Lecture 9. Surface Treatment, Coating, Cleaning

These processes are sometimes referred to as post-processing. They play a very important role in the appearance, function and life of the product. Broadly, these are processes that affect either a thin layer on the surface of the part itself, or add a thin layer on top of the surface of the part. There are different coating and surface treatments processes, with different applications, uses, etc. The important uses include:

- Improving the hardness
- Improving the wear resistance
- Controlling friction, Reduction of adhesion, improving the lubrication, etc.
- Improving corrosion resistance
- Improving aesthetics

9.1. Mechanical hardening of the surface

These methods apply mechanical impulses (e.g. light hammering) on the surface of a metallic part. This hammering action causes tiny amount of plastic flow on the surface, resulting in the work-hardening of the surface layer due to the introduction of compressive residual stresses. Examples of these processes include ***Shot peening*** (uses tiny balls of metal or ceramic), ***Water-jet peening*** (uses a jet of water at high pressures, e.g. 400 MPa), or Laser peening (surface is hit by tiny impulses from a laser) – an expensive process used to improve fatigue strength of jet fan blades and turbine impellers.
Another method is explosive hardening, where a layer of explosive coated on the surface is blasted – the resulting impact results in tremendous increase in the surface hardness. This method is used to harden the surface of train rails.

9.2. Case hardening

This is a very common process that is used to harden the outer surface of parts such as gear teeth, cams, shafts, bearings, fasteners, pins, tools, molds, dies etc. In most of these types of components, the use involves dynamic forces, occasional impacts, and constant friction. Therefore the surface needs to be hard to prevent wear, but the bulk of the part should be tough (not brittle); this is achieved best by case hardening. There are several types of case hardening: in most cases, the chemical structure of the metal is changed by diffusing atoms of an alternate element which results in alterations to the micro-structure on the crystals on the surface.

The basic method is fairly simple: the metal parts are put in an oven, and heated with the atmosphere containing excess of a gaseous/liquid form of the “doping” substance. This causes the dopant to diffuse into the surface. The duration and temperature control the concentration and depth of the doping. Most of these processes are used to case harden steel and other iron alloys, including low carbon steels, alloy steels, tool steels etc.

Process	**Dopant**	**Procedure**	**Notes**	**Applications**
Carburizing	C	Low-carbon steel part in oven at 870-950°C with excess CO_2	0.5 ~ 1.5mm case gets to 65 HRC; poor dimension control	Gears, cams, shafts, bearings
CarboNitriding	C and N	Low-carbon steel part in oven at 800-900°C with excess CO_2 and NH_3	0.07~0.5mm case, up to 62 HRC, lower distortion	Nuts, bolts, gears
Cyaniding	C and N	Low-carbon steel part in bath of cyanide salts with 30% NaCN	0.025~0.25mm case, up to 65 HRC	nuts, bolts, gears, screws
Nitriding	N	Low-carbon steel part in oven at 500-600°C with excess NH_3	0.1~0.6mm case, up to 1100 HV	tools, gears, shafts
Boronizing	B	Part heated in oven with Boron containing gas	Very hard, wear resistant case, 0.025~0.075mm	Tool and die steels

