified. They also offer some flame spray and Teflon coatings.

They have been in the PVD business for many years on a small scale. They have never really advertised their services very widely, and they appear to operate the PVD business essentially as a sideline to their main plating operations. They do some sputter coating and copper ion plating on Pratt and Whitney parts, and they advertise their arc coatings for low temperature deposition of TiN. However, they never appear at PVD conventions or advertise in locales where buyers of PVD coatings are found. They have a large section in the Thomas Register Catalog section, where it is clear that PVD is a minor part of their business.

Although they offer small competition at present, they should be watched since environmental pressures may force them to put more emphasis on PVD in the future, and they probably have the cash flow from their other operations to support significant expansion.

### 3.2.5 IVAC (Cleveland, OH)

IVAC is a very small company, run by George Fisher, that has been in business for some years but has never really grown. They have an old ion implanter, but all their work is tool coatings, including hobs and other tools, medical instruments, and firearms. Their equipment is all built in-house and includes electron beam and hot filament evaporators, ion plating, arc deposition, and sputter magnetron coaters They also carry out R&D for clients.

The management has no strong market drive, and appears content to take on small levels of work. They do, however, advertise with large advertisements in Thomas Register.

### 3.2.6 Multi-Arc (Indianapolis, IN)

Multi-Arc is on a par with Balzers in the number of shops around the country. However, they use arc technology, and in some of their older shops (those that used to belong to Scientific Coatings at the time they were bought by Multi-Arc 10 years or more ago), CVD TiN coatings.

Multi-Arc is very aggressive, willing to take risks and thus has a higher failure rate for new coating applications. Their coatings are not as high a quality as Balzers because they use arc technology, but they are perfectly adequate for most tools, and are even used on some other components such as aircraft wobbler plates.

As with Gold Star, they typically use vans to service their customers. They offer the usual array of nitride and carbide coatings, including TiN, TiAlN, CrN, ZrN, TiC, etc.

Multi-Arc advertises aggressively in tooling magazines and at conventions and trade shows, as well as in Thomas Register. They also give presentations at conferences and write technical and trade publication articles. They have a professional sales force. Their general approach is that they are willing to take on almost any type of job, even those with a low probability of success.

Multi-Arc has an R&D center at their headquarters in Rockaway, New Jersey. They also have recently formed an association of their shops and other similar businesses to trade information on technology and markets. They are now affiliated with D.G.Teer (Kiddeminster, UK) to sell Teer PVD systems; to date none have been sold in the US.

### 3.2.7 Praxair (Indianapolis, IN)

Praxair is the gorilla of the thermal spray coatings industry. They are a large public corporation that grew out of Union Carbide, whose primary products are industrial gases (such as oxygen for the steel industry). Their Surface Technology Division, headquartered in Indianapolis, is about a $500 million operation with plants in major industrial centers such as Chicago. Because the Surface Technology Division grew out of the aircraft engine rebuild market, it concentrates on thermal spray - Detonation Gun, Plasma Spray, Arc Spray, and recently HVOF. Praxair invented the Detonation Gun (or D-gun), and later the Super D-gun, for putting down high quality thick coatings for aircraft engines. Their refusal to licence the technology forced the invention of the High Velocity Oxy-Fuel (HVOF) approach which is now widely used throughout industry.

Praxair is vertically integrated, supplying (and selling) its own gases and thermal spray powders, and is aggressively expanding its coating operations. In 1996 it bought Miller Thermal to expand its thermal spray capabilities.

At its Indianapolis plant Praxair has arc PVD coaters that use its own arc technology, but its PVD operation is small compared with its thermal spray operations, and PVD employs only a few people. At present Praxair does not do toll coating, but uses its PVD facilities for aircraft engine work, such as bearings for GE Aircraft Engines, and presumably for its own internal tool coatings. They specialize in very thick (>10 micron) PVD coatings put down with low stress. **However, Praxair should be watched since they produce high quality (aerospace qualified) coatings and have the resources to expand their PVD markets if they choose to do so.** The probability at this point, however, is that they would not consider toll coating to be profitable enough to warrant management time and resources. They may move into any large-scale coating market that might open up, such as pistons, piston rings, or even decorative markets.

