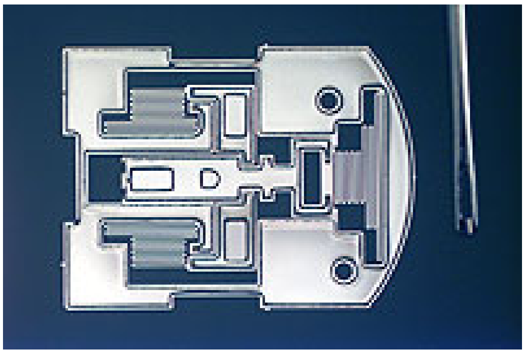
Semiconductor Technologies Drive Medical Device Advances

Medical device manufacturers are coming to realize the potential advantages of three technologies traditionally used in the semiconductor industry. Micro photolithography, thin-film processing, and electroforming are all processes that can offer unique solutions for medical devices. This article reviews the technologies and provides an array of potential application possibilities.



This is an example of a multi-level device with sections that can be moved or manipulated with relationship to other parts of the same structure. The spring-like shapes are movable springs with a cross section of 0.05 × 0.05 mm. The total thickness of the device is 0.2 mm.

By Randy Sablich and Luke Volpe

As medical device designers create new devices and continue the search for ways to improve their existing products, they seek technologies that enable drastic reduction in overall device sizes in order to be less invasive. The search also continues for new materials that are suitable for bodily implants or, at a minimum, are non-reactive with the human body. Although improving device efficiencies and reducing costs are critical considerations, the ability to build the device small enough to carry the required components and still meet the very demanding constraints of the human body will ultimately determine device viability.

It is well understood that the semiconductor industry has spawned many by-product technologies. Three such technologies that have had a dramatic enabling impact on the medical device industry are micro photolithography, thin-film processing, and electroforming (also called electro plating or electrochemical metal deposition). When combined, these three processes enable the formation of extremely small, very precise devices that are used as sensing elements, radio frequency transmitters and receivers, miniature tools used in surgical applications, and implantable therapeutic devices.

Many medical devices have micro components that fall into two categories:

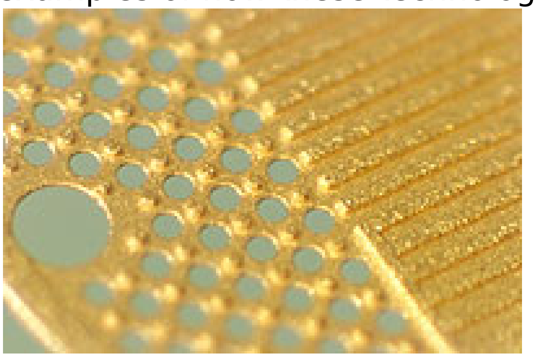
&#149 Free standing electroformed three-dimensional micro structures

Free standing electroformed micro structures are devices that are formed by controlled electrochemical deposition of various metals. These structures may be virtually any shape as long as they can be imaged in a photosensitive, non-conducting resist material. These devices may have features such as holes, walls, posts, grooves, or cantilevered beams with minimum dimensions that range from 0.075 mm down to 0.003 mm. The structures are formed on a temporary substrate and may be composed of multiple electroformed layers. Once the structure has been completely formed, it is removed from the temporary substrate and becomes a completely free standing micro structure.

&#149 Extreme resolution micro flex circuits, also known as ERMF circuits

ERMF circuits are flexible circuits with single or multi levels of conductive traces and spaces that may be as small as 0.003 mm. They typically have very thin (0.007 to 0.025 mm) polyimide substrates and dielectric interlayers. The devices may have integrated circuits attached. The overall size of such devices may be 10.0 mm square or smaller.

Both free standing electroformed micro structures and ERMF circuits are based on the same technologies: micro photolithography, thin-film processing, and electroforming. Although the manufacturing processes are similar, the functions they perform are quite different. Free standing micro structures are complex miniature mechanical devices that have value because of their small size and mechanical strength. ERMFs are largely "two-dimensional" multi-level electrical circuits. These devices are very flexible and, in some cases, may be rolled into cylinders for intravenous use. Both process technologies play a critical roll in the creation of viable components for many medical devices. The following are some examples of how these technologies are used in medical devices.



