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Nickel Anode Forms and Their Use

All electroplating processes have common elements such as the electrolyte, process tank, rectifier, pumps, filters and anodes. Anodes work in concert with the electrolyte (plating solution), rectifier (DC power source) and cathode (part to be plated) to complete the electrical circuit and allow metal deposition from the electrolyte on to the parts.

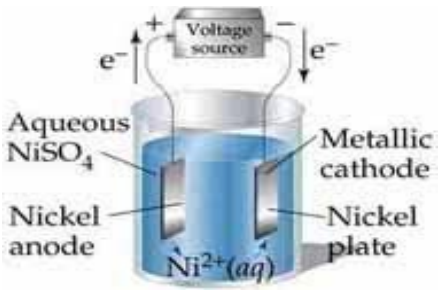

Fig. 1 Simple Nickel Plating Cell

Anodes come in two varieties, soluble and insoluble. Soluble anodes dissolve to replenish the metal deposited from the solution (electrolyte) on to the parts. Soluble anodes are continuously consumed and, therefore, must be regularly replenished. Insoluble anodes do not dissolve, requiring additions of metal in the form of chemical salts or liquids to replenish the metal plated on to parts.

Approximately 1.8 million tons of nickel is produced globally each year. About 68% is used to produce stainless steel. Electroplating, at 9% or about 160,000 tons, is a very distant second in commercial usage. The current global market value of nickel electroplating anodes is about $2.5 billion per year. Along with metals such as copper, tin and zinc, nickel is one of the most common metals commercially electroplated.

When electroplating nickel from either a modified Watts or sulfamate based electrolyte one must decide on which nickel anode form and composition to use. There is, surprisingly, considerable misunderstanding and misinformation as to which nickel anode product to use. The decision of which form to use should be determined based on the plating solution

chemistry, the type of parts plated and coating characteristics desired.

Insoluble anodes are used in limited applications but, in practice, the majority of commercial nickel electroplating uses soluble anodes in a variety of forms and compositions. Forms commonly used are electrolytic squares, rounds, crowns, carbonyl pellets, carbonyl discs and solid bars. Electrolytic and carbonyl nickel anodes differ in the method used to produce them, chemical composition, and shape.

Electrolytic nickel anode is produced by electrodepositing metal from solution onto substrate media to produce either full plate cathodes (30" x 51"), that are then cut into squares (typically 1" x 1") for ease of use; or deposition onto mandrel sheet that is masked to form rounds and crowns (about 1" diameter).

Fig. 2 Electrolytic Ni Squares

Fig. 3 Electrolytic Ni Rounds

Carbonyl forms such as spherical pellets (0.25" – 0.6" diameter) and flat discs (0.6" - 0.8" diameter) are produced using the Mond Process where nickel carbonyl gas is decomposed in an elaborate device to form solid metal spheres that grow to a predetermined size over time. Carbonyl discs are pellets that have undergone a rolling process to flatten them to simplify handling.

Fig. 4 Carbonyl Ni Pellet

Fig. 5 Carbonyl Ni Disc

Nickel bar anodes are among the oldest forms commercially available but make up a very small percentage of the total nickel anodes used in electroplating. Nickel bar anode have undergone changes in manufacturing technique over the years and are now extruded to form a 3" oval bars in 12-14 feet mill lengths. In practice nickel bar anodes are cut to the end user's specification and are drilled and tapped to accommodate a hook that allows them to hang on the anode bar or rail of the plating tank.

Fig. 6 Nickel Bar Anode

While the design is simple, there are technical deficiencies, due to the nature of how nickel bar anodes corrode and dissolve over time while in use. Since dissolution is governed by the electric current applied (Faraday's Law), and more importantly how it is distributed over the anode surface area, the anodes tend to form sword shapes as they dissolve. The result is a gradual change in surface area of the anode that in turn impacts electroplating quality. Best practice dictates maintaining a fixed surface area ratio between anode to cathode. Consequently, bar anodes must be replaced before they are completely consumed, making them more costly to use than other nickel anode forms.