Last year Praxair lost Albert Sue, their primary PVD R&D worker, and have had difficulty in replacing him with someone of a similar caliber.

### 3.2.8 Surf Tech (Cleveland, OH)

The company, run by Ed Yusko, is nearly 2 years old. They have a Mesh IBAD (ion beam assisted deposition) system purchased from Russia. Because of difficulties with getting the equipment fully operational (which took about a year) they have only been in full production for the past year. They offer TiN, AlN, $B_4C$/TiN (Boron Carbide/Titanium Nitride) multilayers, and $MoS_2$/Cr (Molybdenum Disulfide/Chromium) multilayers. They tend to coat a variety of items, including gun drills, indexable inserts, brazed carbide tools (since the coating temperature can be kept low enough not to affect the braze), and tools for machining aluminum and nodular iron (cylinder liners). They also coat plastics and paper-covered rolls for the textile industry.

Because they are new in the industry they presumably have less experience and cash than Multi-Arc and Gold Star. They have advertised very little, and probably are quite limited in production volume since their only equipment appears to be the single Mesh machine.

### 3.2.9 Chicago and Detroit

The Chicago and Detroit regions are on the edge of the ?? shop catchment area, and are well-served by local PVD companies. The Detroit market has been served for a number of years by Balzers (Harrison Twp, MI, and Tonawanda, NY), Multi-Arc (Troy, MI, and Cambridge, ONT), Gold Star, and Ti-Coating. Chicago has long been served by Balzers and Multi-Arc, but in the last three or four years National Coatings (a Chinese company) has entered the market quite aggressively, and Pfauter-Maag of Rockford, IL, who make cutting tools and hobs, have also just begun to enter the general coating market.

Because these companies primarily deal with tooling, a competitor offering coatings for decorative and functional applications could gain entry into the Chicago and Detroit markets. It should be noted however, that market entry based on specialty coatings or processes is possible not only in the upper Midwest but in any part of the US or Canada. For example, 10-ton molds for automotive bumpers and instrument panels are often shipped from southern Ontario to Iowa for processing; a San Diego company is processing tools with specialty coatings for Boeing Aircraft in Seattle, WA.

# 4 Technology and Equipment

## 4.1 Available PVD Technologies

There are three main types of PVD coating used commercially for hard coatings, although there are many modifications of them that differ in detail. They are summarized in **Table 3**, together with the less-commonly used ion-assisted methods. They each have certain advantages and disadvantages, giving different methods an edge for different markets. They all have one thing in common, however - all bombard the growing coating with ions

- to provide sufficient mobility to form a good crystalline structure and
- to densify the coating by "resputtering" material from at the surface into voids that form beneath it.

The three major commercial hard coating technologies all draw their ions from a plasma formed in the gas in the chamber (which is usually at a pressure of a few millitorr). Most hard coatings are compounds that are deposited reactively, by combining the metal with active gas (N or C) at the surface of the growing coating.

**Evaporative PVD** (ion plating): The highest quality coatings are produced by the electron beam evaporation methods (Balzers and Tecvac). Balzers, which uses an electron beam down the middle of the chamber, is regarded as the highest quality coating provider. In this approach, material is evaporated from a 'boat' or crucible, usually with an electron beam, which also supplies electrons for ionization of the chamber gas. The major advantages of this method are its high quality and the low cost of evaporation materials. Its main disadvantages are that the low ionization in the gas requires a relatively high deposition temperature (Balzers uses 450C), and the difficulty of depositing alloys. The Balzers chamber design also limits the size of item that can be processed since the center of the chamber must be kept clear for the electron beam. The Tecvac approach is the same process, but the electron beam comes from below, which frees the center of the chamber, so that the process can be used for molds and dies up to 35" diameter and 500 lbs weight.

**Arc deposition:** This is the most commonly used method for tool coating, although arc coatings are being used in the aircraft industry for auxiliary power unit wobblers and jet engine bearings. Its major proponent is Multi-Arc, but arc machines are also supplied by Hauzer and arc deposition is used by companies such as Goldstar and Praxair.

