Nickel Electroplating Applications & Trends

By Dr. George A. DiBari

Nickel electroplating is one of the few surface finishing processes that can satisfy the requirements of decorative and functional applications. It enhances the appearance, extends the life and improves the performance of materials and products in different environments. This edited version of a presentation at SUR/FIN® '96—Cleveland, shows how innovations have made it possible to vary the appearance and control the corrosion performance and other properties of electrodeposited nickel; giving it the ability to serve a wide variety of uses in decorative, engineering and electroforming applications.

Decorative Electroplating

Nickel plating technology is the result of an evolutionary process that began soon after nickel plating was discovered in 1842. Modern decorative nickel plating, however, is less than 60 years old, beginning with the discovery of organic bright nickel plating just before the second world war. Because these processes make it possible to deposit mirror-bright deposits directly from solution, it is unnecessary to polish nickel coatings after plating. The war slowed the introduction of the new technology, but the pent-up demand for automobiles and consumer products led to rapid growth of bright nickel plating when the war was over.

Automotive Decorative Plating: A Brief History

The growth of bright nickel plating was especially rapid in the automotive industry after 1945. The corrosion performance of single-layer bright nickel coatings, however, proved to be unacceptable because of rapid failure in the severely corrosive environments to which bumpers, grilles and automotive trim are exposed. The growth of bright nickel plating was in jeopardy. Industry-wide efforts were launched involving the automotive companies, leading plating suppliers, Inco laboratories in the U.S. and Europe, members of ASTM Committee B08 and AESF.

During about a 25-year period, those efforts led to the invention of semi-bright nickel plating, the development of double- and triple-layer decorative nickel coatings, and the discovery of processes for increasing the porosity of the decorative chromium coatings that are applied over the bright nickel. High-porosity chromium coatings, in combination with decorative multi-layer nickel coatings, have exceptional corrosion resistance and are capable of protecting steel and other substrates for extended periods of time.[1] New and improved techniques for plating on plastics and on aluminum alloys were also developed during this creative period.

In addition, improved accelerated corrosion tests (CASS and Corrodkote) were developed; electrochemical methods of studying corrosion were applied to coatings; improved ASTM specifications verified by outdoor corrosion performance testing were adopted; and the STEP test was introduced.

All of these innovations improved quality of, and expanded the markets for, decorative electroplated nickel/chromium plating.

In the mid-1970s, however, trends favoring greater use of urethane and other low-density materials, at the expense of nickel/chromium-plated steel bumpers, were set in motion. The elimination of decorative nickel/chromium-plated steel bumpers and trim from almost all automobiles resulted in a steady decline in automotive decorative nickel plating.

Automotive Decorative Plating: Current Status

The decline in decorative nickel/chromium plating in the automotive industry has bottomed out and may be reversing itself. The growing popularity of small trucks and recreational vehicles, many of which have decorative nickel-plated hardware and trim, is the main reason for the reversal. In 1995, 40 percent of the vehicles sold were trucks and recreational vehicles. The Ford F-150 XLT pickup, for example, was the best-

selling vehicle in 1995. This vehicle has been redesigned, and came out in 1996 with bright nickel plus chromium-plated steel bumpers as standard equipment.

Other signs that the downward trend has reversed itself include:

(1) Worldwide growth in the production of decorative-plated styled wheels for trucks and passenger cars.
(2) Reported plans for a new bumper plating plant somewhere in the mid-West.
(3) Expansion of existing automotive plating plants in the U.S. and Canada.

Recognition of the exceptional corrosion performance of decorative multilayer nickel-plus-chromium coatings may have helped halt the decline in automotive decorative plating.[2,3,4] The fact that decorative nickel chromium plating has remained cost-effective, has prompted greater consideration of decorative-plated hardware and trim for model differentiation, and as a way to add value and beauty to existing designs.

Decorative Plating: Non-Automotive

Decorative, non-automotive end uses include furniture components, building hardware, hand tools, wheel goods, major appliances, shopping carts, plumbing fixtures, housewares, luggage hardware, wire goods, motorcycles, mopeds, bicycles and other articles. Because nickel plating has grown at the rate of four percent per year since 1985 despite the decline in automotive uses, it is clear that the non-automotive uses have grown. Decorative nickel plating growth rates generally track gross domestic product rates. The non-automotive sector should continue to grow in those parts of the world where living standards are being steadily improved.

