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COVER STORY: MACHINING

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Acid-Based Machining Dissolves Part-Making Problems

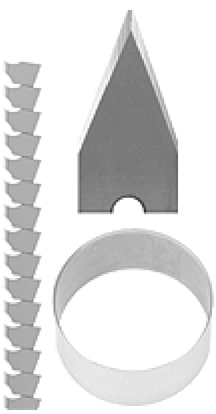
Photoetching promises fast and inexpensive production of thin metal components.

William Leventon

Some machining techniques can be awfully rough on thin metal parts. Using the wrong method on fragile components can result in bending, breaking, melting, or even squashing. That can burn months of valuable time and tens of thousands of dollars.

So some OEMs are turning to a chemical machining technique called photoetching, which employs acids and masks to form parts out of metal sheets. The process goes easy on fragile components and can dramatically cut manufacturing time and costs. But it isn't right for every situation, so medical device firms need to know when to employ it. And since OEMs rarely do their own photoetching, they must also know how to choose a contract etching partner that can meet the needs and requirements of their application.

How It's Done



Photoetched parts like the blade (left), the point (top), and the overhead ring (above) have no slag.

Photoetching begins with a flat piece of material that has been cleaned and covered with a photosensitive coating. To etch the desired part shape, manufacturers use a masking device called a phototool, which is made by photographing the part image on film. Contact printed onto the material coating, phototools are often used in pairs, one on each side of the material. The phototool includes both opaque areas (the cover material that will be etched away) and transparent areas (the cover material that will be protected from etching).

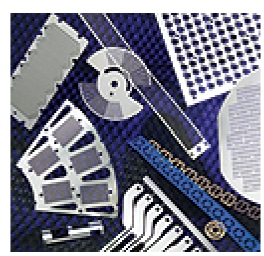
With the phototools in place, the assembly is exposed to light, which reaches the coating only under the transparent areas of the phototool. Exposure prepares these areas for hardening with a developing solution.

When developing is completed, an acidic etchant is applied to the assembly by means of spraying or immersion. The etchant dissolves material not protected by the hardened coating, leaving the desired part shape.

Unlike stamping, photoetching produces burr-free part edges, according to Chip Harvill, medical markets manager for IncisionTech, a Staunton, VA–based etching firm. In addition, Harvill notes, the process leaves behind no slag like that produced by laser cutting.

The smooth surfaces produced by photoetching make it the best choice for manufacturing titanium skull plates, says George Keeler, president of Tech-Etch Inc., a contract photoetcher in Plymouth, MA. A skull plate is actually a mesh that's screwed onto the skull. Tissue grows through the holes in the mesh, binding the plate to the head. The surface of the skull plate must be very smooth, because any projections from the surface of the metal would penetrate the tissue surrounding the plate, Keeler explains.

Another advantage of photoetching is that the process is unaffected by the hardness of the part material. So firms like IncisionTech use it to make needles and surgical stapling devices out of materials such as prehardened 400-series stainless steel. "The etching process doesn't care whether the material is hard or soft," says Harvill. "But a stamping process cares a whole lot whether the material is hard or soft." Such concerns limit the effectiveness of stamping when used on prehardened materials. In most cases, he says, materials must be heat-treated in order to be stamped, which adds some variability to the machining process.



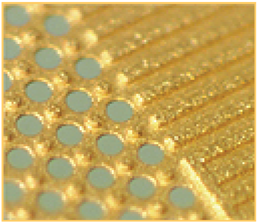
A variety of photoetched pieces from Fotofab Corp. show the possibilities for the process.

Although it changes the shape of materials, photoetching does not change their properties in any way. The same can't be said for laser cutting, which leaves a fairly wide heat-affected zone around the edge of a part, says Jamie Howton, president of Fotofab Corp. (Chicago).

Stamping can also affect material properties. Consider blades for cauterizing equipment, which are thinner along the edges than in other areas of the part. Stamping can be used to make parts with varying thicknesses, but the process requires a high-tonnage press that squashes the metal to produce the thinner areas, Howton explains. This makes the metal harder in those areas, an effect known as work hardening. As a result, parts made this way will have different material properties in areas with different thicknesses. By contrast, he says, photoetching can produce parts with varying thicknesses without affecting the original hardness level of the material.

Electrochemical techniques

Besides photoetching, there are other processes that use chemicals to make parts. Two of these processes get an extra spark from another essential ingredient: electricity.



DRC Metrigraphics can achieve many textures with electrochemical etching.

While photoetching produces clear, clean edges on small flat parts, electrochemical etching puts ultrasharp points on small-diameter rods and wires. In an electrochemical process used by Point Technologies Inc. (Boulder, CO), a number of rods or wires are held in a fixture, which dips the part tips into a solution called an electrolyte. The electrolyte and an electric current combine to remove material from the tips in a process that can be described as “a controlled erosion of metal,” according to John O’Brien, the company’s executive vice president.

