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Decorative Nickel Plating Handbook

Decorative Nickel Plating - Basics

Any experimentation involving nickel concentration must take into account several variables, namely the temperature, agitation, and the nickel-chloride-sulfate mix.

This information covers the basics of bright nickel, duplex nickel plating, and, finally, troubleshooting of the deposits. It is assumed the reader has some understanding of the basic concepts of decorative plating.

History – The first nickel baths used available nickel salts, such as double nickel salts, mineral acid salts, and acetates. Weston recognized the importance of boric acid. Later, Bancroft then recognized the importance of nickel chloride. Finally, Watts put the nickel sulfate, nickel chloride, and the boric acid together to produce the modern Watts-type nickel baths in use today.

BASIC BATH CONSTITUENTS AND OPERATING PARAMETERS

Nickel sulfate – This salt usually supplies most of the nickel ions in the solution. The salt is chosen because it is the cheapest source of nickel (pure grades can be obtained commercially) and has the least effect on the nickel deposit properties. The concentration of this salt is usually between 150 and 450 g/L.

Nickel chloride – This salt is essential for anode corrosion. The minimum concentration is usually 35 g/L to corrode most types of anode material. The anode corrosion is provided by the chloride anion. The chloride ion also provides good solution conductivity. The chloride ion also hardens the deposit and can increase the internal stress of the deposit. For applications requiring low stress and good ductility, the chloride concentration is maintained at a minimum level. In applications where conductivity is desired, the nickel chloride is maintained as high as 150 g/L. Generally, nickel chloride provides twice the conductivity as nickel sulfate.

Nickel metal – (total nickel Equivalent) this is a value of the combined nickel ions from the nickel sulfate and the nickel chloride. This concentration affects the limiting cathode current density. As an example, a Watts solution with a concentration of 180 g/L nickel sulfate (22.3% Ni) and 90 g/L nickel chloride (24.6% Ni) would have 62 g/L of total Ni content. This content may or may not be adequate depending on the current density, chloride content, temperature, or agitation used.

With more regulations for waste treatment, the nickel content is generally held at the lower concentrations to reduce the amount of waste that is waste treated or discharged. Complicated shapes may require higher average current densities and subsequent higher nickel metal concentration. Impurities will be less noticeable with higher nickel content. Low nickel metal content can lead to burned or nodular deposits.

It is therefore desirable to experiment with the nickel concentration of a specific installation to arrive at the most economical concentration. The experimentation must take into account the temperature, agitation, and the nickel chloride concentration.

Boric acid – The main function of the boric acid is to buffer the cathode film. The Watts solution cathode efficiency is less than 100%. Any efficiency less than 100% results in hydrogen gas being released and a reduction in the hydrogen ion. Therefore, there is an increase in pH of the cathode film. If the rise is not controlled, nickel hydrate can form. Nickel hydrate is a green salt that we commonly see as a result of burning in high current density areas. In short, the boric acid buffers the cathode film by replenishing the hydrogen ions in the film which keeps the pH low enough to prevent nickel hydrate formation. Boric acid has been used for many years and offers the advantage of producing minimal side effects on deposit properties.

pH – In the Watts solution, the common range of operation is between 4.0 and 4.5. This range is generally chosen to keep metallic contamination at low values. The hydrate-forming metals are precipitated and filtered out as they form at this pH. Some of the hydrate-forming metals are ferric iron, aluminum, silicon, and trivalent chromium.

The pH also affects deposit properties. For example, low pH will reduce hardness, reduce cathode efficiency, and improve ductility, while high pH will reduce ductility, increase hardness, and increase cathode efficiency. At pH values between 3.0 and 5.0, the changes in deposit properties are minimal. But when values extend outside this range the changes can be more dramatic.

Temperature – The temperature is usually controlled between 50 and 70 degrees Celsius. The deposits are not significantly affected between these ranges. It can be said that at lower temperatures the deposits are slightly harder, less ductile, and are produced with less cathode efficiency.

