Why Use Electroless Nickel Today?

By James Bates

Many automotive parts are currently plated with electroless nickel for wear properties. A slip yoke (part of the front end) and a differential assembly, using an electroless nickel-plated control pin, are in full production in the U.S.

Photos courtesy of Enthone-OMI, Inc.

The unique properties of electroless have resulted in the steady growth of both the number of applications and consumption of electroless nickel (EN) since it recovered from a lull in the mid-1980s. Today, there are approximately 1,000 facilities in North America that are processing EN—most of which are jobshops using proprietary bath formulations. The original Kanigen (catalytic nickel generation) process mixed by the user, however, is still in widespread use, particularly for the petroleum industry. Also, the use of specialized high- and low-phos processes and composite processes has grown rapidly.

The first patent for electroless nickel was awarded in 1950. Most use in the '50s and '60s was for railroad tank cars by operators who licensed the technology. Real commercialization occurred in the late '60s and '70s when metal finishing suppliers began developing proprietary baths and provided technical support to the operators, which made them much easier to use. The market expanded rapidly, especially in the petroleum industry where EN's wear and corrosion resistance significantly extended the life of valves and other components. This came to a screeching halt in the mid-1980s with the crash of the oil and gas industry. Research had been going on to understand the special properties of electroless nickel, however, and this broadened its application as a functional coating into many industries. Growth since the late 1980s has been about five percent per year.[1]

Properties and Applications

Electroless nickel is most often specified by designers today for:

- ❒ Corrosion resistance
- ❒ Wear resistance
- ❒ Plating thickness uniformity

Other properties of EN include:

- ❒ Magnetic response
- ❒ Conductivity
- ❒ Lubricity
- ❒ Ability to improve adhesion of other coatings

The largest single use of electroless nickel is for one of these secondary properties. Memory discs are plated with nonmagnetic, high-phosphorus EN to create a barrier between the aluminum substrate and the sputtered magnetic surface. This prevents electronic crossover from one side of the disc to the other. The phenomenal growth in the computer industry accounts for 20–25 percent of the consumption of electroless nickel for this application alone.[2]

The industries in which electroless nickel is used are broad. They include:

- ❒ Automotive
- ❒ Aerospace
- ❒ Electronics
- ❒ Oil and chemicals
- ❒ Machinery
- ❒ Printing
- ❒ Food

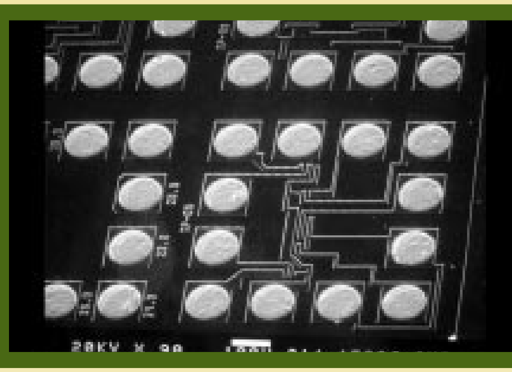
EN is specified for one or several of its properties. The structure changes from fine crystalline to amorphous as phosphorus increases throughout its range of 2–13 percent by weight. The structure is also changed by heat treatment or by co-deposition with particulates such as PTFE, fluorinated carbon particles, silicon carbide or diamond. The difference in structure has major effects on its functional properties, so it is important for the designer to be aware of these differences.

The amorphous nature of high-phos EN processes minimizes or eliminates the intergranular corrosion that occurs with electrolytic nickel (which is about 99 percent nickel by weight and highly crystalline), making it a very effective barrier corrosion protector in neutral or acidic environments. Heat treating enhances hardness and wear resistance, but also increases crystallinity, thereby reducing corrosion resistance. It's a world of compromises, but the ability of electroless nickel to provide a variety of properties is the very reason that its use is so widespread.

In strongly alkaline media such as phosphoric acid, low-phosphorus EN is superior in corrosion resistance to high-phos EN. These different corrosion resistance characteristics, along with inherent wear resistance, have resulted in numerous applications of both low- and high-phos electroless nickel in the chemical process industry.

The as-plated hardness of electroless nickel varies inversely with phosphorus content, from approximately 500–720 HK_{100}, and as such, has good resistance to wear and erosion. Heat treatment can significantly increase this hardness range to 850–950 HK_{100}. Electroless nickel-boron coatings can achieve hardness up to 950–1100 HK_{100}. In these ranges, electroless nickel challenges chrome, and has found applications in such areas as molds to replace hard chrome because of environmental concerns. The thickness uniformity of electroless nickel, which is not subject to high- and low-current-density area deposit variation like electrolytic processes, is a real benefit in these applications. The deposit is further enhanced in some instances with PTFE or fluorinated carbon for release property or sliding wear resistance, or with silicon carbide or diamond for abrasion wear resistance.