The composition of soluble nickel anodes is an important consideration for anyone who operates an electroplating tank. Nickel anodes generally contain greater than 98% nickel by weight and are suitable for most nickel electroplating applications. Trace metallic impurities should always be below the ASTM B39 reference specification for refined primary nickel.

	ASTM B39	Squares	Rounds	Rounds S	Pellet	Pellet S
Ni	99.80	99.99	99.99	99.97	99.99	99.96
NiO	nil	nil	nil	nil	nil	nil
As	0.005	0.001	0.0015	0.001	nil	nil
C	0.030	0.003	0.003	0.003	0.010	0.005
Co	0.150	0.050	0.065	0.050	0.00002	0.00005
Cu	0.020	0.001	0.0009	0.001	0.00005	0.0002
Fe	0.020	0.0005	0.0005	0.0004	0.002	0.005
Pb	0.005	0.0003	0.0003	0.0003	0.00005	0.00002
S	0.010	0.0002	0.0002	0.023	0.00002	0.026

Fig. 7 Nickel Anode Composition

Electrolytic and carbonyl forms (squares, rounds, pellets, discs) found favor among platers because by containing them in an inert (titanium) metal basket it is possible to both maintain consistent anode area and completely consume the anodes resulting in better operational efficiency. Additionally, ease of handling, consistency of size, quality, availability, and operational cost make electrolytic and carbonyl nickel anode the most popular form in use today.

Fig. 8 Nickel Anode Basket

Visit a typical nickel electroplating installation and process tanks will feature titanium anode baskets filled to the brim with either square, round, pellet or disc shaped anodes. This has become the industry standard practice over many decades of production use.

In addition to the variety of physical shapes available as electrolytic and carbonyl nickel anodes there are composition differences which are important to note. Both types of nickel, while produced in a very different manner, are available as sulfurized and non-sulfurized products. Sulfurized nickel (also known as active nickel) is produced by introducing controlled amount of sulfur during the manufacturing process to produce an anode with a high level of electrochemical activity.

The principal advantage to sulfurized nickel anodes is they dissolve at a lower voltage than non-sulfurized nickel anodes. There is some debate as to whether this result in a long-term energy savings as was originally claimed. The undisputed benefit from sulfurized nickel anodes is that nickel chloride levels in electroplating solutions can be lowered which produces deposits with lower internal stress. There are significant benefits in certain electroplating applications for deposits with low internal stress. Non-sulfurized nickel is more widely used than sulfurized and can be used in most nickel electroplating solutions and applications.

The difference between carbonyl and electrolytic is related to production process used to make them. Electrolytic nickel anode forms are produced by electrodepositing heavy thicknesses of nickel onto a form that is designed to produce either the familiar round/crown shape or a large rectangular sheet that is cut into squares of various sizes. This production process is functionally very similar to electroplating and requires many of the same components such as an electrolyte, tank, rectifier, anodes, cathode, filter and pump. It is interesting that the cathodes produced in this manner become anodes for commercial nickel-electroplating applications.

Carbonyl nickel anodes are produced in a very different manner, through the decomposition of toxic nickel carbonyl gas using sophisticated equipment. It can take a month or more to produce carbonyl pellets or discs as they start as small nickel, or nickel oxide, particles not much larger than course sand. The particles, dropped from the top of a tower fall through layers of nickel carbonyl gas forming a thin layer of nickel metal on the surface. The particles are

continuously collected at the bottom and repeatedly dropped until they grow into spherical pellet of a predetermined size. The carbonyl nickel process produces very pure nickel anodes, but its production complexity and capital cost has resulted in very few producers.

In conclusion, nickel electroplating is well established commercial industrial process that provides considerable economic benefit. Nickel anodes are required to operate nickel electroplating and are available in a variety of forms and compositions that have evolved over time. Although nickel electroplating anodes are most often viewed as a commodity it is worth remembering there is a significant amount of technology employed in producing them.