The major effect of temperature is solution conductivity. Lower temperature requires more voltage to maintain a specific current.

As an example, a change in operating temperature from 60 to 66 degrees Celsius will increase the current approximately 10% at the same voltage. The same change in temperature will also decrease the voltage 5% at the same current. This change would plate the same amount of nickel with a 5% reduction in power consumption.

Cathode current density – Generally, cathode current densities between 450-650 A/m2 are used as a good compromise between plating speed and deposit properties.
At lower current densities (108 A/m2 and lower) impurities such as copper and zinc plate out with the nickel and affect deposit properties.

High current densities (greater than 1,080 A/m2) can produce burnt deposits. When combined with some contaminants, such as aluminum, silicon, and phosphate, high current density can also dramatically affect deposit properties.

Anode current density – Anode current density is very important and often overlooked. Generally, the anode current density should be below 325 A/m2 in air-agitated solutions and below 195 A/m2 in mechanically cathode-rod-agitated solutions.

High anode current density can polarize the anode or prevent the anode from dissolving properly, reduce the pH, produce oxidizing conditions, and reduce the nickel content of the solution. The oxidizing conditions can then consume addition agents at a faster rate.

There are also different types of nickel anode material. Different anode materials will polarize at different anode current densities, and at different nickel chloride concentrations, and at higher pH values.

Agitation – This is another important variable that is often overlooked. Agitation provides a uniform temperature, keeps the concentration of the bath ingredients uniform, and allows the use of higher cathode current densities. Agitation also decreases the tendency of gas-type pits in the deposit. The cathode efficiency of the watts solution is generally between 93% and 95%. The low efficiency causes the generation of hydrogen gas that can produce pitting. Pitting is usually controlled through adequate agitation or the use of anti-pitting agents (surface active agents).

Most important is that the agitation is uniform. High and low agitation in the same plating tank will produce deposits that have properties of high impurities, low impurities, high addition agents, and low addition agents. Non-uniform agitation will produce non-uniform deposit properties.

BRIGHT NICKEL PLATING

Modern bright nickel solutions contain additives designed to brighten (provide luster) and provide leveling of the substrate that is below the bright nickel plating layer.

There are generally two types of addition agents used in bright nickel solutions: control agents and brighteners.

There are several types of control agents – these are commonly called carriers or primary brighteners by some suppliers. These control agents are usually present in large amounts. The control agents reduce the internal stress of the nickel deposits, provide some brightening and do not affect ductility of the deposit. The control agents usually contain sulfur that is incorporated into the deposit during electroplating.

There is also a wide variety of brighteners – commonly referred to as secondary brighteners or just brightener. The brightener is usually present in small quantities and controlled within a narrow range. The brighteners work in conjunction with the control agents to provide brightness and leveling.

Brighteners usually increase the internal stress, and decrease the ductility of the nickel deposit (Table 1 shows the effect of addition agents).

In general, the operation of the bright nickel solution is dependent on the deposit properties required, the amount of leveling needed, the cost per pound of nickel plated, and the ability of the deposit to accept chromium.

We will discuss these individually:

Deposit properties – A useful guide for decorative nickel plating is the specification ASTM-B-456 (astm.org). The specification details desired properties and test methods for bright nickel plating.

Ductility – The ability of a material to deform plastically without fracturing. This can be measured by producing a foil of known thickness, then bending a foil within a micrometer until fracture occurs. This will provide a quantitative measure of the ductility. A detailed test method is described in ASTM-B-490.

Sulfur content – This is the amount of sulfur in the deposit usually expressed in mass percentage. The sulfur can be measured by producing a sample of the nickel and analyzing the sulfur content.

