# Small Deposits

## Electroformers build parts by the atom

**By William Leventon, Contributing Editor**


*NiCoForm*

Why use electroforming to produce extremely small parts and features? The answer is often simple.

"In many cases, it's the only way to make these things," said Carl Rodia, engineering consultant to Conard Corp., an electroformer in Glastonbury, Conn.

Electroforming is similar to electroplating, but there are key differences. In electroplating, when electric current is applied to a metal-containing solution, the metal coats a workpiece surface. In electroforming, a similar process is used, but one layer of metal or multiple layers are deposited to create a new part. The layers are deposited onto an object called a mandrel, which can take various forms. After the process is complete, the part is removed from the mandrel or the mandrel is dissolved, leaving just the part.

To meet some of their biggest challenges, micromanufacturers turn to electroforming when it is "virtually impossible" to machine or use other material-removal techniques to create submicron-scale features, Rodia said.

This is because the tools used in material-removal processes must be smaller than the features to be manufactured. "If you want to dig a hole 1' wide, you have to use a shovel that is less than 1' wide," he said. "But in the submicron or nanoscale world, the tools aren't small enough."

In electroforming processes like the one used at Conard, material is electrodeposited atom by atom onto the surface of a mandrel, or master, thereby creating a negative image of that surface and its tiny features. The required masters are usually made with optical systems like the photomask technology used in the semiconductor industry, Rodia explained.

Unlike conventional electroforming, where tolerances rarely reach the micron range, Conard's process, called precision electroforming, produces accuracies down to the submicron or even nanoscale range, according to Rodia.

One key to precision electroforming, he said, is supplying a "very high-purity" current to the electroforming bath that produces the metal deposit. To produce such a current, Conard normally uses a transistor-based or solid-state power supply with filters that remove noise from the current. This noise can affect the size and orientation of the deposited metal grains, which determine the metallurgical qualities of the deposit, Rodia explained.

In addition, he said, Conard "hyper-filters" the electroforming bath to remove particles with a mean diameter down to 0.2µm or less. "We want

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to make sure we're not co-depositing stray particles of carbon or other metals with the metal we're depositing," he explained. "One stray particle can obliterate an entire function of a MEMS-type machine that we are electroforming on a wafer."

Parts turned out by Conard's electroforming process include inserts for injection-molding DVDs. The features on these parts can have a mean diameter down to 0.1μm, according to Rodia. Conard also electroforms micromesh structures used to filter human blood. A photomask transfers the required mesh features to a photoresist that is then metallized.

According to Rodia, more than 90 percent of precision electroforming work is done using sulfamate nickel, which can handle extreme temperatures and pressures. In most cases, he said, this material is also ductile compared to nickel in its ingot state, as well as metals such as tin and copper.

## Making dynamic parts

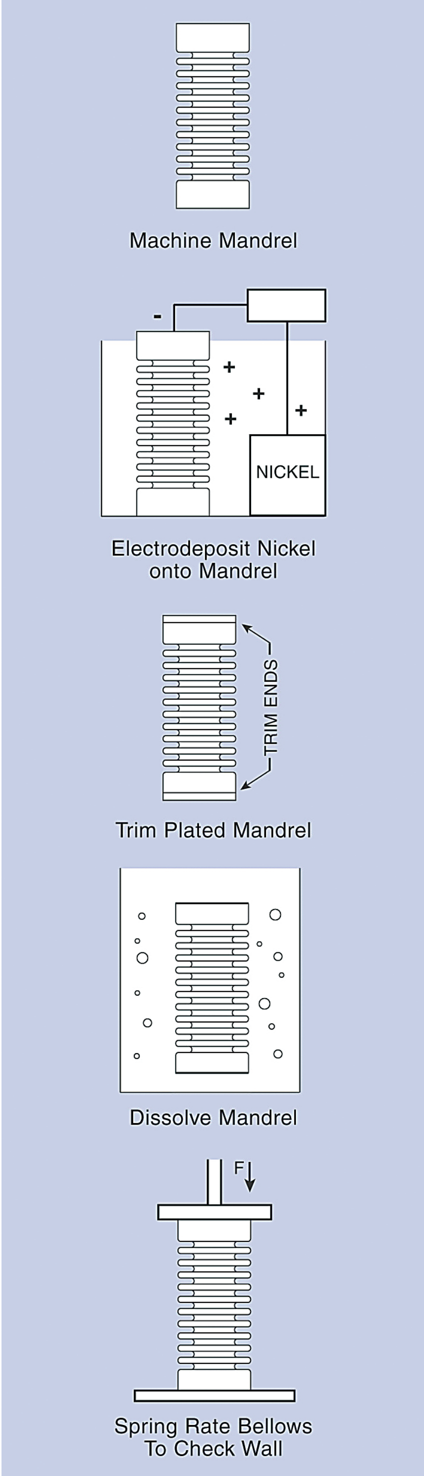
Ductility is a crucial property of electroforms created by Servometer LLC, Cedar Grove, N.J. The company specializes in what it calls "dynamic" parts. These are primarily metal bellows, which are used in applications such as expansion joints. The parts can compress, extend, bend and offset (see photo on page 32). In some cases, the parts survive for long periods of time, according to Paul Hazlitt, the firm's director of engineering services.

