Taking the Stress out of Electroforming

www.nicoform.com

Electroforming of Microfluidic Tooling
In High Strength NiColoy®

© 2010 by NiCoForm, Inc. (Rochester, NY)
NiCoForm, Inc.

The Stats

- Year established - 1999
- Number of employees - 14
- Located in downtown Rochester, NY
- Capabilities and concentration:
  Design, engineering, precision machining and high fidelity electroforming of advanced components in proprietary Ni-Co alloys, NiColoy®
- Main product lines:
  - Catheter tip-forming dies
  - Optical and microfluidic electroforms
  - Electroformed bellows and assemblies
  - MEMS
1. The desired microprofile is produced in silicon, glass or photoresist and used as an original (mandrel) to be replicated in NiColoy® creating a negative replica - mother (shown in red).

2. Using the mother as a mandrel, numerous identical replicas (blue) can be electroformed without additional machining. These hard and wear resistant molds are used for molding or embossing of plastic ‘labs on a chip’.
Electroforming for Optics and Microfluidics

- True replication of pattern features, microprofiles and finishes, freedom from defects (haziness, stains, pits, etc.)
- Overall dimensional accuracy, parallelism and flatness +/-25 micron (.001")
- Electroforms must be hard and wear resistant to assure long service life of molds, corrosion resistant to withstand molding fumes and environmental effects during extended storage periods as well as chemical environments during replication
Common Mandrel Types

What can be replicated?

- Mechanically produced (diamond-turned or machined and polished), laser cut or electroformed metal mandrels: copper, nickel and its alloys, brass, electroless nickel, aluminum, stainless steel
- Etched silicon or glass mandrels - micro- and nanofluidics or optics
- Photoresist or epoxy on glass patterns - holograms, micro arrays, diffraction gratings, screens, etc.
- Plastic originals - molded or machined

Note: the last three mandrel types must be metalized prior to electroforming
Electroforming - the Basics

Atomic scale deposition

Nickel and Cobalt ions are attracted by the negatively charged mandrel, travel to its surface and, gaining two electrons turn into atoms of nickel and cobalt, forming a metallic layer on the mandrel’s surface. The electroformed layer faithfully replicates the microgeometry of the surface.
Assuring Mold Durability

Advantages of NiColoy®

- Traditionally, **Nickel** and **Copper** have been the most widely electroformed metals.
- Although not as strong as steel, Nickel was used for applications requiring strength and wear resistance.
- **NiColoy®,** NiCoForm’s proprietary **Nickel-Cobalt alloy**, is twice as hard as electroformed Nickel and matches stainless steels in hardness, elasticity, tensile strength and corrosion resistance.
NiColoy® in Comparison to Some Engineering Metals

- Tensile Strength, MPa
- Modulus of Elasticity, 10^3 MPa
- Hardness, Rc x10
- Thermal Conductivity, W/m*K

Graph showing comparisons of various metals including NiColoy®, Electroformed Nickel, Stainless Steel, Cobalt, Iron, and Copper in terms of their mechanical and thermal properties.
Precision Electroforming

Key Process Controls

- In-tank stress monitoring - ability to accurately control conditions in the bath thus preventing electroform distortions
- Low-stress Ni-Co electroforming chemistry with a flat section on the stress vs current density curve
- Automatic control of the alloy composition
Electroform Characteristics

- **Thickness** - .005" - 0.250" or greater
- **Hardness** - 40-50 HRc
- **Machineability**: can be ground, milled, EDM machined, drilled, tapped, etc.
- **Mounting** in the mold: can be soldered, brazed, epoxied, bonded with adhesives, tapped and screw-mounted
- **Dimensions** - from fractions of an inch to 20" across
- **Tolerances** on flatness and parallelism - +/- .001" (25 micron)
# When to Electroform?

## Direct Machining vs. ElectroForming

<table>
<thead>
<tr>
<th>Tooling Type</th>
<th>Method of Production</th>
<th>Cost of 4” Insert</th>
<th>Beneficial in</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electroformed Optical Tooling</strong></td>
<td>Optical surface is generated once and repeatedly replicated producing multiple identical molds</td>
<td>$500 - $2,500</td>
<td>Volume production, multi-cavity molds</td>
</tr>
<tr>
<td><strong>Diamond-Turned (Machined)</strong></td>
<td>Each mold is machined sequentially</td>
<td>$3,000 - $20,000</td>
<td>Low volume production</td>
</tr>
</tbody>
</table>
Electroformed Micro-Features

Channels, Grids and Posts

Source: NiCoForm, Inc. for Cornell University, Ithaca, NY
Electroformed Embossing Tools

First and Second Generation Replicas

Lab-on-a-chip microfluidic molds
NiCoForm, Inc. for (name withheld)
Electroformed Optics

Diffractives - Fresnel lenses, Gratings, Lenticulars, Holograms

Molded Fresnel Lenses
Source: Fresnel Optics, Rochester, NY

Electroformed Replica of a Diffraction Grating
Source: NiCoForm, Inc. for GS Optics
Electroformed MEMS

Micro-Patterns in Photoresist

Electroformed MEMS device in SU-8
NiCoForm, Inc. for (name withheld)

Electroformed MEMS devices
NiCoForm, Inc. for (name withheld)
Electroformed Optics

Anti-reflective submicro-structure

Electroformed moth-eye structure
NiCoForm, Inc. for Optical Switch, Inc.
Advantages of Electroforming

How You can Benefit from this Technology

- Multiple replicas from the same mandrel drastically reduce manufacturing costs
- Rapid turnaround - an average form takes 2-4 days to electroform
- Exact replication of intricate surface finishes, geometries and textures, excellent dimensional stability
- Mounting and alignment elements can be incorporated in the electroform
- Desired material properties - hardness, wear resistance, thermal conductivity are assured
NiCoForm’s Electroforming Capabilities

- **Zero-stress** high-strength Nicoloy® electroforms produced from customer-supplied mandrels
- Electroform size - up to 20" x 30"
- Rapid turnarounds
- Competitive pricing
Taking the Stress out of Electroforming