Surface Engineering

(Surface and Coating technologies)

By

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Undergraduate studies

Fourth grade year

First lecture

- General introduction (preface)
- Why are we interested in surface technology?!
- What are we going to study?!
- What is our final goal?!
- What are we responsible for as material engineer candidates?
- What are the rules to be succeeded?
- Are we going to fulfill our motivation?!

Second lecture

- Coatings in general.
- Let us go step by step!
- What do you know about coatings?
- Did you go further?
- Let us state the arts.
- What is must to be known?
- Here we are!!!

Second lecture

- **SURFACE PREPARATION**

The quality of surface preparation, and surface repair on new, or repaint surfaces, significantly affects the amount of preparatory work that will be required for all subsequent repaints. Surface preparation and surface repair are the most important requirements for maximum durability from any paint system. Because the results of surface preparation and repair are quickly concealed by the first coat of paint, the effects are not usually evident until premature paint failure occurs.

The first step should always be a thorough examination of the surface to be painted, checking for peeling and faded paint, dirt, chalking, grease, cracking, knots, bare areas, mildew, rust, nail stains and structural problems. All surfaces, whether painted or unpainted, must be clean, free from shine, sound and dry prior to finishing.

Second lecture

- **General surface preparation**

LOOSE AND PEELING PAINT

Remove as much loose and peeling paint by scraping, wirebrush or power-washing the surface.

Feather-sand rough edges smooth until they blend with bare surface.

DIRT, GREASE, OIL, AND UNDER-EAVE DEPOSITS

Remove these deposits by washing with a detergent solution (TSP) or commercial cleaner recommended for cleaning painted surfaces using a sponge or brush. Protected areas, such as under eaves and overhangs, need special attention to remove invisible deposits that can promote a premature peeling problem. After washing, thoroughly rinse with clean water and allow to dry.

Second lecture

- **General surface preparation**

RUST

Remove all rust by sandblasting, wirebrush, steel wool, sandpaper or naval jelly (rinse thoroughly). See Iron, Steel and Ferrous Metal section for SSPC preparation methods.

CRACKS, SPLITS AND OPEN JOINTS

Cracks, or open joints, where water may enter should be caulked with a high-quality, pintable acrylic caulk. Apply primer over caulked area.

GLOSSY SURFACES

Always dull surfaces with sandpaper or liquid de-glosser. CAUTION - liquid de-glossers are generally not recommended on surfaces to be painted with water-based paints.

Second lecture

- **General surface preparation**

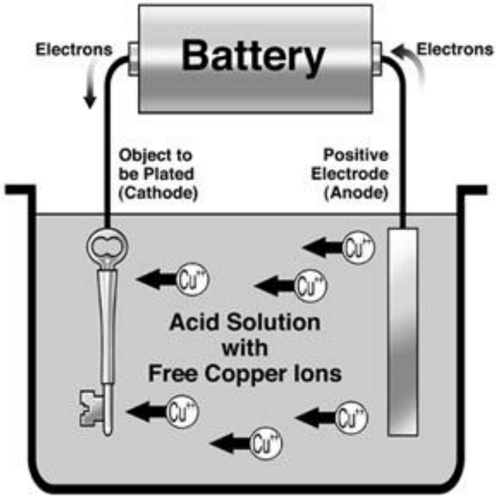
PREVIOUSLY COATED SURFACES

Maintenance painting will frequently not permit complete removal of all old coatings prior to repainting a particular surface. Recognize that any surface preparation, short of removal of all old coatings, may compromise the service life of the new coating system. Check compatibility of previously painted surfaces using a test patch with the coating if there is any doubt on recoatability.

Second lecture

- **Electroplating**

What is Electroplating?



Also knows as electrodeposition, electroplating is using a small sheet of metal in an electrocytic cell to coat another object. It is used to protect objects from damage against rusting and corrosion of metals.

The Chemistry behind electroplating is this: the item to be plated by the metal gets the negative charge and is put into a salt solution of the metal being used to plate the object. The metal being used to plate the item has a positive charge and is placed in the same solution. Therefore, the object to be plated is the cathode, and the metal being used to plate the item is the anode. Because of this, electroplating is a electrolytic cell since the electrons are flowing from positive to negative, where the metal to be plated is being reduced and the metal being used in the process is being oxidized. With the electrons flowing, it is just the law of attraction. The positive ions from the salt solution and the metal being used to plate "stick" onto the object being plated since it has a negative charge. The thickness of the metal plating depends on how long you leave it in the solution, and the flow of electrons.

Second lecture

- **The process:**

- The anode and cathode in the electroplating cell are both connected to an external supply of direct current — a battery or, more commonly, a rectifier. The anode is connected to the positive terminal of the supply, and the cathode (article to be plated) is connected to the negative terminal. When the external power supply is switched on, the metal at the anode is oxidized from the zero valence state to form cations with a positive charge. These cations associate with the anions in the solution. The cations are reduced at the cathode to deposit in the metallic, zero valence state. For example, in an acid solution, copper is oxidized at the anode to Cu2+ by losing two electrons. The Cu2+ associates with the anion SO42- in the solution to form copper sulfate. At the cathode, the Cu2+ is reduced to metallic copper by gaining two electrons. The result is the effective transfer of copper from the anode source to a plate covering the cathode.

- The plating is most commonly a single metallic element, not an alloy. However, some alloys can be electrodeposited, notably brass and solder.

- Many plating baths include cyanides of other metals (e.g., potassium cyanide) in addition to cyanides of the metal to be deposited. These free cyanides facilitate anode corrosion, help to maintain a constant metal ion level and contribute to conductivity. Additionally, non-metal chemicals such as carbonates and phosphates may be added to increase conductivity.

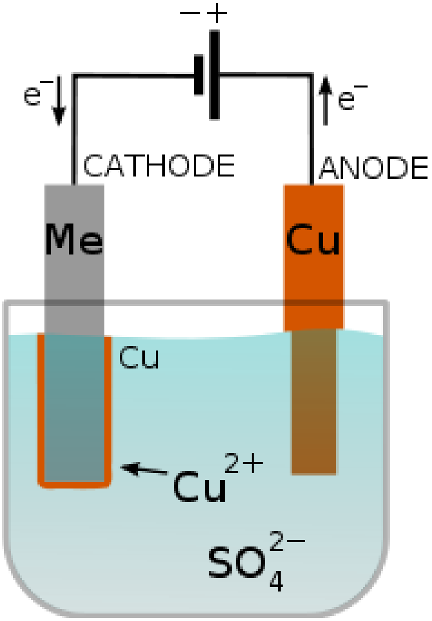
- When plating is not desired on certain areas of the substrate, stop-offs are applied to prevent the bath from coming in contact with the substrate. Typical stop-offs include tape, foil, lacquers, and waxes.

Second lecture

- **Strike**

Initially, a special plating deposit called a "strike" or "flash" may be used to form avery thin (typically less than 0.1 micrometer thick) plating with high quality and good adherence to the substrate. This serves as a foundation for subsequent plating processes. A strike uses a high current density and a bath with a low ion concentration. The process is slow, so more efficient plating processes are used once the desired strike thickness is obtained.

The striking method is also used in combination with the plating of different metals. If it is desirable to plate one type of deposit onto a metal to improve corrosion resistance but this metal has inherently poor adhesion to the substrate, a strike can be first deposited that is compatible with both. One example of this situation is the poor adhesion of electrolytic nickel on zinc alloys, in which case a copper strike is used, which has good adherence to both.



