Congratulations on Your Purchase of...

The Metal Plating Bible

Your #1 Guide For Complete Metal Plating Success!
Dear Customer,

I would like to take this moment to congratulate you on your purchase of the “Metal Plating Bible”. It is without a doubt, the most practical learning guide for the beginner or intermediate plating enthusiast. There’s a lot of information crammed into the next 60 or so pages. You may be tempted to skip around, but if you do, you may risk missing vital pieces of information that will substantially aid you in your metal plating efforts. So do yourself a favor and read this eBook from front to back.

Also, due to the technical nature of Metal Plating, there will likely be many words that you might not understand. Because of this inevitable fact, we have included a glossary at the very end of this digital book. If you ever need to refer to it, just go to the last few pages where you can read it.

Ok, there’s nothing more to say, go ahead get started. The following 63 pages contain all the information you’ll ever need to do your own high quality metal plating. Enjoy!
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CHAPTER 1

<<Introduction to Electroplating>>

Electroplating is the process of coating a metal object with another metal, using electrical current passed through a chemical solution. It is the process that produces a thin, metallic coating on the surface of another metal. The purpose of Electroplating is to improve appearance of the material, protection against corrosion and in certain special processes like printing.

The process of Electroplating involves placing the metal to be plated, (“Metal A”) in the solution of the metal (“Metal B”), with which it has to be plated. The metal to be coated (Metal A) is made the cathode in an electrolytic cell and the anode is made up of another conductor mostly the “Metal B” (metal with which Metal A will get coated). When electric current is applied, the electrode reaction occurring on the cathode is the reduction of the metal ions to metal. E.g., gold ions can be discharged form a gold solution to form a thin gold coating on a less expensive metal to produce "custom" jewelry.

To further illustrate the Electroplating process, let us assume that an object made of one of the copper (Metal A) has to be plated with nickel (Metal B).

The Setup:

Step 1:
Attach a wire to the copper object (Metal A) while the other end of the wire should be attached to the negative pole of a battery (or a power supply). To the positive pole of the battery (or power supply) we connect another wire with its one end connected to a rod made of nickel (Metal B).

Step 2:
Next we fill the electrolytic cell with a solution of the metal salt to be plated. In our present example the nickel chloride salt dissociates in water into positively charged nickel cations and negatively charged chloride anions. As the copper object to be plated is negatively charged it attracts the positively charged nickel cations, and electrons flow from the copper object to the cations to neutralize them (to reduce them) to metallic form.

Meanwhile the negatively charged chloride anions are attracted to the positively charged nickel rod (known as the anode of the electrolytic cell). At the anode electrons are removed from the nickel metal, oxidizing it to the nickel cations. This illustrates that the nickel dissolves as ions into the solution. That is how replacement nickel is supplied to the solution for plating and we retain a solution of nickel chloride in the cell.
Fig. GRAPHICAL REPRESENTATIONS OF THE ELECTROPLATING PROCESS
Anode (Oxidation occurs here)

Cathode (Reduction occurs here)

Source of direct current
Nickel chloride is used here to exemplify the process of electroplating as it is simple to understand. It is not recommended; however, that nickel is used for, say, school science demonstrations because some individuals are quite allergic to it. It is also not recommended that chloride salts be used because they are amenable to release chlorine gas. For school or amateur type demonstration it is recommended to plate copper coins with zinc or nickel coins with copper.

Another common example is the shining work on cars -- bumpers, door handles and manufacturer logo. Much of this begins as a piece of zinc, steel or plastic. The manufacturer uses a copper electroplate, then a nickel electroplate and then chromium depositing over one another. The result is a surface brighter and more corrosion resistant than bare metal or plastic.

Electroplates are applied by immersing the object to be coated in a tank containing the proper chemicals dissolved in water. If nickel is being applied, nickel metal is one of the components of that solution.
Now imagine that the part to be plated is attached to a negative electrical lead (like that on your car battery). Once it is attached to the negative electrical lead it is called a cathode.

The other electrical lead, the positive (+) is in the solution. When current is turned on, the negatively charged part to be plated attracts positively charged metal from the solution (opposites attract). This continues as long as current is on, and the coating or deposit becomes thicker and thicker. But most electroplates are not very thick. One thousandth of an inch (0.001 inch) is regarded as pretty thick.

Since metal is being taken from the solution, it must be replenished. Often this is done by hanging pieces of the metal nickel, if nickel is being plated, for example, in the solution. The chunks of metal are called ANODES, and the positive electrical lead is then attached to them. They dissolve in the solution as metal is taken away by plating. So at this point we have metal being removed from the anode and deposited on the cathode, which are the parts to be plated.

Since a car battery is not a good source of power for this application, electroplaters use electrical current supplied by their power companies. But they must have DIRECT current (DC), while the power company supplies ALTERNATING current (AC). To convert AC to DC electroplaters use a RECTIFIER. Its function is to convert AC to DC.

Metals Plating Metals

The plating of other metals mainly depends on the physical properties and composition of the metal that is going to be plated. Some may not be good conductors, thereby making poor Cathodes for the electroplating process.

Others may not plate well because of a strength-weight ratio of the metal to be plated. If the strength to weight ratio is low, then the plating material may not hold well with the metal. If the strength to weight is high, then the plating will hold well to the metal, ensuring a good bond between the two.

Ideal metals to plate are:

- Steel
- Brass
- Zinc Die castings
- Copper Alloys (Zinc and tin)
- Beryllium
- Aluminum

Before a metal is plated, it must go through a process of Pre-treatment. In the Pre-treatment process, the metal is cleansed and prepared with other chemicals that will quicken or make a more reliable adhesion with the plating metal. The actual plating of metals can be divided into three groups. These are:

- Barrel
- Rack
- Strip (reel-to-reel, continuous)
**Barrel Plating** is used when the plating is done inside of a perforated barrel, and the barrel is rotated to even the plating. It is mainly used in the plating small diverse objects, devoid of sharp and long edges that tend to plate badly.

**Rack Plating** is used for plating objects that are too heavy, too large, or too complicated to barrel plate. These can vary from small things such as keyholes, to large roller. Most rack plating setups are made up of copper rods that conduct electricity very well, and are very durable. The objects are clipped to this copper rack and then put in to the electrolyte solution. The placement of the copper rack in the solution is crucial because if the rack is placed incorrectly, the plating may be lop-sided and uneven.

**Strip Plating** is used when the object happens to be just a strip of metal. This strip of metal is then put through different process stations (or solution tanks), where they are plated at different levels. It can be used for selective plating.

There are other problems that one must contemplate when electroplating nickel. Other than choosing one of the three types of plating, one must also take into consideration some of the following factors:

- Temperature Control
- Agitation
- Filtration and Ventilation
- Power Supplies
- Anodes
- Automated Control

**Temperature Control** is important in most solutions. A few solutions require cooling, others require heating, and some need both. A method of cooling and heating would be to pipe hot or cold water through pipes that go through the solution.

**Agitation** in electroplating increases the density and effectiveness of the plating in some cases. An example of this would be to leave a copper plated substance out in the air. This would improve its luster and durability. A good method that agitates would be Barrel Plating.

**Filtration and ventilation** come into consideration because there may be a need to remove substances that are contained within the electrolyte. These deposits may ruin the plating, and should be removed at a certain interval of time. This turnover rate should be around twice every hour, depending on what solution one is using.

**Power Supplies** are important because certain levels of voltage affect the plating process. A regulated and even current is most ideal. A current that is sporadic or uneven, affects the plating process.

**Anodes** are probably one of the most important things to consider in electro-plating. The anodes work better if they are made up of an alloy that also contains the plating metal. This helps ensure that proper positive ions of the plating metal are conducted through the electrolyte.
**Automated Control** is important where you are electroplating in mass quantities. The more people working on plating process add more human error. More error will downgrade the quality of the plating, making a weaker plating job. To use automated processes however, will lower the percentage of human error and raise the overall quality of the plating to an acceptable level.
Chapter 2

<<Avoiding Contamination, Corrosion and Surface Preparation>>

Avoiding Contamination & Corrosion

Before anything is plated, the parts to be coated must be CLEANED. Electroplaters use CLEANERS for this. They are alkaline materials that remove oils, dirt and rust. In a typical plating line, the part is first immersed in a cleaning tank, then in an electro-cleaning tank (uses power from a rectifier to aid in cleaning), and then into the plating tank.

A typical plating tank has three copper bars suspended over its top:

One connected to the negative lead from the rectifier and two connected to the positive lead. The racks of parts to be plated hang from the bar that is connected to the negative lead, the anodes (metal to be plated) from the positive bars. The solution in the tank may have to be heated or cooled. For this, electroplaters use Immersion Heaters or Heat Exchangers.

The solution becomes contaminated with dirt and other particles, which would cause rough plates. To prevent this, electroplaters use filters.

In some cases the plated part is chromated. Zinc plated parts; for example, will become bluish or yellowish if they are chromated. You can see such appearances on nuts and bolts you buy in a hardware store. The chromate coating is applied by dipping the zinc plated part in a tank containing chromic acid and other chemicals. The acid reacts with the zinc plating to form a zinc chromate. This is called a conversion coating, because the chromic acid solution converts the surface to zinc chromate.

This coating further improves corrosion resistance. There are also black and olive drab conversion coatings. Larger parts are usually plated on racks. But if you have a million nuts and bolts to plate, you don’t want to hang each of them individually on a plating rack. For this reason a plating barrel is used. The parts are dumped into a plastic barrel with holes drilled into the plastic sides. Then the barrel load of parts is immersed into the plating solution. Inside the barrel is a dangler, a piece of flexible metal that reaches down into the load of nuts and bolts to carry current to them.

The current is conducted from part to part by their electrical conductivity and the whole load begins to be plated. The barrel is rotated while current is applied. The nuts and bolts become plated with zinc or cadmium or whatever is desired. This is barrel plating.

If you have lots of racks or lots of barrels and you don’t want to hand carry them from tank to tank you can attach them to a conveyor that moves the racks or barrels from tank to tank, immersing them in each solution for a preset time. This is conveyor based plating, which may be done from an automatic line or from a hoist line.
Understanding and Avoiding Corrosion

There are 3 types of corrosion:

- Auto Corrosion
- Contact Corrosion
- External Corrosion

The most commonly occurring types of corrosion are **Auto and Contact corrosion**.

**Auto corrosion** occurs when a metal is in contact with an electrolyte but is not at the same time in contact with any other electrical conductor, neither metallic nor non-metallic.

Simple case of Iron and Rust creation – In chemically pure iron, corrosion would proceed simply by the exertion of the solution pressure of the metal, in conjunction with the presence of hydrogen ions and the oxygen dissolved in the electrolyte, which depolarize the metal surface, oxidize and precipitate the primary products of solution as ferric hydrate or rust.

In practical cases, auto corrosion proceeds by the galvanic action which is set up as a result of the heterogeneous structure of the metal or alloy.

No commercial metal exists in which there is perfect homogeneity, there is always some characteristic of structure, some slight degree of segregation or the presence of embedded impurities which is sufficient to impart varying potentials or solution pressures to adjacent areas of the metal surface.

For this reason auto electrolysis is set up by which the more electro-positive areas dissolve and, in the case of ferrous material, are eventually precipitated as rust. The pronounced heterogeneity of some alloys, such, for instance, as brass, is no doubt largely responsible for the rapidity with which they frequently corrode, and in the case of iron and iron alloys there is a large volume of evidence to show that heterogeneity, whether induced by structure or segregation, etc., is conducive to accelerated corrosion.

**Contact corrosion** occurs when the metal is in contact with some other conducting material, which is also immersed either wholly or partially in the electrolyte:

If this other conductor is a metal, then the corrosion of the first metal will be either accelerated or retarded, according to the electro-chemical relationship between the two metals.

If the second metal is electro-positive to the first, then it will protect the latter at its own expense by itself corroding or dissolving preferentially, but if it be electro-negative to the first metal then the corrosion of this will be accelerated (or the second metal will receive protection at the expense of the first).
The practical recognition and application of this may be found in the practice of protecting boilers from corrosion by inserting slabs of the more electro-positive metal zinc and in the protective coatings of zinc which are applied to iron products by various processes. Other conditions being the same, the rate of the contact corrosion of a metal is usually greater than the rate of its auto corrosion. If the second conductor is nonmetallic in character, it may generally be assumed to be electro-negative to the metal, and contact between them will therefore result in an accelerated corrosion of the metal.

**External Corrosion** is the result of the passage of a current, generated from some external source, through the metal whilst the latter is in contact with an electrolyte:

If the current flows in that direction which necessitates the metal acting as anode, then corrosion results.

If the current flows in the opposite direction, i.e., from the electrolyte into the metal, the latter receives protection from corrosion which may be complete provided the E.M.F. of the current is sufficiently high.

![Chemical reaction of corrosion on Iron/Steel surface](image)

**Figure:** Demonstrating the chemical reaction of corrosion on Iron/Steel surface

**Surface preparation**
It is commonly accepted and often quoted by electroplaters that *one can make a poor coating perform with excellent pretreatment, but one cannot make an excellent coating perform with poor pretreatment*. Surface pre-treatment by chemical and/or mechanical means is important in the preparation for electroplating. Surface treatment and plating operations have three basic steps:

**Surface cleaning or preparation** - Usually this includes employing of solvents, alkaline cleaners, acid cleaners, abrasive materials and/or water.

