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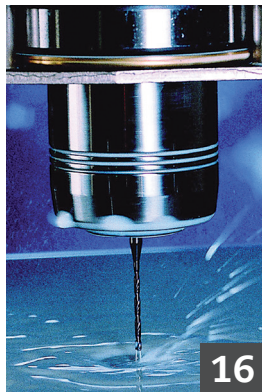


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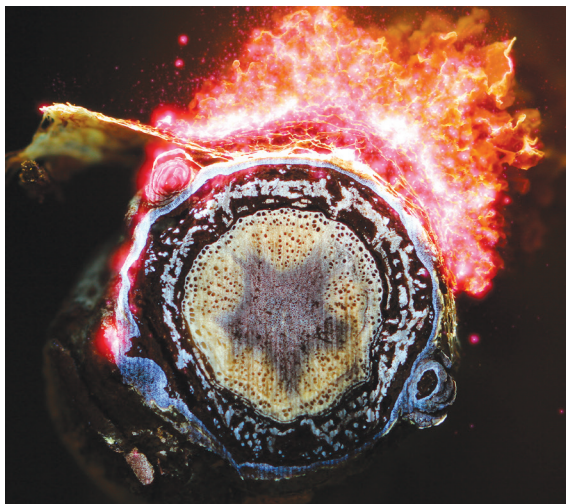
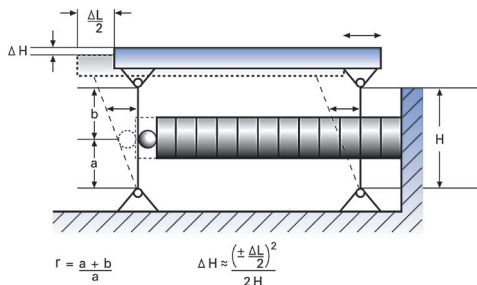
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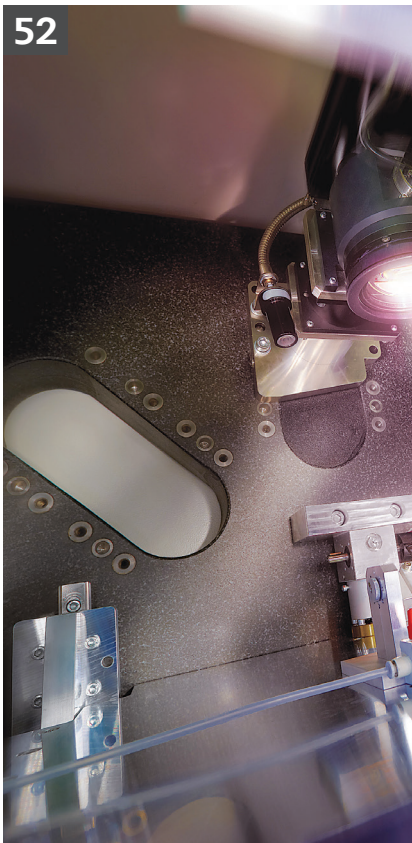


New AM process has part repair down cold

A new cold spray additive-manufacturing process developed by GE researchers is not only capable of building up parts much like traditional AM methods, but can be used to repair old parts, and potentially extend a repaired part's lifecycle.

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Photo courtesy of Fineline
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Learning on the job

One enjoyable aspect of working at a magazine is the “accidental” learning that occurs. Researching topics for articles, attending conferences and talking with manufacturers almost always lead me down unexpected roads, where I find interesting new technologies or gain fresh insights about the industry.

Following is a handful of things I’ve discovered recently:

■ **New focus for manufacturers.** During a presentation at an industry conference, the president and CEO of design-software giant Autodesk Inc., Carl Bass, said manufacturers “used to focus on quality. Now, the focus is on innovation—‘How can I differentiate myself from competitors?’—and agility, the speed at which I get product to market.”