Second lecture

- **Brush electroplating**

A closely related process is brush electroplating, in which localized areas or entire items are plated using a brush saturated with plating solution. The brush, typically a stainless steel body wrapped with a cloth material that both holds the plating solution and prevents direct contact with the item being plated, is connected to the positive side of a low voltage direct-current power source, and the item to be plated connected to the negative. The operator dips the brush in plating solution then applies it to the item, moving the brush continually to get an even distribution of the plating material. Brush electroplating has several advantages over tank plating, including portability, ability to plate items that for some reason cannot be tank plated (one application was the plating of portions of very large decorative support columns in a building restoration), low or no masking requirements, and comparatively low plating solution volume requirements. Disadvantages compared to tank plating can include greater operator involvement (tank plating can frequently be done with minimal attention), and inability to achieve as great a plate thickness.

Second lecture

- **Electroless deposition**

Usually an electrolytic cell (consisting of two electrodes, electrolyte, and external source of current) is used for electrodeposition. In contrast, an electroless deposition process uses only one electrode and no external source of electric current. However, the solution for the electroless process needs to contain a reducing agent so that the electrode reaction has the form:

$$M^{z+} + Red_{solution} \overset{\text{catalytic surface}}{\Longrightarrow} M_{solid} + Oxy_{solution}$$

In principle any water-based reducer can be used although the redox potential of the reducer half-cell must be high enough to overcome the energy barriers inherent in liquid chemistry. Electroless nickel plating uses hypophosphite as the reducer while plating of other metals like silver, gold and copper typically use low molecular weight aldehydes.

A major benefit of this approach over electroplating is that power sources and plating baths are not needed, reducing the cost of production. The technique can also plate diverse shapes and types of surface. The downside is that the plating process is usually slower and cannot create such thick plates of metal. As a consequence of these characteristics, electroless deposition is quite common in the decorative arts.

Second lecture

- **Benefits and hazards**

Electroplating has so many real-world applications that it is invaluable to modern society. Sometimes, it is impractical or impossible to manufacture a product out of a metal with certain properties. With electroplating, however, one is able to coat the surface of an object with a rare or otherwise impractical metal in order to bestow the properties of that metal onto said object. Tin is used to coat cans in order to prevent corrosion, while a chromium coating will increase a metal’s resistance to wear. Similarly, silver and gold are used to coat silverware and jewelry to prevent corrosion and increase value. Another application of electroplating is the thickening of an object.

However, although this process is very useful, it can also be dangerous. In the real world, electroplating is done in a large scale, and so a large amount of waste is produced. The resulting waste is called wastewater in the industry, and must be treated before it is suitable for the sewage system. The wastewater is very corrosive, and contains very toxic heavy metals. Therefore, dispensing it untreated into water sources would harm wildlife and potentially contaminate drinking water. Treating the wastewater, however, must also be done with much care due to its toxicity and corrosiveness. Proper procedure must be followed or else the industrial chemist responsible for this treatment could undergo chemical burns or poisoning.

Second lecture

- **Effects**

Electroplating changes the chemical, physical, and mechanical properties of the workpiece. An example of a chemical change is when nickel plating improves corrosion resistance. An example of a physical change is a change in the outward appearance. An example of a mechanical change is a change in tensile strength or surface hardness which is a required attribute in tooling industry.

- **Cleanliness**

Cleanliness is essential to successful electroplating, since molecular layers of oil can prevent adhesion of the coating. ASTM B322 is a standard guide for cleaning metals prior to electroplating. Cleaning processes include solvent cleaning, hot alkaline detergent cleaning, electro-cleaning, and acid treatment etc. The most common industrial test for cleanliness is the waterbreak test, in which the surface is thoroughly rinsed and held vertical. Hydrophobic contaminants such as oils cause the water to bead and break up, allowing the water to drain rapidly. Perfectly clean metal surfaces are hydrophilic and will retain an unbroken sheet of water that does not bead up or drain off. ASTM F22 describes a version of this test. This test does not detect hydrophilic contaminants, but the electroplating process can displace these easily since the solutions are water-based. Surfactants such as soap reduce the sensitivity of the test and must be thoroughly rinsed off.

3^{rd} lecture

Anodizing Process

Background

- Anodizing process first used in industry in 1923 to protect Duralumin seaplane parts from corrosion using chromic acid.
- Aluminum is most widely anodized metal
- Magnesium, Titanium, and Zinc are capable of being anodized but not used to a wide extent
- Other metals such as tin and copper can be anodized, but rarely practiced

Basic Concept

- Creates or thickens an oxide layer on surface of metal.
- Allows electrical insulation of the given metal.
- Creates opportunity of various decorative effects: dyeing, brightening, preservation of surface texture.
- Increases hardness of the metal, improves corrosion and wear resistance.

3rd lecture

- **Anodizing**

- Is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts.
- The process is called "anodizing" because the part to be treated forms the anode electrode of an electrical circuit.
- Anodizing increases corrosion resistance and wear resistance, and provides better adhesion for paint primers and glues than bare metal.
- Anodic films can also be used for a number of cosmetic effects, either with thick porous coatings that can absorb dyes or with thin transparent coatings that add interference effects to reflected light.
- Anodic films are most commonly applied to protect aluminium alloys, although processes also exist for titanium, zinc, magnesium, niobium, and tantalum.
- This process is not a useful treatment for iron or carbon steel because these metals exfoliate when oxidized; i.e. the iron oxide (also known as rust) flakes off, constantly exposing the underlying metal to corrosion.

3rd lecture

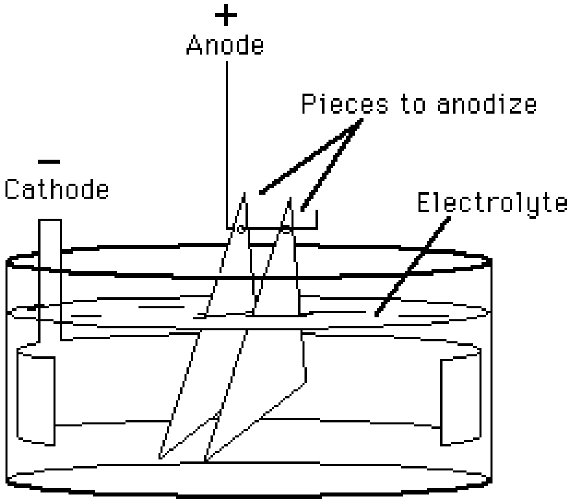
- Anodizg changes the microscopic of the surface and changes the crystal structure of the metal near the surface.
- Anodized aluminum surfaces are harder than aluminum but have low to moderate wear resistance that can be improved with increasing thickness.
- Anodic films are much stronger and more adherent than most types of paint and metal plating, but also more brittle.
- This makes them less likely to crack and peel from aging and wear, but more susceptible to cracking from thermal stress.

In General

The coating thickness and surface characteristics are tightly controlled to meet end product specifications. Aluminum oxide is an extremely hard material that approaches the hardness of a diamond. As a result, the aluminum oxide layer provides excellent wear and corrosion protection

3rd lecture

These inexpensive decorative carabiners have an anodized aluminum surface that has been dyed and are made in many colors



Bath anodizing

Process

3rd lecture

Preceding the anodization process, wrought alloys are cleaned in either a hot soak cleaner or in a solvent bath and may be etched in sodium hydroxide (normally with added sodium gluconate), ammonium bifluoride or brightened in a mix of acids. Cast alloys are normally best just cleaned due to the presence of intermetallic substances unless they are a high purity alloy such as LM0.