During the process, the amount of current running through the tips and into the electrolyte, as well as the number and speed of the dips, is controlled. That means the manufacturer can control the sharpness and taper the shape of the tips.

The firm uses its electrochemical process to put sharp points on needles and surgical instruments such as tungsten tips for electrosurgery electrodes. Formed at the end of tungsten wire, these tips can be brought to a supersharp submicron point in an electrochemical bath, says O’Brien.

Another electrochemical metal-shaping technique also relies on an electrolyte solution. Unlike photoetching, which is a subtractive process that removes materials with acids, electroforming is an additive process in which parts are formed in an electrolytic bath that deposits nickel or other metals onto a patterned conductive surface. Once the deposited metal builds up to the desired thickness, the parts are removed from the solution.

The additive electroforming process can produce smaller part features and tighter tolerances than those delivered by photoetching, according to Chet Ju, vice president of the Metrigraphics division of Dynamics Research Corp. (Wilmington, MA). Using its electroforming process, the company can produce holes with diameters as small as 15 µm, with a variation of ±1 µm, Ju says.

Medical parts electroformed by the firm include a retinal implant with features measured in microns and a water scalpel nozzle featuring very small holes and very tight tolerances. On the downside, Ju notes, the electroforming process has more steps than photoetching, so the parts it makes can be two or three times more expensive than photoetched parts.

Tooling Comparison

Stamping can also require expensive tooling. Costs for stamping tools might run from $10,000 to as high as $100,000, Howton says. Such tools are vastly more expensive than tooling for photoetching, which typically costs $250–$300. This “soft” tooling can be produced in a matter of days, Harvill says, while stamping tools might take anywhere from 4 to 12 weeks to make, depending on their complexity.

By slashing tool-making time, photoetching can dramatically shorten the part production process. Fotofab’s standard lead time is 2 weeks, but the company also offers 5-day, 3-day, and even same-day delivery in some instances, according to Howton.

At Tech-Etch, Keeler says, personnel can turn customers’ CAD drawings into phototools in less than a day. That means tools can be quickly and easily modified if engineers decide to make changes to their designs. The same can’t be said for conventional dies, which are difficult to change once built, Keeler notes.

What’s more, a single phototool can produce several versions of a component at the same time. So during a prototyping process, “you can test five different shapes made in the same run without hard tooling five different things,” Harvill says. “That could save you 3 or 4 weeks in a typical cycle.”

Whether the products are prototypes or production units, photoetching eases the process of shaping complex parts such as meshes for cranial reconstruction. “These meshes have so many perforations that any other kind of machining would be very costly,” says Rick Hoppe, engineering manager for VACCO Industries Inc., a contract photoetcher located in El Monte, CA. “If there are 10,000 perforations in a mesh, we make all 10,000 perforations at once. How long would it take someone to laser cut or punch a part like that?”

VACCO uses photoetching to make mesh parts. The process can yield very fragile components.

VACCO makes these complex meshes in a one-step operation that produces all the perforations, as well as countersinks for the screws used to attach the part to the patient’s skull. If conventional machining techniques were used to make the part, a secondary operation might be required to cut the countersink holes, notes Jeff Bjork, VACCO ’s business and product development manager.

Besides complex components, photoetching is well suited for the production of fragile components.
Stamping can deform and even damage parts such as a respirator flow controls. Made of very thin stainless steel, this delicate part “would probably crack or break if you tried to stamp it,” says Mark Sharman, vice president of VACCO ’s photoetching business unit. “Because of the thinness and critical nature of the part, it can only be etched.”

Limitations

Titanium disks from VACCO have a depth etch inset and an etched through hole.

Along with the advantages of photoetching come some significant limitations. Generally speaking, Sharman says, most photoetching companies don't want to work with materials more than 0.1 in. thick in large volumes because such projects are very time-consuming.

In addition, Keeler notes, the smallest feature that can be etched into a part is a function of the material thickness. His rule of thumb: the minimum size of a part feature is 1–11¼2 times the thickness of the material. Thus, the minimum feature size for a part made of 20-mil material is about 0.02 in. The bottom line: "We can't get down to really small feature sizes when we're working with thicker material," he says.

As material thickness increases, tolerances also get looser in the photoetching process. According to Keeler, the best tolerance that can be held on a 0.02-in.-thick photoetched part would be about ±15% of the thickness, or ±0.003 in. "You can do better than that with laser cutting," Keeler says. "You can make smaller features and hold tighter tolerances."

Competitive Techniques

Among machining techniques, laser cutting and stamping are usually the primary alternatives to photoetching. For very-low-volume jobs, Sharman notes, laser cutting is quicker and less expensive than the other two processes. But the laser quickly loses its edge as volumes increase. "With laser cutting, you increase production volume by increasing the amount of laser equipment you're using," Hoppe explains. "You get no efficiencies out of the equipment as volume increases."

