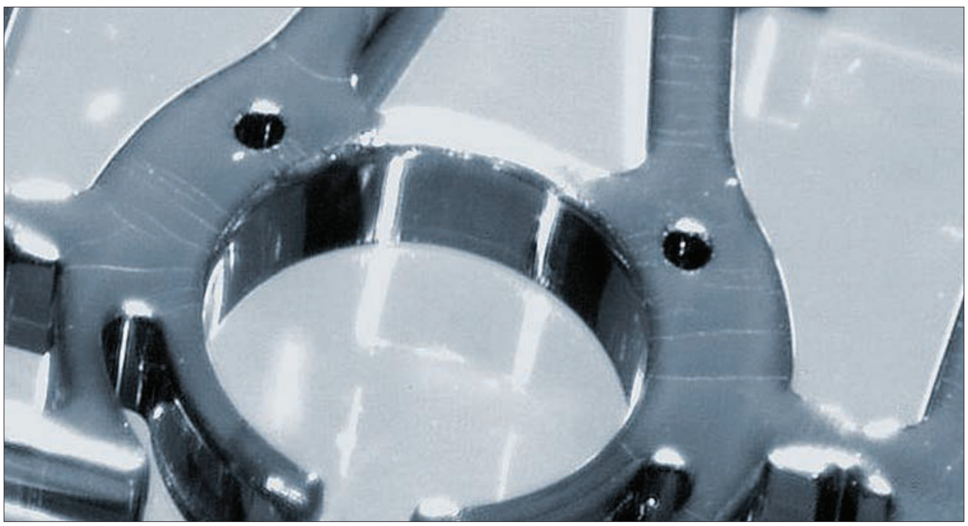
A Recipe for Electroforming Success: The Making of Ultra-Precise, Ultra-Small Three-Dimensional Structures



Precision electroforming is an additive process in which 2-D and 3-D microstructures are formed by electrochemically depositing metal into a precisely formed photoresist mold. Electroforming is ideal for fabricating micron-scale, metallic components as well as for making injection molds used for forming nonmetallic microstructures with nano-scale features.

Choosing a qualified manufacturing partner is critical in achieving total success. By breaking down our own expertise we hope it provides you with a foundation for creating effective requests for proposals (RFPs) and vetting partners for your electroformed component manufacturing needs.

Unlimited Geometries

Metrigraphics can create three-dimensional, single or complex, multilayer microstructures with very high aspect ratios. (Table 1 shows photoresist aspect ratio guidelines.) The geometric options are unlimited because the X, Y, Z structural plane of each layer is formed by a photoresist image. Such structures may be freestanding or connected to comb-like supports to facilitate handling or fixture mounting. We offer micronozzles, inject nozzles, orifice plates, nozzle plates, slits, screens, mesh, disks, and more.

Photoresist	Plated Metals	Minimum Feature	Max Aspect Ratio
AZ1500, AZ9200	NiCo, Ni, Cu, Au	1-12 microns	1:1
AZ9200, NR-9, NR-5, SU-8	NiCo, Ni, Cu, Au	12-50 microns	2:1, 5:1 (BE)
NR-9, SU-8	NiCo, Ni, Cu	50-100 microns	2:1, 10:1 (BE)
SU-8	NiCo, Ni, Cu	100-200 microns	15:1 (BE)
SU-8	NiCo, Ni, Cu	200-500 microns	10:1 (BE)
SU-8	NiCo, Ni, Cu	500-1,100 microns	5:1 (BE)

Metrigraphics electroforming process employs a wide variety of plated materials and commercially available photoresists to produce three-dimensional microstructures with very high aspect ratios possible. Note that aspect ratio depends on the photoresist pattern.

Sample applications:

- Micronozzles
- Microstructures
- Slits
- Micro screen/mesh
- Disks
- Embossing tools

Commonly used materials:

- Nickel cobalt
- Nickel
- Pure gold
- Hard gold

A Recipe for Success

Electroforming is an electroplating process that employs proprietary recipes carried out under carefully monitored conditions by applying a tightly defined set of best manufacturing practices.

Here's how it works:

The process deposits metal onto a (typically glass) mandrel that has been coated with a very thin metal layer covered with photoresist. The photoresist is photoimaged, meaning that it doesn't cover the metal everywhere but exposes a pattern of openings through which the underlying metal is exposed. The pattern is created using photolithography by light shining through a mask, or stencil, onto the photoresist. As more and more metal is deposited, a three-dimensional structure rises from the stenciled pattern.

For example, if the photoresist were patterned in the shape of a donut, the resulting structure would have the shape of a cylinder with walls as thick as the donut and a central opening only as wide as the donut hole.

If the finished devices are to be freestanding, they can be peeled off the mandrel once all metal is added. (Metrigraphics uses a proprietary adhesive agent that enables removal from the mandrel surface following electroplating.) Alternatively, the component may remain attached (to a fixture, for example).

Depositing metal to the height of the photoresist layer results in a cylinder with vertical walls. Sometimes, however, the desired shape is not vertical but rather funnel shaped with rounded edges. For more information, please ask for our Electroforming Design Guide.

Depending on the resolution of the mask image, electroformed features can be extremely tiny — down to 10 microns in the Metrigraphics' process. The size of openings, like a nozzle orifice, can be as small as 25 microns. Hole diameter depends on the amount of metal deposited around an opening in the photoresist. As more metal is added, diameters shrink, eventually to zero if enough metal were to be added. Opening size, however, can be extremely well controlled based on variables that (among other things) determine the rate of metal deposition. These variables are among a number of factors critical to our customers' success in achieving their design goals.