The key to creating these parts is a proprietary nickel alloy the company tweaks to provide a specific ductility. "What we would consider brittle, most electroformers we speak to would consider soft," Hazlitt said. "Some of them have tried to make convoluted parts like bellows, but they just shatter."

The smallest bellows Servometer makes is about 0.020" in diameter. One of the biggest challenges involved in making these tiny parts is producing the mandrels. "We plate onto an aluminum mandrel, which must be machined with the dimensions of the bellows electroform we are making," Hazlitt explained. "But not many [machine shops] are used to dealing with the scale of some of these parts."

During Servometer's plating process, the mandrel acts as the cathode, while the source of the electroform material is the anode. The thickness of the deposited material is a function of the time taken by the process and current in the plating tank. When the process is completed, the mandrel is chemically dissolved, leaving only the electroformed part.

Though the basics of the technology haven't changed recently, the process has benefitted from improvements in electronics. According to Hazlitt, these improvements have given Servometer better control of the current going to each individual mandrel, which results in more uniformity in an array of parts being electroformed simultaneously.




Servometer's electroforming process.

## Special alloy

Another firm applying machined aluminum mandrels for electroforming is NiCoForm Inc., Rochester, N.Y. NiCoForm relies on the mandrels to electroform miniature components for fiber-optic inspection systems. The parts range in size from a little under 1mm to several millimeters in length, with walls as thin as 10μm (see photo on page 28).

These fragile-looking electroforms need rigidity because they are often used to mount lenses and other components. So NiCoForm uses a special nickel-cobalt alloy called NiColoy that allows the company to create parts with greater strength than conventional nickel electroforms, according to Berl Stein, president.

NiColoy is also used to create metal tools for the mass-production of polymer microfluidic and optical parts in processes such as molding, stamping and embossing. In these cases, electroforming is done on fragile or unstable substrates rather than on aluminum mandrels.

"Our proprietary methods enable us to transfer patterns from an etched silicon wafer, which is very fragile and flimsy, to a robust nickel-cobalt-based electroform that will withstand hundreds of thousands of molding cycles." Stein said.

On the downside, the deposition process is slow. Stein said it takes 24 hours to deposit a 250μm to 500μm metal layer. As a result, creating an electroform can take days or even weeks. On the plus side, however, smaller parts can be electroformed in quantities of a few thousand at a time, Stein added.

## Other drawbacks

Another electroforming disadvantage is that it requires a high level of expertise in a number of different disciplines, according to Conard's Rodia. For example, electroforming practitioners need the services of a technician to control the chemistry, an electroplating expert and someone who can create the mandrels or masters onto which the

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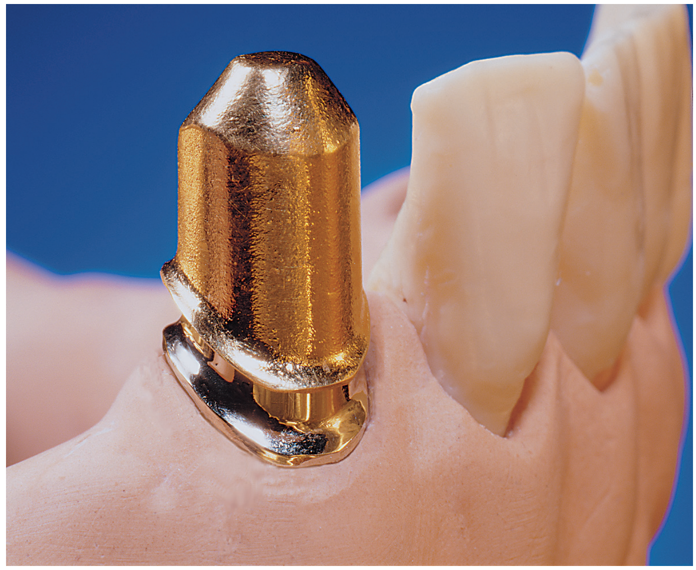
# A dental equipment maker's crowning achievement

**More than 20 years** ago, the German firm Wieland Dental introduced its first dental electroforming system.

"Electroforming is a very precise deposition method," said Rudolf Wagner, Wieland's head of R&D. "That is important for the dental field, where precision is measured in hundredths of millimeters."

In addition, he noted, the atom-by-atom deposition process doesn't produce a typical layered structure. "If you look under a microscope, you don't see a structure like that of a casting," he said. "It's an amorphous structure that is quite tough."

*Wieland Dental*

The Wieland AGC MicroVision system, which makes gold crowns.