■ **Reshored pollution.** Some West Coast smog is caused by pollutants that Chinese manufacturing plants generate while making goods for American consumption. According to a paper released in January by the Proceedings of the National Academy of Sciences, “in 2006 ... on a daily basis, the export-related Chinese pollution contributed ... 12 to 24 percent of sulfate concentrations over the Western United States.” So, U.S. companies move production to China and China returns cheap products and foul air. Talk about a bad deal.

■ **Micromolding biomaterial stents.** The research firm ABMRG expects the global market for coronary stents to top \$13 billion by 2019. The firm identified stents made of bioabsorbable materials as one of the “catalysts” to reaching that figure. (Numerous sources put the current annual stent market at \$5 billion to \$6 billion.) Biomaterials offer numerous advantages. Foremost is that devices made from the materials dissolve in the body. Micromolding them is challenging, however, because of the materials’ thermal sensitivity and price. Some biomaterials cost thousands of dollars a pound.

■ **Flexible, thin electronics.** A skullcap that measures the severity of impacts to the wearer’s head is designed for athletes participating in contact sports (see page 8). The designer of the cap’s electronics, MC10 Inc., claims the highly conformal, thin electronics

are so light that the wearer doesn’t know he or she has the cap on. Elsewhere, researchers at the Swiss Federal Institute of Technology have developed flexible, ultrathin electronic films supple enough to wrap around a human hair, according to a paper published by Nature Communications (www.nature.com). The films can be made transparent, raising the possibility of “smart” contact lenses able to monitor the user’s physiological state.

■ **The Curies.** I knew that in the late 19th century the French brothers Jacques and Pierre Curie discovered the piezoelectric effect (see our column on piezo motion systems on page 24). What I didn’t know was that Pierre married a physicist named Marie Skłodowska. Marie and Pierre were awarded the Nobel Prize for Physics in 1903. Marie Curie, popularly known as Madame Curie, won the Nobel Prize for Chemistry in 1911.

■ **Engineer joke.** I came across an old joke while researching the Curies. During the French Revolution, a priest, a convicted thief and an engineer were to be executed. The priest climbed the stairs to the guillotine, and the executioner asked him if he preferred to be face up or down. “Face up, toward the heavens,” he responded. The blade was released, came down and stopped about 6” from the priest’s neck. Interpreting this as divine intervention, the executioner freed the priest. “I want to look up, too,” said the thief. Incredibly, the blade dropped and stopped inches from his neck. “He must be innocent,” said the executioner, releasing the thief. Finally, the engineer climbed the stairs and requested to be face up. When strapped into place, he turned to the executioner and said, “I see what your problem is.”

Sometimes, accidents on the road to learning raise a smile.