The anodized aluminium layer is grown by passing a direct current through an electrolytic solution, with the aluminium object serving as the anode (the positive electrode). The current releases hydrogen at the cathode (the negative electrode) and oxygen at the surface of the aluminium anode, creating a build-up of aluminium oxide. Alternating current and pulsed current is also possible but rarely used. The voltage required by various solutions may range from 1 to 300 V DC, although most fall in the range of 15 to 21 V. Higher voltages are typically required for thicker coatings formed in sulfuric and organic acid. The anodizing current varies with the area of aluminium being anodized, and typically ranges from 30 to 300 amperes/meter^2 (2.8 to 28 ampere/ft^2).

Aluminium anodizing is usually performed in an acid solution which slowly dissolves the aluminium oxide. The acid action is balanced with the oxidation rate to form a coating with nanopores, 10-150 nm in diameter. These pores are what allow the electrolyte solution and current to reach the aluminium substrate and continue growing the coating to greater thickness beyond what is produced by autopassivation. However, these same pores will later permit air or water to reach the substrate and initiate corrosion if not sealed. They are often filled with colored dyes and/or corrosion inhibitors before sealing. Because the dye is only superficial, the underlying oxide may continue to provide corrosion protection even if minor wear and scratches may break through the dyed layer.

Conditions such as electrolyte concentration, acidity, solution temperature, and current must be controlled to allow the formation of a consistent oxide layer. Harder, thicker films tend to be produced by more dilute solutions at lower temperatures with higher voltages and currents. The film thickness can range from under 0.5 micrometers for bright decorative work up to 150 micrometers for architectural applications.

3rd lecture

Bright Dip
Rinse
Rinse
Rinse
Rim Spray Rinse
Desmut
Barwash Rinse

Future Anodize
Anodize
Anodize
Rinse
Rim Spray Rinse

Rinse Transfer
Rinse Transfer

Rim Spray Rinse
Rinse
Rinse
Etch
Rim Spray Rinse
Rinse
Rinse
Acid Clean
Rim Spray Rinse
Rinse
Alkaline Clean

Electrocolor
D.I. Rinse
D.I. Rim Spray Rinse
Gold Dye
D.I. Rinse
D.I. Rim Spray Rinse
Seal
Seal
Seal
Future Seal

Load Area
Unload Area

- Process Variables:
  - Cycle Time
  - Voltage
  - Current Density
  - Electrolyte Chemistry
  - Electrolyte Concentration
  - Electrolyte Temperature

3rd lecture

Areas of Applications

- Entertainment Industry

- Military/Aerospace

- Commercial

3rd lecture

Anodizing equipments

- DC power source
- Racks or jigs to support work pieces
- Electrolytic solution:
  - Sulfuric
  - Chromic
  - Oxalic
  - Phosphoric

- Solution, water, dye, and sealing tanks

3rd lecture

General Questions

Is anodizing environmentally friendly?

Yes, anodize does not entail the use of heavy metals nor does it produce toxic waste.

What substrates or base metals can be anodized?

The three substrates that can be anodized are aluminum, titanium, and magnesium. Steel or stainless steel cannot be anodized.

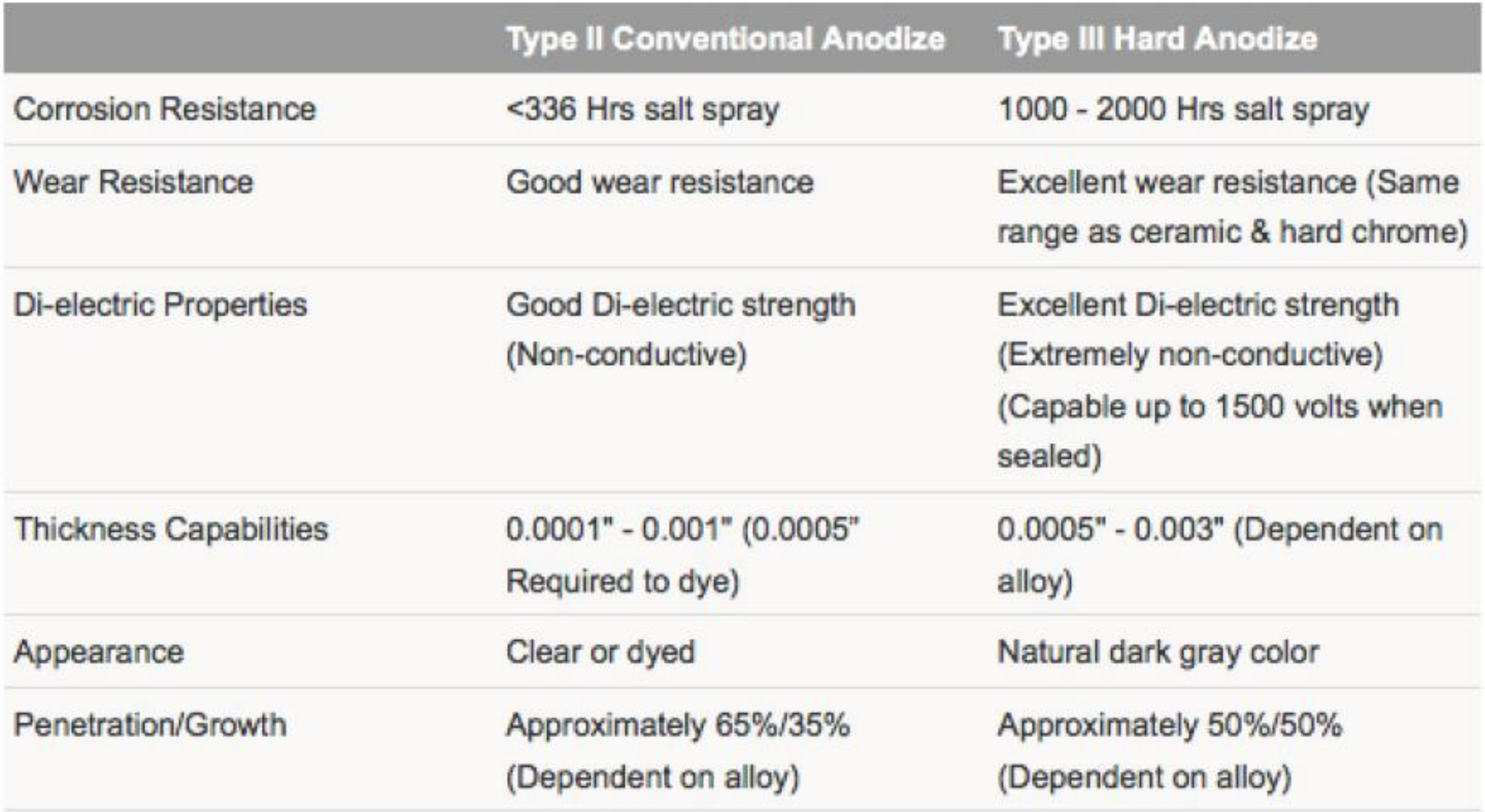
What alloys are best for anodizing?

In general, wrought alloy series 1000-7000 provide the best corrosion and aesthetic properties than cast alloy. Specific alloy choice to match performance needs should be discussed on a case-by-case basis. For more information on alloy series and their effects on the anodize process, please visit our Alloy Specs section of the Knowledge Base.