The major advantages of arc deposition are that it is a very forgiving process, especially in terms of coating adhesion, and it requires very little process control. Its main disadvantage is that it produces small "spits" several microns across, known as macroparticles, which give the coating a rough surface and a matte finish. This makes it unsuitable for decorative coatings and some tooling applications as well, such as mirror-finish molds for CDs. There are now some ways around this problem, such as the ducted arc, in which the arc plasma is directed along a curved channel or around an obstacle to trap the particles. This is awkward and inefficient.

A recent innovation is MEVVA (Metal Vapor Vacuum Arc) deposition, which was developed by ISM in San Diego, in which the material comes from a high intensity metal ion source. However, ISM's technology has not gained acceptance in the US, the company has gone through serious financial problems and is currently restructuring.

**Sputtering:** Sputtering produces very high quality coatings, and can be done over very large areas (Airco C-mag and racetrack targets can be 6-10 feet long). It is used for architectural glass, electronics, and, more recently tools and decorative finishes (watchstraps, bezels, automotive lights, pens, etc.). Sputtered coatings are generally high quality (although they do sometimes contain trapped particles similar to macroparticles). Sputtering can be done at low temperatures (although it requires close process control and good cleaning to do so successfully), and almost any material can be sputtered, including complex materials (such as hydroxyapatite - bone) that must be RF (radio frequency) sputtered.

Traditionally, sputtering has always been the slowest deposition method, but High Rate Reactive Sputtering (HRRS), developed by Bill Sproul at BIRL, has improved deposition rates (although not to the speed of evaporation). In order to sputter coatings reactively at high rates one must keep good control of the partial pressure of the active gas to prevent its poisoning the cathode, which reduces the deposition rate by an order of magnitude. (Oxide coatings are especially difficult in this respect.) The process can be controlled by partial pressure monitoring with closed loop feedback control, which is an additional complication. For high volume production, the cost of sputter targets is the primary cost factor in the process, and one often encounters difficulty in obtaining sufficiently strong targets of brittle materials such as chrome.

**Table 3**. Commercially available PVD technologies

| Technology | Advantages | Disadvantages | Applications | Manufacturers |
|---|---|---|---|---|
| **Evaporation** - ion plating, e-beam PVD, hollow cathode | Highest quality<br>Low material cost<br>Fast deposition | High temperature<br>Limited coating materials | Tools - cutters, molds, dies<br>Small optical | **Balzers** (e-beam); **Tecvac** (e-beam) **Ulvac** (hollow cathode) |
| **Sputtering** - balanced magnetron, unbalanced magnetron (UBM), DC, RF | High quality<br>Almost any material | Slow deposiition<br>High material cost<br>High level of control needed | Tools - cutters, molds, dies<br>Decorative<br>Large optical | **Hauzer**, **Teer** (UBM); **Leybold** (balanced); **Airco** (C-mag) |
| **Arc** - cathodic, anodic, random, steered, confined, ducted | Good adhesion<br>Wide process window | Macroparticles<br>Limited alloys | Tools - cutters, molds, dies, aircraft parts | **Multi-Arc** (steered); **Hauzer** (confined); **VacTec** (anodic) |
| **Ion-assisted -** sputtering, evaporation, ion sputtering, Metamode | Wide process window<br>No bias | Unproven track record<br>Line-of-sight beam | Tools - molds, tools<br>Optics | **Mesh** (sputtering); **Commonwealth Scientific** (electronics); **OCLI** (optics) |

Recent advances are Unbalanced Magnetron (UBM) sputtering, which increases ion bombardment by spilling the magnetic field of the magnetron out into the working volume of the vacuum chamber. Hauzer combines arc cleaning at the beginning of the process (for good adhesion) with sputtered coating deposition (for high quality) in its Arc Bond Sputtering (ABS) machine.

**Ion-beam assisted (enhanced) methods:** There are several ion beam based (IBAD) methods that have been developed, although none have yet moved into widespread commercial use.