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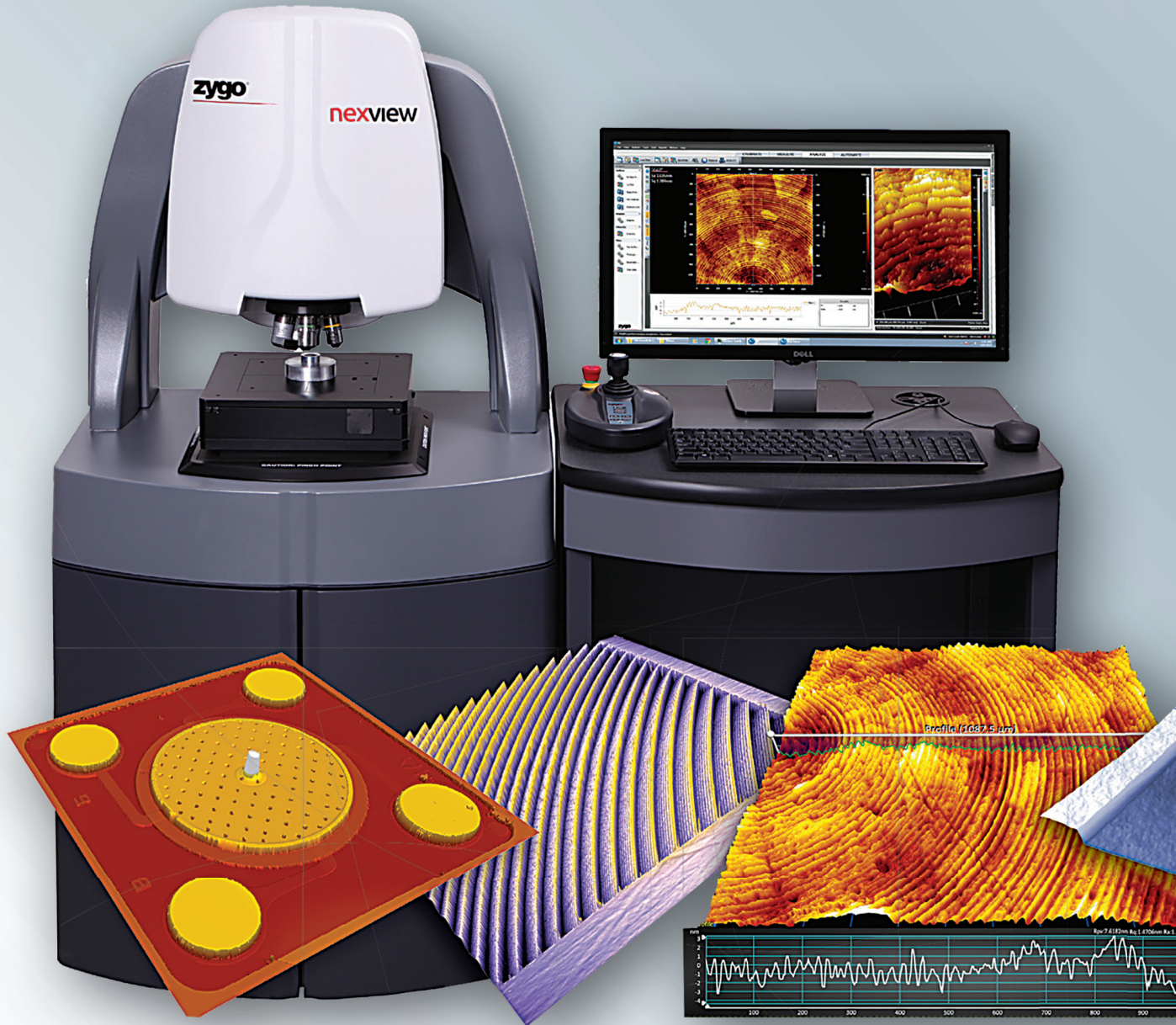
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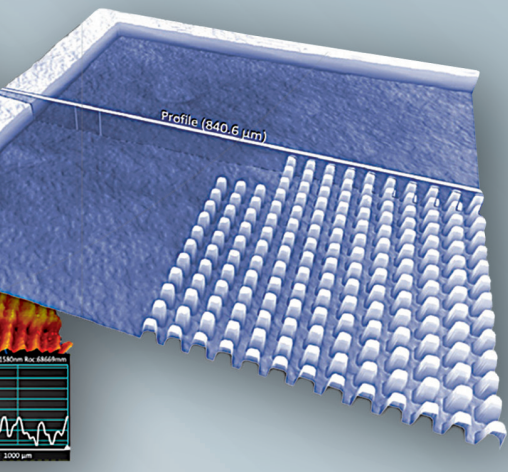
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Wearable electronics indicate impact level in sports activity

The crowd noise is deafening at the championship football game as the quarterback nails his intended receiver, who is instantly hit hard from behind by the conference's meanest cornerback. Slow to stand up, but desperate to keep



The Reebok CHECKLIGHT sports impact indicator positions wearable electronics directly on the athlete. LED lights illuminate yellow or red depending on severity of impact.

the indicator's sensors, embedded in a skull cap and held directly to the head to provide impact data, receive an impact above the programmed head-injury-criterion thresholds, a yellow (moderate impact) or red light (more-severe



formance, IPC-compliant (lead-free) substrates in a custom layer stack. Component placement and trace routing are optimized for medium bending and twisting cycles with tight bend radii. Circuits are assembled via a standard surface mount/reflow process, followed by component-epoxy underfill to improve bend, twist and impact durability. The company then uses a custom high-throughput impact simulator to test the circuits and final product.