**Surface modification** - That includes change in surface attributes, such as application of (metal) layer(s) and/or hardening.

**Rinsing or other work-piece finishing operations to produce/obtain the final product** –

Success of electroplating or surface conversion depends on removing contaminants and films from the substrate. Organic and nonmetallic films interfere with bonding by causing poor adhesion and even preventing deposition. The surface contamination can be extrinsic, comprised of organic debris and mineral dust from the environment or preceding processes. It can also be intrinsic, one example being a native oxide layer.

Cleaning methods are designed to minimize substrate damage while removing the film or debris.

If the chemistry and processing history of a metal surface is known, one can anticipate cleaning needs and methods. In practice, extrinsic organic and inorganic soils originate with processing of the substrate before plating, as well as from the environment. Specific residues include lubricants, phosphate coating, quenching oils, rust proofing oils, drawing compounds, and stamping lubricants.

In short, the mixture of potential contaminants to which a part is exposed is typically complex. Again in case of a metal substrate it must be remembered that all metals form oxide and inorganic films to a degree with environmental gases and chemicals. Some of these are protective against continuing attack such as the aluminum oxide formed on aluminum alloys.

That phenomenon is the reason of the usefulness of aluminum siding on some homes. On the other hand, some are non-protective, such as iron oxide on steel. Some of these films can even be plated directly with nickel over aluminum oxide over aluminum being an example. The cleaning and activation steps must account for the fact that surface oxide re-forms at different rates on different metals.

Specifically, in case of iron or nickel the oxide re-forms slowly enough that the part can be transferred from a cleaning solution to a plating bath at a normal rate. In case of aluminum or magnesium the oxide re-forms very fast such that special processing steps are required to preserve the metal surface while it is being transferred to electroplating.

Cleaning processes are based on two approaches – Physical Cleaning and Chemical Cleaning.
In Physical Cleaning, mechanical energy is introduced to release both extrinsic and intrinsic contaminants from the (metal) surface. Examples are ultrasonic agitation and brush abrasion.

In Chemical Cleaning contaminant films are removed by active materials, dissolved or emulsified in the cleaning solution. Extrinsic contaminants are removed with surface-active chemicals while the chemical energies involved are modest. Intrinsic films are removed with aggressive chemicals that dissolve the contaminant and often react with the surface (metal) itself. The energy involved in surface preparation is substantial.
Chapter 3

<<Controlling Thickness and Most Used Tools>>

Thickness of coating is the most important parameter, which decides the quality of coating and therefore it needs to be controlled.

Controlling the thickness of the electroplated object is generally achieved by altering the time the object spends in the salt solution. The longer it remains inside the bath, the thicker the electroplated shell becomes but there must also be an adequate amount of metallic ions in the bath to continue coating the object. The shape of the object will also have an effect on the thickness of the coating. Sharp corners will be plated thicker than recessed areas. This is due to the electric current present in the bath since it flows more densely around corners.

Before electroplating an object, it must be cleaned thoroughly and all blemishes and scratches should be polished. As mentioned, recessed areas will plate less than sharp corners, so a scratch will become more prominent, rather than being smoothed over by the plated material.

Determining Coating Thickness

There are five basic, non-destructive methods of determining coating thickness. Each method is devised to achieve cost-effective, accurate, and repeatable results. These methods are:

- X-Ray fluorescence
- Eddy-current
- Magnetic induction
- Beta backscatter
- Micro-resistance

Each method is particularly suited to a specific coating(s)/substrate combination. We'll discuss below each system and applications for each.

X-Ray Fluorescence

When a material is subjected to x-ray bombardment, some of its electrons will gain energy and leave the atom, creating a void in the vacated shell, thereby releasing a photon of x-ray energy known as x-ray fluorescence.

The energy level or wavelength of fluorescent x-rays is proportional to the atomic number of the atom and is characteristic for a particular material. The quantity of energy released will be dependent upon the thickness of the material being measured.

Basically, the x-ray fluorescence unit consists of an x-ray tube and a proportional counter. Emitted photons ionize the gas in the counter tube proportional to their energy, permitting spectrum analysis for determination of the material and thickness.
X-ray fluorescence is the most precise measurement method, especially for small-diameter parts, or dual coatings such as gold and nickel over copper.

**Eddy-Current**

The eddy-current technique is used for measuring both non-magnetic, metallic coatings (zinc, cadmium, copper, etc.) over steel as well as non-conductive coatings over non-ferrous metals such as anodize or paint over aluminum.

When a conductive material is subjected to an AC magnetic field from a probe, eddy-currents occur in the material in proportion to the frequency and resistance. The induced eddy currents generate an opposing magnetic field which alters the circuit reactance and the output voltage of the probe. The change in output voltage is used to calculate the coating thickness. Electrical conductivity between the coating and substrate should differ by a ratio of 2:1 for optimum accuracy.

Non-conductive coatings introduce a gap (lift-off) between the probe and non-ferrous base material. This gap produces a loss in eddy current penetration which is compared to a measurement directly on the base material to determine coating thickness.

With conductive coatings over steel, eddy currents are generated in both the coating and ferrous base material. Eddy current loss in both materials is proportional to the coating and substrate material thickness and will range somewhere between readings taken directly on pure samples of each material. The eddy current loss differential is used to calculate coating thickness.

**Magnetic Induction**

This principle is used for measuring the thickness of a non-magnetic coating (zinc, cadmium, paint, powder coating, etc.) over a steel substrate.

The probe system is essentially the secondary of a transformer circuit that reacts to the presence of a magnetic material. The circuit efficiency and output voltage increase when the probe is brought near a magnetic surface, providing parameters which may be used to measure the distance (coating thickness) from the magnetic surface.

**Beta Backscatter**

Beta rays are electrons emitted from unstable radio isotopes. If a highly collimated beta source is directed at a plated sample (gold over nickel on a printed circuit board, for instance), the electrons will penetrate the plating material and be reflected back (back scattered) toward the source. They can be collected and counted with a Geiger-Mueller tube for subsequent conversion to coating thickness. The atomic number of the coating material must be sufficiently different (at least four atomic numbers) from the atomic number of the base material to achieve accurate readings of coating thickness.

**Micro-resistance**

The new micro-resistance method of determining plating thickness is ideally suited for printed circuit board plated-through-holes and for surface copper measurements.
This technique requires precise measurement of the resistance of the copper cylinder that forms the plated through hole. Once this parameter is known, it is combined with data on the board and hole aspect ratio to calculate the average copper plating thickness. Calculations are performed automatically by software associated with the measurement device.

Specially designed, pyramidal, electrically isolated probe tips simultaneously inject current and take voltage-drop measurements. The resistance is then calculated by Ohm's Law.

For electro coatings, powder coating and paint over a non-ferrous substrate, use the eddy-current method. Use the magnetic induction method on a ferrous substrate.

**Portable Tools to Measure Thickness**

HELMUT FISCHER offers a family of *hand-held instruments* with features to meet the individual requirements of customers.

The DUALSCOPE® MP0R/ MP0RH are designed for quick and easy measurements. This economic instrument accurately and conveniently displays the coating thickness readings on two LCD displays: on a large front panel display and a top panel display. It features an ergonomic design with an integrated constant pressure probe allowing easy one hand operation.

The possibility of a statistical evaluation of the measurement series exists, with an integrated radio transmitter for wireless online or offline transmission of the measurements directly to a computer, up to 10 – 20 m (33 – 66 feet) away.

The DUALSCOPE® MP0R/ MP0RH utilize both the eddy current test method according to DIN EN ISO 2360, ASTM B244 and magnetic induction test method according to DIN EN ISO 2178, ASTM B499. It is used to measure non-conductive coatings on non-ferrous metals as well as non-ferrous metal coatings and non-conductive coatings on iron and steel. It will automatically recognize the material to be measured and utilize the appropriate test method.

The DUALSCOPE® MP0RH has a considerably larger measurement range. The DUALSCOPE® MP0R/ MP0RH is ideal for measuring:

- Non-ferrous metal coatings (e.g. chromium, copper, zinc etc.) on steel and iron.
- Paint, lacquer and synthetic coatings on steel and iron.
- Electrically non-conductive coatings on non-ferrous metals such as paint, lacquer, synthetics on aluminum, copper, brass, zinc and stainless steel.
- Anodized coatings on aluminum.
Chapter 4

<<Types of Electroplating>>

**Electroless Plating** is just what the name implies. It is a way to coat one metal with another without passing current. Certain chemicals cause this to happen. The most common example you will see advertised is electroless nickel. The reason it is applied is that there are some limitations in electroplating when complex shapes are being coated. Often you cannot electroplate deep recesses and holes or interior passages. Electroless plating plates anything that is wetted by the solution.

Electroless plating is more expensive than electroplating in most cases, and is slower to build up a given thickness of deposit, which explains why it is used only for certain applications.

**Barrel Plating** is used when the plating is done inside of a perforated barrel, and the barrel is rotated to even the plating. It is mainly used in the plating small diverse objects, devoid of sharp and long edges that tend to plate badly.

**Functions of barrel plating:**

The primary function of barrel plating is to provide an economical means to electroplate manufactured parts that also meet the customer’s specific finishing requirements.

The four most important functions are:

- Engineering applications, such as building up the thickness of metal to change the physical size of a part or to provide a good surface for some other treatment such as painting or screening.
- Decorative coatings such as Bright Nickel, Brass, and Antiquing.
- Cosmetic uses such as Zinc plating to improve shelf life and selling ability.

But by far, the most important use of barrel plating is to extend the corrosion protection of the customers’ parts.

**Barrel plating fundamentals and the Production Process**

a) Parts need only to be free-flowing enough to enter the mouth of the barrel.
b) Loads should not exceed half the volume of the barrel or improper tumbling will occur and a loss of plating uniformity.
c) The surface area of the plated parts should generally be about 25 sq. feet for every foot length of the barrel at a 14 inch diameter.
d) Parts must be able to tumble freely to insure a good plating distribution. Such interior protrusions as breaker bars, dimples or ribbed sides should be used as necessary.
e) The rotation of the barrel while in the plating tank is also very important. Typically a speed of 3 to 6 RPM is considered adequate but faster speeds facilitate a more uniform deposit even though there may be some physical wear on the barrel itself. As long as the parts themselves will not be harmed it is more desirable to maintain as fast a rotational rate as is practicable.
f) Barrel sizes and hole perforations should be chosen with care depending on the size of the parts to be plated. Too small a hole will trap solution by capillary action and drag the chemicals all along the plating line. Too small a barrel and the parts will not tumble properly.

Quality control

- Proper and on-going training is extremely important for successfully barrel plating any part.
- Records should be kept regarding all of the important parameters involved in each step along the plating cycle. These should include things such as part description, load size, voltage, time, thickness readings, chemical additions and also any problems which may have taken place during the cycle.
- All relevant data and notes should be routinely reviewed to assure that the product will remain at a consistent level of quality and that the process can be continuously improved.
- There are numerous quality systems which the customer may require the barrel electroplater to employ such as the ISO 9000 standard which is one of the more recent attempts to help barrel electroplaters achieve the highest level of customer satisfaction possible.

The single, most important, factor to be considered when purchasing barrel plating equipment is to understand that the equipment you are buying is part of a system. Your plating line is a kind of an industrial ecosystem. Every component barrels, tanks, rinsing system, etc. affects the results generated by every other component. Any kind of slightest change in one piece of equipment can result you to pay the penalty further down the line. This principle applies to both new equipment purchases or the repair and retrofitting of existing plating lines.

COMMON PROBLEMS ASSOCIATED WITH BARREL PLATING

How can one limit the amount of or recover the waste in the barrel plating process.

Barrel plating has existed—in one form or another—since the close of the Civil War. And while the technology has seen some radical improvements in the last 140 years, modern day barrel plating is not without its challenges.

Problem: Spikes in Cyanide Concentration

During a plant visit, along with a careful analysis of their operations it showed that periodically, the conventional horizontal barrel line is over-loaded with work and the oscillating barrel line is then used to plate the over-load. Unfortunately, the over-load consists of cup-shaped parts that create a very high drag-out, as the oscillating barrel line carries these cups into the rinse system without emptying them over the plating tank prior to transfer. A normally rotating barrel would empty the cups over the tank (as is done on your other plating line) and would do a better job of rinsing these parts. After measuring the drag-out rate it was found to be about 1.5 gallons per barrel.
As a result of operating the oscillating line on these parts, a large amount of cyanide entered the rinse system after plating. Even a well working waste treatment system can be over-loaded by a spike in cyanide concentration. The systems were designed around 100-500ppm of cyanide, while the spikes were around 2000-2500ppm.

The solution to the problem is to not use the oscillating barrel plating line on cup shaped parts.

Problem: Damaged Parts

Since tin is a soft metal, it can easily be abraded in a barrel plating operation. The factors to look at include the condition of the electrical contacts, barrel rotational speed and use of ballast.

An examination of the parts under the microscope (see photo) indicated that some severe scraping is going on in at least some of the barrels you are using. The following corrective actions should be considered:

Change Method of Electrical Contact

The barrels used employ conventional danglers, which can build up in metal to the point of being abrasion sources. Button contacts or rod contacts may be gentler.

