INTRODUCTION TO ELECTROFORMING
## TABLE OF CONTENTS

2 Introduction

2 What is electroforming?

3 The electroforming process

5 Modern applications of electroforming
Introduction to Electrofarming

One of the major trends occurring in the world of manufacturing is what has become known as “additive manufacturing.” Additive manufacturing, in general terms, is a fabrication method that allows manufacturers to “grow” parts one particle at a time. This has greatly expanded the range of what is possible to make, especially for industries that are coming to rely on what is known as “micro manufacturing,” or, the creation of complex parts that are just a few microns thick.

While the excitement about 3D printing is what is driving a majority of the attention toward additive processes, the truth is that they have been around for decades in the manufacturing of component parts for a variety of diverse industries.

The process known as **electroforming** has been a key player in the world of additive manufacturing. Electroforming, or e-forming as it is sometimes called, is a process of electrodeposition that is capable of creating precise articles on a micron, or even sub-micron, scale. As a recent feature article in Micro Manufacturing put it, OEMs are turning to electroforming when it is “virtually impossible” to machine the parts and features that call for precision and complexity on the micro level.

In this whitepaper, we will examine what makes electroforming unique, the process and some of its modern applications.

### WHAT IS ELECTROFORMING?

Several definitions of electroforming exist, each of them similar but with their own nuances. ASTM B892-93, however, has supplied a single concise definition that satisfies nearly all practitioners of this fabrication method, which is as follows:

“Electroforming is the production or reproduction of articles by electrodeposition upon a mandrel or mould that is subsequently separated from the deposit.”

**Differentiating electroforming from other, similar processes**

Even with this precise definition, there may still be some confusion about what electroforming is due to the presence of other technologies with similar names and principles. They all use chemistry to affect the property of metals, but the processes and end results are very different.
**Electroplating** is a process similar to electroforming, but with one major difference. Electroplating is the process of depositing a metal onto the surface of a pre-existing **workpiece** for the purpose of altering the qualities of the part’s surface.

**Electropolishing** is the process of connecting a workpiece to the positive output of a DC power supply, submerging it in an electrolytic solution and then connecting the negative output to a cathode. The application of DC current causes oxidation on the workpiece’s surface, and the oxidized particles transfer to the cathode. This is done to remove burrs, sharp edges and other surface iniquities. Thus, electropolishing is often referred to as the **opposite of electroforming**.

By comparison, with electroforming, a metal is deposited onto a mandrel, from which it is later separated to make a **completely new part**.

---

**THE ELECTROFORMING PROCESS**

In this section, we will look at the most common metals used in electroforming, the process itself and some of the dimensional and design capabilities that electroforming allows practitioners to achieve.

The electroforming process starts with two electrodes - an anode and a cathode – that are submerged in a conductive electrolyte bath that contains a metal salts solution (usually nickel) and a source of DC power.

**The electrolyte bath**
According to the Nickel Development Institute, nickel is the most popular metal for e-forming applications due to its favorable properties, as well as its versatility. The mechanical properties can be manipulated into a variety of ways by selecting the appropriate electrodeposition conditions.

The two most commonly used electrolytes are nickel sulphamate and Watts solutions. These solutions give operators the opportunity to affect several material characteristics of the finished product. Properties such as hardness, ductility, strength and internal stress can be varied just by changing the makeup of the electrolytic solution. One way in which the solution can be altered is through codeposition, in which the operator alloys the nickel with another metal to increase the hardness while keeping the internal stress low.

For example, nickel cobalt alloys with 10–15 percent cobalt are commonly used in electroforming. This particular alloy is useful because it has internal stress low enough for the electroforming process while enabling the creation of an alloy-enhanced finished product.
Mandrels and anodes
Attached to the cathode is what is known as a mandrel or template – a substrate on which the electroformed part will be molded. Mandrels can be made out of many different materials, but the most common is brass. Having a conductive mandrel is useful in electroforming because it allows the electrodeposit to adequately bond to it, preventing any early separation during the process.