According to MC10, it took 3 years to develop the indicator, including seven rounds of wear and field testing in multiple sports. During development, Reebok worked with head trauma experts and professional athletes, including Matt Hasselbeck, backup quarterback for the Indianapolis Colts.

To date, MC10 has raised \$60 million from various venture partners and strategic investors.

—Alan Richter

Crescent Manufacturing's Richard Hrinak answers five fastener questions

Screw-making machines have been in use since the 18th century, and screws are one of the most common types of fasteners in manufacturing.

Crescent Manufacturing Operating Co., Burlington, Conn., has been making fasteners since 1960, with products ranging in size from 5/16-18 and 5/16-24 screws with 0.3" major diameters, down to 00 size microscrews, which measure 0.047" in diameter.

Crescent President Richard Hrinak said the company's cold-heading processes, its primary method of screw manufacturing, cannot make screws much smaller than 00. (The company has made 000 screws measuring 0.034" in diameter in the past, but low demand led it to discontinue that product line).

Hrinak said the increased use of Swiss-style screw machines has kept



Richard Hrinak

playing, the receiver correctly guesses four when the trainer asks how many fingers he's holding up and is given the green light to continue playing.

That's hardly sufficient in this age of heightened concern about repeated concussions causing chronic traumatic encephalopathy and other neurological diseases. That's why Reebok developed the CHECKLIGHT sports and activity impact indicator to measure the severity of blows to the head when worn during play rather than rely solely on subjective evaluation.

The impact indicator incorporates conformal electronics technology from MC10 Inc., Cambridge, Mass., to help ensure the product is comfortable and doesn't distract an athlete, according to Steven Fastert, director of product development for MC10. "MC10 reshapes high-performance electronics into ultrathin systems that stretch, bend and flex with the body," he stated. When

impact) is activated until the device is reset. The product is not a concussion diagnostic tool; it notes when the player should be assessed for injury.

"It serves as an extra set of eyes for parents, coaches and athletic trainers," stated Elyse Winer, manager of marketing and communications for MC10.

In addition, the product provides an impact count for tabulating the total number of tiered exposures endured throughout a game, season or career.

The electronics module measures 7.0"×3.6"×0.4", weighs 16.4g and incorporates two sensors: a 3-axis accelerometer and a 3-axis gyroscope. A microprocessor running MC10's proprietary algorithms measures linear acceleration from the accelerometer and rotational acceleration from the gyroscope.

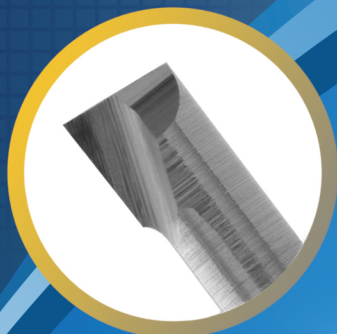
The conformal manufacturing process, Fastert explained, starts with a base circuit board fabricated using a standard flex-circuit process, but with high-per-



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the industry moving forward in recent years, producing screws as small as the 0000, which has a 0.021" major diameter.

MICROmanufacturing: What are the main applications for Crescent Manufacturing's microscrews?

Hrinak: Electronics, aircraft controls, medical devices and computers, as well as other types of controls. When I first came to the company, we were doing a lot of screws for Kodak and Polaroid. There were a lot of tiny fasteners in their cameras, so there was very high volume for the 6 or so years we were working with them, before those types of cameras went the way of the Dodo bird.

MICRO: What methods does Crescent use to manufacture microscrews?

