Practical issues in pre-treatment and coating of Aluminum
Surface treatment of aluminum

- Anodizing

- The most effective and popular surface treatment on aluminum
Surface treatment of aluminum

Properties of anodizing layers

- Corrosion resistant
- Wear resistant
- Good adhesion
- Electrical isolation
- Thermal isolation

- No electrical conductivity
- Limited chemical resistance
- No thermal conductivity
- No ductility
- No solderability
Surface treatment of aluminum

Alternative metal coatings

- Chemical Nickel
- Nickel
- Silver
- Gold
- Copper
- Tin
- Chromium

The big advantage

Electrical conductivity and chemical resistance of the metal coatings

The big disadvantage

Electrode potential of aluminum against other metals and the adhesion of the metal coatings
Surface treatment of aluminum

Alternative electrolytic and electrochemical metal coatings

- Wear resistance
- Corrosion resistance
- Electrical conductivity
- Thermal conductivity
- Ductility
Surface treatment of aluminum

Chemical Nickel

- Main properties
  - High wear resistance
  - Good corrosion resistance wenn layer is pore free
  - Uniform layer thickness
  - Basecoating for other metals

- Advantages against anodizing
  - No electrostatic charging
  - Chemical resistant in alkaline environment

- Disadvantages against anodizing
  - Corrosion when layer is thin and porous
  - Adhesion of the layer
Surface treatment of aluminum

Chemical Nickel
Surface treatment of aluminum

Silver

- Main properties
  - High electric conductivity
  - Good chemical and oxidation resistance
  - Solderability

- Advantages against anodizing
  - Ductility
  - Chemical resistance in alkaline and acid environment
  - Lubricity

- Disadvantages against anodizing
  - Difference electrode potential between silver and aluminum
  - No wear resistance
  - Adhesion of the layer
Surface treatment of aluminum

Silver
Surface treatment of aluminum

Gold

- Main properties
  - low electrical contact resistance
  - Extremely good chemical and oxidation resistance
  - Solderability

- Advantages against anodizing
  - Chemical resistant in practically all environments
  - Reflection in laser and infra-red applications

- Disadvantages against anodizing
  - Difference electrode potential between gold and aluminum
  - No wear resistance
  - Adhesion of the layer
Surface treatment of aluminum

Gold
Surface treatment of aluminum

The anodized coating

- Anodized aluminum

- The anodized layer is formed out of the material itself
- In principle always a good adhesion of the coating
Surface treatment of aluminum

The plated metal coating

- Chemical nickel plated aluminum

- The chemical nickel layer is plated on the aluminum
- Adhesion of the coating is not always good
Surface treatment of aluminum

The principles of adhesion

Fig. 3. Schematische voorstelling van de metallische binding (element Na)

Atomic bonding in a metal
Surface treatment of aluminum

The bonding of a coating on a metal substrate

Good adhesion

Bad adhesion

Pre-treatment is necessary
Surface treatment of aluminum

Pre-treatment before anodizing

- Alkaline cleaning in Aluminium cleaner
- Rinsing
- Etching in alkaline Aluminium etch
- Rinsing
- Desmutting in oxidizing acid
- Rinsing

Anodizing

Plating
Surface treatment of aluminum

The reason of the bad adhesion on aluminum

Due to its low standard potential aluminum will always form a thin aluminum oxide layer in an oxygen containing environment.
Surface treatment of aluminum

The principle of plating aluminum

- Aluminum is covered with a zinc layer by ionic exchange
- Aluminum cannot form oxidelayer
- Zinc layer dissolves in the plating bath
- The metallayer is plated on the oxidefree aluminum

Good adhesion
Surface treatment of aluminum

Conventional Pre-Treatment before plating

- Alkaline cleaning in Aluminium cleaner
- Rinsing
- Etching in alkaline Aluminium etch
- Rinsing
- Desmutting in HNO₃\HF acid
- Rinsing
- Zincate treatment
- Rinsing