Before production, the mandrel is coated in a photo resist. On a separate sheet of metal, outlines of the finished parts are created out of photo resist while leaving a blank space where the parts will be electroformed. From there, a phototool exposes images of the opposites of the parts on the blank spaces, which are not coated in resist. One can add multiple layers of resist to allow the nickel deposits to grow thicker as needed.

The anodes are a suitable form of nickel that will sufficiently dissolve under the anodic condition. The anodes are to dissolve during the process so that they can replenish the nickel taken out of the salts solution by the cathode.

Adding the DC current and filters
Once the cathode/mandrel and anode are put into the electrolyte bath, a DC current is passed between the two electrodes. Once the charge is added, the metallic ions, Ni++, are converted into atoms on the mandrel’s surface. As the current is sustained, these atoms build up, layer by layer, to form a continuous deposit.

In electroforming, it is important that a high-purity solid state current be used in conjunction with a filtration system to remove the “noise” from the current. The filters used in the process prevent nickel particles with a mean diameter of 0.2µm or more (this is considered “noise”) from reaching the cathode. This is critical for component parts with extremely tight tolerances where even one stray particle can lead to a dysfunctional part.

Once the deposit has reached the desired level, the current is switched off. Finally, the finished parts are removed from the mandrel, which can be used for additional production runs. Because the mandrels can be used for multiple batches, “tooling” costs for electroforming are generally low.

Design capabilities
While both 3D and flat parts can be fabricated through electroforming, the great majority of electroformed parts are for flat or “low profile” applications. These parts often have holes and other design features that are too small for other fabrication methods to reasonably accommodate.
Introduction to Electrofarming

As a practical matter, we have the ability to electroform parts that have a thickness between .0005” and .005”. Holes and other design features on an electroformed part can be brought down to about .0002” in diameter. With electroforming, we can also hold some very tight tolerances of about +/- .0001”.

Modern Applications of Electroforming

Now that we’ve looked at the steps of the electroforming process, we can start to see how it is used to create a variety of parts in different industries and products.

Screens and meshes

According to the Nickel Development Institute, screen and mesh products are the most popular applications of electroforming. Examples of this include small centrifuge screens foils, filters and precision screen sieves. Often, these screens require holes that are only a few microns in diameter, with very tight call outs for the tolerances.

The screens and meshes are used in a diverse array of finished products. Some examples include kitchen appliances, filtration in certain medical devices, inkjet and 3D printers, optical encoders, MEMS devices and several other applications that demand precise screens, meshes and sieves in order to fulfill their own functions.

Moulds

Various moulds have also become a prominent application in this industry. The most well-known example of this are the moulds or “stampers” used for the injection moulding of polycarbonate resins that are used to make CDs, DVDs and other optical read-out discs. They can also be used for various mouldings for plastics.

For each disc, an electroformed nickel “stamper” is created and the polycarbonate material is cast onto it. The stamper creates the unique pattern of submicron pits in the surface of the disc, which encodes its content. Accurately made pits are critical for high quality sound on a CD.

Microelectronics (MEMS)

The trend in the MEMS industry is toward highly complex devices with smaller circuits. The designs of these products has left very little room for error, often leaving just a few microns between each separate component.

Electroformers often find themselves tasked with making sensors, actuators and ligatures that must be attached to the semiconductors and circuits in increasingly small sizes without sacrificing performance. The high level of precision afforded to electroforming thanks to the control that operators have over the electrolytic bath, DC current and filters makes this possible. As OEMs in the MEMS space demand ever-smaller component parts, they should turn to electroforming to achieve what would be impossible by conventional fabrication methods.
"Electroformers build parts by the atom," Micro Manufacturing http://www.micromanufacturing.com/content/electroformers-build-parts-atom
"Electroforming - a unique metal fabrication process," Ron Parkinson, Nickel Development Institute
"Electroforming today," S.A. Watson, Nickel Development Institute
"Electroforming - a unique metal fabrication process," Ron Parkinson, Nickel Development Institute