Maintenance of Electrical Contacts

One of the frequently neglected tasks in barrel plating is maintenance of the dangler. As metal builds up on the electrical contacts within a barrel, they develop sharp edges that can cause damage to a moving load. If the electrical contacts have any heavy build-up of metal, this must be removed on a more frequent basis.

Change the Barrel Speed

The barrel speed may cause too much friction between the dangler and parts and between the parts themselves. If possible change to rotational speed of the barrel. By lowering the speed, you may also need to lower the barrel loading. The best combination of barrel loading and speed will have to be determined by trial and error.

Use/Change Ballast

Ballast can be used to keep parts separated during plating, reducing damage from contact with sharp features on the parts and also improving coverage.

If you are not using ballast, it is recommended to try this. Common ballast is copper beads as which comes in a variety of sizes. But you need to experiment with both shape and size to arrive at the optimum combination.

Problem: Plating Solution "Growth"

This is the most common reported problem. In most cases it is a case of more drag-in than drag-out from the plating solution. The chloride zinc process typically contains a high concentration of wetting agent (surfactant), which lowers the surface tension of the
plating solution and results in better drainage of the barrel as the barrel is removed from
the plating tank. Since the rinse before the plating tank does not contain any wetter, the
barrel does not drain as well before going into the plating tank. Over time, the difference
in drag-in volume vs. drag-out volume causes the plating solution to “grow.”
If there is a drag-out rinse, try going into this rinse before you bring the barrel into the
plating tank. Since the drag-out rinse will contain some of the wetter, this may solve the
problem. Some wetter may need to be added to the drag-out rinse to bring the surface
tension closer to that of the plating solution.

Solution: If there is no drag-out tank, some wetter may be bled into the last rinse prior
to plating. Heating the last rinse before plating may also help, as warm water drains
better than cold.

**Brush Plating**

Brush plating is an electrochemical process that uses systems to electroplate, anodize,
and electro polish localized areas on both OEM components and parts that need
coatings for repair and dimensional restoration.

Brush systems are portable. Unlike their tank counterparts, brush plating systems use
very small volumes of solution (usually only one or two gallons) and hand-held tools to
apply the deposits and coatings onto localized areas. These hand-held tools are covered
with an absorbent material that is saturated with a solution and then brushed or rubbed
against the part. Brush plating requires different hand-held tools for each different
solution in the operation.

A portable power pack (rectifier) provides the direct current required for all the
processes. The power pack has at least two leads. One is connected to the tool and the
other is connected to the part. The direct current supplied by the power pack is used in a
circuit that is completed when the tool is touching the work surface.

The work surface is prepared using the same types of tooling and equipment that are
used for the final finishing operation. As with a tank plating process, brush plating
requires good preparation of the work surface to produce an adherent deposit.

Brush plating has come a long way from the early days of tank plating when it was a
common practice to touch up bad spots on plated parts using solution saturated rags
wrapped around pieces of pipe.

Today, brush plating and anodizing systems are used to selectively apply engineered
deposits and coatings in very precise thicknesses for both OEM and repair applications.
Brush plating and anodizing are now completely divorced from their tank counterparts,
although some of the equipment and terms still resemble those used in tank processes.
Tools, equipment and solutions, however, cannot be used interchangeably between
brush and tank systems.

Since it is more difficult to control temperature and current density in portable finishing
processes than in tank processes, it was necessary to develop complete, integrated
portable finishing systems for commercial applications. These systems were developed
for operators who are not familiar with tank finishing techniques.
Today, brush plating systems are available for electroplating, anodizing, hard coating and electro-polishing. These systems vary in their sophistication and coating capabilities. Small pen-type systems apply only flash deposits on small areas. Larger, more sophisticated systems use power packs with outputs up to 500 amps and are capable of producing excellent quality finishes and high thicknesses on large surface areas.

**Anodizing** is an operation performed mainly on aluminum. The effect is to develop an oxide coating on aluminum. Again, this is conversion coating: the surface is converted from aluminum to aluminum oxide.

Unlike plating, the part to be coated is connected to the anode --- not the cathode. The part is immersed in a dilute solution of sulfuric acid, current is passed, and the part is anodized an oxide coating forms. The oxide coating is harder and more corrosion resistant than bare aluminum.

Some aluminum pots and pans are anodized, and door and window frames are often anodized. There are ways to make the anodizing pick up the color of brass or bronze or black, as well and almost any color of the rainbow.

**Plating on plastics**

Plastics cannot be plated in the same way as metals because plastics are not electrically conductive. Thus one cannot immerse a plastic part connected to the negative lead and expect it to plate. Instead, electroless plating is applied first to get a conductive surface, and then the electroless plated parts are electroplated. Many automotive parts, including grilles and all manner of decorative trim have been plated plastic.

**Making Printed Circuits Boards**

The simplest printed circuit begins with a plastic board that has copper foil glued onto its surface. The circuit paths are made by printing onto the copper foil coatings that resist the etchants used. These coating or resists are applied in the shape of the circuits that must remain. Then the exposed copper is etched away and the circuit paths remain.

The resist is removed and you have a rudimentary printed circuit. Some circuits or portions of them are plated with tin or tin lead to provide solder ability or with gold to provide contact reliability. So this is another market for plating chemicals and equipment. Many small electronic parts are also plated with tin or tin lead or gold or other metals, to provide various electrical properties.

A printed circuit board consists of "etched conductors" attached to a sheet of insulator. The conductive "etched conductors" are called "traces" or "tracks". The insulator is called the "substrate".

The vast majority of ‘printed circuit boards’ are made by adhering a layer of copper over the entire substrate, sometimes on both sides, (creating a "blank PCB") then removing unwanted copper by etching in an acid or ferric chloride solution, leaving only the desired copper traces. A few PCBs are made by adding traces to the bare substrate usually by a complex process of multiple electroplating. Some PCBs have trace layers inside the PCB and are called multi layer PCBs. These are formed by bonding together separately etched thin boards. After the circuit board has been manufactured,
components are connected to the traces by soldering (usually by passing their leads through holes pre-drilled in the board)

There are three common methods used for the production of printed circuit boards:

**Silk screen printing** - Using etch-resistant inks to protect the copper foil. Subsequent etching removes the unwanted copper. Alternatively, the ink may be conductive, printed on a blank (non-conductive) board. The latter technique is also used in the manufacture of hybrid circuits.

**Photoengraving** - The use of a photo-mask and chemical etching to remove the copper foil from the substrate. The photo-mask is usually prepared with a photo-plotter from data produced by a technician using computer-aided PCB design software. Laser-printed transparencies are sometimes employed for low-resolution photo-plots.

**PCB Milling** - The use of a 2 or 3 axis mechanical milling system to mill away the copper foil from the substrate. A PCB milling machine (referred to as a 'PCB Prototyper') operates in a similar way to a plotter, receiving commands from the host software that control the position of the milling head in the x, y, and (if relevant) z axis. Data to drive the Prototyper is extracted from files generated in PCB design software and stored in HPGL or Gerber file format.

PCBs are rugged, inexpensive, and can be highly reliable. They require much more layout effort than either wire-wrapped or point-to-point constructed equipment. Originally, every electronic component had wire leads, and the PCB had holes drilled for each wire of each component. The components' leads were then passed through the holes and soldered to the PCB trace.

This method of assembly is called *through-hole* construction. Soldering could be done automatically by passing the board over a ripple, or wave, of molten solder in a wave-soldering machine. Through-hole mounting is still used.

However, the wires and holes are wasteful. It costs money to drill the holes, and the protruding wires are merely cut off.

Most PCBs have alignment marks and holes (called fiducials) to align layers and permit the PCB to be mounted in equipment that automatically places and solders components. Some designs place alignment and etch test-patterns on break-off tabs that can be removed before installation.

Layers may be connected together through drilled holes called *vias*. Either the holes are electroplated or small rivets are inserted. High-density PCBs may have *blind vias*, which are visible only on one surface, or *buried vias*, which are visible on neither, but these are expensive to build and difficult or impossible to inspect after manufacture.
Chapter 5

<<Electroplating of Different Metals>>

Platinum Electroplating

Platinum is rare, scarce, and very costly and is considered one of the most precious metals. Platinum electroplating is used to coat electrodes that are used in the refining of oil, and in the manufacturing of fertilizers, acids, and explosives. The automotive industry uses platinum plated catalytic converters to treat automobile exhaust emission. In the medical industry, platinum plate is used on instruments such as catheters and connectors for surgical equipment. The electrical and electronics industries use platinum plating for low voltage and low energy contacts. In electroplating, platinum is often used to coat titanium, niobium, or stainless steel anodes. It is also used in the jewelry industry.

Platinum is considered a premium protective finish over sterling silver and nickel base metal. Platinum's luster is much purer than silver or gold, enhancing the brilliance of gemstones and diamonds. Platinum electroplate coatings typically range from 0.5 to 5 microns depending on the application. It is applied utilizing a rack fixture that is submerged in a chloroplatinic acid or a sulfate based platinum solution. The finished product can range in color from tin white to a matte gray finish depending on the base metal finish, activation process, and the thickness of the platinum coating.

Platinum electroplating is accomplished by placing the electrode tips into a solution of platinum chloride and applying a small current such that the platinum in solution is reduced, causing platinum deposition at the tip of the metal electrode. We can plate the electrodes using a solution of hydrogen hexa-chloro-platinate (8% PtCl4 by weight) with a multi-channel, constant-current plating device.

Rhodium Plating

Rhodium is white in color and a precious metal, of the platinum group. Rhodium is the hardest of all of the precious metals. It provides the most wear resistant finish possible for the most demanding environments. It is one of the most suited metals for plating of parts such as sliding electrical contacts that require protection from corrosion or galling. Rhodium provides a bright, attractive finish that is non-tarnishing. Under-plating of nickel should be used when parts are of corrosion or heat resistant steels. When under-plated with nickel it provides a mirror surface that is highly reflective.

Surfaces other than nickel, silver, gold, or platinum should be either nickel-plated or nickel over copper plated.

Rhodium plating is widely used on high voltage switch gear, silverware, silver models, medals, white gold jewelry and top end furniture fittings to prevent tarnishing / corrosion as well as due to its hardness it makes the surface scratch resistant.

As rhodium is a relatively inert metal, it cannot be stripped from the more active base material without damaging the less active substrate in the case, if an item is damaged and require repairs. Also, rhodium is plated from an acid solution which has poor throwing power. It cannot generally be used on items with deep cavities without some consideration to masking, jigging, pumping and shielding. As it is an expensive process,
the areas that do not require coating can be masked with special masking tapes and paints.

Of the platinum group metals, rhodium has found wide acceptance in decorative precious metals applications. Rhodium has several desirable properties – it has a brilliant white color, high reflectivity, and hardness, which makes it very popular with the jewelry and faux jewelry industries.

Rhodium can provide excellent tarnish protection for sterling silver and silver plated flatware and hollowware from quite thin deposits. Typically, rhodium electroplate is deposited on precious and faux jewelry, sterling and silver plate to a thickness of 0.05 to 0.125 microns (2 to 5 micro inches). This thickness of rhodium is produced in about 20 to 60 seconds from phosphate, sulfate or phosphate-sulfate baths.

**Rhodium on Steel**

For rhodium to get plated on steel, it is needed to activate in order for the rhodium to adhere to the surface. Rhodium plating on the steel does not conceal surface flaws or blemishes. Many electroplaters typically use either a woods nickel strike or an acid gold strike to cover the steel with a thin layer of metal to achieve adhesion. For best results it is advisable to choose a good pre-plate of bright nickel, 5-10 microns in thickness. This will help level out any minor surface waves that may exist in the material, and should not interfere with any build tolerances on the surface. This is followed by a final layer of rhodium and at least .50-1.0 microns of rhodium are recommended.

**Silver Plating**

Silver plating offers the highest electrical conductivity of all metals. It is a semi-precious metal that gets oxidize rapidly. Silver plating is best suited for engineering purposes, as for soldering, electrical contact characteristics, high electrical and thermal conductivity, thermo-compression bonding, provides wear resistance to load-bearing surfaces, and spectral reflectivity, good corrosion resistance, and other electrical applications.

**Silver Plating - Grades**

A. With supplementary tarnish-resistant treatment.
   B. Without supplementary tarnish-resistant treatment

**Silver Plating – An Useful tool for Corrosion Protection**

For applications where corrosion protection is important, the use of silver plating with an electrodeposited nickel undercoat is advantageous.

**Silver Plating – Under-plate Recommendations**

Silver plating on steel, zinc and zinc-based alloys should have an undercoat of nickel over copper.

Silver plating on copper and copper alloys should have a nickel undercoat. Copper and copper alloy material on which a nickel undercoat is not used, and other base metals where a copper undercoat is employed, should not be used for continuous service at a temperature in excess of 300 degrees F (149 degrees C). Adhesion of the silver plating
is adversely affected because of the formation of a weak silver and copper inter-metallic layer.

**Silver Deposit and Tarnish**

Tarnishing is a natural process that occurs on the surface of silver jewelry. Tarnish starts as a light yellow discoloration of silver; it then starts to change to darker shades of brown as the tarnish gets to be more severe. In extreme cases the tarnishing of silver could look very dark and almost black.

Tarnishing occurs due to certain climatic conditions and also due to certain ingredients that are present in some materials. One such chemical that causes silver to tarnish is hydrogen sulfide (H₂S) and things that contain this chemical will cause silver to tarnish quickly. Materials that stimulate silver tarnish are wood, felt, rubber bands, food items like eggs, onions etc.