Engineering Applications

There are many applications where a decorative finish is not a consideration. Rather, nickel and nickel alloy deposits are used to improve corrosion resistance, and to enhance wear and other surface properties. Here are some examples:

Batteries

Components of nickel-cadmium, nickel hydride, nickel-iron and other batteries are sizeable markets for nickel plating. Nickel-plated steel strip is used for making battery electrodes, battery cans and other components. When electric vehicles operated with nickel hydride batteries become a reality, the demand for battery-related nickel plating will increase.

General Motors will be the first major auto maker to introduce an electric passenger car, a two-seater that will be available in Los Angeles, San Diego, Phoenix and Tucson in the fall of 1996. Powered by a lead acid battery,it will need to be recharged every 90 miles. If the debut is successful, attention will shift to nickel hydride batteries that retain their charge longer than conventional lead acid batteries.

Compact discs and video discs for entertainment and education are made from electroformed nickel stampers.

Electronics

The electronics industry uses nickel and nickel alloy coatings deposited electrolytically and electrolessly for engineering purposes at various stages in the manufacture of computers, telecommunications equipment and consumer electronics. Some specific examples are:

- Gold-nickel and palladium-nickel alloy electrodeposits are generally applied over thin layers of nickel on contacts, connectors and lead frames. Nickel functions as a diffusion barrier in many cases, and improves reliability and quality.[5]
- Electrodeposited nickel is used as a sputter etching mask in some methods of interconnecting chips and chip carriers; to protect molybdenum in complex thermal ceramic modules; and to render dielectrics conductive in photofabrication manufacture.[6]
- The manufacture of magnetic recording devices and disks requires an assortment of nickel-containing surface finishing processes. For example, some magnetic recording disks are manufactured by electrolessly depositing nickel on the diamond-turned substrate; highly polishing the electroless nickel coating, and then coating with cobalt. Thin film heads used for high density magnetic recording are made by photofabrication techniques that require the electrodeposition of nickel-iron alloys with closely controlled magnetic properties.[6]

The electronics industry will expand over the long-term and provide a growing market for electrodeposited and electrolessly deposited nickel and nickel-alloy coatings.[7]

Zinc-Nickel Plating

The electrodeposition of thin, zinc-nickel alloy coatings on auto-body steel as a base for paint has created a large new market for nickel.[8,9] Alloying zinc with 8–12 percent nickel improves its corrosion resistance. The enhanced corrosion resistance of the alloy allows thinner coatings to be specified than if pure zinc were used. The appearance after painting is improved, because zinc-nickel coatings are thin and less susceptible to orange-peeling during fabrication.

Zinc-nickel alloy coatings are being specified for plating individual components for automotive applications and are often mentioned as replacements for cadmium.

Composites & Amorphous Coatings

Composites are coatings that contain minute particles dispersed throughout a metallic matrix, and are made by electrolytic and electroless processes. Electrodeposited nickel containing

Plumbing fixtures made of brass and plastics are plated with nickel-chromium.

silicon carbide particles was developed to coat internal housings of Wankel engines, and is being applied to the inside surfaces of cylinders of the new aluminum-silicon lightweight V8 engine developed by BMW.[10] Electroless nickel deposits containing particles of PTFE for lubricity and enhanced wear are becoming commercially important.

Electrodeposits exist that have such a small grain size that they yield no X-ray diffraction pattern at all and are, therefore, amorphous or noncrystalline. An example is an electrodeposited nickel-phosphorus alloy containing 10–25 percent phosphorus that has been applied in electroforming small parts.[11] Amorphous metals and alloys are of interest, because they may possess increased corrosion resistance and improved magnetic, electric, superconductivity, mechanical strength and hardness characteristics. This relatively new technology holds promise for the future of coatings for engineering applications.

Electroless Nickel

There are some trends in electroless nickel worth mentioning. A greater understanding of the properties of the deposits and how they are affected by phosphorus content has made it possible to satisfy a variety of engineering specifications. Most important, perhaps, are the efforts being made to develop techniques for extending the life of electroless nickel solutions that could significantly lower the cost of applying these coatings.[12] There are many cases where electroless nickel is a satisfactory substitute for electrodeposited chromium and that realization has led to new uses.