Leveling – The amount of leveling provided by a bright nickel deposit is important to provide a cosmetically acceptable deposit. Some applications will require a bright, smooth deposit without regard to thickness or corrosion protection. In these cases, the ability of the deposit to level or smooth out base metal imperfections with the minimal amount of nickel thickness becomes critical. In general, increasing the brighteners will increase the leveling ability of a bright nickel bath. Leveling is often measured by prescratching a test panel then over plating the panel with nickel. The panel is then evaluated after plating to determine the nickel deposits' ability to level or fill in the scratches.

Recent advancements have been made at Columbia Chemical that incorporate the use of precision ground hull cell panels in tandem with a profilometer to quantitatively measure the leveling of the nickel solutions. Visit www.columbiachemical.com to read more about this breakthrough in Nickel leveling measurement.

Table 1: Effect of Addition Agents on Deposit Properties

	Watts Nickel	Watts Nickel and Control agent	Watts Nickel and Brighteners (No control Agent)	Watts Nickel with Control agent and Brighteners
Ductility	100%	100%	100%	10-20%
Stress	30 KPSI Tensile	5 KPSI Compressive	>30 KPSI Tensile	0-5 KPSI Tensile or Compressive
Potential	-90 mV	-140 mV	-90 mV	-160-180 omV
Sulfur	<0.005%	0.04%	<0.005%	0.04-0.12%
Brightness	Dull	Some brightness	Some brightness	Bright
Leveling	<5%	<20%	<30%	60-75%
Structure	Columnar	Columnar (finer grain)	Columnar (finer grain)	Laminar

Cost per pound of nickel plated – The cost of the control agents and brighteners needed to plate a kilogram of nickel. According to Faraday's Law, 914 A-hr will deposit one kilogram of nickel. If the quantity and price of the addition agents consumed during 914 A-hr is known, then the cost is easily computed. Consumers should use this method to obtain an accurate cost determination since control agents and brighteners can be consumed at different rates.

Ability of a deposit to accept hexavalent chromium – This is an often overlooked property that consumers should be wary of when changing control agents or brighteners. The types and levels of addition agents chosen in a system can affect the ability of the nickel deposit to accept a hexavalent chromium plating layer. Often the nickel deposit can become either too active or passive to accept a chromium layer. Usually, high brightener, or an improper mix of brightener, will cause poor chromium acceptance. In the case of trivalent chromium plating the underlying bright nickel layer is not normally rendered passive and is not an issue.

Troubleshooting Decorative Nickel Plating Solutions- Duplex Nickel

This section on troubleshooting decorative nickel focuses on duplex nickel plating. The deposition of two layers of nickel on a given substrate has its advantages. However, caution must be taken to ensure adequate adhesion between the nickel layers and finish performance.

Duplex nickel refers to the deposition of two layers of nickel. This involves one layer of sulfur-free (SF) semibright nickel and one layer of bright nickel. The sulfur-free semibright nickel layer is the bottom layer, and the bright nickel layer is the top layer.

SEMIBRIGHT NICKEL LAYER

The sulfur-free semibright nickel layer is usually deposited from a Watts bath. A typical composition and operating conditions are listed in Table 2.

The semibright nickel deposit must be sulfur-free and have a structure that is predominantly columnar. The deposit should also have good ductility, leveling, and grain structure that is fine grained over a wide current density. The surface must not be grainy in order to allow the BN to do the best job. The deposit should also be low in internal stress (this can be very important when plating on plastics).

Stress will increase with increasing nickel chloride content; leveling and color will also be affected by nickel chloride content. Deposits will tend to be less uniform in color and have reduced leveling with increasing nickel chloride content.

Semibright deposits may range in thickness from 10 to 30 micrometers. As mentioned previously, if the semibright nickel deposit is grainy the subsequent bright nickel deposit will have difficulty obtaining a fully lustrous deposit. Recommended thickness ranges for different applications may be obtained from ASTM-B-456 or ASTM-B-604.

