Bowman Analytics: General Metal Finishing Applications and Performance

Introduction

Many industries use metal finishing in their manufacturing processes including automotive, electronics, aerospace, hardware, jewelry, heavy equipment, appliances, tires, telecommunications, etc. Without metal finishing, products made from metals would last only a fraction of their present lifespan because of corrosion and wear. Finishing is also used to enhance electrical properties, to form and shape components, and to enhance the bonding of adhesives or organic coatings. Sometimes the finishes are used to meet consumer demand for a decorative appearance. Overall, metal finishing alters the surface of metal products to enhance:

- Corrosion resistance
- Wear resistance
- Electrical conductivity/resistance
- Solderability
- Cosmetic appearance
- Chemical resistance
- Hardness
- Etc.

Metal finishers use a variety of materials and processes to clean, etch, and plate metallic and non-metallic surfaces to create a part that has the desired surface characteristics. Electrolytic plating, electroless plating, and chemical and electrochemical conversion processes are typically used in the industry.

Common Metal Finishing Processes

Metal finishing comprises a broad range of processes that are practiced by most industries which manufacture metal parts. Typically, manufacturers perform the finishing after a metal part has been formed. Finishing can be any operation that alters the surface of a part to achieve a certain property. Common metal finishes include paint, lacquer, ceramic coatings, and other surface treatments. This manual mainly addresses the plating and surface treatment processes.

The metal finishing industry generally categorizes plating operations as electroplating and electroless plating. Surface treatments consist of chemical and electrochemical conversion, case hardening, metallic coating, and chemical coating. The following sections briefly describe the major plating and surface treatment processes in order to provide a context for the more in-depth information in the chapters that follow.

Electroplating

Electroplating is achieved by passing an electric current through a solution containing dissolved metal ions and the metal object to be plated. The metal object serves as the cathode in an electrochemical cell, attracting ions from the solution. Ferrous and non-ferrous metal objects are plated with a variety of metals including aluminum, brass, bronze, cadmium, copper, chromium, gold, iron, lead, nickel, platinum, silver, tin, and zinc. The process is regulated by controlling a variety of parameters including voltage and amperage, temperature, residence times, and purity of bath solutions. Plating baths are almost always aqueous solutions, therefore, only those metals that can be reduced in aqueous solutions of their salts can be electrodeposited. The only major exception to this principle is aluminum, which can be plated from organic electrolytes

Plating operations are typically batch operations in which metal objects are dipped into a series of baths containing various reagents for achieving the required surface characteristics. Operators can either carry the parts on racks or in barrels. Operators mount parts on racks that carry the part from bath to bath. Barrels rotate in the plating solution and hold smaller parts

The sequence of unit operations in an electroplating process is similar in both rack and barrel plating operations. A typical plating sequence involves various phases of cleaning, rinsing, stripping, and plating. Electroless plating uses similar steps but involves the deposition of metal on metallic or non-metallic surfaces without the use of external electrical energy

Electroless Plating and Immersion Plating

Electroless plating is the chemical deposition of a metal coating onto an object using chemical reactions rather than electricity. The basic ingredients in an electroless plating solution are a source metal (usually a salt), a reducer, a complexing agent to hold the metal in solution, and various buffers and other chemicals designed to maintain bath stability and increase bath life. Copper and nickel electroless plating commonly are used for printed circuit boards (Freeman 1995).

Immersion plating is a similar process in that it uses a chemical reaction to apply the coating. However, the difference is that the reaction is caused by the metal substrate rather than by mixing two chemicals into the plating bath. This process produces a thin metal deposit by chemical displacement, commonly zinc or silver. Immersion plating baths are usually formulations of metal salts, alkalis, and complexing agents (e.g., lactic, glycolic, or malic acids salts). Electroless plating and immersion plating commonly generate more waste than other plating techniques, but individual facilities vary significantly in efficiency (Freeman 1995).

Chemical and Electrochemical Conversion

Chemical and electrical conversion treatments deposit a protective and/or decorative coating on a metal surface. Chemical and electrochemical conversion processes include phosphating, chromating, anodizing, passivation, and metal coloring. Phosphating prepares the surface for further treatment. In some instances, this process precedes painting. Chromating uses hexavalent chromium in a certain pH range to deposit a protective film on metal surfaces. Anodizing is an immersion process in which the part is placed in a solution (usually containing metal salts or acids) where a reaction occurs to form an insoluble metal oxide. The reaction continues and forms a thin, non-porous layer that provides good corrosion resistance. Sometimes this process is used as a pretreatment for painting. Passivating also involves the immersion of the part into an acid solution, usually nitric acid or nitric acid with sodium dichromate. The passivating process is used to prevent corrosion and extend the life of the product. Metal coloring involves chemically treating the part to impart a decorative finish

Metallic Coatings (Vapor Deposition)

Metallic coatings change the surface properties of the part from those of the substrate to that of the metal being applied. This process allows the part to become a composite material with properties that generally cannot be achieved by either material alone. The coating's function is usually as a durable, corrosion-resistant protective layer, while the core material provides a load-bearing function. Common coating materials include aluminum, coated lead, tin, zinc, and combinations of these metals.

Other Surface Finishing Technologies

Other commonly used finishing technologies that do not fall into the plating or chemical and electrochemical conversion processes include cladding, case hardening, dip/galvanizing, and electro-polishing.