The size of the electroless market is roughly 2,200 metric tonnes (4.8 million lb) of nickel metal, equivalent to 10,000 tonnes (22 million lb) of nickel sulfate. Electroless nickel has been growing at the rate of five percent per year since 1975 and has increased the demand for high-purity nickel sulfate significantly.[13]

Coinage

Nickel and nickel-containing alloys traditionally make up the bulk of the world's coinage. As a result of inflation and other factors, there is a continuing need to find ways to mint coins with intrinsic metal values that do not exceed their denominational ones. A method that has been patented and licensed by Sherritt, Specialty Metal Products Division, Toronto, is being applied in Europe, South Africa and China.[14] The method involves minting steel coin blanks, electroplating the blanks with nickel in bulk, and striking them after electroplating. Success appears to depend on strict control of the mechanical properties of the basis material and of the nickel deposit using various means, including heat-treatment.

Electroforming

Nickel electroforming was conceived 150 years ago at the same time that the plating process itself was discovered and is the first practical application of nickel plating. It involves electrodeposition onto a mandrel or mold that is subsequently separated from the deposit to yield a component or manufactured article made entirely of electrodeposited metal. Nickel is used in the largest number of applications, because of its intrinsic physical and mechanical properties. The products that are made by electroforming enrich our lives daily.

Notable trends are the growing size of some electroformed molds containing up to 12.5 tonnes of nickel. Conversely, the combination of X-ray lithography and electrodeposition has led to the production of microminiature movable devices of various kinds that are tiny enough to pass through the eye of a needle. Recent applications have been discussed in the other literature.[15,16]

Economic & Other Trends

There are trends that will continue to influence the future of nickel plating and, in some cases, may overshadow technical factors.

Nickel Plating Markets

The consumption of nickel for electroplating closely tracks overall economic activity, because of its many diverse applications. In times of economic recession, the consumption of nickel for plating declines. In times of economic expansion, consumption increases. As stated earlier, nickel electroplating has grown at an average rate of four percent per year since 1985. Worldwide consumption of nickel metal for plating is now about 75,000 metric tonnes (165 million lb) and will continue to grow with the expansion of the world economy. Growth has been greatest in Japan, Taiwan, China and other Asian countries. Markets in the U.S. and Europe are stable, but may begin growing again if the decline in automotive decorative plating reverses itself.

Pollution Prevention & Control

Regulations to prevent pollution of land, air and water, and to protect safety and health in the workplace, will continue to affect surface finishing technically and commercially. Technically, much activity is focused on finding substitutes for hazardous materials and making process changes to comply with government regulations. Commercially, plating shops that were only

marginally profitable have gone out of business. There are now 2,800 decorative nickel/chromium plating shops in the U.S.[17] compared to about 3,500 in 1970. The trend has likely run its course.

The impression that some countries enjoy a competitive advantage because they do not enforce pollution prevention regulations is no longer true. The government of Taiwan is now enforcing its environmental regulations vigorously. Japan has always had strict pollution control laws and is changing its approach to safety and health in the workplace. New plating shops in mainland China are required by law to have waste treatment plants. Pollution prevention and control has become a universal concern.

Quality & Standardization Activities

Quality initiatives and standardization activities are closely related. ISO 9000 series of standards are based on the principle that standard operating procedures make it possible to measure performance with respect to quality. If quality performance is measured accurately, then procedures can be improved until error-free performance is achieved. Quality or excellence is worth pursuing in nickel electroplating and other areas, because it leads to growth, while poor quality discourages it.

Electroplating Process Control

Underlying quality and standardization activities is the continuing need to improve electroplating process control. The trend is shifting from simply monitoring the process to controlling it by means of computers: adjusting the composition of the plating solution; monitoring impurity levels; controlling pH, temperature and current density; measuring thickness *in-situ;* adjusting current distribution to obtain uniformly thick deposits; monitoring and controlling stress continuously; and adjusting the concentrations of organic additives to control the electrochemical characteristics of individual nickel layers. This trend should be encouraged because it is likely to lead to genuine improvement in the quality of electrodeposited nickel coatings.

The Future Looks Bright

The versatility of nickel electroplating is evident. Once again, although there has been a worldwide decline in decorative plating for automotive uses, the trend may be reversing itself because of the growing popularity of small trucks and recreational vehicles that have retained brightwork and new applications, such as electroplated styled wheels. Non-automotive decorative end uses will grow as people strive to raise their standards of living. Engineering applications will expand because of the increased demands being placed on industrial materials. Electroforming meets the challenge of making products and components that are difficult or impossible to make any other way.

Economic trends, pollution control regulations, standardization activities and efforts to improve process control will affect the future of nickel plating. Perhaps the most important of these is process quality control. Improved process control will make it possible to exploit the full potential of electrodeposited nickel coatings in decorative, engineering and electroforming applications.

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Household appliances shine with nickel-chromium finishes.

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