Anodizing

Plating
Surface treatment of aluminum

Optimized Pre-Treatment before plating

- Alkaline cleaning in Aluminium cleaner
- Rinsing
- Etching in alkaline Aluminium etch
- Rinsing
- Desmutting in HNO₃\ HF acid
- Rinsing
- Zincate treatment
- Rinsing
- Removal of zincate layer in HNO₃
- Rinsing
- Zincate treatment
- Rinsing
Surface treatment of aluminum

Details of the pre-treatment

- **Alkaline cleaning**
  - Removes oils and grease

- **Alkaline etching**
  - Removes the aluminium oxide
  - Removes the outside surface of the aluminum which contains contamination
  - Does not remove the metal alloy elements and the silicon particles
  - Roughens the surface of the material
  - Alternative processes (dull or bright etching) available
Surface treatment of aluminum

Details of the pre-treatment

- **Desmutting in HNO₃\ HF acid**
  - Removes the metal alloy elements and the silicon particles
  - Also dissolves some aluminum
  - Very stable and reliable process
  - Parts become dull
  - Problem with dimensions when parts have to be replated
  - Environmental problems when using HF

- **Zincate treatment**
  - Solution is a mixture of an alkaline etch an zincate ions
  - Etches the aluminum surface and replaces it by zinc
  - Several commercial solutions available
  - Some solutions contain also other metals than zinc
Surface treatment of aluminum

Details of the pre-treatment

- Advantages of this process
  - Very stable and reliable process
  - Suitable for every aluminum alloy
  - There is a lot of experience with this process

- Disadvantages of this process
  - Roughens the surface of the material
  - Parts become dull
  - Problems with dimensions when parts have to be replated
  - Environmental and health related problems when using HF
Surface treatment of aluminum

Alternative pre-treatment before plating

- Alkaline cleaning in Aluminium cleaner
- Rinsing
- Ultrasonic cleaning in alkaline cleaner
- Rinsing
- Etching in mild alkaline Aluminium etch
- Rinsing
- Desmutting in oxidizing agent
- Rinsing
- Ultrasonic cleaning in alkaline cleaner
- Rinsing
- Desmutting in oxidizing agent
- Rinsing
- Zincate treatment
- Rinsing
- Removal of zincate layer in oxidizing agent
- Rinsing
- Zincate treatment
- Rinsing
Surface treatment of aluminum

Alternative pre-treatment

- Advantages of this process
  - Does not roughens the aluminum
  - Does not change the surface condition of the part
  - Suitable for every aluminum alloy
  - Parts can be replated several times
  - No health or enviromental problems

- Disadvantages of this process
  - More pre-treatment steps
  - More expensive
  - The treatment is more critical
  - Not that much common experience with this process
Surface treatment of aluminum

Problems with the plating of aluminum

- Chemical nickel process
  - Good adhesion only up to 2 MTO
  - Use a chemical nickel-strike
  - Use a chemical nickelbath based on nickelacetate
  - Too much zinc dissolved in the bath
  - Use another zincate process which gives thinner layers
  - Use a zincate which contains also other metals
  - Overetched in the zincate
  - Lower the immersion time in the zincate
  - Improve the time between rinsing and zincate

- Pollution of the bath with stabilizers from the zincate
  - Use another zincate process
  - Improve the rinsing process after the zincate
Surface treatment of aluminum

Problems with the plating of aluminum

- Electrolytic plating copper process
  - Immersion plating due to electrode potential difference
  - Lower the pH of the alkaline bath
  - Use a copper-strike

- Chemical imbalance
  - Make sure that the ratio between copper and cyanide is OK
  - Check the amount of carbonate in the bath

- Electrical contact of the part
  - Make sure that the contact is firm and secure
  - Make sure that the current is correct and instantly

- Pre-treatment contaminated
  - Controll the process regular
  - Discard when there are traces of metal contaminations
Surface treatment of aluminum

Resume

- Plating can be a good alternative for anodizing aluminum when conductivity and chemical resistance is required

- Corrosion resistance of plated coatings is not as good as anodizing due to the difference in cathode potential

- Plating aluminum is more difficult and more critical than anodizing

- Plating aluminum requires know how and experience