Giving Our Customers What They Want

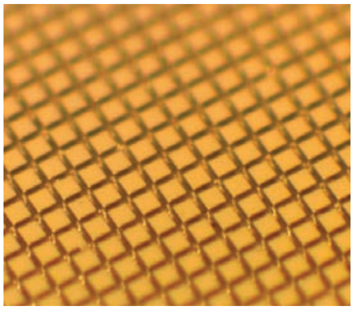
Metrigraphics' customers have very high standards when it comes to selecting the source of their electroformed parts. They look for extreme capabilities in areas like:

- Feature size
- Feature controllability
- Surface uniformity
- Batch consistency
- Component ruggedness

In other words, our customers want parts whose features and surfaces are uniformly the size and shape specified (e.g., not warped or rough). They also want parts durable enough to perform well in the application environment for which the parts are intended. Success factors generally involve the condition of the electrolytic bath during plating.

These include:

- The chemical makeup of the electrolyte bath
- The chemical balance and pH of the bath
- Cleanliness of the bath
- Bath temperature
- Room temperature
- Current density



Electroforming at a Glance

An almost infinite variety of microstructures can be electroformed, depending on the pattern and dimensions of the photoresist layer. Top: a microembosser. Bottom: a fiber-optic clip.

Electroplating is a process that uses electrical current to bond metal to metal in an electrolytic cell, or container, filled with a chemical mixture called a bath. Besides the bath the cell also contains a positively charged source of metal (the anode) and a negatively charged target (the cathode). In electroforming, the cathode is the mandrel's metal layer and any metal deposited there.

The electrolytic bath consists of dissolved salts (copper sulfate, for example) that provide ions to enable the flow of electric current through the bath from anode to cathode. The electric current ionizes the anode's metal; the ions are dissolved in the bath and then flow to the cathode where they bond to, and build up, the electroformed part. The rate at which metal is added (plated) to the cathode is proportionate to the current density — i.e., the more electric current applied, the faster the plating.

Current density is a key parameter that impacts quality of the part. If plating happens too fast or too slow the part's surface is more likely to be uneven. Another consequence of too-high current is stress — i.e., pressure within the deposit that can cause metal to warp, shrink, crack, or even break, once deployed in the customer's application.

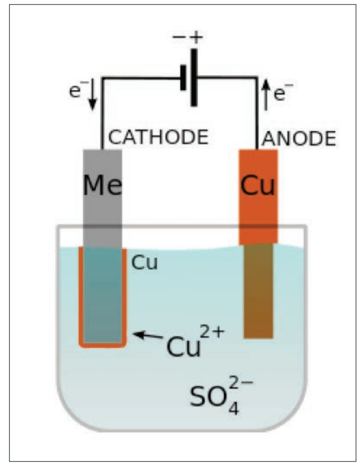
Another reason chemical balance is key is so that salts do not precipitate out of the bath, as these solids could strike the part and cause damage. Environmental dust could also cause damage if it were allowed to get into the bath. Even a 2-micron size piece of lint can do serious damage to a circuit with features in the 5-micron range. To protect against such hazards, Metrigraphics has developed and strictly follows a number of best-manufacturing practices, process controls, and quality assurance procedures.

Key Electroforming Success Factors

Here are five of the most significant ways Metrigraphics ensures the quality of its electroforming process:

Knowledge capture and reuse. When a customer comes to Metrigraphics with a new project, our deep knowledge captured from thousands of previous projects over many years enables us to gain quick and clear insights into process design and set-up for best results at lowest risk with fastest turnaround.

Constant monitoring. We continually monitor key parameters like current density, chemical balance, and bath and ambient temperature to ensure that the process stays on track with the recipe prescribed for a particular part. This helps achieve uniform results consistent with a given recipe, but also provides a benchmark against which to potentially fine-tune the recipe for even better results.



Electroplating at a Glance

In electroplating, metal (Me) such as copper (Cu) from a cathode passes to and bonds with an anode through the action of an electric current in an electrolytic bath containing ionizing salts, such as copper sulfate. Source: Wikipedia.

Visual parts inspection. Electroplating is a "fluid" process — conditions of the bath will drift with time and with the number of batches processed. That's why we visually inspect parts as they come out of the bath to make sure that specifications such as geometry, surface smoothness, and feature size are being met. If they're not being met then we will take mitigating measures such as replacing bath filters, replacing the bath, or adjusting the recipe.

Quality of manufacturing facilities. Whether your electroformed part can meet design specifications, perform as intended in your application, or stand up to environmental challenges has a lot to do with the capabilities of the manufacturing equipment and processes involved in making the part. Those capabilities include state-of-the-art systems for computer-aided design, photolithography masking and imaging, the layering of metals at an almost atomic level, and ultrapure manufacturing equipment and clean rooms.

Electroforming manufacturing experience. Advanced skills are required throughout the electroforming production cycle. Product and process engineers must know what will work and what won't so as to meet the application's design, mechanical, environmental, and cost criteria in high volumes at high yield — and within tight market windows.

Got a Significant Electroforming Market Opportunity?

Talk to us. We will be happy to assist you in coming up with a manufacturing solution that meets all your criteria for success.

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