This image shows a section of a solid gold implantable three-dimensional micro structure. Clearly shown are a series of 0.05 mm diameter posts that are 0.022 mm tall. Also shown are 0.05 mm wide × 0.022 mm deep channels with a pitch of 0.1 mm. The through holes are 0.1 mm diameter and the base foil is 0.01 thick.

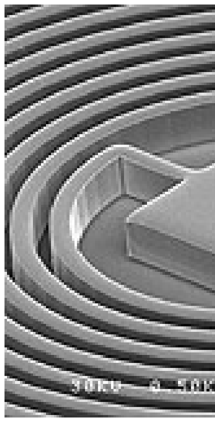
&#149 Small apertures or nozzles

Just as the free standing electroformed three-dimensional micro structure technology has made possible the jetting nozzles for inkjet printers, it can also be used to fabricate nozzles for fluid applications such as water jet devices, flow control devices/flow measurement devices, or, when combined in larger arrays, for limiting or blocking (filtering) light or fluids. Nozzles may take the form of multi hole atomizing or filter screens with apertures as small as 0.001 mm. The maximum hole size, in most cases, is limited only by the device design requirements. Aperture holes may have straight side-walls or be funnel shaped. Other applications such as fluid jetting or controlled dispensing typically use single hole aperture plates. Aperture foil thickness may be as thin as 0.005 mm and can be as thick as the device design dictates. Some of the electrochemically deposited materials have excellent hardness and spring qualities, with hardness in the 550 Vickers and modulus of elasticity (Young's modulus) values in the 25.2 Mega Pascal per square inch.

Free-standing three-dimensional micro structures (Figure 1) may be solid single metal or over plated with a non reactive coating such as gold. In some permanent implant applications, the entire structure can be solid gold. In other applications, the core material or over plating may be a more durable material to protect from wear or corrosion.

&#149 Three-dimensional combinations of "paths" and "buckets" (blind holes)

Blind holes can be created to form micro fluidic devices that may collect, measure, combine, and otherwise sample varieties of liquids or particles. These devices can be used in assay sampling, lab on a chip applications, drug discovery, and general clinical analysis. In some permanent implant applications, these devices may be used to enhance, restrict, or control movement or flow of bodily fluids (Figure 2). In other devices, two or more micro structures may be bonded together to form functioning assemblies. Three-dimensional micro structures may be formed as multi-level devices, allowing the formation of multiple channels and fluid chambers on more than one level. Minimum feature sizes of walls, bucket chambers, or channels in such devices may be as small as 0.003 mm. As a general rule, the maximum depth of blind holes (bucket chambers) and channels is typically not more than three times the minimum feature size. In extreme requirements situations, there are some materials available that allow 10:1 thickness to feature aspect ratio.



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&#149 Small coil-like devices

Coil-like devices can be created and used as radio frequency (RF) induction systems for transmitting and receiving data in and out of the body. The small size and inert materials lend themselves well to a variety of product applications. These devices may be free standing or have some minimal dielectric support structure. They can also be formed on rigid substrates such as glass, quartz, or silicon or on a flexible substrate such as polyimide (Figure 3). It may also be possible to use the ERMF process, described in the next paragraph, to address or actually process the RF signal by mounting the appropriate integrated circuit chips on the ERMF circuit.

&#149 ERMF Circuit

The other form of micro structure that has the potential to revolutionize the medical device industry is the extreme resolution micro flex (ERMF) circuit. The manufacturing process used in building ERMF devices utilizes all three of the above mentioned semiconductor by-product technologies.

These devices are currently being used in applications such as angioplasty procedures, hearing and sight improvement devices, and blood chemistry monitoring systems.

Some devices in use today have minimum conductive trace and space dimensions of 0.005 mm. These devices may also have multi-layers of conductive traces. In some applications, completed packaged devices including driver chips are being used intravenously.

The combination of these process and technologies has opened a new world of possibilities for the medical device designer. New materials are being added to the design portfolio and new applications are being discovered every day. Working closely with the manufacturing company can often result in improved overall design approaches that take better advantage of the properties of these processes.

This technology as applied to micro sized medical devices is quite new. As more medical device designers become aware of this capability, it will likely have an even more dramatic impact on the overall growth of the medical device industry.

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