The Mesh system, from Russia, combines sputtering with an ion beam at 2 or 3 kV. The Metamode process developed by OCLI (Santa Rosa, CA) combines sputter deposition with sequential oxygen ion bombardment to produce optical coatings on flat substrates. Geoff Dearnaley at Southwest Research Institute (SWRI) has developed an ion beam method of cracking oil vapor onto the surface to form a hard, lubricious coating, although this method is not being offered by any commercial vendor. A number of eyeglass lens coaters have installed low energy ion sources in their evaporation chambers to enhance coating adhesion and quality. Systems of this type have been supplied to optics and electronics companies by Commonwealth Scientific (Alexandria, VA) and Ion Tech (Ft Collins, CO). Other related processes include plasma CVD (PCVD) offered by Metroline (Corona, CA).

**Table 4**. Most commonly used approaches for different markets.

| Market/application | Most common method | Equipment suppliers |
|---|---|---|
| Tools | Arc | Hauzer, (Multi-Arc for in-house) |
| | Evaporation | Tecvac, (Balzers for in-house) |
| | UBM sputtering | Teer, Hauzer |
| Decorative | Sputtering | Hauzer<br>Leybold |
| Functional (wear) | Arc | Hauzer, (Multi-Arc for in-house) |
| | Evaporation | Tecvac, (Balzers for in-house) |
| | UBM sputtering | Teer, Hauzer |
| | PCVD | Metroline |
| Functional (corrosion) | PCVD | Metroline |
| Small plastic moldings | Sputtering | Leybold |
| Architectural glass | Sputtering | Leybold<br>Airco |

**Deposition temperature:** In general one can in principle trade off ion bombardment (whether from an ion beam or a plasma) for temperature - the more bombardment the lower the temperature needed. However there are practical limitations:

< Raising the bombardment raises the deposited energy, and hence the temperature.

< The lower the temperature the more difficult it is to obtain good adhesion and structure, and the more stringent the process control needs to be.

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

## 4.2 Commercially available PVD equipment

Balzers and Multi-Arc equipment are not available for sale to job shops, since they compete with Balzers' and Multi-Arc's own toll coating operations. It should be recognized that deposition facilities must include a proper cleaning line, methods for stripping the coating, and a set of quality-control test instruments - microhardness, adhesion, film thickness, optical microscopy, and (for decorative work) color.

### 4.2.1 Mesh ion beam assisted deposition

Approximate cost - $250,000

Coating volume - ring 24" OD by 5" thick by 30" high

**Advantages and disadvantages of the Mesh system:** Because we have no direct experience with this system, we must base our opinions on conversations with users and our own experiences with sputtering (including the Hauzer system) and high energy ion beam assisted sputtering (which we developed at Ionic Atlanta). There are two primary considerations

1. Will the technology work well and cost-effectively for ???'s projected markets?

2. What will be the probable **total time and cost** to put into full production?

Our concerns over how well the technology will work stem from the fact that the equipment is almost untried outside Russia, its use of Russian components will make it difficult to service, it uses a unique technology that has not been widely tested in the US market, and its usable chamber space is small. We have discussed our concern over the sequencing of deposition and ion bombardment with John Keem, who agrees with the concern, but says that it appears to make no practical difference. We have discussed the equipment with Ed Yusko, who said that it took him a year and a lot of reworking of all systems - mechanical, electronic, cooling - to put his machine into full production. Technical and market support is also a concern, as it is for any foreign machine. John Keem is expecting to provide technical and spares support once he has enough machines in place (6 or more). However, there appears to be no support concerning markets, coatings for different markets, jigging, etc., such as would be supplied by Hauzer, Tecvac, and to a lesser extent Teer.

Although the capital cost is the lowest, both the cost of upgrading and the cost of lost sales during the shakedown period of, say 6 - 12 months should be factored in. Clearly, there will be a learning curve for any equipment, but, if Surf Tech's experience is common, the shake down time for the equipment itself is likely to be longer than with other systems on the market. This will limit cash flow during the first year of operation.

Chamber size and design limit the size of objects that can be coated, excluding most dies and molds, which would be too big for the limited coating volume. The directionality of the ion beam will preclude the coating of complex shapes that cannot be accessed by line-of-sight methods. (However, many complex shapes cannot be properly accessed by plasma methods either). Low temperature deposition will be possible (taking into account the caveats noted above), allowing access to markets for brass items such as door hardware and plumbing fixtures.