What is the difference between Type II “conventional anodize” and Type III “hard anodize”?

Type III or hard anodize offers a more dense aluminum oxide layer. To produce this requires increased electricity consumption and a super cooled electrolyte bath. Perhaps the best way to illustrate differences between type II “conventional anodize” and type III “hard anodize” is in the following chart. Notice the enhanced attributes of hard anodize versus conventional anodize.

3rd lecture



	Type II Conventional Anodize	Type III Hard Anodize
Corrosion Resistance	<336 Hrs salt spray	1000 - 2000 Hrs salt spray
Wear Resistance	Good wear resistance	Excellent wear resistance (Same range as ceramic & hard chrome)
Di-electric Properties	Good Di-electric strength (Non-conductive)	Excellent Di-electric strength (Extremely non-conductive) (Capable up to 1500 volts when sealed)
Thickness Capabilities	0.0001" - 0.001" (0.0005" Required to dye)	0.0005" - 0.003" (Dependent on alloy)
Appearance	Clear or dyed	Natural dark gray color
Penetration/Growth	Approximately 65%/35% (Dependent on alloy)	Approximately 50%/50% (Dependent on alloy)

3rd lecture

Will anodize affect the adhesion of paint or subsequent coatings?

Anodize will promote the adhesion of paint and subsequent coatings.

Will anodizing hide scratches?

Anodizing will provide minimal cover-up for surface scratches because anodize mimics original substrate finish. To further enhance anodize appearance consider aggressive etching, hand polishing, or surface blasting.

3rd lecture

Advantages

- Process is well suited for mass production
- Minimal impact on dimensional tolerances
- Durability and life of treatment
- Color stability
- Easy to maintain
- Aesthetically pleasing
- Cost
- Health and safety

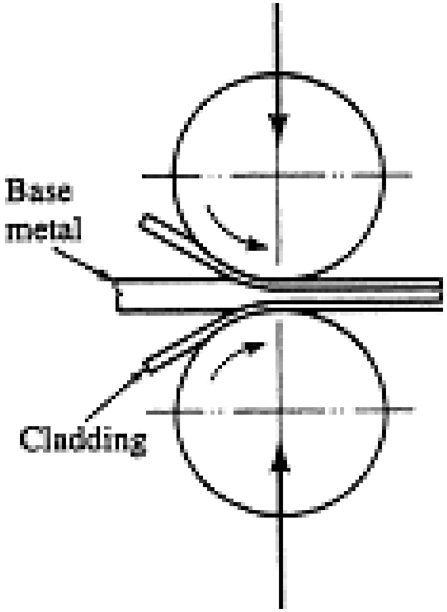
3rd lecture

Disadvantages

- Limited selection of metals can be anodized
- Bulk anodizing of small items can be difficult or impossible given certain processes
- Small gaps in coating are produced at points of contact with jigs or fixtures
- Oxidation layers need to be removed from jigs and fixtures after every use

4th lecture

Cladding



Cladding is the bonding together of dissimilar metals. It is different from fusion welding or gluing as a method to fasten the metals together. Cladding is often achieved by extruding two metals through a die as well as pressing or rolling sheets together under high pressure.

Cladding (Hints)

4th lecture

- Cladding is the bonding of metals with a thin heated layer of corrosion resistant or conductive metal, by applying pressure with rolls or other means.
- A typical process is Al-clad in which a corrosion resistant layer of Al-alloy is clad over Al. Another application is stainless steel clad over steel, reducing the need for using a full Cr- Ni- alloy base metal.
- Steel wires are clad with Cu using extrusion dies. Here, the surface layer imparts electrical conductivity, while the core provides strength and rigidity.
- Cladding may be performed on either one or both sides by pressing the sandwich together under high pressure, and a temperature approximately half of the melting point of the base metal for a suitable period of time, typically 1 hour.
- This combination of pressure, temperature, and time resulting in a condition at interface(s) is known as diffusion bonding. When sufficient transfer of atoms at the interface has occurred - hence the time factor is important - a strong and permanent bond will have been created. Providing adequate pressure and a sufficiently slow traverse speed are used, it is possible to diffusion bond clad strip as a continuous process.
- Surface preparation ensuring thorough cleaning and degreasing is vital for successful bonding.

4th lecture

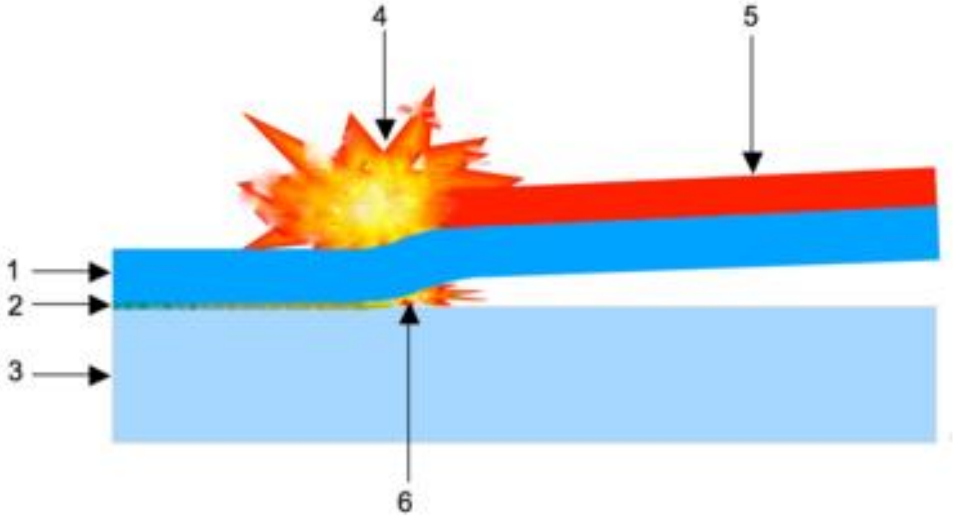
Roll welding

In roll welding, two or more layers of different metals are toughly cleaned and passed through a pair of rollers under sufficient pressure to bond the layers. The pressure is high enough to deform the metals and reduce the combined thickness of the clad material. Heat may be applied, but is not necessary if one of the metals is ductile. Bonding of the sheets can be controlled by painting a pattern on one sheet; only the bare metal surfaces bond, and the un-bonded portion can be inflated if the sheet is heated and the coating vaporizes. This is used to make heat exchangers for refrigeration equipment.

4th lecture

Explosive welding

In explosive welding, the pressure to bond the two layers is provided by detonation of a sheet of chemical explosive. No heat-affected zone is produced in the bond between metals. The explosion propagates across the sheet, which tends to expel impurities and oxides from between the sheets. Pieces up to 2 x 6 metres can be manufactured. The process is useful for cladding metal sheets with a corrosion-resistant layer.