Hrinak: We do cold heading and thread rolling, which gives us the ability to produce pretty high volumes. We're also able to hold tolerances of ± 0.005 ", which is very close, though not as close as Swiss screw machines. We did some triple-aught parts for a while, but

'With screws, you can take something apart and put it back together. Nothing else lets you do that over and over. You can open something up, inspect it, repair it, check things out and close it right back up again.'

it's really impractical because of the size of the parts. They're usually produced on a Swiss machine, which has higher cycle times but can be much more precise.

MICRO: How is the manufacturing of microscrews more challenging than producing their larger counterparts?

Hrinak: The biggest challenge with cold-heading screws is making sure you

get all the parts out of the machine, that none of them get lost in the transition. Your handling policies and procedures have to really be tight if you're running a screw that small. And if you need them to be heat-treated, plated, finished or any other outsourced process, small parts can be challenging for some service providers. All of our heat-treaters and platers are very familiar with the products that we make, especially with the 0 and 00 screws. Even some of the screws that get bigger in diameter are still so small that a lot of companies don't want to work with them.

MICRO: What has contributed to the screw's longevity as a means of joining parts?

Hrinak: You can take something apart and put it back together. Nothing else lets you do that over and over. You can open something up, inspect it, repair it, check things out and close it right back up again. Then there are adjustment screws that do things you

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can't do with plastic. Sure, some people make plastic screws, but they just don't measure up in terms of serviceability.

MICRO: How has the fabrication and application of microfasteners advanced over the last 5 years?

Hrinak: A lot of people are doing more with cutting now, using Swiss-machined parts. There are a few companies around the country that specialize in that and have advanced the microcrew industry through mastering that process. Some manufacturers work with 000 and 0000 screws and even smaller. I can't imagine working with something that small.

—Evan Jones Thorne

Developing effective micropart cleaning strategies

Manufactured parts are a challenge to clean. And, as is the case with designing and manufacturing them, cleaning parts becomes more challenging as they get progressively smaller and more complex.

For more than 20 years, the “Cleaning Lady,” Barbara Kanegsberg, and the “Rocket Scientist,” Ed Kanegsberg, have worked with manufacturers to evaluate and improve their cleaning processes. Through their independent consulting company, BFK Solutions, Pacific Palisades, Calif., the pair have helped companies turn cleaning efforts into a value-added en-



As electronic circuit boards become more functional, the cleaning of electronics assemblies has become a critical process.

deavor that increases yields and improves quality. They can, for example, aid with process optimization and validation, cleaning product and equipment selection, cleanroom usage and worker education.

One of BFK's services is developing cleaning solutions for manufacturers of small components used in microelectronics, medical devices, military and aerospace applications, and an assortment of miniature and nano devices.

“Ed (Kanegsberg) often points out [that] as parts become smaller, the surface-to-volume ratio in-

creases, so that, for nanosized parts, the surface is the product,” explained Barbara Kanegsberg. “The cleanliness and attributes of the surface become increasingly important to product performance.”

SMALLstuff

University researchers develop microscale windmill technology

Researchers at the University of Texas at Arlington have developed a power-generating micro windmill. Research associate Smitha Rao and electrical engineering professor J.-C. Chiao designed and built the device, which at its widest point is about 0.07” (1.8 mm).

The windmill was tested successfully in September 2013 in Chiao's lab. It operates without fracturing because of its aerodynamic design and durable nickel-alloy construction. The fabrication cost of making one windmill is the same as making hundreds or thousands on a single silicon wafer, meaning the devices could be mass-produced very inexpensively.

“Imagine that they can be cheaply made on the surfaces of portable electronics,” Chiao said, “so you can place them on a sleeve for your smartphone. When the phone is out of battery



A micro windmill developed at the University of Texas at Arlington.

power, all you need to do is to put on the sleeve, wave the phone in the air for a few minutes and you can use the phone again.”

Chiao said because of their small size, thousands of the micro windmills could be affixed to flat panels that are mounted on building walls to harvest

energy to power lighting, security devices, environmental sensors and wireless devices.