### 4.2.2 Teer Coatings unbalanced magnetron sputter system

Cost - about $300,000 and up

Chamber size -17" diameter by 17" high (and up), 4 unbalanced magnetrons

This system offers essentially the same advantages as the Mesh system. However, it is based on the commercially more established UBM approach that was first used industrially in about 1992. There is currently one Teer machine in the US, at the Naval Aviation Depot in Cherry Point, NC. It too had a considerable shake-down period, but this was in a government facility with support from Penn State University, who had no previous experience with this approach.

### 4.2.3 Tecvac electron beam deposition system

Cost - about $500,000, including installation, training, starter spares, know-how

Chamber size - 40" cube, coating zone is entire chamber

Since it is based on the well-established ion plating method similar to that used by Balzers and others, it produces very high quality coatings, but is restricted in deposition temperature to >400EC for TiN and probably about 250EC for CrN. The Tecvac equipment is a turnkey system. General electronic and vacuum spares are commercially available in the US, including vacuum pumps and gauges, and power supplies, but mechanical machine components are only available from Britain. Full technical support is available. Because Tecvac uses their machines for their own toll coating business, they offer a good depth of process and market experience, mostly in tools, but also in other market areas, including automotive components, knives, and a limited number of decorative applications.

### 4.2.4 Hauzer arc and arc-bond systems

Cost - $1.2 - 1.5 million

Chamber size - 1m cube. Coating ring approx. 24" OD by 6" thick by 22" high

This is the most expensive, but also the most versatile system on the market. It has become quite widely used in the US for both functional and decorative coatings. Because it is now well established, information is available for marketing and process development. General electronic and vacuum spares are commercially available in the US, but machine-specific components are only available from Holland. Hauzer machines are turnkey systems with full technical support available.

### 4.2.5 Leybold

Cost - varies with system (tends to be high)

Leybold sputter deposition systems tend to be very expensive, but are also very high quality. They include a system that operates on a rapid (2 minute or less) cycle for coating plastics straight off the production line, and a new system that coats small volumes in a rapid (5 minute) cycle.

### 4.2.6 Cemecon

Cost - varies with system (tends to be high)

This equipment is unique in that the magnetrons can be moved around inside the vacuum chamber. This provides a high degree of flexibility, but it also means that the coating conditions are not well defined, which could lead to problems of reproducibility.

## 4.3 Competing Processes

There are a number of competing processes that could impact some of the PVD coating markets. A few examples of some of these processes are:

< An increasing number of platers offer electroless or electroplated nickel coatings. For example, Nimet Industries (South Bend, IN) - offers a range of different coating processes, including anodizing, dry film lubricants, and chromate conversion, but also has proprietary nickel-based electroless coatings that are very lubricious as well as being wear and corrosion resistant. Nimet coatings include NiCoTef, a fluoropolymer-enriched composite nickel coating and NiTuff - a composite of hard anodize and a fluoropolymer.

< Microsurface Coatings of Morris, IL offers a combination PVD hard coating (deposited by a local coating shop) with an overlayer of lubricious tungsten disulfide. Other duplex hard/lubricious coatings are being offered by more and more companies, including SurfTech in Cleveland.

< Plasma nitriding is a strong competitor to coating for large molds (up to 20,000 lbs. The cost is about $0.50-0.75 per pound. The process is done by companies such as Sun Steel Treating of South Lyon, MI and Advanced Heat Treat in Waterloo, IA. Molds are commonly shipped large distances for this treatment.

## APPENDIX 1 - INDUSTRY STATISTICS OF THE ?? CATCHMENT AREA

# APPENDIX 2 - EXAMPLES OF POTENTIAL CUSTOMERS

This is a representative sampling of manufacturing industries in the ?? catchment area, listed by SIC code, which use tooling, or produce components, that are potential PVD applications. This list is not meant to be comprehensive; smaller companies are generally not included; figures for annual sales and number of employees are estimates only, based on data obtained from 1996-97 manufacturing directories, investment analyses, and similar sources.