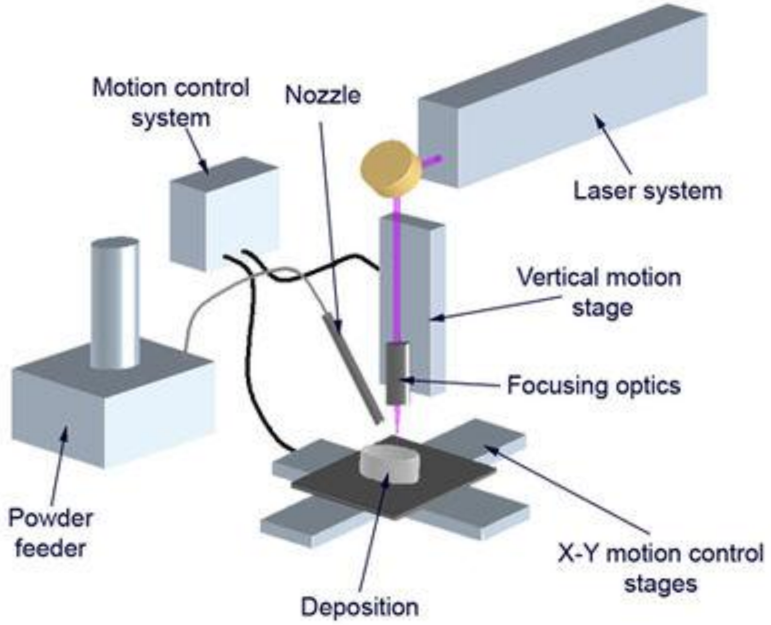
1 Flyer (cladding). 2 Resolidified zone (needs to be minimised for welding of dissimilar materials). 3 Target (substrate). 4 Explosion. 5 Explosive powder. 6 Plasma jet

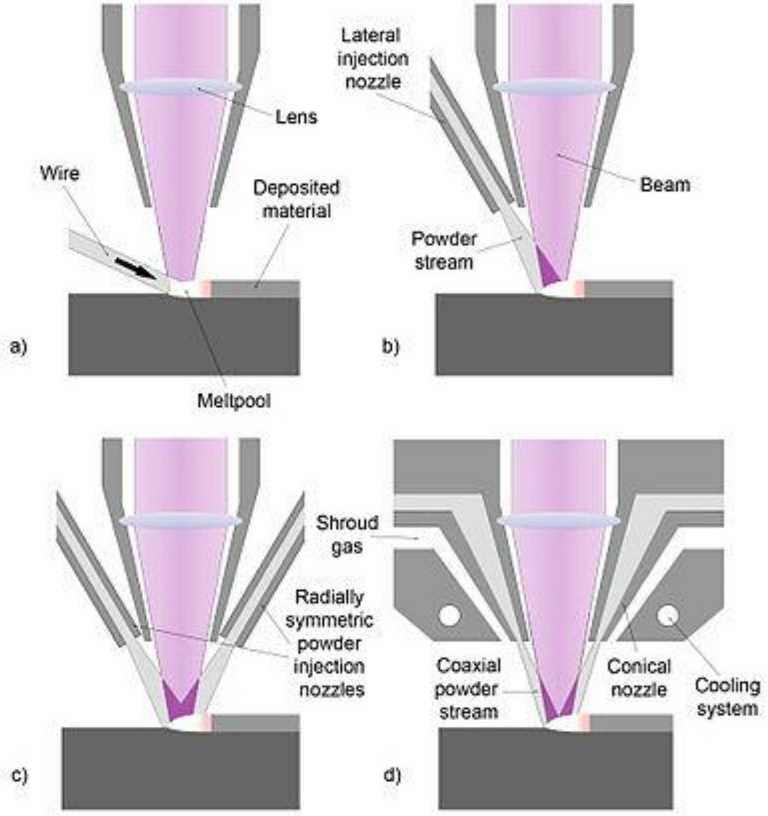
4th lecture

Laser cladding

Laser cladding is a method of depositing material by which a powdered or wire feedstock material is melted and consolidated by use of a laser in order to coat part of a substrate or fabricate a near-net shape part (additive manufacturing technology) .

It is often used to improve mechanical properties or increase corrosion resistance, repair worn out parts, and fabricate metal matrix composites





4th lecture

Process

The powder used in laser cladding is normally of a metallic nature, and is injected into the system by either coaxial or lateral nozzles. The interaction of the metallic powder stream and the laser causes melting to occur, and is known as the melt pool. This is deposited onto a substrate; moving the substrate allows the melt pool to solidify and thus produces a track of solid metal. This is the most common technique, however some processes involve moving the laser/nozzle assembly over a stationary substrate to produce solidified tracks. The motion of the substrate is guided by a CAD system which interpolates solid objects into a set of tracks, thus producing the desired part at the end of the trajectory.

The different feeding systems available

4th lecture

Process

A great deal of research is now being concentrated on developing automatic laser cladding machines. Many of the process parameters must be manually set, such as laser power, laser focal point, substrate velocity, powder injection rate, etc., and thus require the attention of a specialized technician to ensure proper results. However, many groups are focusing their attention on developing sensors to measure the process online. Such sensors monitor the clad's geometry (height and width of deposited track), metallurgical properties (such as the rate of solidification, and hence the final microstructure), and temperature information of both the immediate melt pool and its surrounding areas. With such sensors, control strategies are being designed such that constant observation from a technician is no longer required to produce a final product. Further research has been directed to forward processing where system parameters are developed around specific metallurgical properties for user defined applications (such as microstructure, internal stresses, delusion zone gradients, and clad contact angle).

4th lecture

Advantages

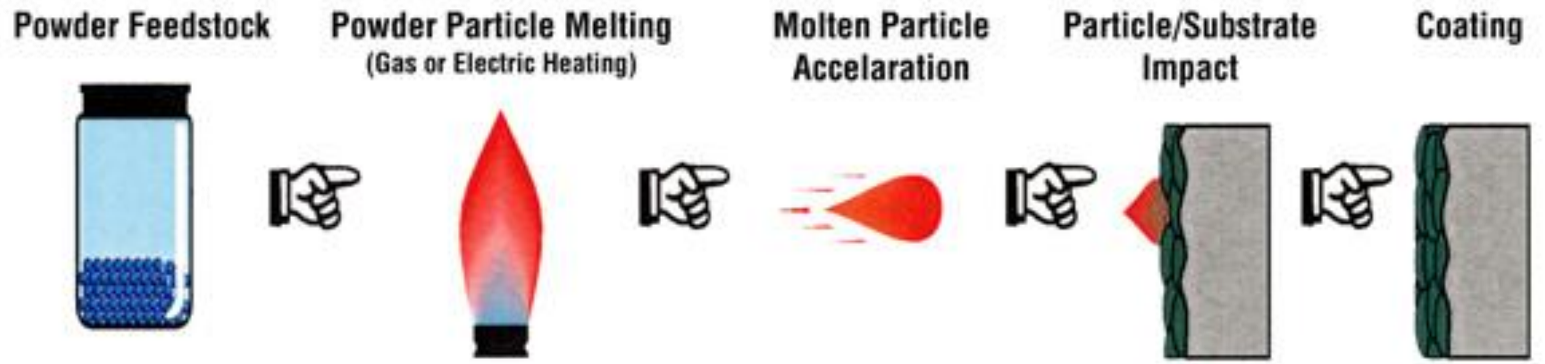
- Best technique for coating any shape => increase life-time of wearing part by 6-7 years.
- Particular dispositions for repairing parts (ideal if the mould of the part no longer exist or too long time needed for a new fabrication).
- Most suited technique for graded material application.
- Well adapted for near-net-shape manufacturing.
- Low dilution between track and substrate (unlike other welding processes and strong metallurgical bond.
- Low deformation of the substrate and small heat affected zone (HAZ).
- High cooling rate => fine microstructure.
- A lot of material flexibility (metal, ceramic, even polymer).
- Built part is free of crack and porosity.
- Compact technology.

