Plating & Surface Coatings

Training Objective

After watching the program and reviewing this printed material, the viewer will become familiar with the various plating and surface coating methods used in industry.

- Basic plating and surface coating technology is explained
- The various methods are presented
- Specific applications are described
- High production methods are detailed

Plating & Surface Coating Processes

The use of plating and surface coatings to finish part surfaces is widespread in manufacturing. Applied as thin films, these coatings provide protection, durability, and/or decoration to part surfaces. The most common plating and surface coating technologies used include:

- Electroplating
- Electroless Plating
- Conversion Coating
- Hot Dipping
- Porcelain Enameling

Electroplating

Electroplating is a process by which a thin layer of metal is cathodically deposited on another metal, plastic, or other substrate material that is, or has been made electrically conductive. The process occurs in an electrolytic solution consisting of certain chemical compounds that make the solution highly conductive.

Direct current is used for Electroplating. The positively charged plating metal ions within the electrolytic solution are precipitated, or drawn out of the solution to coat the negatively charged conductive part surface. As the current flows, the metal ions in the solution gain electrons at the part surface and transform into a metal coating. The positively charged plating metal is referred to as the 'anode', while the part to be plated is called the 'cathode'.

This process, referred to as electrolysis, was explained in 1883 by Michael Faraday, and is known as Faraday's Law. In summary, Faraday's Law states that the amount of metal deposited by an electric current passing through a solution is directly related to the quantity of electricity that flows. Also, the amount of plating material deposited is directly related to the weight of that plating metal. This relationship determines plating time and current levels to deposit a coating of a given thickness.

Most metals can be electroplated, the easiest being iron, copper, nickel, zinc, silver, and gold. Other more difficult metals include stainless steel, aluminum, magnesium, and lead. Metals commonly used as plating material include nickel, copper, chromium and various precious metals such as gold and silver.

Electrolytic solutions will often contain additives used to brighten or enhance the uniformity of the plating metal and can also influence hardness and corrosion resistance.

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Electroless Plating

Electroless plating is also known as autocatalytic deposition. The plating metal, in an ionic state within a plating solution, is deposited onto a substrate surface that has been rendered catalytic by chemical reaction. When a layer of metal forms on the part surface, that layer, and subsequent layers, becomes the catalyst which results in a continuous chemical reaction adding more metal coating on the part.

The electroless plating solutions contain metal salts, reducers, complexing agents, PH adjusters, and stabilizers. These solution baths operate around 200°F or 90°C. Coating thickness depends upon immersion time.

The principle advantage of the electroless process is in its ability to create uniform coating thicknesses regardless of part geometry. The process also allows the plating of non- and semi-conductive surfaces, as well as conductive surfaces. As such, the process is often used to plate non-conductive parts with a conductive coating in preparation for electroplating operations. Electroless plating is a much slower process than the electroplating process.

The most common deposited metals are nickel and its alloys along with copper, cobalt and gold. Nickel plating provides for high wear and corrosion resistance.

Conversion Coating

Using conversion coatings processes, strongly adherent coating materials are formed on metal surfaces by chemical or electrochemical reactions between a solution and the ions formed by the metallic surface immersed in the solution. The most common chemical conversion coatings are:

- Phosphate coatings
- Chromate coatings
- Oxide coatings

Each of these coatings imparts specific surface qualities on the parts treated.

Phosphate coatings transform metal substrates into new surfaces that have non-metallic, non-conducting, water-insoluble properties.

Chromate coatings impart superior corrosion resistance and like phosphate coatings provide a bonding base for paints and lacquers. Chromate coatings are also moisture and abrasion resistant.

Oxide coatings, usually black, are applied to ferrous metal surfaces, and with some solution modification to non-ferrous surfaces as well. While black oxide coatings are used primarily for decorative purposes, they provide a good base for paint as well. Additionally, oxide coated parts are commonly post treated with sealing lubricants to aid in corrosion resistance and to improve lubricity.