Table 2: Typical composition and Operations Conditions for a Watts Bath

Nickel Sulphate	300 g/L
Nickel Chloride	35 g/L
Boric Acid	45 g/L
Temperature	54 degrees C
Antipitting Agent	33 cc/L
pH	3.5-4.5
Agitation	Air or Mechanical
Current Density	2-7 ASD
Organic Additives	As recommended by the supplier

ADDITION AGENTS

Semibright addition agents should be capable of producing a uniform columnar and ductile deposit over a wide current density operating range. The addition agents should be sulfur-free and can be compounds that are aromatic and aliphatic. The concentrations of these additives are usually low and recommended by the supplier.

Examples of these additives are:

- Aliphatic compounds with olefinic or acetylenic unsaturation
- Formaldehyde-type compounds
- Carboxylic acids
- Aromatic compounds
- And anionic wetting agents or combinations thereof

The addition agents should be capable of producing a deposit that has less than 0.005 mass% sulfur and a minimum of 80% (0.45 by Chrysler) ductility. Greater ductility may be required where mounting, or when the use of the electroplated articles involves dimensional distortion.

ADVANTAGES

The two layers of nickel will have superior corrosion protection than a single layer of nickel of equal thickness. This can lower the cost by reducing the amount of nickel needed to achieve a defined corrosion requirement.

The semibright nickel layer has superior ductility; therefore, the composite layer will also have superior ductility.

DISADVANTAGES

Some semibright solutions are sensitive to metallic impurities and may require electrolytic purification.

The semibright nickel and subsequent bright nickel must be applied in such a way as to prevent adhesion problems between the two layers. The transfer time between the two nickel coatings should be rapid; bi-polar conditions must also be avoided. In some installations, it may be necessary to have a lower-than-normal voltage on the exit from the SF semibright nickel plating tank, and a live entry with lower-than-normal voltage into the bright nickel plating solution.

Some of the semibright nickel additives may yield decomposition products that must be controlled to an acceptable level. If the solution is not maintained properly, the build-up of breakdown products could adversely affect deposit properties – such as stress, leveling, color, and ductility.

CORROSION PROTECTION

The bright nickel is anodic to the semibright nickel. The bright nickel corrodes preferentially to the semibright nickel. The corrosion of the semibright nickel is reduced because the bright nickel corrodes sacrificially to the semibright nickel. Corrosion will proceed laterally, dissolving the bright nickel instead of dissolving the SF semibright nickel.

The overall corrosion performance is governed by the duplex nickel total thickness, the ratio of the SF semibright nickel thickness to the bright nickel thickness, and the potential difference and sulfur content of the deposits. The preferred ratio is 75% SF semibright and 25% bright nickel; however, ratios of 60% to 75% SF semibright nickel with 25% to 40% bright nickel thickness will produce satisfactory results.

A typical potential difference between the SF semibright nickel and the bright nickel deposits would be from 100 to 200mV with the bright nickel being more active (less noble) than the SF semibright nickel. The potential, the total thickness, and the ratio of the SF semibright nickel to the bright nickel thickness may be checked by using the industry-

accepted method outlined in ASTM-B-764. This method anodically strips the deposit at a constant current density while measuring the potential differences. (Figure 1 shows the corrosion mechanism of duplex nickel).

MICRODISCONTINUOUS CHROMIUM

Microdiscontinuous chromium is defined as the presence of pores, cracks or a combination of both in a chromium layer and can be produced by the following:

1. Plating a thin, low-sulfur layer of nickel that has inert particles co-deposited. This bath is commonly called a micro-porous nickel strike. The subsequent chromium layer then has pores or nickel exposed where the inert particles were located.
2. Plating a microdiscontinuous chromium, such as a trivalent chromium bath, over a low-sulfur nickel strike. Most trivalent deposits are micro-porous at low thickness and micro-cracked at high thickness. The chromium deposit is therefore usually referred to as being microdiscontinuous.
3. A microcracked nickel strike solution, which induces cracking into the subsequent chromium layer. This is accomplished by stressing the nickel deposit to induce cracking in the chromium layer.
4. Another method would be to impinge the chromium with sand or other hard particles. The sand, or other fine particles, is dropped from a distance above the plated particle. The impingement of the particles produces microprosity in the chromium deposit.
5. Plating a highly stressed or microcracked chromium deposit. Additives are added to the chromium plating solution, which highly stresses the deposit and causes microcracks.