High humidity in the climate also hastens the silver tarnish process.

The factors that can cause silver tarnish are wide and varied, and is evident that the process of silver tarnishing can hardly be avoided because silver tarnish is a natural process and occurs with silver of all purities.

Silver jewelry is generally made from silver that is around 92.50% pure and this is done to increase the hardness of silver. Sterling silver as it is normally referred to (925=92.50% purity), is an alloy of silver and other metals.

The tarnishing of sterling silver has nothing to do with the percentage of silver in the alloy. It would be safe to assume that all silver will tarnish. It is possible to clean tarnished silver jewelry and the procedure followed will depend on the degree of tarnish that is present on the silver jewelry.

**Brass Plating**

Brass plating is primarily used as a decorative finish. However, the process is also used for some engineering applications, such as brass-plated steel wire promotes adhesion to rubber in steel-belted tires and as an anti-galling coating. Brass is also plated on the surfaces of bearing materials.

For bright decorative brass finishing, material is first plated with bright nickel, followed by a brass flash plate for 35-90 sec. Such finishes are used in wire goods, decorative lamps, furniture hardware and builder’s hardware.

Heavy brass deposits (0.0003-0.0006 inch) are used for finishes that will be buffed, burnished, antiqued and/or oxidized. Some of the brass plating is removed with antiquing and oxidizing processes and, therefore, the minimum thickness for such processes is 0.0003 inch.

Heavy brass deposits are not as bright as brass plated over bright nickel. To obtain bright finishes with heavy brass deposits, they must be buffed or burnished. Addition agents can refine the grain of the brass so that the amount of burnishing or buffing is greatly reduced.
**Gold Plating**

**Gold** is unique for its yellow color. It is a precious metal and does not oxidize in air, so its electrical conductivity stays uniform over long periods of time. It is ideally suited for electroplating applications. Gold plating offers good corrosion resistance, good solderability, and when alloyed with cobalt, it has very good wear resistance. Gold is commonly used in electrical switch contacts, connector pins and barrels, and other applications where intermittent electrical contact occurs.

**Gold Plating - gold electroplating specification**

**Specification: Gold Plating, Electro-deposition**

- **Type I** 99.7% gold minimum; hardness grades A, B, or C. Gold plating used for general-purpose, high-reliability electrical contacts, solderability, and wire wrap connections.
- **Type II** 99.0% gold minimum; hardness grade B, C, or D. A general-purpose, wear-resistant gold. It will not withstand high-temperature applications because the hardening agents in the gold plating will oxidize.
- **Type III** 99.9% gold minimum; hardness grade “A” only. Gold plating for semiconductor components, nuclear engineering, thermo-compression bonding, and high-temperature application.

**Gold Plating - purity and coating thickness**

Co-deposited impurities can make soldering more difficult, and for this reason gold plating with high purity is preferred. Soldering requirements are best achieved when gold coatings range between 0.00005 and 0.0001 inch (50 and 100 micro inches) of thickness.

**Gold Plating - hardness grades**

- 90 knoop, maximum
- 91-129 knoop, inclusive
- 130-200 knoop, inclusive
- 201 knoop, minimum
- Gold over silver is not recommended for electronics hardware

**Gold Plating - underplate recommendations**

When gold is applied to a copper rich surface such as brass, bronze, or beryllium, copper metal ions from these base metals will diffuse into the gold layer and degrade its hardness and non-oxidizing properties. An anti-diffusion under-plate such as nickel (electroless or sulfamate) should be applied to prevent this. We recommend electroless nickel under gold where part flexure of deformation is not expected and a bright finish is desirable. Where part flexure or deformation is expected, we recommend sulfamate nickel as the under-plate because of its higher ductility.
**Palladium Plating**

Palladium is white in color, harder than cobalt gold, and is precious, it also retains the non-oxidizing property so is used in electrical connector applications. Palladium electrodeposits have better ductility, which provides superior contact bending tolerance, lower porosity, and superior resistance to corrosion than hard gold. This makes palladium an excellent candidate for applications such as reed switches or relay contacts.

However, palladium has a generally lower wear resistance in sliding contact, such as pin/socket interfaces, than gold. Palladium mated against pure Palladium has less wear resistance than palladium mated against gold or a palladium surface with a thin overlay of gold.

When under-plated with a flash of soft gold, palladium also demonstrates excellent solderability.

**Electroless Nickel Plating**

Nickel is a silver white, hard metal with satin to bright luster. It can be plated uniformly in recesses, blind holes and cavities, does not build up on edges, and has very high wear endurance. Higher phosphorus variations provide superior corrosion resistance. Nickel is often applied as a base layer for its leveling, smoothing and barrier characteristics which provide resistance to attack of some base metals by electrolytic metals such as, cyanide copper or silver. Nickel is a hard metal with generally poor ductility that is not recommended for applications where a part of flexure is required.

**Electroless Nickel plating - corrosion inhibitor**

As a corrosion inhibitor, nickel is used to protect iron, copper, or zinc alloys against corrosive attack in rural, industrial or marine atmospheres depending upon the thickness of the nickel deposit.

Nickel, with its leveling and pore-filling characteristic, is also an excellent undercoat for the precious metals by reducing the total amount of the precious metal required to achieve performance specifications.

**Electroless Nickel plating - engineering purposes**

Electroless nickel plating intended for engineering purposes is used for wear resistance, abrasion resistance and such corrosion protection of parts as the specified thickness of the nickel plating provides. Heavy deposits of the electroless nickel plating may be used for build up of worn or undersized parts, or for salvage purposes, and to provide protection against corrosive chemical environments.

**Watts Nickel per QQ-N-290A - Nickel plating**

Watts nickel is an electrolytic system that provides very bright, decorative finishes. It also provides corrosion resistance according to thickness, good abrasion resistance, and a low coefficient of thermal expansion. It has a relatively low tensile strength and hardness.
and relatively high internal stress and therefore is not recommended in engineering applications where part deformation or flexure may occur.

**Teflon Electroless Nickel Plating**

The co-deposit of electroless nickel & Teflon contains 15% Teflon particles dispersed in an electroless nickel matrix. It is a hard, ductile finish, brown in color, which has superior anti-friction characteristics. This is ideally suited to high cycle mechanical sliding applications. In addition this is a good electrical conductor and provides corrosion resistance.

**Sulfamate Nickel Plating**

Sulfamate nickel provides the lowest hardness, lowest internal stress and highest ductility of all the nickel plating systems. The finish is dull; and is used as an engineering finish and not a decorative finish. Sulfamate nickel has excellent solderability good corrosion resistance. The high ductility of sulfamate nickel makes this product an excellent candidate for applications where part flexure or deformation, such as crimping, will occur.

Note: As nickel finishes become brighter, they become harder and less ductile. Bright nickel finishes are not recommended if parts are intended for flexure applications or will be bent or cramped in manufacturing operations subsequent to electroless nickel plating.

**Tin Plating & Tin Alloys**

Tin is a silver-colored, ductile metal whose major application is to impart solderability to otherwise unsolderable base metals. Tin has generally good covering characteristics over a wide range of shapes. It is an electrolytic process.

Tin and its salts are reported to be non-toxic and non-carcinogenic and are approved for food container and food contact applications.

**Tin plating - soft, ductile finish**

Tin does not tarnish easily and can serve as a low cost decorative finish, although care must be exercised in subsequent part handling as tin is a soft, ductile finish that can scratch or mar easily.

Alloying tin with lead to reduce it’s melting point for soldering and to prevent "whiskering". See specific descriptions below for details on each of the various tin systems.

**Tin plating - corrosions protection & conductivity**

Tin is a good electrical conductor and has historically been utilized for its combined corrosion protection and conductivity in aerospace avionics radio frequency applications.

- Primarily used to facilitate solderability to base metals that have poor solderability.
- A ductile, bright finish. Can serve as a low cost decorative finish.
• Bright acid tin’s ductility will help prevent galling of base metals in friction contact applications.
• It applies well to most base metals; will act as a stop-off barrier in nitriding high strength steels; has a bright appearance; and provides some corrosion resistance.

Tin plating - corrosion properties

For indoor environments, tin provides anti-corrosion properties to copper and copper alloys, and ferrous metals. Note that tin is not an optimal choice for corrosion protection where outdoor environments are expected.

Tin should be not less than 99.5% pure except where alloyed for special purposes.

Tin plating – Alkaline brightening system

Alkaline brightening system provides excellent solderability, corrosion resistance with a .02% bismuth content to stabilize the structure of the metal deposit and stop "whiskering" in extreme temperatures. Finish is dull in appearance, very soft and is easily marrable.

60/40 & 90/10 Tin Lead

The co-deposition of lead with the tin reduces the risk of whisker growth. Metal filaments, or whiskers, sometimes grow spontaneously from the surface of electrodeposited metals such as tin, cadmium, and zinc within a period that may vary from weeks or months to years. These whiskers are about 0.0001 inch (2.5 µm) in diameter, can grow up to 3/8 inch (10 mm) long and can have a current carrying capacity of as much as 10 mA.

Tin plating - melting points

Tin is also alloyed with lead to reduce the melting point of tin. This provides flexibility in selecting soldering temperatures that will not impart too much thermal energy to delicate assemblies.

• 60/40 melting point range is 361°- 374°F
• 90/10 melting point range is 450°- 464°F

Copper Plating

Copper is the second most common metal plated, behind nickel. It provides a soft, red, ductile, solderable surface. Copper is an excellent electrical conductor. However, it is not often used as a final plate, because it tarnishes easily.

As copper has excellent leveling properties and very high throwing efficiency, it makes an excellent undercoat for most other metals. In addition, because copper is ductile, it polishes easily to a high shine so that it supports a bright, shiny finishing metal above it.
Copper is able to fill sharp corners and surface imperfections, allowing smooth and uniform coverage of the base metal. The throwing and leveling properties of copper insure that pinholes and subsequent blistering of finish metals will be avoided.

Copper makes an excellent undercoat on aluminum, which is a base metal that most other electrodeposited metals will not attach to. Copper is the only metal that can be electroplated onto zinc die casts. Generally copper is applied as an under-plate in thickness between 100 and 200 micro inches.
Chapter 6

<<Preparation of Electroplating Kits for Different Metals>>

Parameters for Plating of different Metals

<table>
<thead>
<tr>
<th>Metals</th>
<th>Temperature</th>
<th>Voltage</th>
<th>Time</th>
<th>Anode(+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOLD</td>
<td>140°F</td>
<td>6V</td>
<td>30 sec</td>
<td>24K gold</td>
</tr>
<tr>
<td>RHODIUM</td>
<td>80 – 100°F</td>
<td>4V</td>
<td>20 - 30 sec</td>
<td>14K or platinum</td>
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<tr>
<td>COPPER</td>
<td>100°F</td>
<td>6V</td>
<td>30 + sec</td>
<td>copper</td>
</tr>
<tr>
<td>NICKEL</td>
<td>70°F</td>
<td>2V</td>
<td>3 - 4 min</td>
<td>nickel</td>
</tr>
<tr>
<td>SILVER</td>
<td>70°F</td>
<td>2V</td>
<td>30 + sec</td>
<td>silver</td>
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<tr>
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<td>180°F</td>
<td>10V</td>
<td>60 sec</td>
<td>stainless steel</td>
</tr>
</tbody>
</table>

Nickel Plating

From a rusted component to a Nickel plated lasting showpiece in three hours.

For decorative work, the time required for Nickel plating will range from 1/2 hour up to 3 hours according to the thickness of the Nickel plate required. The plating solution is reusable. 1kg of the Nickel salts (as supplied in the workshop kit) will last for over 13,000 sq cm of .001 (25 micron) Nickel plating without the need to replenish or replace. The salts will store for many years in liquid or solid form. Nickel plating can be carried out at any temperature from 15 degree centigrade up to 35 degree centigrade, although slightly better results are obtained at 24 degree centigrade or higher.

The comprehensive instructions supplied with each Nickel plating kit will guide you through all the stages of the plating process from the initial preparation of the parts to be Nickel plated through to the finished product with hints and tips to get the very best from your kit.

The Nickel plating process can be used as a substitute for Zinc or Cadmium plating. The finish is dictated by the preparation. For a matt finish wire brushings is sufficient. If the surfaces are polished prior to being electroplated they can be buffed up to achieve the beautiful sheen of the original.

Kit Contents

| 1kg of Nickel plating salts | Makes approx 6 liters |
| 2 Nickel plating anodes     | gives 1,000 sq inches of plating |
| 150g of degreasing salts    | makes 5 liters of degreaser |
| 150g fine pumice powder     | to scour the parts before plating |
30m of copper wire to suspend the objects
1 set of comparator papers to check the condition of the solution
1 set of instructions comprehensive instructions and tips
5 pairs of polythene gloves to avoid contaminating the degreased parts

Extra items you will need:

- A plastic bowl or bucket or small fish tank
- 12v battery or a 12vdc battery charger
- 1 or more standard automotive type 12v bulbs

**Gold Plating**

1. For articles made of karat gold, gold-filled, rolled-gold plate, nickel, copper, and brass.

**Preparation**

- Buff and polish item to be plated.
- Steam clean and boil out.
- Rinse.
- Electroclean.
- Rinse again.