5th lecture

Thermal spraying

What is Thermal spraying?

thermal spraying, a group of coating processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semimolten condition to form a coating. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials.



Thermal Spray Coating Process

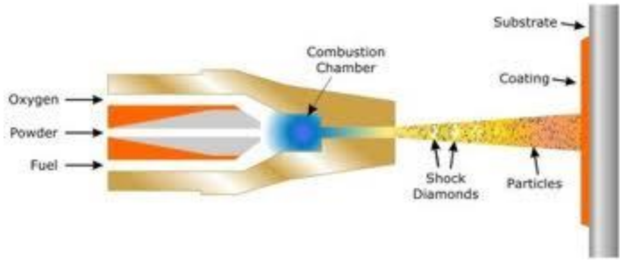
5th lecture

What is Thermal spraying?

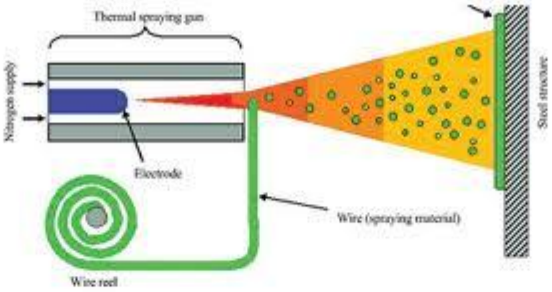
In addition to using chemical means to plasticize the in-put consumables electrical currents are also used. Typically, electrical energy is used to create a heat source into which powder, and more recently wires, are fed, melted/plasticized and conveyed onto the surface to be coated. Major, commercially employed electrical methods, used to construct coatings include non-transferred arc plasma, RF plasma, and wire arc. Based upon the two heat sources a "family tree" of thermal spray methods can be constructed as noted below.

5th lecture

Methods



- Molten Metal Flame Spray
- Ceramic Rod Flame Spraying
- Cold Spray
- Detonation Flame Spraying
- Electric Arc Spraying
- High Velocity Oxy/Fuel Spraying (HVOF)
- Nontransferred Plasma Arc Spraying
- Powder Flame Spray
- RF Plasma Spraying
- Wire Flame Spraying

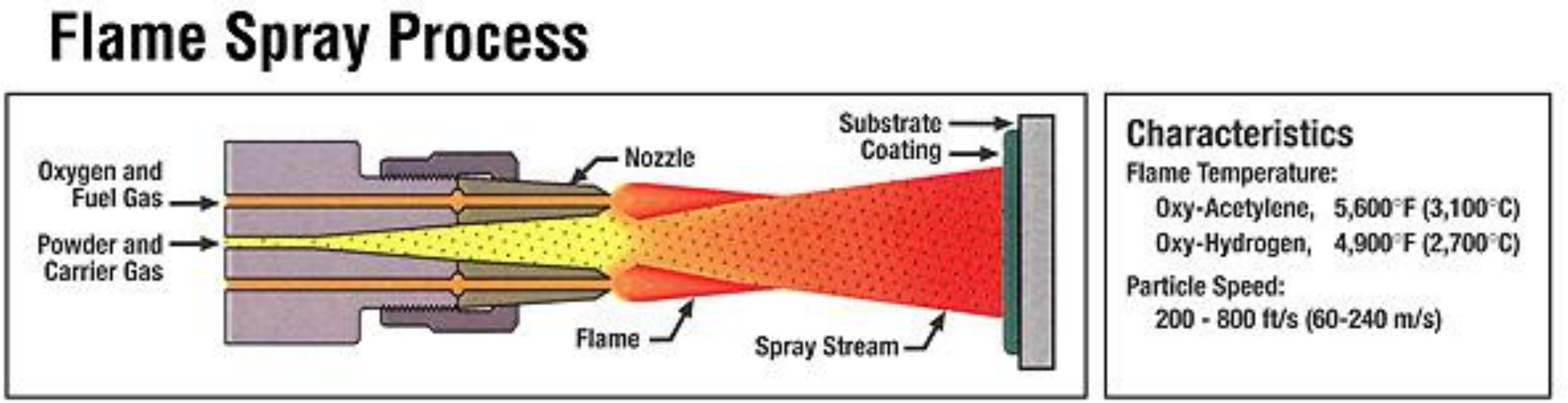


5th lecture

Methods

Molten Metal Flame Spray

molten metal flame spraying, a thermal spraying process variation in which the metallic material to be sprayed is in the molten condition.



Flame Spray Process

Characteristics

Flame Temperature:

Oxy-Acetylene, 5,600°F (3,100°C)

Oxy-Hydrogen, 4,900°F (2,700°C)

Particle Speed:

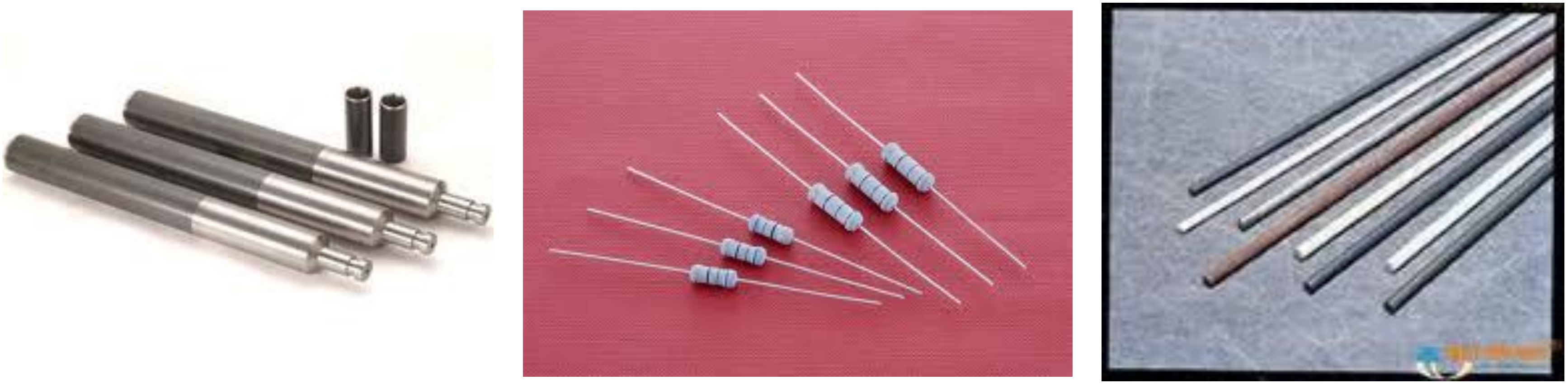
200 - 800 ft/s (60-240 m/s)

5th lecture

Methods

Ceramic Rod Flame Spraying

ceramic rod flame spraying, a spraying process in which material to be sprayed is in ceramic rod form.