Wear resistance, uniformity and lubricity characteristics are the reasons for most applications in the automotive, aerospace, textile, printing and food industries. These are too numerous to list here, but some examples include gears, bearings, bushings and brake cylinders in the automotive industry; compressor cases, stator blades and vanes, actuation hardware, hydraulic components and landing gear in aircraft; feed rolls, thread guides, heddles, spools and combs in the textile industry; and printing rolls and copier rollers in the printing industry. In the food industry, all articles and materials in direct contact with food require individual approval from the FDA, which has limited applications of this nature, but electroless nickel is used extensively in such non-contact applications as conveyor systems, bearings, rollers and packaging equipment.



Electroless nickel bumps coated with immersion gold can be formed on aluminum circuits, replacing the tin-lead solder bumps used in the "flip-chip" packaging of semiconductors.

Electronics Applications

The electronics industry uses electroless nickel extensively for its corrosion resistance, uniformity and solderability, and as an underlayer to apply gold. Literally billions of the common TO-3 transistor capsules have been EN-plated since their inception in the 1950s, and aluminum heat sinks that require transistors to be soldered to them are typically EN-plated as well. Electroless nickel, followed by electroless gold, is used on many printed circuit boards to replace the hot-air solder leveling process to apply solder mask.

Other electronics applications include:

- ❒ Connectors
- ❒ Microwave components
- ❒ Transistor chips
- ❒ EMI shielding

Specifications

There are several specifications covering electroless nickel for engineering requirements. Recently published standard ASTM B733 is proving very helpful in specifying the right electroless nickel for a given application. It has call-outs for four different service conditions, three test types and five post-treatment classes.

MIL-C-26074 is the traditional specification for electroless nickel. The military is trying to replace it with SAE specs AMS 2404 and AMS 2405, which are commonly used in aerospace applications. Attempts to eliminate it, however, have resulted in confusion and resistance.

All of these specifications have strong points and drawbacks, so care must be taken to get the need met without causing an impossible requirement or prohibitive cost.

Process & Bath Operation Advancements

Competition in the electroless nickel industry is keen, so the metal finishing suppliers conduct extensive research in order to separate themselves from one another. Their efforts are aimed at specialized processes for various applications, improvements to make the baths more stable, longer lasting, and faster in deposition rate. Significant advancements have been made in the last few years.

Regenerative Processes

There is a great deal of development activity now toward regenerative processes where bath life can be extended tremendously—theoretically, forever. This has a number of positive implications:

- ❒ Reduction of chelated waste treatment volumes
- ❒ Reduced bath makeup costs
- ❒ Consistent deposit characteristics and plating rate

Chemical by-products of the plating process and contaminates build up as electroless nickel baths age, resulting in a finite bath life. The concept is to remove the unwanted materials and replenish the bath with additives to keep the process in balance, in addition to the nickel and reducing agents that are normally consumed. The methods being developed include chemical precipitation and filtration, ion exchange in combination with chemical precipitation, and electrodialysis.[3,4] Some of these are in use today, but insensitivity to some of the contamination that can occur in a typical job shop, or the capital cost involved with electrodialysis systems, has limited widespread installations. Use will grow as the research continues.

More commonly used are automatic controllers that measure bath concentrations at frequent intervals and make needed replenishments in small amounts as constituents are consumed. The advantage of these systems is that the nickel and reducing agents are kept at nearly constant levels. This results in more consistent plating rates and longer bath life because they are not being shocked with heavy additions. These systems are relatively inexpensive and some are SPC-capable since they record concentrations and replenishments, as well as other critical data, such as pH and bath temperature.

Where Will It Go From Here?

The future of electroless nickel is not entirely clear. A new technology eliminating EN on memory discs would put a serious damper on total consumption. Fortunately, no such technology is pending.

On the other hand, the unique functional properties of electroless nickel; environmental directives to replace more hazardous materials, such as chrome and cadmium; better specifications; ongoing research, and better processes and operating systems suggest that electroless nickel will continue to find wide-ranging applications in a broad number of industries. It is incumbent on the industry to make engineers and designers aware of the problem-solving capabilities of electroless nickel to continue its acceptance and growth. P&SF

References

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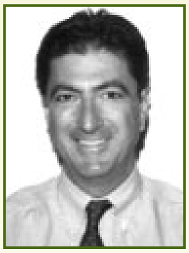
About the Author



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