The researchers' work attracted the attention of Taiwanese fabrication company WinMEMS Technologies Co., which approached Rao and Chiao to brainstorm novel device designs and fabrication applications.

Rao's design for the windmill blends origami concepts and conventional wafer-scale semiconductor fabrication. WinMEMS is currently exploring the commercialization of the micro windmills.

“It's very gratifying to, first, be noticed by an international company, and, second, to work on something like this where you can see immediately how it might be used,” said Rao. “However, I think we've only scratched the surface on how these micro windmills might be used.”

Cleaning smaller parts requires addressing unique considerations such as shape, spacing and wettability. For example, cleaning agents must penetrate blind holes and tight spaces to contact the soil to be removed, she said. "Perhaps as important, [the] residual cleaning agent has to be displaced, because the cleaning agent can itself become a residue and adversely interact with the surface."

Critical cleaning is the cornerstone of the Kanegsbergs' approach, an idea that may run counter to preconceived notions. "Historically," she said, "we think of precision cleaning as being conducted in a controlled environment using a well-documented, tightly controlled set of processes. However, we can do things precisely, but they still may not be correct or optimal."

In critical cleaning, the concept is to perform the correct quantity and quality of cleaning at the right point in the process and to clean in a timely manner. Critical cleaning can occur at any stage of a manufacturing process, including initial fabrication in an environment that "looks more like a repair station than a cleanroom," she said. It is about picking the appropriate process for the application instead of relying on previous successes, restricting the process to a particular method or always choosing the same cleaning agent. The Kanegsbergs usually devise at least two ideas for a manufacturer to consider.

Factors in choosing a cleaning process include determining the required level of cleanliness; avoiding material compatibility problems; minimizing initial capital outlay and ongoing process costs; addressing regulatory requirements; and considering the skill levels of workers.

Preferably, the process will include a site visit so the Kanegsbergs can talk to key workers and observe the cleaning practices in place. Prior to the visit, they look at written processes; view any photos and video clips; and review the cleaning agents in use, the company's current cleaning processes and its cleaning equipment. In addition, they attempt to learn as much as possible about supply-chain partners and their part-cleaning processes.

Barbara Kanegsberg said that they sometimes find differences between a company's written procedures for cleaning and a company's actual practices, and other times they find the processes are not being adhered to at all.

"I try to find out why," she said. "There may be a lack of education about the cleaning process or the cleaning process is ineffective or impractical. If so, I coordinate with the engineers and designers to achieve more effective critical cleaning."

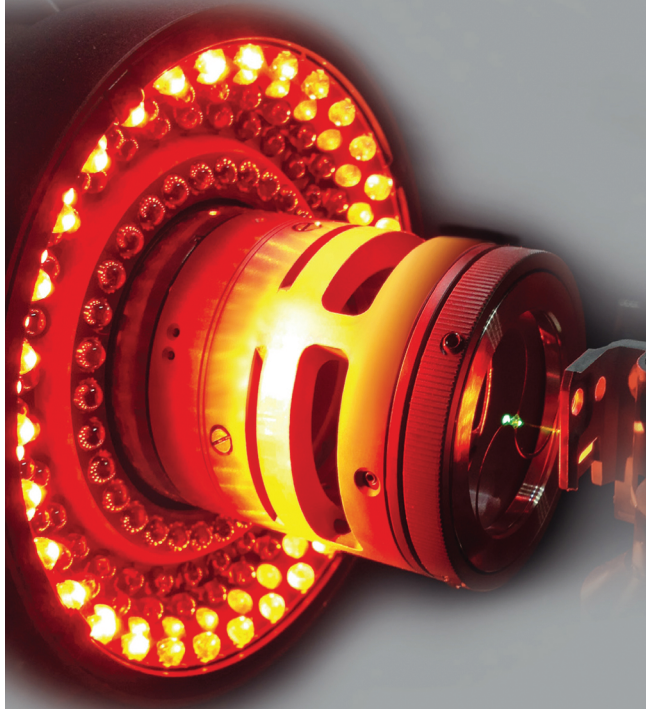
—Larry Adams

Robotic control in micropart manufacturing, assembly

Robotic part assembly and the ability to remove excess material from small parts are strengths of a new motion-control method that relies on force sensing, not position. ABB Robotics' Integrated Force Control (IFC) relies on discrete



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software that enables a robot to adapt to process variations using real time external inputs, such as when it senses a burr on a part—much as a human would when assembling the part.