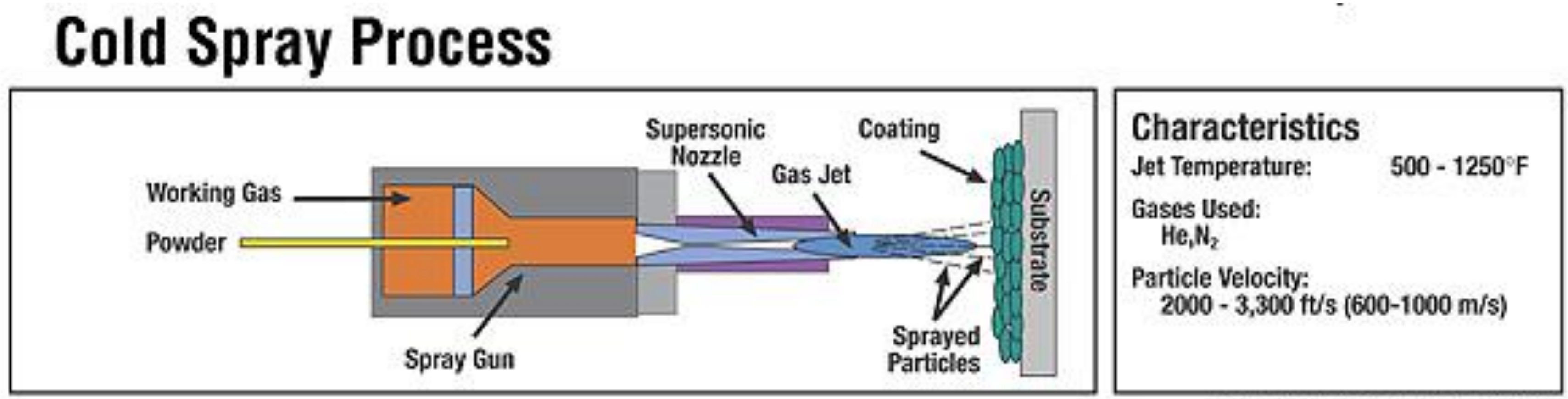


5th lecture

Methods

Cold spray

cold spray, a kinetic spray process utilizing supersonic jets of compressed gas to accelerate near-room temperature powder particles at ultra high velocities. The unmelted particles, traveling at speeds between 500 to 1,500 m/sec plastically deform and consolidate on impact with their substrate to create a coating.



Characteristics

Jet Temperature: 500 - 1250°F

Gases Used: He, N_2

Particle Velocity: 2000 - 3,300 ft/s (600-1000 m/s)

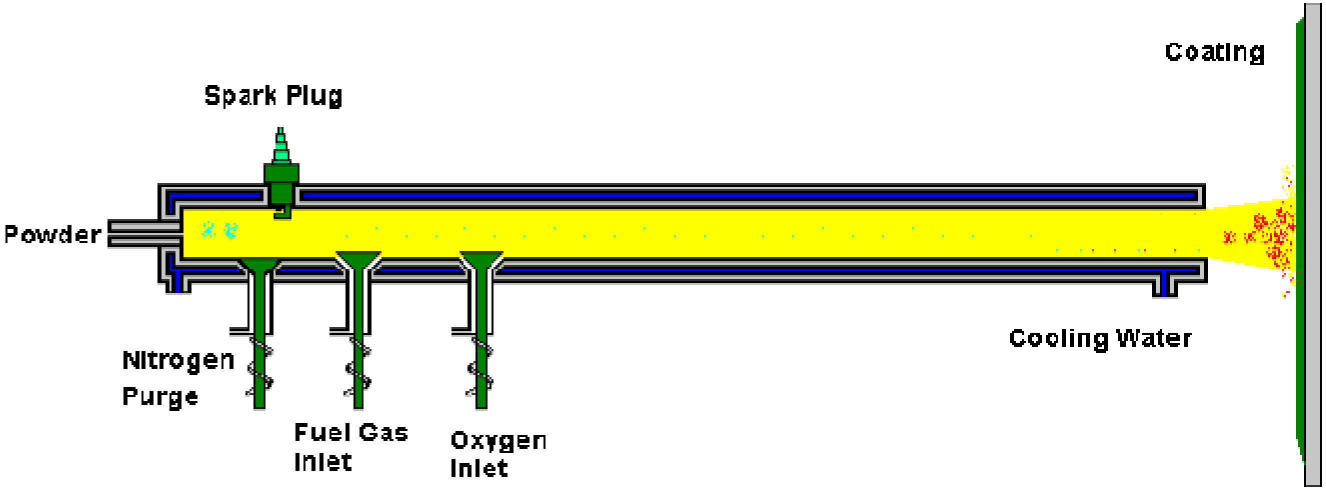
Photo Courtesy of ASB Industries

5th lecture

Methods

Detonation Thermal Spraying Process

The Detonation gun basically consists of a long water cooled barrel with inlet valves for gases and powder. Oxygen and fuel (acetylene most common) is fed into the barrel along with a charge of powder. A spark is used to ignite the gas mixture and the resulting detonation heats and accelerates the powder to supersonic velocity down the barrel. A pulse of nitrogen is used to purge the barrel after each detonation. This process is repeated many times a second. The high kinetic energy of the hot powder particles on impact with the substrate result in a build up of a very dense and strong coating.



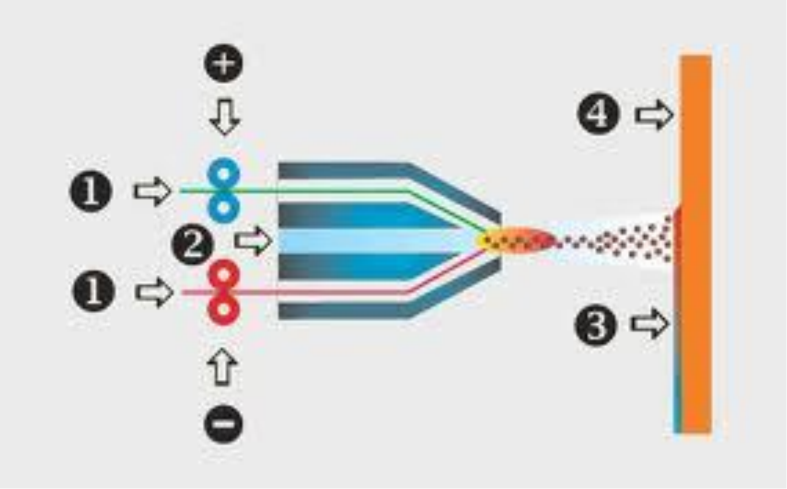
5th lecture

Methods

Electric Arc Spraying

electric arc spraying, a thermal spray process in which an arc is struck between two consumable electrodes of a coating material. Compressed gas is used to atomize and propel the material to the substrate. (1)

The electric arc spray process utilizes metal in wire form. This process differs from other thermal spray processes in that there are no external heat sources as in any the combustion gas/flame spray processes. Heating and melting occur when two electrically opposed charged wires, comprising the spray material, are fed together in such a manner that a controlled arc occurs at their intersection. The molten metal is atomized and propelled onto the prepared workpiece by jets of compressed air or gas.