(Of the five methods above, number 1 is the most commonly used. Recent regulations have caused a number of platers to convert to method number 2).

As with the duplex nickel, the potential of the nickel strike layer beneath the chromium is critical to provide the best corrosion mechanism. The potential of the nickel strike should be slightly more noble than the underlying bright nickel layer.

If the nickel strike is more active than the bright nickel, the nickel strike will corrode preferentially to the bright nickel. This will cause the pores to be very large on the surface and will become visible to the eye.

If the nickel strike is more noble than the bright nickel, the bright nickel will corrode preferentially to the nickel strike, and the pores on the surface will remain small and less visible. (See Figures 2 and 3).

Figure 2 shows corrosion of the bright nickel (more active) preferential to the low-sulfur layer (more noble). The result is a small surface pore diameter.

Figure 3 shows corrosion of the low-sulfur layer (more active) preferential to the bright nickel layer (more noble). The result is a large surface pore diameter, which may be objectionable visually.

Figure 1

Duplex Nickel – showing preferential corrosion of the bright nickel layer. The corrosion proceeds horizontally along the more active (anodic) bright nickel layer rather than through the more noble (sulfur free) semi-bright nickel layer.

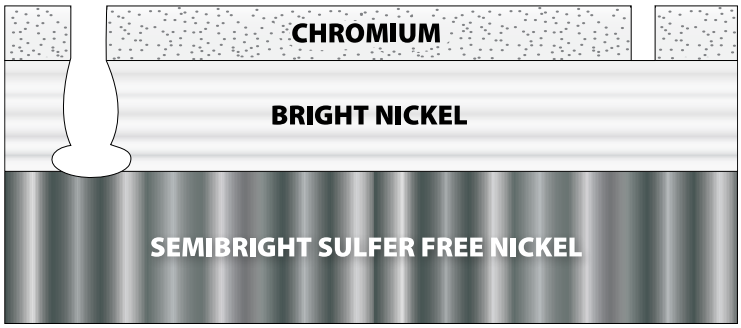


Figure 2

Microporous Nickel is more noble than the underlying bright nickel producing the proper corrosion. Small pores are not visible to the eyes from above.

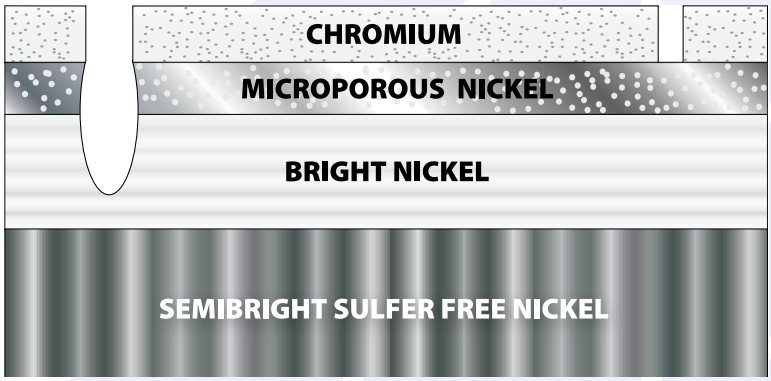
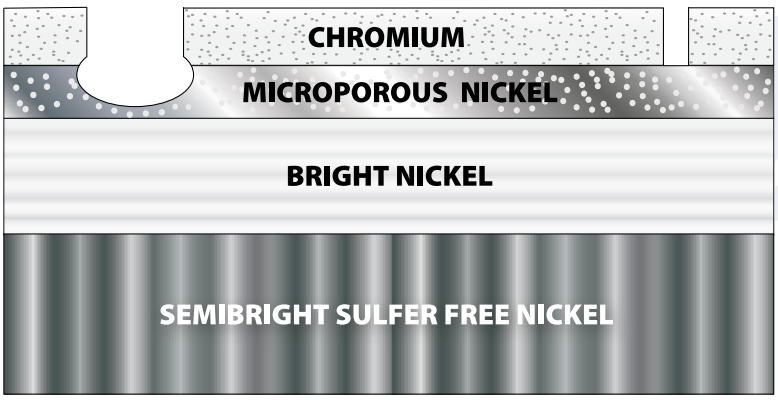


