Ultrasonics in Cleaning & Electroplating

By Dr. S.B. Awad

This is another in the P&SF series of articles on the basics of plating shop operation. It is intended for the newcomer to the industry, as well as a review for experienced operators.

Careful preparation and cleaning of various types of metal components is *indispensable* prior to surface treatment or final assembly. Surface coating operations that require such care include vacuum deposition, electronics, electrolytic and electroless deposition of metals onto various components, various dip coatings etc. Surface preparation of parts is essential for achieving good and firmly adhered coatings. Traces of residual surface contaminants[1] or corrosion can drastically alter surface properties such as wettability, adhesion, and optical or electrical characteristics. An early report attributed poor results in electroplating to inadequate understanding of ultrasonics as a method of surface preparation.[2]

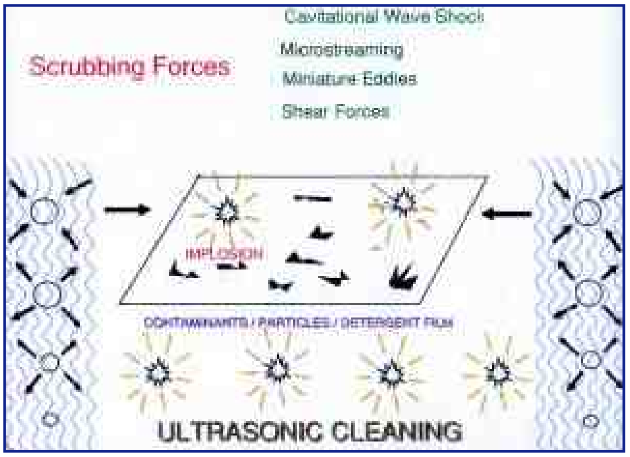

Fig. 1—Ultrasonic cleaning.

The focus of this article is the basics of the ultrasonic process and the value added by applying ultrasonics in two areas: surface preparation and electrolytic metal deposition (electroplating) of various parts and devices.

Cleaning with Ultrasonics

Cleaning with ultrasonics offers several advantages over conventional cleaning methods. The cleaning action relies on cavitation or micro-implosions generated in a solution by high-intensity ultrasonic waves.

Complete removal of contaminants is achievable, particularly when intricate parts with irregular surfaces or internal passages are being cleaned. The micro-mechanical scrubbing action of ultrasonic cavitation is directionless and can reach wherever there is a liquid or wetted surface. The released energies reach and penetrate deep into crevices, blind holes and areas that are inaccessible to other cleaning methods. The removal of contaminants is consistent and uniform, regardless of the complexity and the geometry of the parts.

Ultrasonic cleaning uses high-frequency sound waves transmitted into a cleaning solution/liquid. When a solution is subjected to rapid oscillation from the high-frequency sound waves, minute vacuum bubbles are generated that grow to a certain critical size, based on a number of variables, then implode. This phenomenon is known as *cavitation.* When cavitation occurs on or near a contaminated surface, mechanically held contamination is released, soluble materials will rapidly dissolve and oil and similar contaminants are then easily displaced by the cleaning chemicals. The ultrasonic energies reach everywhere, into crevices, blind holes and areas that are inaccessible by other cleaning methods (Fig. 1).[3]

Ultrasonic waves are mechanical pressure waves formed by ultrasonic generators. A typical generator produces ultrasonic frequencies greater than 20 kHz, or 20,000 cycles per second (Fig. 2). This energy is used to drive transducers, devices that transform electrical energy into mechanical vibrations that are then transferred into a cleaning solution to do the work. There are many types of transducers, but the most commonly used types for generating ultrasonic vibrations are piezoelectric (quartz crystal or ceramic), magnetostrictive (causing a metal rod, for example, to be squeezed and released by a strong magnetic field), electromagnetic, pneumatic and other mechanical devices. The piezoelectric type is the most widely used technology in cleaning and welding applications. It offers a wide range of frequencies, from about 20 kHz to the megahertz (millions of cycles per second) range.

Typically, piezoelectric (PZT) transducers are mounted on the bottom and/or the sides of cleaning tanks. The transducers can be mounted in various designs and sizes in sealed stainless steel containers and immersed in the cleaning solution/liquid. The push-pull transducer rod is a recent immersible transducer design patented by Martin Walter Co. This immersible is made of two PZT transducers mounted on the ends of a titanium rod. The generated ultrasonic waves propagate perpendicularly to the resonating surface. The waves interact with liquid media to generate cavitation implosions.

The energy released from an implosion in close proximity to a contaminated surface collides with

Ultrasonic & Megasonics Generation

- High Power Generator
  Low-frequency Current 50–60 Hz → High & Ultra-high Frequency 20 KHz–X MHz
- Transducer Assembly (PZT)
  HF or UHF Current + Transducer → Ultrasonic or megasonic waves

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- Sonic Waves + Liquid Medium → Cavitations and/or microstreaming

Fig. 2—Ultrasonic & megasonics generation.

and fragments or disintegrates the contaminants, allowing the detergent or the cleaning solvent to displace it at a very fast rate. The implosion also produces dynamic pressure waves that carry the fragments away from the surface. The implosion is also accompanied by high-speed micro-streaming currents of the liquid molecules.