**Plate**

- Gold plate

**Completion**

- Rinse.
- Soda rub.
- Rinse again.
- Alcohol dip.

2. For articles made of white metals or contaminated with soft solder - including most costume jewelry.

**Preparation**

- Buff and polish item to be plated
- Steam clean and boil out.
- Rinse
- Electroclean
- Rinse again
Plate

- Copper plate (an under plate that prepares the item for receiving gold plate)
- Rinse Gold plate

Completion

- Rinse
- Soda rub
- Rinse again
- Alcohol dip

Rhodium Plating

1. On articles made of karat gold and platinum

Preparation

- Buff and polish item to be plated.
- Steam clean and boil out.
- Rinse.
- Electroclean **In rhodium plating use 14K or platinum holding wire instead of copper**
  - Rinse again.

Plate

- Rhodium plate.

Completion

- Rinse.
- Alcohol Dip.

2. On articles of silver, palladium, gold-filled, rolled-gold, white metal, or contaminated with soft solder - including most costume jewelry.

Preparation - as above

Plate

- Gold plate (flash under plate) 10-15 seconds to prepare item for receiving rhodium plate.
- Rinse Rhodium plate.

Completion - as above
**Silver Plating**

Bowls and hollowware can be plated on the inside by filling bowls with solution and suspending silver anode inside. Negative plating lead wire is attached to item being plated. Positive lead wire is attached to anode.

**Procedure**

- Plating solution at room temperature.
- Immerse silver anode connected to positive lead wire.
- Attach negative lead wire alligator clamp to handling wire on item to be plated.
- Dial 2V and turn switch to "On Position".
- Immerse article 30 seconds or until completely covered with silver. Article will usually emerge with a dull milky color.
- Brighten color by buffing with a bristle brush.

It is important to realize what type of silver plating finish is required on the part to be plated. If a highly polished surface is required, the part must be buffed to a high shine before plating. If a matt finish is required, then the part should be blasted or buffed with something like a Britex wheel.

The steps to achieve a brilliant silver finish are:

- Buff & Polish
- Degrease & Rinse
- Acid Activate (with battery acid, not supplied)
- Plate with Flash Copper (Steel, Pot Metal & Pewter only)
- Plate with Silver
- Acid Activate
- Treat with Silver Conditioner (prevents tarnishing)
- Potassium Hydroxide is used to raise the PH of the solution when required. The system must be maintained at a PH of 8.8-9.5.
Cadmium Plating:

Cadmium plating generally is performed in alkaline cyanide baths that are prepared by dissolving cadmium oxide in a sodium cyanide solution. However, because of the hazards associated with cyanide, noncyanide cadmium plating solutions are being used more widely. The primary noncyanide plating solutions are neutral sulfate, acid fluoborate, and acid sulfate. The cadmium concentration in plating baths ranges from 3.7 to 94 g/L (0.5 to 12.6 oz/gal) depending on the type of solution. Current densities range from 22 to 970 A/m² (2 to 90 A/ft²).

Copper Plating

Copper cyanide plating is widely used in many plating operations as a strike. However, its use for thick deposits is decreasing. For copper cyanide plating, cuprous cyanide must be mixed with either potassium or sodium to form soluble copper compounds in aqueous solutions. Copper cyanide plating baths typically contain 30 g/L (4.0 oz/gal) of...
copper cyanide and either 59 g/L (7.8 oz/gal) of potassium cyanide or 48 g/L (6.4 oz/gal) of sodium cyanide.

Current densities range from 54 to 430 A/m² (5 to 40 A/ft²). Cathode efficiencies range from 30 to 60 percent. Other types of baths used in copper plating include copper pyrophosphate and copper sulfate baths. Copper pyrophosphate plating, which is used for plating on plastics and printed circuits, requires more control and maintenance of the plating baths than copper cyanide plating does.

However, copper pyrophosphate solutions are relatively nontoxic. Copper pyrophosphate plating baths typically contain 53 to 84 g/L (7.0 to 11.2 oz/gal) of copper pyrophosphate and 200 to 350 g/L (27 to 47 oz/gal) of potassium pyrophosphate. Current densities range from 110 to 860 A/m² (10 to 80 A/ft²).

Copper sulfate baths, which are more economical to prepare and operate than copper pyrophosphate baths, are used for plating printed circuits, electronics, rotogravure, and plastics, and for electroforming and decorative uses. In this type of bath copper and sulfate and sulfuric acid form the ionized species in solution. Copper sulphate plating baths typically contain 195 to 248 g/L (26 to 33 oz/gal) of copper sulphate and 11 to 75 g/L (1.5 to 10 oz/gal) of sulfuric acid. Current densities range from 215 to 1,080 A/m² (20 to 100 A/ft²).

Zinc Plating

The value of zinc as a rust-proof finish for iron and steel has long been appreciated. Zinc plating is being used on an increasing scale, particularly for components which would formerly have been cadmium plated.

ZINC FAST

Zinc Fast is a complete system that has made it possible for the small operators to achieve fully professional results without any previous experience in electro-plating. "Zinc Fast XL" gives excellent value for money and, most important, allows the user full Control of the operation.

How fast is "Zincfast XL"?

A 10 MicrQn (UN) Average coating is achieved in less than 20 minutes. Passivation takes appx.30 seconds.

The "WORKSHOP XL" Kit contains all the necessary chemicals for 12 liters. of Plating Solution and 12 liters of Passivating Solution. The Degreasant, the Copper Wire for suspending the parts, the pH papers and high Purity Anodes are all included in the Kit.

To electro-plate you will need a l2 Volt battery, Plastic containers for the Plating and Passivating tanks 'and l2 Volt light bulbs for regulating the Amperage as used with the Nickel Plating System.
Kit Contents:

- 1 x litre Zinc Fast concentrate
- 1 x2.4kg 625CDP
- 1 x2.4kg 625CDP
- 1 x300g 3AB
- 1 x500cc IB brightener
- 1 x250cc MB brightener
- 1 x250cc wetter
- 1 x250cc 3CRP passivation
- 1 x250cc nitric acid
- 1 x250cc hydrochloric acid
- 1 x150g activax degreasant
- 1 x200g sodium hydroxide
- 1 xcomparator papers
- 1 xcomparator papers (set2)
- 5 pairs of gloves
- 3 xpure zinc anodes
- 1 reel of copper wire
- 1 instruction booklet

You will also need plastic containers

- 1 metal container
- 12vdc car battery
- 12vdc light bulbs
Chapter 7

<<NICKEL PLATING IN DETAIL>>

Types of Nickel Plating Solutions

*Sulfate Solutions.* The most common nickel plating bath is the sulfate bath known as the Watts bath. Typical composition and operating conditions are shown in Table I. The large amount of nickel sulfate provides the necessary concentration of nickel ions. Nickel chloride improves anode corrosion and increases conductivity. Boric acid is used as a weak buffer to maintain pH.

The Watts bath has four major advantages: 1) Simple and easy to use; 2) Easily available in high purity grades and relatively inexpensive; 3) Less aggressive to plant equipment than nickel chloride solutions; and 4) Deposits plated from these solutions are less brittle and show lower internal stress than those plated from nickel chloride electrolytes.

*High Chloride Solutions* - Chloride baths have an advantage over sulfate baths in deposition speed; not necessarily in current density, but in improved current distribution.

*All-Chloride Solutions* - The advantages of all-chloride nickel plating solutions include the following: 1) Low voltage; 2) Good polishing characteristics; 3) Heavy coatings can be deposited; 4) Low pitting; 5) Improved cathode efficiency; and 6) No need to cool the plating solution.

See Table I for composition and operating parameters.

However, there are disadvantages to this bath as well: 1) Highly corrosive; 2) Nickel chloride is sometimes less pure than nickel sulfate (particularly important in bright nickel plating); 3) Mechanical properties of the deposit are not as good as those from the Watts bath.

*Fluoborate Solutions* - In nickel fluoroborate baths, the electrolyte is maintained at a pH of 2.0-3.5 using fluoroboric acid. Metal content is maintained at up to 120 g/liter of nickel, which is much higher than in a Watt's bath. Because of this, higher current densities are necessary.

Nickel coatings deposited from this type of bath have properties similar to those deposited from Watt's baths; however, these coatings are usually specified for heavy nickel applications and electroforming.

Anode dissolution in a nickel fluoroborate bath not containing chloride is better than in a nickel sulfate solution with nickel chloride.

Disadvantages of fluoborate baths include the following:

1) High cost of chemicals;
2) Throwing power less than that of sulfate solutions.
Sulfamate Solutions - This bath is based on the nickel salt of sulfamic acid, and the pH is adjusted using sulfamic acid, nickel oxide or carbonate. When intensive agitation is used in solutions with a high nickel concentration, current densities up to 500 asf can be achieved.

Nickel coatings from this type of bath usually have very low stress values and high elongations. Another advantage is that it is possible to operate the sulfamate bath without difficulties related to anode dissolution at low chloride levels or even without chloride. The principle advantage of this bath is that it can be operated at nickel concentrations of 180-200 g/liter. This allows for the use of high current densities without losing the properties of the coating.

Current Fluctuations while plating with a nickel sulfamate solution

This bath is based on the nickel salt of sulfamic acid, and the pH is adjusted using sulfamic acid, nickel oxide or carbonate. When intensive agitation is used in solutions with a high nickel concentration, current densities up to 500 asf can be achieved.

Nickel coatings from this type of bath usually have very low stress values and high elongations. Another advantage is that it is possible to operate the sulfamate bath without difficulties related to anode dissolution at low chloride levels or even without chloride. The principle advantage of this bath is that it can be operated at nickel concentrations of 180-200 g/liter. This allows for the use of high current densities without losing the properties of the coating.

There can be a lot of reasons, stopped barrel, bad power supply, current to the barrel, dirty barrels that do not allow solution transfer and barrel danglers that are not riding with the load. All these can occur intermittently. Also, check to see if the parts are not over etched before the going into the nickel bath. We doubt that there is really an effective practical way to reduce the throwing power significantly, but the theoretical factors are:

- Low solution concentrations increase throwing power (by starving the HCD areas), so high concentration should reduce it.
- Low temperatures increase throwing power the same way, so high temperature should reduce it.
- Good agitation reduces throwing power.

Types of Nickel Plating

Bright Nickel - Bright nickel plating baths are used in the automotive, electrical, appliance, hardware and other industries. It’s most important function is as an undercoating for chromium plating, helping finishers achieve a smooth bright finish as well as a significant amount of corrosion protection.

Bright nickel plating baths use combinations of organic agents to achieve bright nickel deposits. There are two classes of these organic additives. The first class is the aromatic sulfonic acids, sulfonamides and sulfonamides that contain the functional group =C-SO₂.

Saccharin is a widely used example of this type of brightener. Nickel deposits plated using these additives are mirror bright initially; however as the nickel builds, brightness
This first class of brighteners incorporates sulfur into the bright nickel, reducing corrosion resistance.

Table I—Composition and Operating Parameters

<table>
<thead>
<tr>
<th>Nickel Plating Baths</th>
<th>Composition</th>
<th>Watts</th>
<th>High Chloride</th>
<th>All Chloride</th>
<th>Fluoborate</th>
<th>Sulfamate*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel Sulfate (oz/gal) NiSO₄ • 6H₂O</td>
<td>20-40</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel Chloride (oz/gal) NiCl₂ • 6H₂O</td>
<td>6-12</td>
<td>12</td>
<td>32</td>
<td></td>
<td>0-3</td>
<td></td>
</tr>
<tr>
<td>Nickel Fluoborate (oz/gal) ni(SO₃HNO₃)₂ • 4H₂O</td>
<td></td>
<td></td>
<td></td>
<td>45-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boric Acid (oz/gal)</td>
<td>4-6</td>
<td>4-5</td>
<td>4</td>
<td>4</td>
<td>4-6</td>
<td></td>
</tr>
<tr>
<td>pH Range</td>
<td>2.0-5.2</td>
<td>2.0-2.5</td>
<td>0.9-1.1</td>
<td>3.0-4.5</td>
<td>3.5-4.5</td>
<td></td>
</tr>
<tr>
<td>Temperature (F)</td>
<td>90-160</td>
<td>100-160</td>
<td>100-145</td>
<td>90-160</td>
<td>90-140</td>
<td></td>
</tr>
<tr>
<td>Current Density (asf)</td>
<td>10-80</td>
<td>10-80</td>
<td>60-100</td>
<td>50-100</td>
<td>5-280</td>
<td></td>
</tr>
<tr>
<td>Anodes</td>
<td>Nickel, bagged, cast rolled, depolarized or carbon type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtration</td>
<td>Continuous, turnover once every 1-4 hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*This bath is used in electroforming as well as situations where a low stress/no stress deposit is needed. It allows you to deposit a lot of nickel in a shorter period of time. The sulfamate nickel is more expensive than other types of nickel baths.

Brighteners in the second class, also called levelers, have inorganic metal ions and organic compounds. These may include butynediol, coumarin, ethylene cyanohydrin and formaldehyde. These are used as leveling agents because they increase surface smoothness, as the nickel deposit thickness increases. See More on Brighteners and Levelers in Chapter 11.