Figure 3

Microporous Nickel is more active than the underlying bright nickel causing large visible surface pit.



Troubleshooting Decorative Nickel Plating Solutions- Impurities

Adherence to optimum plating conditions as well as some good old common sense goes a long way in preventing frequently encountered problems.

Impurities in nickel solutions can be classified as inorganic or organic. Note that the effects of two or more impurities may be additive, e.g., the effect of iron plus silicon will be greater than the effect from the concentration of the individual impurity.

INORGANIC IMPURITIES

Hydrate-forming impurities include ferrous iron, ferric iron, aluminum, trivalent chromium, and silicon.

SILICON AND ALUMINUM

Effects – These impurities can produce hazes generally in the MCD to the HCD areas at concentrations as low as 0.02-0.04 g/L. They can also cause fine roughness that will produce what is sometimes called stardust or salt and pepper. Aluminum can also cause cracking of the deposit.
Sources – Parts, zinc die-cast, water supply.
Removal – High pH treat solution.

IRON

Effects – Iron may cause roughness at pH values above 3.8 at concentrations as low as 0.02 g/L. The roughness will vary according to the amount of iron present and the pH.
Sources – Iron may come from fallen parts, water source, or the unplated areas inside steel tubes.
Removal – When iron dissolves it will be ferrous iron; it will then oxidize to ferric iron. Ferrous iron will plate out of solution. In air-agitated solutions the iron will be present as ferric iron. It is common practice to first oxidize the ferrous iron by adding hydrogen peroxide to a solution in which the pH has been adjusted to 3.5-4.0. After the ferrous iron has had time to oxidize to ferric iron, the pH of the bath is raised to a value over 5.0 to precipitate the ferric iron.

CHROMIUM

Effects – Trivalent chromium can produce a haze or fine roughness at concentrations as low as 0.02 g/L. Hexavalent chromium, at concentrations as low as 0.0025 g/L, can cause dark streaks, peeling, or high current density gassing. Hexavalent chromium can also cause adhesion failure in duplex nickel plating due to its ability to passivate nickel.
Sources – Cleaners, rack tips, carry-over from chromium plating bath or chromic acid etch baths, poor rack coatings, etc.
Removal – Hexavalent chromium must first be reduced to trivalent chromium. The reduction can be achieved by using dummy cathodes or reacting with organics. The hexavalent chromium can also be reduced by adding sodium bisulfite, but extreme caution

will be needed since excess sodium bisulfite will affect the low current density areas. The supplier of addition agents should be consulted prior to this treatment to ensure its compatibility with the addition agent system and to ensure the treatment is performed properly. Once the chromium has been reduced to trivalent chromium the solution can be high pH treated to precipitate the trivalent chromium and be removed by filtration.