The IFC method uses tactile sensing that allows a robot to react to its surroundings in real time, adjusting its path and speed based on feedback from a force sensor; helping to avoid damaging a workpiece. This automates complex tasks such as material removal and small parts assembly, where dexterous handling of workpieces and tools are required.

After the robot senses contact with a part or fixture, a constant data stream containing six channels of force-torque data is transmitted to the robot, which then decides how to alter the position, orientation or speed of the component or tool.

When using IFC, the key element is tolerance or, put another way, “what is the smallest reaction force a robot can be fed to generate an appropriate posi-

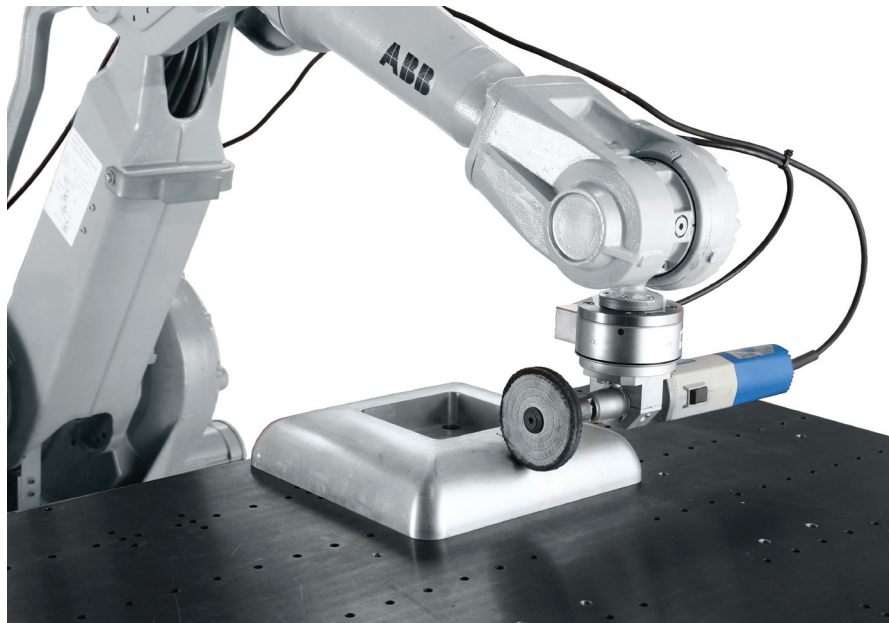


ABB Robotics

Robotic buffing of an aluminum machine component using ABB integrated force control and a manual buffing tool.

tion response.” The robot has a joint resolution (the smallest amount it can

move) as low as 0.001° , and in force control mode will react to the smallest positional difference that the robot measurement system and force sensor can detect.

The assembly of a small electronic or medical device would likely fall within this tolerance range.

When employing IFC, the robot must “understand” the limiting factors associated with the process, which are typically found on engineering drawings.

Robotic polishing, deburring, grinding and premachining are material-removal applications suited to IFC. As with assembly, the limiting factor is not part size or weight, but whether the part can be held in a fixture or manipulated by the robot.

If, for example, a tool cannot safely remove the material at the prescribed feed rate without breaking, the robot will sense the impending failure and slow the feed rate. Alternatively, it can reposition the path of the cutting tool for a less aggressive thickness for the next pass or the next few passes.

—Nick Hunt,
manager of technology and support
at ABB Robotics North America,
Auburn Hills, Mich.