Wagner and his colleagues haven't allowed their company's technology to grow long in the tooth over the years, making constant improvements that led to their latest offering, the AGC (Auro Galva Crown) MicroVision system, which makes gold crowns. In a 4-hour process, the machine normally deposits a 0.2mm gold layer that can yield up to six crowns.

The Wieland process does not produce the environmental headaches that come with other electroforming systems. Instead of using a toxic cyanide bath, "our bath is a sulfide-based solution that is not harmful to the environment," Wagner said. "You might even be able to drink it."

*—W. Leventon*

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metal is deposited, Rodia said.

Electroformers must also deal with thorny issues related to the use of chemicals—including treating and disposing of wastewater produced by the electroforming process—in order to comply with state and federal environmental regulations.

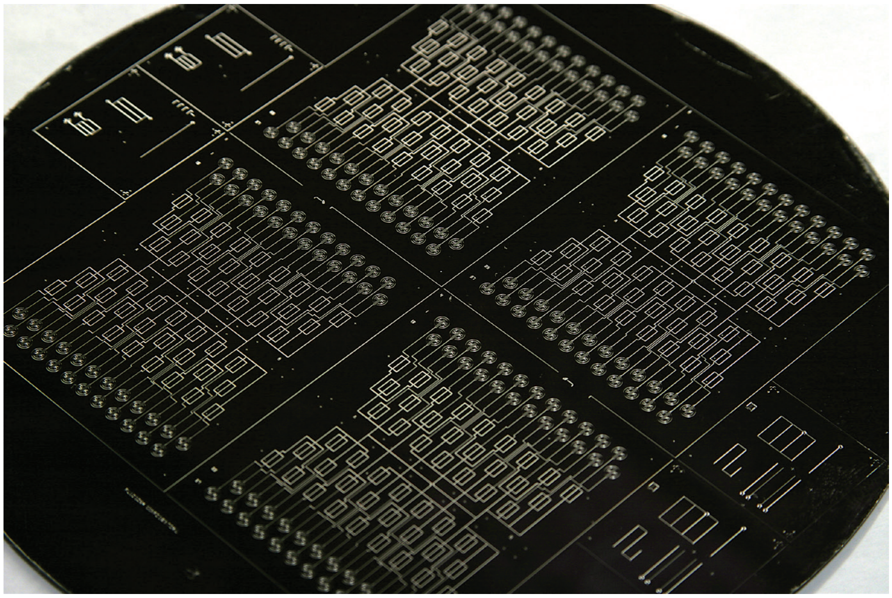
Then there is the issue of material choices, which are restricted mainly to nickel and nickel alloys. "We use some copper as well, but that doesn't 'throw' as well as nickel, so it's more difficult to get into very fine features on a resist," said Barry Eggington, estimator for the electroforming department at Tecan Ltd., Weymouth, England.

In Tecan's electroforming process, an electrolytic bath is used to deposit metal onto a conductive patterned surface, which can be either glass or polished metal. When the plated material has reached the desired thickness, the finished part is stripped off the mandrel.

Tecan uses its electroforming process to make small components such as washers and hearing aid parts. Eggington said the company regularly creates features as small as 10μm, and sometimes electroforms features down to 5μm.

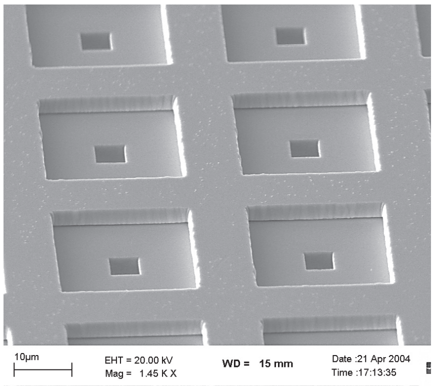
He added that electroforming can produce finer and more precise features than photoetching, which his company also performs. In addition, electroforming creates much finer and smoother features than laser machining, he said, and can produce many features in parallel.

"It's not serial production like you get with a laser, where you produce one feature and then the next," he said. To manufacture a sieve, for example, several million features are produced at the same time.



NiCoForm

An electroformed mold for a microfluidic mold from NiCoForm.




Tecan

Servometer

Left: A shadow mask with 3μm × 8μm apertures with an integral support layer. This gives the mask more strength as the first level, containing the apertures, is only about 5μm thick to minimize shadowing during vacuum deposition. Right: Electroformed bellows for a high-frequency interconnection.

## No more phototools?

Tecan creates the required resist patterns for its electroforms using phototools consisting of a chrome pattern created on a glass substrate. With an eye toward eliminating the time and cost involved in making these phototools, Eggington looks forward to the possible use of laser direct imaging to create electroforming resists. Guided by data from a CAD file, a laser would "write" directly on the resist, exposing the areas necessary to produce the desired resist pattern.

Laser direct imaging systems have been developed for PCB manufacturing, but Eggington believes the technology is still years away from matching the smallest electroformed features.

"We're nowhere near it yet," he said. "But the technology is getting to the point where you could consider trying 10μm to 15μm features with some of the high-end equipment." μ

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