ZINC, COPPER, IRON (FERROUS), LEAD, AND CADMIUM

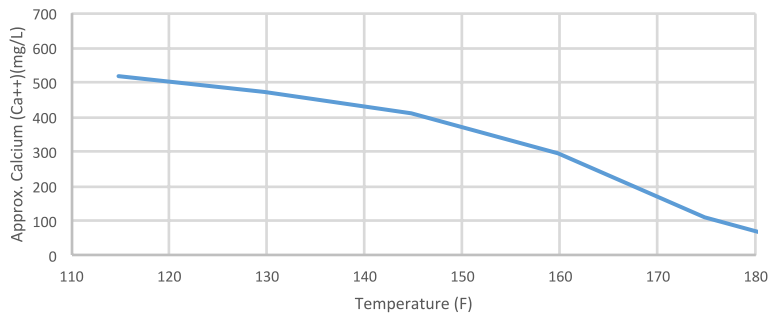
Effects – These impurities generally cause low current density darkness and striations. These impurities cause defects similar to high secondary brightener.
Sources – Fallen parts that are made of copper, brass, leaded brass, leaded steels, solution washing, tank bussing, fallen carriers on automatic lines and solution carry over.
Removal – These impurities are usually plated out by low current density electrolysis (dummy plating). It is best to have as much cathode area as possible with pH at 3-3.5 with high agitation.

CALCIUM

Effects – Can cause needle-like roughness at concentrations as low as 0.1 g/L depending on the temperature. The calcium has limited solubility in the nickel solution. Typically this is 0.5 g/L maximum.
Sources – Hard water supply.
Removal – Since calcium has a lower solubility at higher temperatures, it can be partially removed by raising the temperature of the solution and filtering. Filtration at 70 degrees Celsius can remove approximately 50% of the calcium. The elevated temperature procedure must be performed in a spare tank, and the solution must not be allowed to cool during filtration, or the calcium will redissolve.

Another more effective method to reduce calcium is to add Sodium Biflouride. The Fluoride will form the less-soluble Calcium Fluoride, which will precipitate out of solution. The procedure will also precipitate magnesium; therefore a quantity of Sodium Bifluoride equal to or slightly less than the stoichiometric quantity to precipitate both calcium and magnesium should be used. A high pH treatment should be used after the treatment. This treatment should be used with caution as excess fluoride left in the solution will attack titanium anode baskets or heating/cooling coils.

Figure 1: Solubility of calcium sulfate relative to temperature



MAGNESIUM

Effects – The impurity is fairly harmless and nickel solutions can usually tolerate g/L

quantities. It will, however, add to the salt content and act as nickel in salting out properties of the solution.
Sources – Hard water supply, fallen parts containing magnesium.
Removal – See removal of calcium.

PHOSPHATE

Effects – Can create high current density cracking or poor ductility at concentrations as low as 0.025 g/L.
Sources – Cleaner drag-in.
Removal – Add ferric iron (e.g., ferric chloride) at a concentration slightly more than the stoichiometric amount necessary to precipitate iron phosphate. Raise the pH to a value >5.2. This will precipitate the less-soluble ferric phosphate. Then perform a high-pH treatment on the solution to remove the excess iron.

NITRATE

Effects – Reduces cathode efficiency, hurts the leveling, and causes high current density gassing. (Behaves like chromate). Nitrates are reduced by hydrogen to form several by-products such as ammonia. Ammonia tends to increase stress and reduce ductility. Since ammonia cannot be easily removed, it is important that ammonia or nitrate does not enter the solution.
Sources – Stripping solutions, nitric acid dips.
Removal – Can be reduced by promoting hydrogen gassing, using low cathode area and high current density. High concentrations may require disposal of the solution.

ORGANIC IMPURITIES

Effects – Low ductility, high stress, hazes. The effects vary depending on the impurity and the concentration. Note that many organic impurities cannot be easily removed using the usual treatment procedures; therefore, every effort should be made to eliminate the entry of this class of impurities.
Sources – Some examples are buffing compounds, sizing from anode bags, uncured rack coatings, stop-off lacquers, decomposition products from wetting agents, organic stabilizers from hydrogen peroxide, oil, grease, paint spray, or new or patched tank linings.
Removal – Perform an activated carbon treatment, or – on some occasions – a combination oxidation/carbon treatment. The combination oxidation/carbon treatment is sometimes chosen to oxidize the organic impurity to another form that can be removed later by carbon.