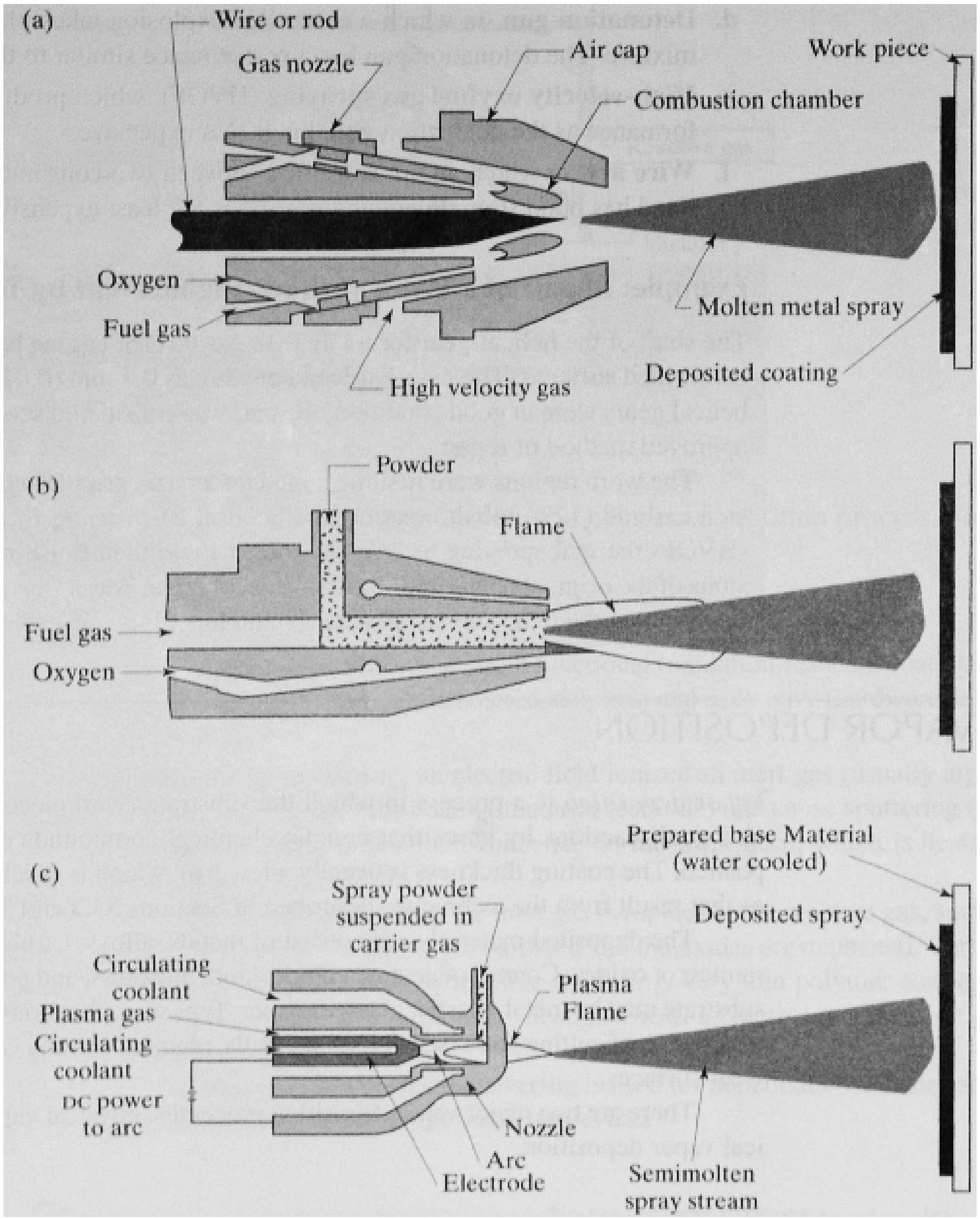
9.3. Thermal spraying

Metal is melted in a specially designed spray gun (using oxy-fuel, plasma, or other means to heat the sprayed metal till it melts). High pressure gas then sprays the liquid metal, depositing a layer on top the part similar to a painting process.

9.4. Vapor deposition

In these processes, the layer of deposited material is very thin – only a few microns. In the ***vacuum evaporation process***, the metal to be deposited is heated in an enclosed oven at high temperature and very low pressure; some of the metal vapor deposits as a thin layer on the part. The surface can be coated not only with metal, but also with some carbides, nitrides, or ceramics. Typical applications include surface coating of cutting tools, e.g. drills, reamers, punches, dies etc.

A very important coating process is ***Sputtering*** – it is important because of its extensive use in production of electronic chips. Here, an electric field ionizes an inert gas (e.g. Argon), and the ions are used to bombard the coating substance. Atoms of the coating material (on the cathode), when hit by the ions, are knocked out of the lattice, and later get deposited on the surface of the part by condensation. Aluminum sputtering is used to create most internal connections in VLSI chips in semiconductor manufacturing.



[source: Kalpakjian and Schmid]

Figure 1. Thermal spraying processes (a) thermal wire spray (b) Thermal metal powder spray (c) Plasma spray

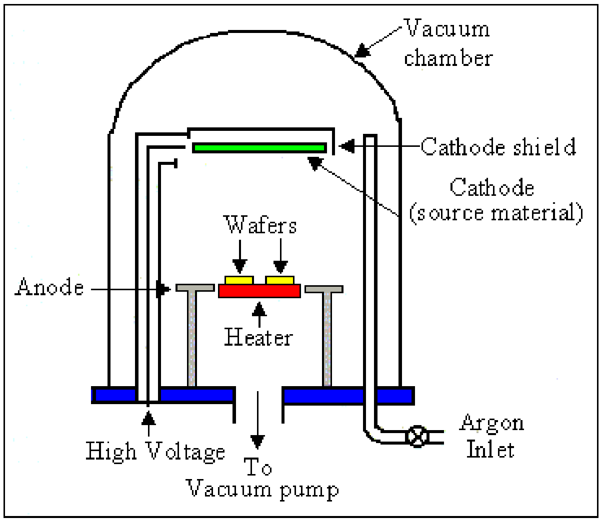


Figure 2. Sputtering processes [source: ece.utep.edu]

9.5. Electroplating

This is a process by which a thin layer of metal is deposited on the surface of an electrically conducting part. The part is used as a cathode, and the depositing material forms the anode. The electrodes are dipped in a solution of the appropriate salt, such that on application of voltage, the metal from the anode is dissolved into the solution, and deposited on the cathode. A simple example of this process is copper plating using $CuSO_4$ solution, using Copper anodes.