Semi-Bright Nickel - At first, coumarin was used to obtain a high-leveling, ductile, semi-bright and sulfur-free nickel deposit from a Watts nickel bath. However, coumarin-free solutions are now available. A semi-bright nickel finish is semi-lustrous, as the name
implies. However, it was specifically developed for its ease of polishing and buffing. Or, if subsequently bright nickel plated, buffing can be eliminated. Brightness and smoothness are dependent on operating conditions.

The reason semi-bright nickel finishes are so easily buffed and/or polished is that the structure of the deposit is columnar, whereas the structure of a bright nickel finish is plate-like (lamellar). However, the structure can be changed with additives, a change in pH, current density or even an increase in solution agitation. This is not a problem unless it affects properties such as internal stress.

Internal stress can be compressive or tensile. Compressive stress is where the deposit expands to relieve the stress. Tensile stress is where the deposit contracts. Highly compressed deposits can result in blisters, warping or cause the deposit to separate from the substrate. Deposits with high tensile stress can also cause warping in addition to cracking and reduction in fatigue strength.

Watts baths and high-chloride type baths can produce high tensile stress. During bright-nickel plating, stress-reducing additives are used, but these co-deposit sulfur materials that affect the physical and/or engineering properties of the deposit. Saccharin is often used as a stress reducing agent. Nickel sulfamate baths can deposit pure low-stressed finishes without using additives.

Other Types of Nickel - To obtain other types of finishes such as satin nickel, organic additives are used and deposition conditions are altered. Deposits from a Watts bath are usually 7-10 mm thick, with the appearance dependent on the temperature and/or pH. At higher temperatures and a pH of 4.5-5.0, nickel deposits are matte. At 122F and a pH of 2.5-3.5, deposits are bright.

Black nickel plating is lustrous and has a black or dark gray color. Plating is done with little or no agitation. Occasionally it is necessary to remove hydrogen gas (bubbles) from the part's surface using wetting agents. The pH of the bath ranges from 5-6, and the temperature varies from ambient to 140F. Current density remains at approximately 0.5 A/dm2.

The coatings average 2 mm thick and corrosion resistance is limited, therefore they are usually lacquered or coated with oil or grease. If the black nickel must have good corrosion resistance, an undercoating such as bright or dull nickel, zinc or cadmium is necessary.

Barrel Nickel Plating

Barrel plating solutions are relatively similar to rack plating solutions; however, operating conditions may differ, although not radically. The pH is usually maintained at about 4, unless plating zinc die-casting, in which case a pH higher than 4 may be necessary. However, anode corrosion is better at a lower pH, and anode area is limited. The anode area should be as large as possible to avoid the liberation of oxygen and chlorine.

Temperatures can vary for barrel nickel plating from 86-104F for some solutions and 104-140F for others. Current density can also vary. For a typical barrel, approximately 24-32 inches long and 16 inches in diameter, the load is 300-600 amps per load or
between 1-1.5 A/dm2. Other considerations are the barrel loading, surface area and coating thickness.

There are some special considerations for barrel plating: 1) Parts must be able to move about freely in the barrel; 2) Precise surface preparation is essential, including thorough rinsing; and 3) When the electrolytes are used to full capacity, low-current-density treatment should be used continuously.

Properties of Nickel Deposits

**Thickness** - Corrosion resistance is often intimately related to the thickness of the coating; however, the functional requirements of the coating are also important. Micrometer readings are used most often to determine coating thickness.

**Hardness** - Certain addition agents, such as saccharin or naphthalene sulfonic acid, can increase the hardness of a nickel deposit. Wetting agents may also increase hardness. Nickel deposits plated from Watts nickel baths, sulfamate or fluoborate baths can rise to 650 HV (HV is Vickers hardness). Heavy nickel baths produce deposits with hardness between 250-350 HV.

Hardness is not only a result of addition agents but is also affected by the plating bath composition, temperature, current density and other operating conditions.

**Ductility** - Ductility can be measured using a tensile testing machine; however this test is specific to measuring plated thin foils.

**Nickel Plating without use of Cyanide**

This can be done using the NICKELSOL process. The NICKELSOL process is a hydrogen peroxide-sulfuric acid formulation designed to strip nickel and copper from aluminum, plastic and stainless steel.

The NICKELSOL process can replace nitric acid strippers, which cause the evolution of harmful NOx fumes.

The NICKELSOL process does not contain cyanide or chelating agents and treatment of the subsequent rinse water is reduced to simple neutralization and precipitation.

The NICKELSOL process offers the following advantages:

- The bath can be regenerated indefinitely, eliminating frequent dumping and the related waste treatment cost
- The economical recovery of the dissolved nickel and copper is made possible by crystallization.
- The system, in most cases, is readily adaptable to most existing automatic, semi-automatic and manual operations
- Simple control and maintenance
The NICKELSOL Process may be used in almost any industrial application where the removal of nickel and copper from base surfaces of aluminum, plastic and stainless steel is required. The bath composition can be adjusted to meet the specific operating requirements.
Chapter 8

<<Metal Plating for Polymers>>

Polytetrafluoroethylene (PTFE) is better known by the trade name Teflon®. It's used to make non-stick cooking pans and anything else that needs to be slippery or non-stick. PTFE is also used to treat carpets and fabrics to make them stain resistant.

What's more, it's also very useful in medical applications. It can be used for making artificial human body parts, because human bodies rarely reject it.

These materials can be used to make a variety of articles having a combination of mechanical, electrical, chemical, temperature and friction-resisting properties unmatched by articles made of any other material. Commercial use of these and other valuable properties combined in one material has established PTFE resins as outstanding engineering materials for use in many industrial and military applications.

Table 9a shows data that an EN/PTFE process should be able to fulfill to meet today's environmental and economical needs. To achieve the "perfect coating" and the required lifetime, it is necessary to modify the electroless nickel electrolyte and the manufacturing of the dispersion to develop an improved proprietary process.

A nice side effect of this was that the lifetime of the plating solutions was extended to five metal turnovers or more under normal job-shop conditions. Customers using EN/PTFE coatings of the newest generation report generally the same deposition quality for five metal turnovers or more. Also, the incorporation rate of the PTFE remains at about 25 to 30% volume during the entire bath life.

To incorporate higher PTFE content does not appear practical because the plating rate is reduced and the nickel matrix becomes more fragile, increasing the wear rate. Also, agglomeration of PTFE particles is hardly a problem.

TABLE 9a- EN/PTFE Coating Characteristics:

- PTFE incorporation - Variable in between 15 - 30 volume - %
- Particle size - 0.3 - 0.5 mm
- Bath lifetime - About 5 MTO
- Deposition Rate - 5 mm/h at 28 volume % up to 5 MTO
- Agitation during Plating - None
- Wear properties - A widely held prejudice is that only hard coatings can solve wear problems. That is correct for abrasive wear, but for nearly all other problems, a reduction of the coefficient of friction can handle it and is sometimes even better. The main reason for the success is that forces that could fatigue one or both partners are reduced, so less wear is transferred into the material.

In the top view, the color is coordinated with height, and in the hardness map with hardness. Even on the surface, the PTFE is uniformly distributed so phenomena such as fretting and galling are minimized. The comparison of a heat-treated electroless nickel and hard chromium layers shows why hardness is not the main factor for low wear. Both layers have an overall hardness of about 1000 Hv (Vickers hardness) 0.1.
The EN coating is abraded more quickly than the chromium coatings, because EN has a higher coefficient of friction. Even though the EN/PTFE coating is much softer (320-400 Hv 0.1), the coefficient of friction is lower than that of hard chromium (about 0.07 to 0.1 for EN/PTFE and 0.12 to 0.25 for hard chromium). Therefore it wears more quickly.

Because of the fatigue behavior of the coating, PTFE and EN particles are broken out of the surface. In the case of the very smooth surface, the small Ni-P particles can increase the wear on the next layer of the coating, and the PTFE balls are simply wiped away.

Against that the PTFE particles remain longer in the area of wear and can be used like ball bearings on the rougher surface. The Ni-P particles are too small to increase the wear on the rough surface.

Comparison to PVD/CVD coatings (PVD: physical vapor deposition. CVD: chemical vapor deposition)

In comparison to other wear-protective coatings such as PVD and CVD, there are some other advantages of soft dispersion coatings:

- Because the hardness of the deposited layer is similar to that of the substrate (in most cases), there is no need for a hardening process before plating the protective layer. This is necessary in a PVD or CVD system to achieve an appropriate adhesion. Similar to the PVD/CVD processes, the surface has to be purely metallic (no oxides).
- Because of PTFE’s softness, the coating can store and dissipate more energy in small volumes before it is plastically deformed.

The EN/PTFE coating can use the base material as a support structure because of the similar hardness.

Because of the porosity-free deposition, it is possible to get another degree of freedom for the deposit’s lifetime (thickness).

The corrosion behavior is much better than that of PVD/CVD coatings (EN: 500 hrs at a plating thickness of 12mm).

The "soft dispersion coatings" cannot increase the wear at the tribological partner in the system.

In most PVD/CVD coatings, corrosion resistance is a problem. To cope with that, some companies apply "sandwich coatings." Usually plating of 10mm of a high-phosphorus EN layer (d=10mm) below the thin ceramic layer can help with the problem.
<table>
<thead>
<tr>
<th>Selected Applications Industry</th>
<th>Market and Parts Part</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air and space</td>
<td>Connectors</td>
<td>corrosion, wear</td>
</tr>
<tr>
<td>Hydraulics (oil/water)</td>
<td>Piston</td>
<td>corrosion, wear</td>
</tr>
<tr>
<td>Robotics</td>
<td>Hinges</td>
<td>tribo-ox, wear, corrosion</td>
</tr>
<tr>
<td>Automotives</td>
<td>piston rings, valves, injection nozzles, carburetor, oil pumps</td>
<td>tribo-ox wear, wear, fuel management, wear, corrosion, fuel management, energy cons.</td>
</tr>
<tr>
<td>Electronics</td>
<td>switches, magnetic coils</td>
<td>tribo-ox, wear</td>
</tr>
<tr>
<td>Synthetics</td>
<td>molds, nozzles</td>
<td>anti-adhesive, time, yield</td>
</tr>
<tr>
<td>Textile</td>
<td>cutting tools, guides</td>
<td>noise, lifetime</td>
</tr>
<tr>
<td>Pneumatics</td>
<td>Pistons</td>
<td>lifetime</td>
</tr>
<tr>
<td>Pharmaceutics</td>
<td>stamps, molds</td>
<td>anti-adh., yield</td>
</tr>
<tr>
<td>Food</td>
<td>plates, pots</td>
<td>anti-adh., time</td>
</tr>
</tbody>
</table>
Galling and corrosion problems are covered best by EN/PTFE dispersion layers. This is because of the anti-adhesive and hydrophobic properties of the surface and the thermal conductivity of the coating. While ceramic coatings are electrical and thermal insulators, EN/PTFE coatings have electrical and thermal conductivity.

Different applications for EN/PTFE coatings

Table 9b shows some of the most common applications for EN/PTFE coatings.

New improvements in the coatings have helped in many industries: drilling equipment for paper; gardening tools; gas meters; and spiral pumps. In automotive industries there are new parts tested to avoid noise and wear or reduce weight and costs (Table 9c).

Combining electroless nickel deposits with sub-micron PTFE particles has not yet reached its peak. That is due not only to a lack of information, but also to the quality of the solid layers. The consistency was not good enough, and the results differed too much, so that many electroplaters did not dare apply this coating in high-tech applications. Since improving the chemistry and the deposit, most applications can now be approached successfully. Also, the life of the electrolyte convinces some of the electroplating industry customers to use this trend-setting coating. Many problems can be solved where some years ago no one thought this could be done with a soft coating.

Only some physical properties have to be changed and many applications could be managed easily.
Chapter 9

<<PLASTIC PLATING>>

Decorative plating of plastics and other metal finishing techniques

In the past years the coating of plastic gained more and more significance, especially in the automotive supplier industry.

The reason that plastic parts can not be easily electroplated is because plastic is a nonconductor of electricity. Plastics can be metallized though, through numerous plating processes. For starters, the parts must be perfectly clean from any oil, grease or any plastic injection mold compounds. If the parts are not cleaned properly, the metal will peel off over time from the plated plastic part.

Then you process the plastic part in a very aggressive chromic/sulfuric acid bath to etch the plastic surface (make small pits on the surface). Then you place the plastic part in a palladium chloride bath to place metal particles in the previous pits made on the plastic surface. After this palladium metal deposition, one can electroplate the part with copper metal and then chrome plate or many other various metals such as nickel or gold.

Plating can be successfully performed on many plastics, including ABS, polypropylene, polysulfone, modified poly-phenylene oxide, polycarbonate, polyester, and nylon, to provide a decorative finish or a hard surface for wear and corrosion resistance. Plating can improve physical properties of the plastics part, such as tensile and flexural strength and the heat deflection temperature. Because of their light weight and Nickel ease of design, plastics have been used in many applications to replace zinc die castings, brass, and steel.

The total cost to plate plastics is competitive with metals. Because of their light weight and ease of design, plastics have been used in many applications replace zinc die castings, brass, and steel. The total cost to plate to plastics is competitive with metals. Product design of parts to be plated is particularly critical in determining the success of the plating operation. Basic plastics design practices should be followed to achieve a good molding in the un-plated product, and it is advisable to have the design reviewed by the electroplater. Because the proper choice of resin for products to be plated is of basic importance, the resin supplier should be consulted while the product is in the design stage.