SOLUTION PURIFICATION TREATMENTS

Carbon treatment:

1. Transfer solution to a clean and suitably lined treatment tank equipped with heat and mechanical agitation.
2. Adjust pH of the solution to 3.0-3.5.
3. Adjust temperature of the solution to 150-160 degrees Fahrenheit.
4. With agitation, slowly stir in four to eight pounds per 100 gallons of activated carbon, avoiding dusting.
5. Agitate for a minimum of two hours.
6. While maintaining the temperature, allow the solution to settle for one hour or more.
7. Clean the plating tank; inspect and replace anode bags as required.
8. Filter the solution back into the previously cleaned plating tank using a filter precoated with suitable filter aid. Draw solution from near the top to avoid picking up loose sludge, which could restrict the filter flow and even stop-up the filter.
9. It is advisable to maintain an even rate of flow by adding about one pound/100

gallons filter aid. This should be added slowly in the treatment tank at or near the suction hose as the level of the solution is reduced.

10. Make additions as necessary to the plating tank; adjust solution level, temperature and pH as required. [Raise the pH by circulating solution through clean filter packed with nickel carbonate and filter aid; lower the pH by adding diluted (1:1) sulfuric acid.]
11. Resume plating operations.

HIGH pH TREATMENT

1. Transfer solution to a clean and suitably lined treatment tank equipped with heat and mechanical agitation.
2. Adjust temperature of the solution to 150-160 degrees Fahrenheit.
3. Prepare a slurry of nickel carbonate and water, on a basis of eight pounds of nickel carbonate to one gallon of water, preferably with a mechanical stirrer. Do not add dry nickel carbonate directly to the solution in the treatment tank – always use a slurry.
4. Slowly add the nickel carbonate slurry to the heated solution in the treatment tank, stirring constantly. The amount of nickel carbonate added will vary with the original pH of the solution. As a rule, five pounds of dry nickel carbonate per 100 gallons of plating solution is usually sufficient.
5. While temperature is maintained, the solution should be stirred for one hour, or more. Check the pH of a filtered sample and adjust again with the nickel carbonate until the pH is at least 5.0.
6. Allow the solution to settle for at least eight hours, preferably overnight.
7. Clean the plating tank; inspect and replace anode bags as required.
8. Filter the solution back into the previously cleaned plating tank using a filter precoated with a suitable filter aid. Draw solution from near the top to avoid picking up loose sludge, which could restrict the filter flow & even stop-up the filter.
9. It is advisable to maintain an even rate of flow by adding about one pound per 100 gallons filter aid. This should be added slowly in the treatment tank at or near the suction hose as the level of the solution is reduced.
10. Adjust solution level and lower pH using diluted (1:1) sulfuric acid.
11. Adjust temperature and additives as required.
12. Resume plating operations.

COMBINATION CARBON/HIGH pH TREATMENT

Perform steps 1 through 5 listed under CARBON TREATMENT followed by steps 3 through 12 under HIGH pH TREATMENT

OXIDATION TREATMENT USING HYDROGEN PEROXIDE

1. Pack filter with activated carbon, approx. one to two pounds per 100 gallons of plating solution when possible. Transfer the solution to the treatment tank, fitted with heat and mechanical agitation, through the packed filter. Clean the filter.
2. Allow the solution to cool to 100-110 degrees Fahrenheit and adjust pH to 3.5.
3. Add slowly with agitation the required amount of 100 volume (30%) hydrogen peroxide. Depending on the severity of the treatment, the quantity of peroxide will vary from 0.5 to 3.0 gallons per 1,000 gallons of plating solution.
4. Agitate and maintain temperature for at least two hours.
5. Follow steps 1 through 5 as listed under CARBON TREATMENT.
6. Follow steps 3 through 12 as listed under HIGH pH TREATMENT.
   (Note: the use of carbon is to remove organic products oxidized by the peroxide; the high pH treatment is necessary to remove residual peroxide).

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