The electrochemical method of conversion coating is also known as 'anodizing'. This term stems from the fact that the part to be coated is the 'anode' rather than the 'cathode' as in electroplating. Anodizing provides corrosion protection, and also increases abrasion resistance, decorative appeal, paint and adhesive adherence, and electrical insulation. Aluminum and magnesium are the most commonly anodized metals, but titanium, zinc, and zirconium can be anodized as well.

The most common anodizing electrolytic solutions are sulfuric acid based. The rate at which the process takes place is dependant on voltage, current density, type of solution, and solution temperature. Using sulfuric based solutions anodized coatings are generally transparent and extremely thin. Hard anodizing is done at higher levels of electric current and voltages, but with lower solution temperatures. These anodized coatings have greater resistance to corrosion and abrasion and are thicker than standard anodized coatings.

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Hot Dipping

The most common hot dipping process is galvanizing. Galvanizing involves immersing parts in a molten zinc bath which has a temperature of 835°F to 855°F or 445°C to 460°C. The molten zinc and the part substrate react chemically, resulting in a zinc-iron alloy coating having a almost pure zinc outer layer. Precleaning of the parts is particularly important, and includes caustic cleaning, pickling, and fluxing in sequential steps. Parts are immersed in the molten zinc until they reach the same temperature as the zinc bath.

Galvanizing can be applied to large or small fabricated or semi-fabricated parts, as well as to coil stock.

Porcelain Enameling

Porcelain enameling is widely used in industrial, household, and architectural applications, and is typically applied to steel, cast iron, and aluminum. Porcelain enameling is the deposition and fusion bonding of alkali borosilicate glass more commonly known as 'frit'. The process occurs at temperatures between 800°F to 1400°F, or 425°C to 760°C . As it melts, the frit bonds chemically to the metal substrate resulting in a unique coating that imparts high heat, corrosion, chemical, and electrical resistance. Porcelain enamel coatings with decorative colors can also be achieved.

The porcelain coatings consist mainly of the frit. Other materials such as clay, bentonite, electrolytes, and coloring oxides are also present. these coatings are commonly applied suspended in water, either by dipping or spraying. The coating may also be electrostatically applied as a dry powder. As with all coating methods, meticulous cleaning of the substrate is critical.

Once applied, water-borne porcelain coatings may be air dried or dried by radiant heat prior to firing in a furnace. Dry powder porcelain enameling coatings may be fired immediately.

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Review Questions

1. In electroplating the solution is:
a. non-conductive
b. conductive
c. autocatalytic
d. the cathode

2. The type of current used in electroplating is:
a. alternating
b. direct
c. oscillating
d. pulsating

3. The electroplating principle is explained using:
a. Ohm's Law
b. Dixon's Law of Physics
c. Faraday's Law
d. Moore's Law

4. Electroless plating in relation to electroplating:
a. is less expensive
b. produces less uniform coatings
c. is a slower process
d. is limited to non-conductive parts

5. Black oxide coatings are used primarily for:
a. electric resistance properties
b. decorative purposes
c. friction reducing properties
d. abrasion resistance

6. The conversion coating process known as anodizing is a:
a. non-electrical process
b. electrical process
c. chemical process
d. electrochemical process

7. Galvanizing occurs at:
a. 1000^{o}F to 1200^{o}F or 535^{o}C to 650^{o}C
b. 850^{o}F to 935^{o}F or 450^{o}C to 500^{o}C
c. 835^{o}F to 850^{o}F or 445^{o}C to 460^{o}C
d. 535^{o}F to 650^{o}F or 280^{o}C to 340^{o}C

8. Porcelain enameling occurs by:
a. magnetic attraction
b. fusion bonding
c. adhesive bonding
d. catalytic conversion

9. The main component of the porcelain coating is called:
a. enamel
b. the coloring oxide
c. clay
d. frit

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Answer Key

1. b
2. b
3. c
4. c
5. b
6. d
7. c
8. b
9. d