Pre-plate Cycle

Since plastics are nonconductive, they must first be processed through a pre-plate cycle, during which a metallic coating is deposited by an electroless plating process to make the plastics part conductive. The pre-plate cycle consists of etching, neutralizing, catalyzing, acceleration, and electroless plating.
Etching

The etch bath consists of a highly concentrated acid solution of chromic and sulfuric acid. The solution oxidizes selective areas as on the plastics part. The holes produced by the oxidizing action are absorbing sites that hold small metallic particles that serve as activators for electroless plating. The hole size influences adhesion and other physical properties. After etching, the plastic is thoroughly rinsed.

Neutralizing (sensitizing)

The neutralizing bath containing mild acids or alkaline solutions chemically neutralize the acids from the etching bath.

Catalyzing

In this step, a catalytic film is put on the oxidized surface to prepare for electroless metal disposition. It is done in two steps, in step 1 the liquid is immersed in a bath, step 2 involves another solution that prepare the plastic to be plated by nickel.

Acceleration

The accelerator bath removes the entire chemical that remains after the Catalyzing procedure. It also ensures a rapid coverage of electroless deposits.

Electroless Plating

The plating bath is the final bath of the pre-plate cycle. A thin deposit of metallic file is deposited on the plastics part. It can be made of nickel or copper depending on the objects application. Electroless plating helps electroplated plastics in a corrosive environment.

Plating

There are many ways to plate plastics. Some of them are:

- Strike bath
- Acid copper bath
- Semi-bright nickel bath
- Chromium plating bath

Plating Processes for Plastics

Plastics may be coated with metals to provide Electro Magnetic Interference (EMI) screening by a number of methods.

Vacuum metallization

Vacuum metallization has been specifically developed for coating plastic components with a pure aluminium coating to provide high levels of EMI/RFI shielding. It is the most environmentally friendly shielding process, requiring no solvents and producing no
harmful by-products. The coatings have a smooth metallic appearance and are highly ductile and adhere to most engineering plastics. The process deposits a pure layer of aluminium (99.8%) and, as aluminium dissolves in sodium hydroxide, parts are easy to recycle. Coatings produced offer considerable weight saving and very high shielding. Parts can be coated selectively using multi-impression masking tools.

Conductive paint spraying

A wide range of metal-loaded paints are used to provide EMI/RFI protection, although silver or silver-plated copper-loaded paints are the most commonly specified. Historically, all paints contained harsh solvents (usually MEK) to improve adhesion to the substrate. However, the trend towards thin-walled mouldings involving blends of polycarbonate and ABS has amplified the need to minimise the impact of the coating on the substrate. This has resulted in the development of "Safe on Substrate" technologies. These paints are formulated using mild solvents and can be mechanically removed to allow the plastics to be recycled.

Electroplating

Two types of electroplating process are commonly used for EMI shielding of plastic enclosures: electroless and electrolytic plating. These coatings have the unusual ability to combine aesthetic appeal, wear and corrosion resistance with very high levels of shielding. A nickel layer is chemically or electrically deposited over a layer of pure copper. The process does not lend itself to selective finishing; hence it is usually specified on internal components. For recycling, parts are dipped in an acid solution to remove the plated parts.
Tin-lead (SnPb) solder has been widely utilized for electrical connections because of its convenience, economy, and electrical and mechanical characteristics. As a result of recent environmental concerns regarding lead (Pb), the requirement for Pb-Free semiconductors has been receiving increasing attention within the semiconductor industry. Countries around the world continue to enact stricter bans on the content of hazardous materials in semiconductors. Such legislation has prompted the semiconductor industry to develop environmentally friendly products.

The semiconductor industry is under pressure to develop environment friendly interconnection and packaging technologies.

Lead and lead alloys have had a long history of being components in solder and in connector leads for a good reason: the lead/tin compound known as solder forms good electrical connections with other materials such as copper and silver at the relatively low temperature of 183°C. The resulting joints are reliable and the process is cost effective. So finding Pb-free replacements involves a combination of materials science and clever process control. Process control is, in fact, the key. "It is getting tougher to make a reliable joint," says Philips' van de Water. "The window for success (in the soldering process) is getting smaller."

Semiconductor companies have four primary problems to solve when designing Pb-free packages: solderability, reliability, whiskers, and moisture sensitivity. Not surprisingly, the attributes are interrelated.

Solderability relates largely to the ability to melt the Pb-free solder at temperatures close to those of lead-based solder and lead coatings. Compatibility with the equipment used in most of today's wave-soldering assembly lines is an imperative if it to be kept in service with a minimum of retrofitting. Reliability addresses the strength of the joint; and, moisture sensitivity determines how long the component may be kept in storage before it is attached to a board.

Solderability

Conventional Pb-based soldering takes place in a range of 215° and 240°C for lead frame devices. Due to higher melting temperatures, matte tin requires a range of 235° to 260°C and this potentially has an impact on reliability. Tests have shown that tightly managing the temperature profile during the soldering process provides an acceptable solution, says van der Water. Other package types have similar results.

Reliability

The reliability of a solder joint can be compromised by changes in temperature while the chip is in service and is known as thermo-mechanical solder fatigue. Joint failure follows a well known process that begins with diffusion and re-crystallization. Crack initiation and growth follow until the fracture can actually be observed.
Testing the reliability of solder joints has been conducted by cycling the product through a range of temperatures from -40° to 125°C for 10,000 cycles. Solder fatigue failure is visualized and analyzed using a technique called Weibull statistics. Many package types have been tested. Reliability has been comparable to conventional connectors and solder pastes.

**Whiskers**

As previously mentioned, when pure tin is used for plating a lead frame, the growth of tin filaments has been identified as a potential reliability problem. If these "whiskers" grow long enough they can conceivably short circuit two pins. Irregular intermetallic growth at the copper-tin interface causes stresses that extrude the tin whisker from the surface. Whisker growth is not immediately apparent. It occurs during storage at ambient temperatures—not during the soldering process—so countermeasures must be taken.

One approach is to make the tin layer thicker. This dramatically reduces the length of whiskers because a thicker tin layer can absorb more stress. In test results reported by ST Microelectronics, maximum whisker length decreased 160 microns to less than 10 by increasing the thickness of the tin layer from 1.82 microns to 10 microns.

Another approach is to post-bake the component at 150°C for an hour. It was found that the higher temperature created bulk diffusion in the material and regular intermetallics. No whisker growth has been observed under these circumstances.

Still another approach involves chemically pre-treating the tin surface of the lead frame to create a matte—as opposed to shiny—finish. A matte finish has proven to be less susceptible to whisker formation that a shiny tin finish. There is no reason for choosing just one of these solutions because they are, in fact, compatible.

**Moisture Sensitivity**

If any component is stored outside a dry pack for a significant amount of time moisture can accumulate which will change its solderability and reliability characteristics. Pb-free components are more inclined to be susceptible to moisture but using a different soldering profile (245°C for packages greater than 350 mm² and 250°C for packages smaller than 350 mm²) helps alleviate the problem, says Freescale's Mike Thomas.

Every Pb-free SMD package will have to be re-qualified according to JEDEC standards, however, and the Moisture Sensitivity (MSL) classification of some will drop, which means more care will have to be taken when they are stored and used in board manufacturing facilities.

For lead-free products, there are different types of solder pastes available and would work in board reflow at 260° C and below:
<table>
<thead>
<tr>
<th>Composition</th>
<th>Melting Point (°C)</th>
<th>Range (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn/Ag4.0/Cu.5</td>
<td>217°C</td>
<td>(240-255°C)</td>
</tr>
<tr>
<td>Sn/Ag2.5/Cu.8/Sb.5</td>
<td>216°C</td>
<td>(225-240°C)</td>
</tr>
<tr>
<td>Sn/Ag3.5</td>
<td>221°C</td>
<td>(245-255°C)</td>
</tr>
<tr>
<td>Sn/Cu.75</td>
<td>227°C</td>
<td>(250-260°C)</td>
</tr>
<tr>
<td>Sn/Bi3.0/Ag3.0</td>
<td>213°C</td>
<td>(225-244°C)</td>
</tr>
</tbody>
</table>
CONTROLLING HAZARDS IN THE ELECTROPATING INDUSTRY

The Occupational Safety and Health Regulations 1996 set down specific requirements for workplaces that use hazardous substances. These cover such things as:

- Labeling of containers
- Material Safety Data Sheets (MSDS)
- Induction and safety training
- Record keeping
- Risk reduction; and
- Health surveillance

The Regulations say employers, main contractors and self employed persons must:

1. Identify hazardous substances;
2. Assess the risk of injury or harm; and
3. Reduce the risk by:
   4. Preventing exposure to the hazardous substance
   5. Means other than personal protective equipment; and
   6. Where 1 and 2 are not practicable, by the use of personal protective equipment.

The Act says employees must take reasonable care of their own safety and health and avoid adversely affecting the safety and health of others. They must comply within reason with safety instructions, use personal protective equipment provided and report hazards or injuries.

Manufacturers of hazardous substances must prepare a material safety data sheet. Suppliers of hazardous substances must ensure containers are adequately labeled. They must provide a current MSDS to the workplace when first supplying a hazardous substance, and thereafter when requested.

Designers, manufacturers, importers and suppliers must ensure, as far as practicable, that people installing, maintaining or using their plant are not exposed to hazards.

**Risks:**

Workers at electroplating workplaces may be exposed to hazardous substances.

These substances are mainly in the form of:

- Fumes
- Vapors or mists
- Metal dusts
Other hazards in electroplating involve the use of:

- Electricity
- Mechanical plant
- Manual handling

**What are the health risks?**

Workers exposed to electroplating chemicals can develop:

- **Short term** throat, lung, sinus, skin and eye irritation and burns
- **Long term** health problems such as asthma, heart, lung and nerve disorders and Cancer

The risk of developing health effects depends on how much chemical is absorbed into the body. In addition, electrolysis releases hydrogen bubbles which, unless safely contained or ventilated, can:

- Become explosive
- Carry other chemicals in a toxic mist

**What are the hazardous substances?**

Hazardous substances in electroplating include:

- **Solvents** such as methylene chloride, phenol, cresylic acid (a chemical similar to phenol)
- **Gases** such as hydrogen cyanide
- **Acids** such as chromic acid, sulphuric acid and hydrochloric acid
- **Alkalis** such as sodium hydroxide (also known as caustic soda)
- **Cyanides** such as sodium and potassium cyanide
- **Heavy metals** such as nickel, chromium, cadmium and lead
- **Toxic wastes**

These substances are commonly used or produced in the:

- Preparation
- Coating
- Polishing of metal items

**CONTROLLING HAZARDS IN THE ELECTROPATING INDUSTRY**

**When can chemical exposure occur?**

People working in electroplating industry can be harmed when:

- Containers leak or spill during transport, storage, decanting or disposal
- Explosive or toxic gas or fumes build up during storage in confined areas
- Operators are splashed by items entering or leaving plating tanks
• Excessive bubbling or fuming occurs in acids, caustic or other chemicals
• Dust is breathed in during buffing or grinding of plated items
• Excessive hydrogen or oxygen is emitted during electrolysis or anodizing, causing an explosive or flammable atmosphere
• Local exhaust ventilation fails, or is inadequate to handle escaping gases, fumes and mists
• Overhead gantry cranes, hooks or slings fail when lowering or lifting items from dip tanks
• Residue liquid and sludge is removed from dip tanks
• Maintenance and repair work is done to tanks
• Chemical wastes are disposed of in sewers before being properly neutralized
• Chemical wastes are disposed of at tipping sites without proper authority approvals

How can hazardous substances enter the body?

Hazardous substance can enter the body through:

• The skin or eyes, following contact with liquids or droplets
• The lungs and nasal passages, when fumes, droplets, gases or dusts are inhaled
• The mouth, when eating or smoking with contaminated hands

How can hazards be identified?

Workplace hazards can be identified through:

• Checking packaging or container labels and material safety data sheets
• Regular communication between workers, supervisors and employers about likely hazards
• Regular inspection of workplaces, plant and equipment
• Regular review of tasks and procedures
• Checking of previous incident and injury records for recurring situations

How can risk be assessed?

General hazards:

The risk of injury or harm from general workplace hazards can be assessed by:

• Assessing the likelihood of the hazard causing injury or harm, eg. very likely or remotely possible
• Assessing the likely severity of injury or harm, eg. serious or minor injury
• Checking records of previous incidents and injuries where hazards have caused injury or harm
• Checking plant and equipment to make sure hazards are properly controlled
Hazardous substances:

In addition, the risk of injury or harm from hazardous substances can be assessed by:

- Obtaining information about the hazards
- Checking work processes to make sure hazards are adequately controlled;
- Conducting atmospheric monitoring to determine levels of exposure to chemicals such as chromic acid
- Conducting health surveillance to detect any adverse health effects from chemicals at an early stage

How can risk be reduced?

Risk can be reduced by using control methods, in the following order of priority:

- Eliminate or remove the hazard – eg. do not use a chemical or item in the plant if it is not required.
- Substitute or replace it with safer plant, equipment or substance.
- Isolate it from workers – eg. enclosed systems for chemicals, relocation of employees or physical barriers.
- Introduce engineering controls – eg. guarding or exhaust ventilation.
- Administrative controls – eg. limiting workers’ time spent near the hazard.
- Personal protective equipment – eg. safety goggles and respirators. While essential for some work procedures, these should be last in the list of priorities.