Common Applications Performance

The accuracy of specified range is typically with in 1uin or +/- 5%, whichever is greater for the top layer; 3uin or +/- 10%, whichever is greater for the second layer; 5uin or +/- 15%, whichever is greater for the third layer. The data below is with 12mil collimator with 30 second total analysis time.

Au coating

- **Typical Elemental Layer Structures**

Table1. Applications

Top layer	Middle layer	Substrate
Au	Ni, NiP, PdNi, PdCo, Pd, Ag	Cu alloys, Copper PCB, , Stainless Steel, Ceramic, etc.

- **Precision**

Table2. Au/Ni/Cu

Element	Tested Range [µm]	2σ Precision [µm]
Au	0.025-1.7	0.005 @ 0.10
Ni	0.025-15	0.05 @ 3.90

Table3. Au/Pd/Ni/Cu

Element	Tested Range [µm]	2σ Precision [µm]
Au	0.025-2	0.006 @ 0.24
Pd	0.25-2	0.012 @ 0.11
Ni	1-10	0.059 @ 3.76

Ag coating

- **Typical Elemental Layer Structures**

Table4. Applications

Top layer	Middle layer	Substrate
Ag, AgPd	Ni, NiP	Cu alloys, Copper PCB, , Stainless Steel, Ceramic, etc.

- **Precision**

Table5. Ag/Cu

Element	Tested Range [µm]	2σ Precision [µm]
Ag	0.025~60	0.018@ 0.85 0.047@ 3.84

Table6. Ag/Ni/Cu

Element	Tested Range [µm]	2σ Precision [µm]
Ag	0.025~5	0.018 @ 0.85
Ni	2~16	0.14 @ 3.7 (underneath Ag @ 0.85),

Cr coating

- **Typical Elemental Layer Structures**

Table7. Applications

Top layer	Middle layer	Substrate
Cr	Ni, Cu	Al, Fe, Zn, Cu Alloys, Stainless Steels, W Alloys, Tool Steels

- **Precision**

Table8. Cr/Fe

Element	Tested Range [µm]	2σ Precision [µm]
Cr	0.025~20	0.06 @ 5.28

Table 9 Cr/Ni/Cu/Zn

Element	Tested Range [µm]	2σ Precision [µm]
Cr	0.25~1.0	0.007@ 0.4
Ni	2~18	0.18@ 9.15
Cu	5~15	0.92 @ 12.9

Ni coating

- **Typical Elemental Layer Structures**

Table10. Applications

Top layer	Middle layer	Substrate
Ni, NiP, NiFe, NiV, NiCo, NiW	Cu, Mo, MoMn, Ag	Al, Ti, Fe, Zn, Cu Alloys, Ni Alloys, Stainless Steels, Copper PCB, PZT, WCo, Kovar, etc.

- **Precision**

Table11. Ni/Fe

Element	Tested Range [μm]	2σ Precision [μm]
Ni	0.025~38	0.11 @ 10

Table12. Ni/Cu/Zn

Element	Tested Range [μm]	2σ Precision [μm]
Ni	1~8	0.07 @ 4.2
Cu	2~10	0.08 @ 5 (underneath 4um Ni)

Zn coating

- **Typical Elemental Layer Structures**

Table13. Applications

Top layer	Middle layer	Substrate
Zn, ZnNi, ZnFe, ZnCo, ZnAl	Ni, Cu, NiP, Sn, SnZn,	Al, Cu Alloys, Fe, Ni Alloys, Stainless Steels

- **Precision**

Table14. Zn/Fe

Element	Tested Range [μm]	2σ Precision [μm]
Zn	0.025~25	0.04 @ 4 0.14 @ 11.5

Table15. ZnNi/Fe

Element	Tested Range [μm]	2σ Precision [μm]
ZnNi	0.025~18 μm, 8~12 wt% Ni	0.09 @ 12 μm, 0.08 @ 10.6 wt% Ni

Ti coating

- **Typical Elemental Layer Structures**

Table16. Applications

Top layer	Substrate
Ti, TiC, TiCN, TiN, TiAlN	Al, Fe, W Alloys, Tool Steels, Ni Alloys, Stainless Steels

- **Precision**

Table17. Ti/W

Element	Tested Range [µm]	2σ Precision [µm]
Ti	0.025~12	0.04 @ 5.3

Sn coating

- **Typical Elemental Layer Structures**

Tabl18. Applications

Top layer	Middle layer	Substrate
Sn, SnBi, SnAg, SnCu, SnNi, SnCo, SnZn	Ni, NiP, Cu, Zn, MoMn	Al, Fe, Zn, Ni, Cu Alloys, CuPCB, Stainless Steels

- **Precision**

Table19. SnPb/Cu

Element	Tested Range [µm]	2σ Precision [µm]
SnPb	1~32 µm, 5~95 wt% Pb	0.08 @ 5.2 µm, 0.26 @ 90 wt% Sn

Table20. Sn/Ni/Cu

Element	Tested Range [µm]	2σ Precision [µm]
Sn	0.025~12	0.03 @ 1
Ni	1~8	0.07 @ 3.72

Table21. Sn/Cu

Element	Tested Range [µm]	2σ Precision [µm]
Sn	0.025~20	0.09 @ 4.8