An Overview Of Pulse Plating

By Norman M. Osero

Applications in electronics continue to dominate but other industries are beginning to benefit.

Pulse plating is a method of depositing metal on a substrate using interrupted direct current (dc). These pulses are often employed at a rate of 500 to 10,000 times per second. They favor the initiation of grain nuclei and greatly increase the number of grains per unit area. The intended result is a finer-grained deposit with better characteristics and properties than conventionally plated coatings.

The electronics industry has been and continues to be the major user of pulse plating. In fact, pulse plating has become a requirement in many cases where the process and/or product specifications are highly restrictive and sophisticated.

We will discuss some of the principles, practices, and applications of pulse plating, then conclude with a forecast of what the technique might hold for the future. We will begin with a discussion of equipment and wave shapes.

Pulsing Equipment

Early equipment for pulse plating consisted of a dc rectifier and chopper circuit, which provided low-frequency pulses with little regard for pulse frequency, rise-and-fall times, and regulation. Semiconductor regulators were added to the dc rectifier, resulting in a pulse power supply that offered switching frequencies up to 10 Hz with fast rise-and-fall times. In recent years, pulse power supplies have been changed to offer complex waveform capabilities (e.g., pulse reversing, pulse-on-pulse, and duplex pulses).

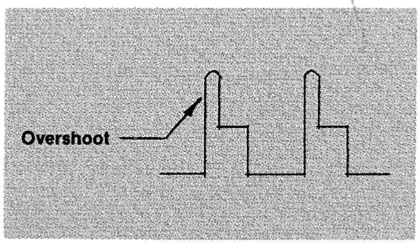

Fig. 1—High-current spikes at start of on-time.

Single-direction pulse power supplies are referred to as *unipolar* types. They have been the workhorse of pulse platers and represent about 90 to 95 percent of those in the market. They are available as add-on switches (converters) to be used with a separate dc rectifier or as an integrated supply with the dc portion and the switching circuits contained in one unit. The latter type is the most common arrangement.

Converter pulse systems usually feature saturated or low-voltage-loss switches. They depend on the dc rectifier to provide current or voltage regulation. One disadvantage of this approach is that any ripple on the dc output is passed through the switch to the plating bath. When a current-regulated dc rectifier is used, its output voltage will rise during the pulse off-time, charging the rectifier filter capacitors and yielding high-current spikes at the start of the on-time of the pulse (Fig. 1).

SCR or thyristor-controlled dc power supplies often will not operate well with switching applications. At low output voltage or current, the SCRs are operating at a very low phase angle and the ac ripple component is very high.

Integrated pulse power supplies consist of a dc rectifier and pulse switch circuits in one unit. They are more commonly used than those with an add-on switch to the dc rectifier. Integrated supplies offer the advantage of being able to better control the amplitude and ripple of the output current. Also, the dc portion of the supply is designed to be compatible with pulse switching techniques. These systems offer current or voltage regulation and are usually more readily applied to plating because of their ease of operation.

Wave Shapes

Pulse power supplies are offered with two basic wave shapes: *sine* and *square* wave. The modified sine-wave system uses the power-line frequency of 50 to 60 Hz half wave or 100 to 120 Hz full wave as its time base. The output pulse usually has a fast turn-on time and a slow sinusoidal turn-off time. Its advantage is lower cost by comparison with square-wave systems. However, because lower frequencies have not shown the benefits of higher ones, the modified sine-wave system (Fig. 2a) has not found wide acceptance for pulse applications.

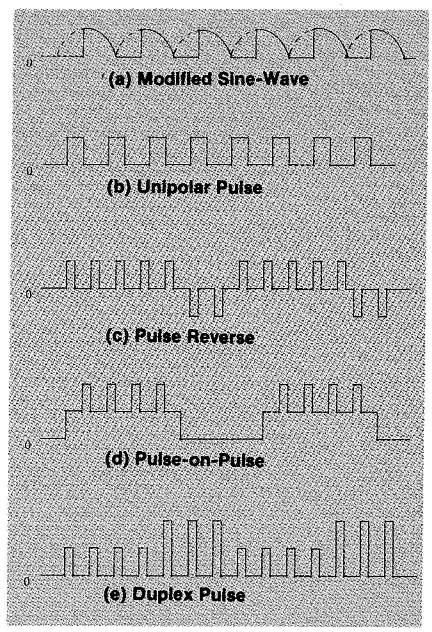

Fig. 2—Wave shapes.