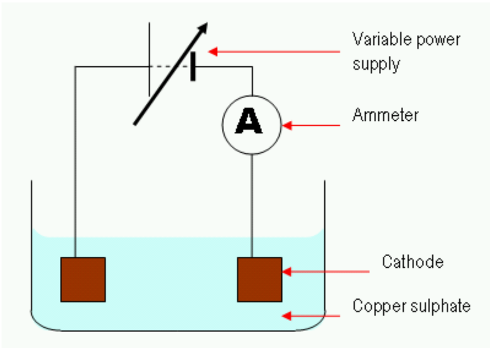


Figure 3. Copper plating

9.6. Electroless plating

In this case, the plating is achieved by a purely chemical reaction in the solution that causes the metal to be deposited. This process can be used to plate non-conducting parts with a layer of metal. The most common use of this process is deposition of Nickel –the reduction of Nickel chloride in solution by Sodium hypophosphite, which causes Ni metal to be deposited on the part. The deposited metal is not in crystalline form, so this process is followed by heat-treatment and quenching. Ni-coating using this method is used for making tool coatings that are quite hard (up to 1000 HV).

9.7. Anodizing

This is a very common process – many common Aluminum parts are surface treated by anodizing to give them a different color (usually black, red, blue, etc). The process uses the metal part as an anode; using electrolytic process, a layer of hard metal oxide is formed at the anode (i.e. on the surface of the part). Common examples include aluminum parts, such as picture frames, car-body parts, door-knobs and other building fixtures, bathroom fixtures and racks, sporting goods, e.g. baseball bats, and so on.

9.8. Painting

Of course, the most common surface treatment is painting. Examples of its functional value include: (i) car body paints are corrosion resistant; (ii) boats are painted with anti corrosion paint with (toxic) chemicals to avoid growth of barnacles, seaweed etc. Examples of aesthetic or decorative value are too numerous.

Paints are of three types:

(a) ***Enamel***: oil-based paints that produce a smooth surface and glossy appearance

(b) ***Lacquers***: these are resin based paints that dry to a thin coat after the solvent evaporates out. Common examples are varnish used in painting wood.

(c) ***Water-based paints***: common examples include several wall paints and home-interior paints.

The most common methods of paint application include:

(i) Dip coating: part is dipped into a container of paint, and pulled out.

(ii) Spray coating: one or more spray guns move along the surface of the part to give a uniform coat of paint; this is the method most commonly used in painting auto bodies, home appliances, e.g. fridge doors, etc.

(iii) Electrostatic spraying: Here the paint particles are given an electrostatic charge and the spray is achieved by applying a voltage difference across the paint particles and the part.

(iv) Silk-screening: this is the most common method of painting patterns, text, etc on top of most products. Tine holes are made in a thin (silk-like) sheet, corresponding to the pattern that needs to be painted. The screen is kept on top of the part in the correct position, and the paint is poured n top of the screen. A roller (or squeegee brush) is used to squeeze the paint out through the holes in the silk screen and onto the part. The screen is removed and the part is sent to dry in an oven. Silk screening has several very important uses:

1. It is used extensively in the textile industry to create colored patterns on textiles (e.g. logos on T-shirts).

2. It is used to paint almost all text and patterns on all electronics products – e.g. all numbers, text and symbols on your mobile phone!
3. It is used to deposit patterns of solder-paste on top of printed circuit boards. Lead-less electronic chips are placed on top of these patterns, and a process called wave-soldering then solders the chip to the circuit board. We will see this process in detail later.

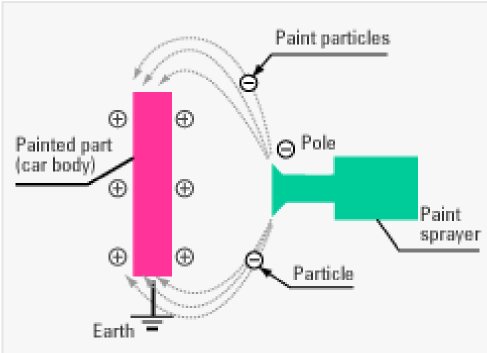


Figure 4. Schematic of an Electrostatic Spray Painting process

Figure 5. Automated spray painting of a car body in a BMW plant

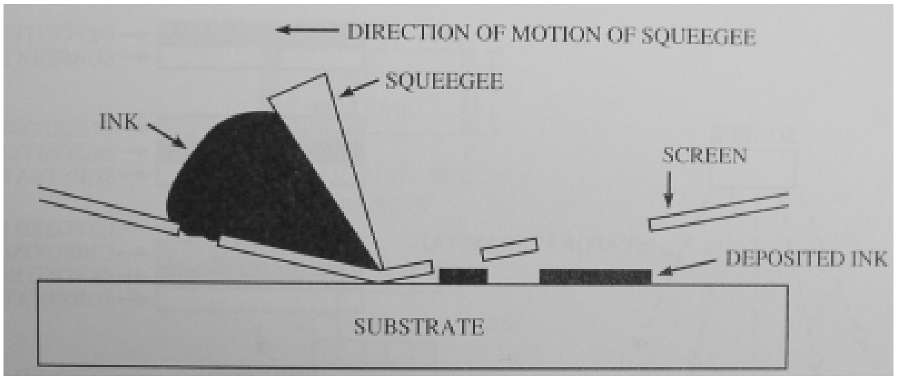


Figure 6. Schematic of Silk screening