What information and training is required?

- All workers must be informed of hazards from exposure to harmful substances.
- They must be given information, instruction, training and supervision in safe procedures, including personal protective equipment.
- Workers should know how to identify hazards, and to report them to a supervisor.
- Training on hazardous substances must include potential health effects of the substances used, control measures, correct use of protective equipment and the need for and details of health surveillance.
- Workers from non-English speaking backgrounds may have special needs and should be provided with information in their first language.
- Training should be ongoing, with regular revision of safe procedures.

Controlling plating tank hazards

- Substitute hazardous substances with less hazardous ones.
- Where possible, pump chemicals into plating tanks rather than pouring manually from containers.
- Pumps need to be cleaned before use with a different chemical.
- Use local exhaust ventilation along one or more sides of the tank to remove mists and vapors.
- Use a suppressant to minimize the amount of mist generated during electro plating.
• Minimize risk of items accidentally dropping into tanks, splashing operators.
• Ensure overhead cranes, hooks and slings are regularly maintained.

Controlling cyanide hazards

• Acids and cyanides are an explosive combination, and should be clearly labeled and stored in locked, dry places, well away from each other.
• Articles treated in acid baths should be thoroughly rinsed with water before being placed in plating tanks.
• Drainage should be designed so there is separation of acid spillage from cyanide spillage or effluent.

Buffing, grinding and polishing

• Newly electroplated surfaces on heavy machinery parts are usually finished with portable or fixed grinding machines.
• Finer finishes on personal, hobby or household items are achieved with buffing and polishing wheels, containing various polishes and waxes.
• These processes generate large amounts of metal dusts, some of which are hazardous if inhaled.
• Local exhaust ventilation should be fitted to grinding and buffing machines to remove dust as it is generated.
• Where substances that are known to be carcinogenic are used, exposure levels should be kept as low as possible
Chapter 12

<<Miscellaneous Topics>>

Treating Metal Plating Effluents

The field of electroplating or metal finishing today is moving away from large manufacturing operations and into smaller job shops. With increasingly strict regulations governing metals in wastewater and increasing costs for disposal of metal-contaminated waste, many metal finishers find that implementing pollution prevention measures such as filtering or treating process water to reduce or eliminate metal contamination and allow water reuse is the best option, both environmentally and economically. Plating processes in this sector include chrome, bright and electroless nickel, zinc, copper, tin, conversion coatings, and more.

Because metal plating has many significant environmental aspects and is a highly polluting industry, there are many resources available to help the metal plating industry improve its environmental performance. Trade associations have websites with technical guidance, suppliers, and discussion forums where questions can be asked and answered, all for free. There are several major programs focused specifically on helping the sector with pollution prevention. Researchers looking for cost-effective ideas for improvement should examine the sites dedicated to environmental improvement, and the trade association sites.

The tables below list low-cost or no-cost solutions to reduce waste and pollution in any metal plating company, including ones in developing countries. All of these ideas have been proven to help small companies, anywhere in the world, save money while protecting the environment.

Top Low-Cost Solutions to Increase Efficiency and Reduce Waste in Metal Plating Operations

<table>
<thead>
<tr>
<th>Solution</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install spill containment</td>
<td>Spills can be contained and managed to prevent losses of valuable resources.</td>
</tr>
<tr>
<td>Lengthen dragout time</td>
<td>Allows more chemical to drip back to process tank, so reduces the amount of chemical introduced in rinse water.</td>
</tr>
<tr>
<td>Establish dragout timing</td>
<td>Post dragout times on signs at tanks to remind employees. A drain time of at least 10 seconds has been demonstrated to reduce dragout by 40+%, compared to the three-second industry average.</td>
</tr>
<tr>
<td>Install drain boards or drip guards</td>
<td>Boards and guards minimize spillage between tanks and are sloped away from rinse tanks so dragout fluids drain back to plating tanks.</td>
</tr>
<tr>
<td>Use conductivity sensors</td>
<td>These sensors indicate the cleanliness of the rinsed water. They cost only a few hundred dollars to order, and can greatly improve plating quality and prevent unnecessary dumping of rinsed water.</td>
</tr>
<tr>
<td>Agitate rinse bath</td>
<td>Agitation promotes better rinsing. Agitate water or part manually or with mechanical means (stirring or air bubbling).</td>
</tr>
<tr>
<td>Reuse spent acid/alkaline</td>
<td>Spent acid can be used to neutralize an alkaline waste stream. Spent alkali can be used to neutralize an acid waste stream.</td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Evaporation</td>
<td>Concentrate rinsed water and captured dragout liquids for reuse; the water condensate can also be reused. Mechanical evaporators or simple boilers can be used.</td>
</tr>
<tr>
<td>Increase temperature bath</td>
<td>Evaporates bath water so relatively clean waste rinsed water can be reused as bath makeup water. Reduces solution viscosity so more chemical drains back to process tank during dragout. <em>Do Not Use On Cyanide or Hexavalent Chromium Baths.</em></td>
</tr>
<tr>
<td>Optimize concentrations bath</td>
<td>Run tests with successively lower bath concentrations to find the minimum level needed to achieve quality. This saves money by reducing overuse of chemicals and reduces contamination in wastewater. Remember that concentrations recommended by vendors are usually higher than the minimum needed for quality.</td>
</tr>
</tbody>
</table>

**How to restore old chrome plated parts**

When chrome plated finishes become scratched or marred there really isn't much you can do with them. Beyond cleaning it with metal polish and keeping it waxed, there isn't much you can do yourself. The items can certainly be rechromed by a plating shop. Some people use chrome polish to help shine the surface, but if the surface is scratched, it will eventually corrode.

Your best bet is to take them to a custom plating shop in your area. They will strip the chrome and hopefully any underlying nickel or copper. Conversely, some shops will only strip the chrome and polish the nickel and reapply another layer of nickel, perhaps acid copper, perhaps copper buff and more nickel and chrome. As you can see, the process can be quite extensive and therefore, rather expensive.

Most people assume we just "dip it in a vat" and the part miraculously emerges with the shiny, reflective surface we all associate with nickel/chrome. Please be aware that there is a tremendous amount of manual labor involved in stripping the parts, buffing them, and replating them, so you should expect that you will pay considerably more than you probably expected.
What are Organic Additives

Organic additives (carriers, brighteners, levelers) work to increase the current density or plating rate that can be maintained with satisfactory throwing power.

The additives fall into three main categories:
- Carriers
- Brighteners
- Levelers

Carriers increase the polarization resistance and are current suppressors. The suppression is a result of the carrier being adsorbed to the surface of the cathode; this results in increasing the effective thickness of the diffusion layer. The result is better organization. This gives rise to a deposit with a tighter grain structure. The carrier modified diffusion layer also improves plating distribution without burning the deposit.

The brightener is a grain refiner. Its random adsorption may produce a film that will suppress crystallographic differences. Alternatively, brighteners may be adsorbed preferentially on particular active sites such as lattice kinks, growth steps, or tops of cones, or surface projections in general; growth at these locations is then blocked.

Levelers or leveling agents are inhibitors present at low concentrations in the electrolyte as compared to the depositing metal. In case of a micro profile, the diffusion layer does not follow the profile contour, but is maximum at the valleys and minimum at the peaks. Consequently, in absence of a leveling agent, depositing ions diffuse more rapidly to the peaks than to the valleys, and deposits grow more rapidly on the peaks, resulting in an exaggerated profile.

With good solution agitation, the leveler will accumulate more rapidly and readily at the peaks and it will inhibit growth or deposition. The valleys will allow faster deposit growth and allow the valleys to catch up to the peak, thus creating leveling.
Well, that’s about it! If you’ve read this far than you can now call yourself a **metal plating expert**. You should now have a solid grasp of exactly what is entailed in the metal or electroplating process, across a huge range of possible metal plating applications and situations.

We hope that you have enjoyed reading the “Metal Plating Bible”, and most of all, we hope you can now feel confident doing your own metal plating, in your own specific plating situation. Metal plating of course, is a technical and oftentimes advanced topic by nature.

This guide has been an extensive attempt to take what was normally an activity that only chemistry experts could partake in, and give beginners and other not so knowledgeable people a step-by-step guide that they could learn from to form their own metal plating action plan.

On that note, I would like to wish you (my treasured customer) a pleasant evening, and the best of success in your future metal plating activities! And remember, I’m always an email a way if ever need assistance.

Warm Regards,
Craig Bellinger
Owner and Co-Author
**Anion** - A negatively charged ion or radical which is attracted to the anode because of the negative charge.

**Anode** - The positively charged electrode at which oxidation or corrosion of some component occurs (opposite of cathode). Electrons flow away from the anode in the external circuit.

**Barrel plating (or cleaning)** - Plating or cleaning in which the work is processed in bulk in a rotating container.

**Brass** - An alloy consisting mainly of copper (over 50%) and zinc, to which smaller amounts of other elements may be added.

**Brightener** - An agent or combination of agents added to an electroplating bath to produce a smooth, lustrous deposit.

**Cathode** - The negatively charged electrode of an electrolytic cell at which reduction occurs.

**Cation** - A positively charged ion that migrates through the electrolyte toward the cathode under the influence of a potential gradient. See also anion and ion.

**Cell** - Electrochemical system consisting of an anode and a cathode immersed in an electrolyte. The anode and cathode may be separate metals or dissimilar areas on the same metal. The cell includes the external circuit, which permits the flow of electrons from the anode toward the cathode. See also electrochemical cell.

**Chromate coating (chromating)** - A corrosion protection technique; can be applied to steel, aluminum, magnesium, and zinc. It results in the formation of metal oxide on the surface of the work piece which reacts to form metallic chromates. Chromating of aluminum and magnesium improves corrosion resistance considerably. With steel it is much less permanent.

**Conversion coating** - A coating produced by chemical or electro-chemical treatment of a metallic surface that provides a superficial layer containing a compound of the metal; for example, chromate coatings on zinc and cadmium or oxide coatings on steel.

**Corrosion** - The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.

**Electrochemical Cell** - An electrochemical system consisting of an anode and a cathode in metallic contact and immersed in an electrolyte. The anode and cathode may be different metals or dissimilar areas on the same metal surface.

**Electro-deposition** - The deposition of a substance on an electrode by passing electric current through an electrolyte.
**Electroless plating** - A process in which metal ions in a dilute aqueous solution are plated out on a substrate by means of autocatalytic chemical reduction. Electroless plating uses a redox reaction to deposit metal on an object without the passage of an electric current.

**Electrolysis** - Production of chemical changes of the electrolyte by the passage of current through an electrochemical cell.

**Electrolyte** - (1) A chemical substance or mixture, usually liquid, containing ions that migrate in an electric field. (2) A chemical compound or mixture of compounds which when molten or in solution will conduct an electric current.

**Electrolytic cells** - An assembly, consisting of a vessel, electrodes, and an electrolyte, in which electrolysis can be carried out.

**Electro-cleaning** - An electrochemical cleaning process by which a metal is first made the cathode in an electrolytic cell. When current is applied, electrolysis of water occurs at the surface of the metal. This results in generation of Hydrogen gas. This gas creates a highly efficient scrubbing action. Following initial treatment as a cathode the circuit is reversed so that the metal is the anode. Oxygen gas, which is generated at the surface, produces a final cleaning action.

**Electrolytic etch** - A technique generally applied to steels which attack the surface to produce a clean, oxide free material. It is often used prior to electroplating, especially chromium plating. Since it preferentially attacks edges it will open us small cracks in the surface of the metal. Due to this, this process can be used to inspect finishes for flaws.

**Etching** - Etching is sometimes used a surface preparation technique prior to electroplating or for removal of metal such as in the printed circuit industry where material not required on the finished product is removed by a chemical solution. It can also be used as an inspection technique due to its ability to accentuate surface cracks and defects.

**HCD - High Current Density** - High amperes per surface area

**Indicator (pH)** - A substance that changes color when the pH of the medium is changed; in the case of most useful indicators, the pH range within which the color changes is narrow.

**Leveling** - Electrodeposited materials tend to be concentrated at sharp corners, peaks, and ridges, therefore, when a metal with a rough surface is electroplated, the rate of deposition will be faster on convex irregularities resulting in an accentuation of the item's original roughness. To counteract this effect, additives are added to the electrolyte solution to produce a polarization effect concentrated at the peaks and ridges. This polarization effect lowers the current density at the peaks and reduces deposition rates. The net result is to smooth or "level" the surface of the metal.

**Reducing agent** - A compound that causes reduction, thereby itself becomes oxidized.

**Sensitizing** - A relatively non-specific term used to cover a range of metal finishing processes that improve the treatment ability of a metal for subsequent processes. It
often refers specifically to a part of electroless plating procedure on plastics or non-metal surfaces. After the surface has been etched it is reacted with solution that deposits a very thin film of a metal or metallic compound. The surface is then referred to as sensitized.

**Substrate** - Surface material or electroplate upon which a subsequent electro-deposit or finish is made.

**Solder plating** - The term covers deposition of an alloy of 60% tin and 40% lead that is widely used in the electrical and electronics industries. It provides two valuable features, corrosion resistance and "solderability".