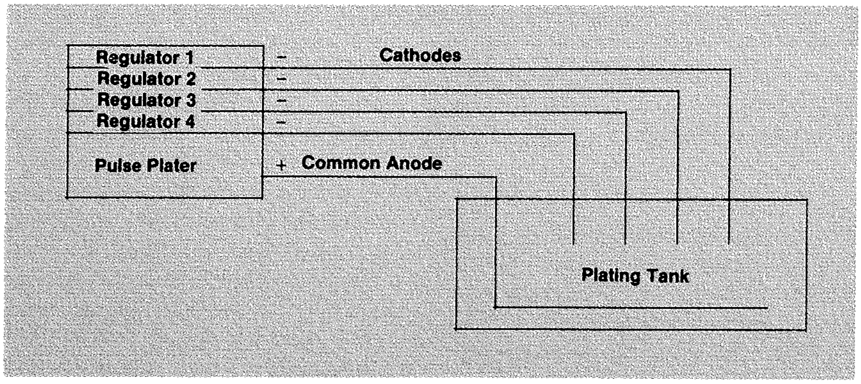

Fig. 3—Typical multiple-output pulse system.

Square-wave (Fig. 2b) pulse power supplies feature a time base that is independent of the power-line frequency. They operate over a wide frequency range up to and often exceeding 10 kHz. These systems are successfully applied to both precious and base metals for electronic, microelectronic, and decorative applications. The wide operating parameters allow the user the most flexibility in determining the optimum operating parameters for a specific application.

Power supplies that deliver *complex* pulse wave shapes (Fig. 2c) are also being applied to many processes. Pulse-reversing units feature a train of pulses in the cathodic direction followed by a train in the anodic direction. Some manufacturers offer equipment that allows independent control of forward and reverse pulse timing and amplitude. Converter systems for pulse reversing usually offer the same pulse amplitude in both directions and independent timing to allow the user to vary the average current.

Pulse-on-pulse systems (Fig. 2d) offer complex wave shapes that have pulses at one amplitude riding on top of those of a lower amplitude. *Duplex* systems (Fig. 2e) feature a burst of pulses at one level followed by a burst at another, all in one direction. Pulse-on-pulse and duplex systems are used mainly for research.

Because of the vast variety of plating processes and products, manufacturers of pulse power supplies have had to offer a great deal of flexibility in their equipment. Some companies offer custom-designed systems or standard equipment that can be adapted to the user's requirement.

These custom-designed products usually command a higher price than standard equipment. However, customized products offer the customer a piece of equipment that is often a better answer for his needs. Also, these custom-made units sometimes *evolve* into new standard products that can be offered at a more attractive price. Multiple-output pulse platers are an excellent example of this (Fig. 3). They allow precision control of the current to each cathode for improved part-to-part thickness uniformity.

Application Overview

Now let's outline some of the current and prospective uses of pulse plating:

• *Connectors:* Pulse plating is being used to a large degree for plating nickel and gold on electronic connectors and switch contacts. Some contacts are barrel plated with gold over the entire surface. But the cost of gold and concerns for minimizing its use have led manufacturers to develop selective plating methods for applying the gold only on the contact areas. Stripe plating of nickel and gold has been very successful with pulse deposition.

A reduction in stress of the pulse-plated nickel deposits has allowed manufacturers to stamp and form contacts after plating. The economic gains have far surpassed the relatively high cost of pulse power supplies. A pulse cycle of 1.0 millisecond on and off is typical for depositing cobalt- and nickel-hardened gold.

• *Lead Frames:* Manufacturers of semiconductor lead frames are using pulse plating to increase the reliability of wire bonds and to enhance deposition speed. This has been accomplished through the use of proprietary high-speed gold and silver plating solutions specially formulated for pulse deposition. Peak voltages in the range of 40 V are required to deliver the high peak amperes that are necessary.

• *Fine Patterns:* The microelectronics industry has recognized the advantage of pulse plating for high-density circuitry. A report by Missel et al.[1] on the square profile of pulse-plated circuit paths describes the process and advantages.

Typically, dc plating results in mushroom-shaped deposits, which limit the proximity of one line trace to another in fine pattern plating. With the use of pulse technology, circuit traces can be positioned closer together without shorting one another. Companies that manufacture high-density circuits have been able to increase the number of circuits on a given surface dimension. Increased circuit density in thin-film magnetic heads for computer disc drives allows for greater magnetic strength of the head.

• *SAW Technology:* Pulse plating is being studied for use in Surface Acoustic Wave (SAW) technology, which is employed in the manufacture of high-frequency (10 MHz to 1 GHz) oscillators, filters and resonators for cable television, satellite communications, modems and radar applications.

• *Electroforming:* This is a very important application for pulse power supplies. Nakamura[2] reported that pulse deposition could be used to produce stronger electroformed copper and nickel parts with thinner walls and lighter weight. Also, companies are using pulse deposition to electroform nickel venturi valves for cryogenic applications, where it is very important to maintain exact replication of the machined aluminum mandrel.