Not so with photoetching, which produces an entire sheet of products at one time. "Let's say your part is 1 × 1 in. and your metal sheet is 12 × 12 in.," Keeler says. "You get 144 parts from that sheet, all in one operation. You don't have to go around the periphery of each part with a laser beam." In this case, therefore, the part cost would be much lower than the cost of laser cutting the parts.

But cost calculations change again when part quantities are in the millions, Howton says. For very-high-volume jobs, an expensive stamping die is a cost-effective option. "It makes sense to amortize the price of a $100,000 stamping tool into the cost of 5 million parts a year," he says. "Photoetchers tend to lose competitiveness at that level of production."

When parts are complex, however, photoetching can compete with stamping even in higher-volume jobs. This is because the cost of a photoetched part depends on the amount of room it takes up on a sheet of metal, not on the complexity of the part.

On the other hand, complexity has a great deal to do with the cost of a stamped part. Consider a part with numerous holes in it, each of which is created by a punching process. The more holes in the design, the more punches are required to stamp the part—and the more the process costs.

In the photoetching process, however, "we cut all the holes at the same time," Howton says. "We don't care whether the part has one hole or 10,000 holes. It still costs us the same to make it."

In-House or Not?

Not all photoetching work is done by contract manufacturers. Medical OEMs may decide to keep the work in-house if there are confidentiality concerns about a particular product, Hoppe says. Then there are situations in which an OEM can tailor the photoetching process for making a single high-volume product using a single material and phototool, with no changes in the process from one day to the next. According to Sharman, an OEM might find that keeping such a focused, unvarying operation in-house is more efficient than contracting out the work.

In most cases, though, OEMs turn photoetching work over to contract firms. The main reason for this is that most companies don't want to deal with a process involving hazardous chemicals that require treatment under strict environmental controls, Keeler says. In addition, he notes, OEMs see the advantage in letting experts handle the photoetching process and the creation of phototools.

But how do OEMs choose the right photoetcher? First of all, they must find one that handles their part material. The following materials are etched by at least some contract manufacturers:

• Titanium. Implants such as stents and pacemakers are often made of this material. But there are few companies that excel at etching it, according to Mike Lynch, vice president of operations at United Western Enterprises Inc. (Camarillo, CA).

• Lead. VACCO processes the material, but many etchers don't because of its softness and lead contamination concerns, according to Bjork.

• Elgiloy. Some implantables are made of this material. Tech-Etch processes it using a special etching chemistry. But for environmental reasons, VACCO doesn't use the strong acids that are needed to dissolve this chemically resistant metal.

• Tungsten. Tech-Etch processes this material. But Keeler says few of his competitors etch tungsten because the process requires special etchants and equipment.

• Plastics. In addition to metals, some firms etch plastics. VACCO photoetches Kapton polyimide material into fishhook-shaped parts that are molded into lenses for cataract surgery. Those parts help to position the lenses on the eyes of patients, Hoppe explains. Any process used to make this part must ensure its cleanliness. Some machining operations could embed contaminant particles in the soft Kapton material. Near the end of the photoetching process, however, extraneous substances are removed from the part with an alkaline solution, minimizing the chance of contamination, Sharman says.

The size of the parts they make also differentiates photoetchers. Some of them process parts in a very limited size range, Bjork notes. VACCO handles everything from very small components to parts the size of an elevator. The firm also etches parts up to 1¼8 in. thick. “Some etching companies won’t even look at parts that thick,” he says.

Then there is the size of the photoetchers themselves. If you need parts in a hurry, a small etcher might be faster than a larger one. According to VACCO’s Sharman, some small competitors can produce parts in 2 or 3 days. “We just can’t do that because of our size, structure, and quality systems,” he says. “It takes us more than 2 days just to inspect parts, let alone manufacture and ship them.”

Secondary Operations

OEMs might also want an etcher capable of handling some secondary operations. For example, flat etched materials can be made into three-dimensional parts in a process called forming. “Some etching firms outsource their forming, which adds another layer of engineering, expenses, and profit margins to the process,” Keeler says. “But we do our forming in-house.”

Forming is one of a number of secondary operations performed by Tech-Etch. Others include plating, heat treating, and assembly. Keeler estimates that secondary operations occur on almost half of the parts his company etches.

In some cases, etched parts require secondary operations to produce more-precise dimensions. “If a component needs a hole diameter that’s ±0.0001 in., it’s very hard to repeatedly generate that level of precision in a photoetching process,” Harvill says.

Photoetchers usually overcome this limitation by employing a secondary machining operation. Using a laser or a conventional CNC machine on holes and other part features, IncisionTech can tighten tolerances to improve on the dimensional outcome of the photoetching process, Harvill says.

In addition to all these factors, medical OEMs might want to consider the amount of experience contract photoetchers have in making parts for medical device companies. Lynch thinks this is important because medical device firms operate under strict FDA requirements that complicate and lengthen the process of making changes to products. Among other things, this means that suppliers for device firms can’t immediately change their processes when they think they’ve discovered a better way of doing something. “It’s a different world,” Lynch says of medical device work. “We understand that.”

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