The abundance of cavities generated in a solution increases with frequency, but the energy released by individual cavities decreases and becomes milder, and is therefore ideal for small particle removal.[4] For example, at lower frequencies (20-30 kHz), a relatively smaller number of high-energy powerful cavitations is generated (Fig. 3). At higher frequencies (40-200 kHz), more cavitations with moderate or lower energies are generated. Lower frequencies are more appropriate for cleaning heavy and large-size components, while mid-range frequencies (40-80 kHz) are recommended for cleaning a variety of surfaces. Higher frequencies are good for cleaning delicate components, as well as for their effectiveness in the rinse steps. For example, at 68 kHz and 132 kHz, the cavitation abundance is high enough and mild enough to completely remove detergent films and small particles without inflicting surface erosion. Selecting the proper frequency for a particular application is very important and must be carefully investigated.

Ultrasonic Cleaning Equipment

Ultrasonic aqueous (water-based) batch cleaning equipment consists of at least four steps: ultrasonic wash, minimum of two ultrasonic separate (or reverse cascading) water rinse tanks and heated recirculated clean air for drying. The last drying step is not included if the after-cleaning operation includes an aqueous bath, as in electro- or electroless plating. Ultrasonic transducers are bonded to the outside bottom surface, or to the outside of the side walls or provided as immersibles inside the tanks. The latter is usually the preferred method when large tanks are under consideration. Two types of immersibles are commercially available in various sizes and frequencies. The traditional sealed metal box contains a multi-transducer system and the recently patented[5] cylindrical immersible which is powered by two main transducers at both ends, known as push - pull immersibles.

Automation of ultrasonic cleaning system is well established. Automation includes a computerized transport system able to run different processes for various parts simultaneously, as well as data monitoring and acquisition. Advantages of automation are numerous, including consistency, achieving desired throughputs and full control on process parameters.

Typical tank size ranges from about 2.6 gal (10 liters) to 660 gal (2,500 liters), based on the size of the parts, production throughput and the

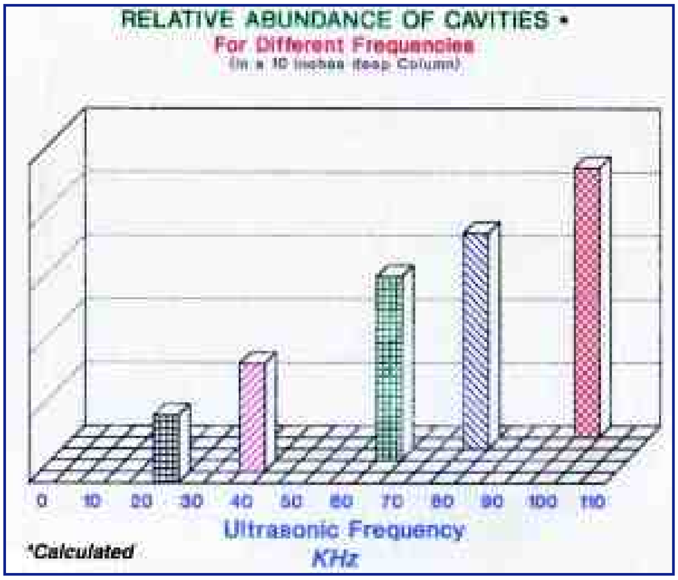

Fig. 3—Relative abundance of cavities for different frequencies.

required drying time. A whole automatic machine can be enclosed to provide a clean-room environment. Process control and monitoring equipment consist of flow-controls, chemical feed-pumps, in-line particle count, TOC measurement, pH, turbidity, conductivity, refractive index etc. The tanks are typically made of corrosion-resistant stainless steel or electropolished stainless steel. Titanium nitride or similar coating is used to extend the lifetime of the radiating surface in the tanks or the immersible transducers.

Cleaning & Chemistry

It is important to understand that the use of ultrasonics does not eliminate the need for proper cleaning chemicals, as well as implementing and maintaining the proper process parameters. Cleaning with ultrasonics using only plain water is workable, but only for a short time. The question then is how long it will work before failing to clean. In fact, cleaning is more complex than just extracting the contaminants from the surface. Soil loading and encapsulation/dispersion of contaminants are determining factors for the effective lifetime of the cleaning medium and the cleaning results.

Parts Handling & Orientation

For best use of ultrasonic cavitations in cleaning, parts must be racked on a fixture or arranged in one layer and placed in an open mesh (preferably wire screen) basket and immersed in the ultrasonic tank. Stacking in layers is not recommended. Parts must be one-and-a-half to two inches from the radiating surface. For cleaning with constant rotation, special requirements must be considered. For best results, it is recommended that the parts be positioned so that all surfaces receive equal exposure to ultrasonic energy. Parts must be oriented to maximize drainage as well.

Applications that require rotation of parts include flat parts or small parts with deep blind holes. Designs for fully automated ultrasonic rotation systems are well established and are commercially available. Vertical oscillation of parts in the wash and the rinse steps may be essential in certain applications. P&SF

References

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5. Assigned to Martin Walter Co./Crest Ultrasonics Corp.

About the Author

Dr. Sami B. Awad is vice president of technology at Crest Ultrasonics Corp., P.O. Box 7266, Trenton, NJ 08628. He has close to 20 years' industrial experience in developing new chemistries and processes for general and ultrasonic precision cleaning and surface preparation/treatment. He has received more than 15 U.S. and international patents. He holds a PhD in organic chemistry and has served as a professor of chemistry on the faculties of Drexel University and Cairo University, Egypt. He has served as R&D scientist with Atochem and as a principal scientist with Henkel Corp./Surface Technology Group (Parker + Amchem). Dr. Awad is the author of more than 25 academic papers in organic reaction mechanisms.