Moreover, pulse power is being used in the electroforming of diamond cutoff wheels for the semiconductor industry. Improved properties of the pulsed nickel deposit result in better wear characteristics and heat transfer away from the cutting edge. Optics manufacturers are using pulsing techniques to electroform exacting molds for contact lenses. The nickel deposits exhibit little or no stress. Molds for light-reflecting products (e.g., reflectors for cars and bicycles) are also being pulse electroformed. Reflectivity is said to be uniform over the full surface of the reflector.

Finally, pulse electroformed nickel for large machined parts has improved machinability. Pulsed current has reduced hydrogen embrittlement and treeing of the deposit. Reduced pitting has resulted in less scrap being generated during the machining operation.

• *Etching:* Most applications of pulse power supplies are those where metal is being deposited. However, they are also being used to etch fine patterns in high-temperature metal alloys. Pulse etching has proven to be far superior to alternative methods in some cases. The capability to etch very sharp corners and straight walls in deep crevices by comparison with conventional etching methods has yielded products that meet exacting design requirements.

• *Waveguides:* A smooth surface topography in high-frequency waveguides is important for the reduction of radio-frequency losses in transmission. Pulse-plated gold deposits exhibit reduced surface roughness for improved waveguide performance.

• *Decorative Work:* Many high-technology jewelry manufacturers are using pulse techniques to apply gold, rhodium and silver. Some decorative platers report that pulse plating allows better deposition into recessed areas of complex shapes while minimizing overplating at high-current-density areas.

• *Circuit Boards:* Some PC board companies have been using pulse plating for tin-lead alloys and copper for a number of years. They report being able to maintain a very consistent tin-lead alloy content over the entire surface of a panel (4 to 5 ft^2). The resulting deposits are said to exhibit excellent characteristics with regard to infrared solder reflow.

Copper deposition using pulse-reversing techniques was shown by Hall et al.[3] to offer significant improvements in through-hole plating and elongation and thermal properties of the deposit. Ratios of up to 10:1 in board thickness to hole diameter are said to be possible.

With the increased demands on circuit board makers to produce boards with smaller holes and closer line widths and spaces, it would appear that pulse plating will become an increasingly important method. The challenge for rectifier manufacturers is to offer the PC industry power supplies that can deliver the large currents required for copper plating, and at an economical price.

• *Electroless Nickel:* The application of pulsed current to electroless nickel has been shown by Mallory and Lloyd[4] to increase the deposition rate by a factor of several times while yielding deposits with physical properties similar to those of conventionally applied EN. This is an unconventional application of pulse power supplies, though perhaps it may become a significant one. R&D in this field could result in pulse plating becoming a very large and important part of the "electroless" process.

A Forecast

Many companies have been using pulse plating primarily to obtain an improvement in deposit properties as a result of grain refinement. Others claim improvements in throwing power and thickness distribution, but the superior metallurgical properties by comparison with conventional dc plating are the major benefit. Nonetheless, it should be pointed out that pulse plating is not a panacea and that it is still an evolving technology.

Finishing and manufacturing engineers are continually requesting plating solutions that offer specific deposition results for stated pulse operating parameters. Solution formulators are being called upon to answer these needs. Contrary to the theory that pulse plating eliminates the need for solution additives, we feel that baths developed for pulse deposition will continue to use additives in order to achieve optimum and repeatable results.

There is also the possibility that pulse power will become a commonly used tool for other electrochemical processes (e.g., electrodischarge machining, electroetching, and electrocleaning). Electrical current can be defined and controlled more easily than can the chemical makeup of the solutions employed for these operations. This marriage of chemistry and the highly predictable and controllable parameters of electrical current could well result in future electrochemical processes that are easier to use and maintain and that deliver improved results.

The electronics industry continually pushes process technology to new horizons. The dynamics of this industry results in manufacturing processes that often experience a very short life. The process that was good yesterday may not even be used today. In the extreme, processes are sometimes outdated before they are even put to use.

This technological change is evidenced by new manufacturing methods for circuit boards, GaAs wafers, and microelectronic components. Greater demands to place more and more electronic circuits on a given substrate may result in line widths and spacings between lines that cannot be achieved with dc plating or even by altering solution chemistry.

Pulse power supplies will be changing continually to take advantage of new electronics technology—e.g., microprocessor control, smaller components, and greater current-handling semiconductors. However, the real future of pulse power supplies lies not in the equipment technology but in the sophisticated processes that require the use of pulse power to achieve the desired results.

Finally, it is worth noting that the AESF has become increasingly active in this area. Its Third International Pulse Plating Symposium is scheduled for October 28-29 in Washington, DC, and authors are nearing completion of a society-sponsored book on the subject.

Yes, the future of pulse plating is now! □

References

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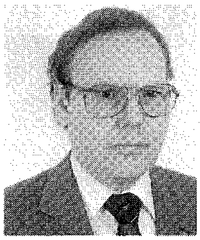

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