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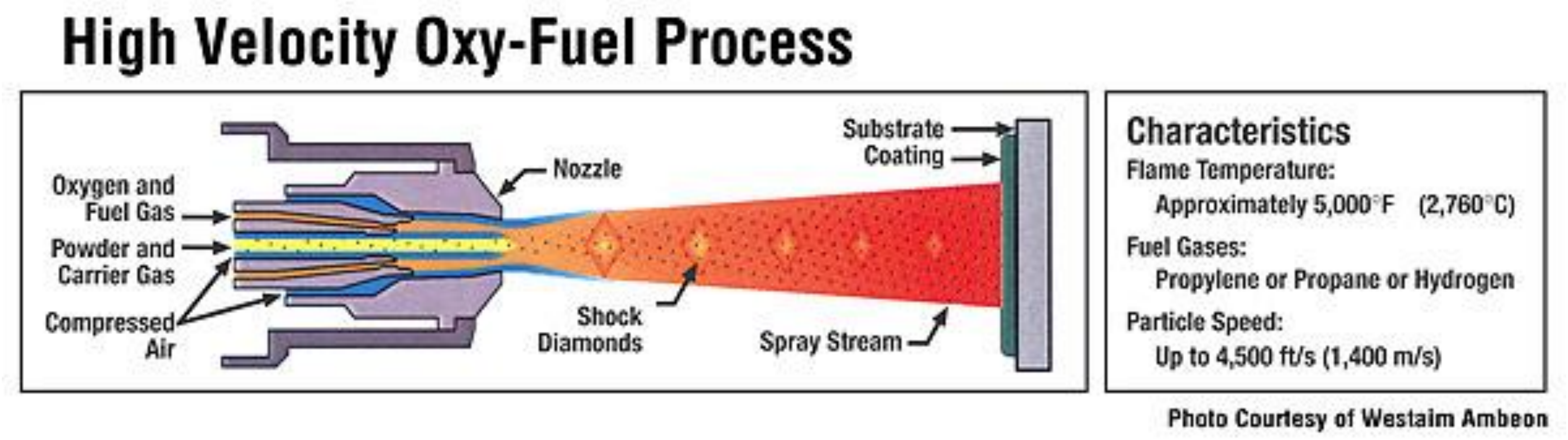
Methods

High Velocity Oxy/Fuel Spraying (HVOF)

The technique was referred to as High Velocity Oxy-Fuel (HVOF). The process utilizes a combination of oxygen with various fuel gases including hydrogen, propane, propylene, hydrogen and even kerosene. In the combustion chamber, burning by-products are expanded and expelled outward through an orifice where at very high velocities. Often times they produce "shock diamonds" exiting the spray gun as in the graphic below.



Characteristics

Flame Temperature:
Approximately 5,000°F (2,760°C)

Fuel Gases:
Propylene or Propane or Hydrogen

Particle Speed:
Up to 4,500 ft/s (1,400 m/s)

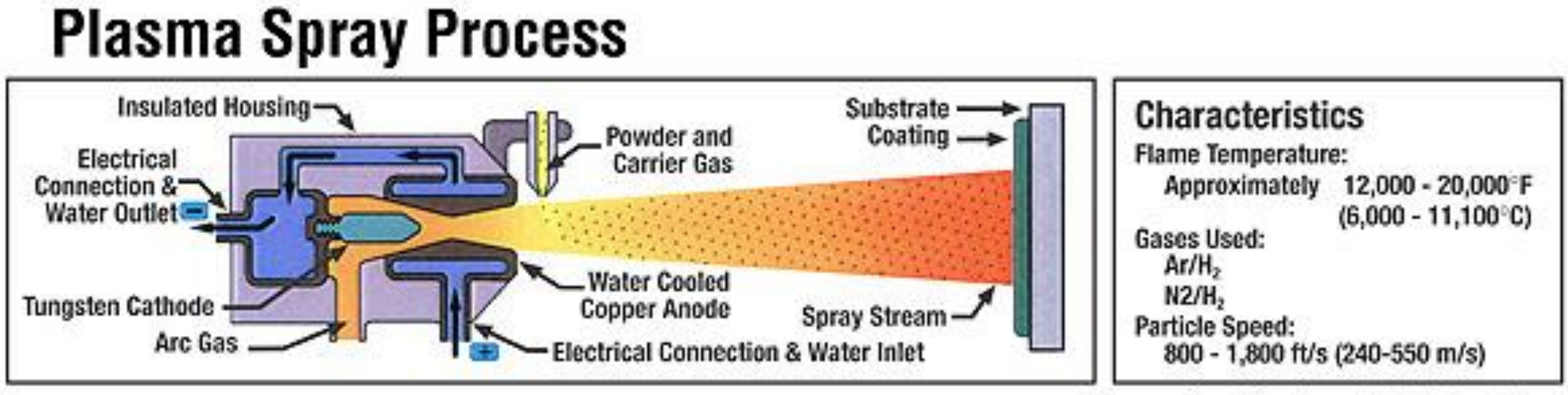
Photo Courtesy of Westaim Ambeon

5th lecture

Methods

Nontransferred Plasma Arc Spraying

plasma spraying, a thermal spray process in which a nontransterred arc is a source of heat that ionizes a gas which melts the coating material and propels it to the workpiece. Plasma is an ionized gaseous cloud composed of free electrons, positive ions, neutral atoms and molecules. Because of its unique properties some have referred to it as the "fourth state of matter". Plasma is generated whenever sufficient energy is imparted to a gas to cause some of it to ionize



Characteristics

Flame Temperature:
Approximately 12,000 - 20,000°F (6,000 - 11,100°C)

Gases Used:
Ar/H_2
$N2/H_2$

Particle Speed:
800 - 1,800 ft/s (240-550 m/s)

Photo Courtesy of Westaim Ambeon

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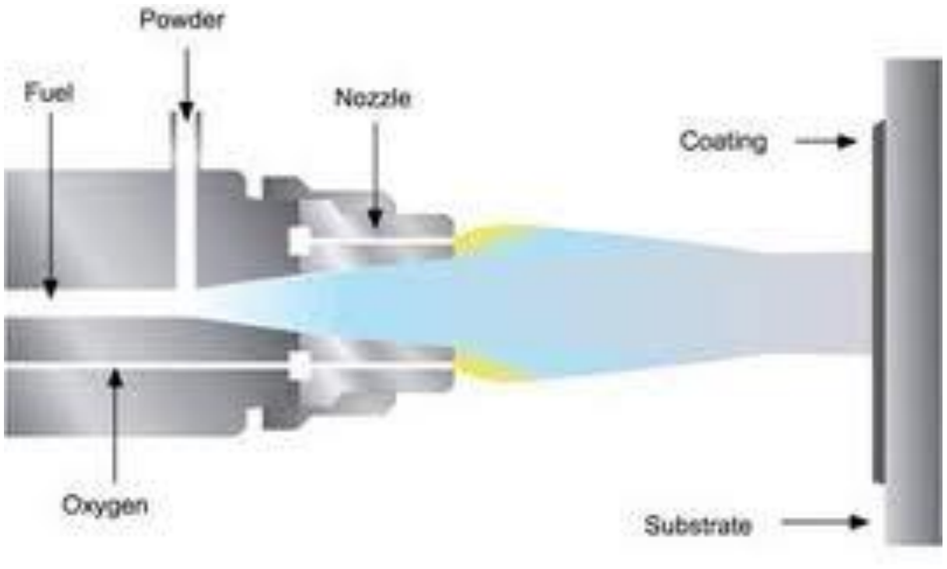
Methods

Powder Flame Spray

Powder flame spraying, a thermal spray process in which the material to be sprayed is in powder form.

Powder flame spraying is probably the simplest of all the spray processes to describe - feed a powder through the center bore of a nozzle where it melts and is carried by the escaping oxy-fuel gases to the work piece. Unfortunately, this approach yields coatings high in oxides and with void contents approaching 20 volume percent (v/o).



5th lecture

Methods

RF Plasma Spraying

RF plasma, a system in which the torch is a water-cooled, high frequency induction coil surrounding a gas stream. On ignition a conductive load is produced within the induction coil, which couples to the gas, ionizing it to produce a plasma.