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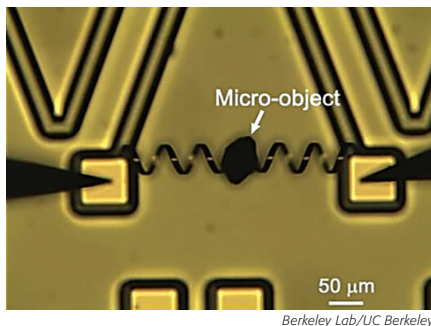
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Man-made micro muscles

Vanadium dioxide is known for its ability to change size, shape and physical identity, but researchers have discovered it can also be used as “muscle.” A research team at the U.S. Department of Energy’s Lawrence Berkeley National Laboratory has developed a microrobotic torsional muscle/motor that, for its size, is a thousand times more powerful than human muscle. It can catapult objects 50 times heavier than itself over a distance five times its length within 60 milliseconds.

Vanadium dioxide is coveted by the electronics industry because it is one of the few known materials that acts as an insulator at low temperatures and a conductor at 67° C (152.6° F) and above. Vanadium-dioxide crystals also undergo a temperature-driven structural phase transition whereby, when warmed, they rapidly contract along one dimension while expanding along the other two.



A vanadium-dioxide-based micromuscle.

This makes vanadium dioxide an ideal candidate for creating miniaturized, multifunctional motors and artificial muscles, researchers said.

“Miniaturizing rotary motors is important for integrated microsystems and has been intensively pursued over the past decades,” said project leader Junqiao Wu, a physicist who holds joint appointments with Berkeley Lab’s Materials Sciences Division and the University of California-Berkeley’s Department of Materials Science and

Engineering. “The power density of our micromuscle, in combination with its multifunctionality, distinguishes it from all current macro- or micro-torsional actuators/motors.”

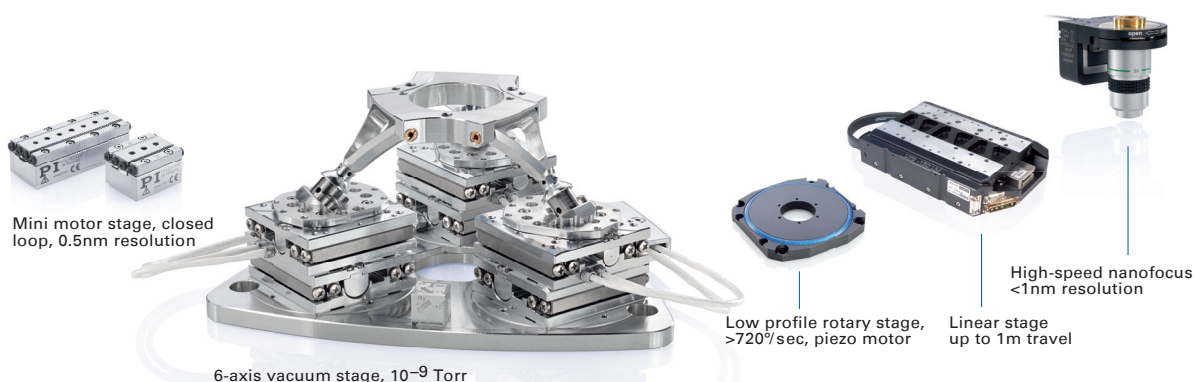
Wu and his colleagues fabricated their micromuscle on a silicon substrate from a long, V-shaped bimorph ribbon comprised of chromium and vanadium dioxide. When the ribbon is released from the substrate, it forms a helix consisting of a dual coil connected at either end to chromium electrode pads. Heating the dual coil actuates it, turning it into either a microscale catapult, in which an object held in the coil is hurled when the coil is actuated, or a proximity sensor, in which remote sensing of an object causes a rapid change in the micromuscle’s resistance and shape that pushes the object away.

The muscles demonstrated reversible torsional motion over 1 million cycles with no degradation, and rotational speeds of up to 200,000 rpm.

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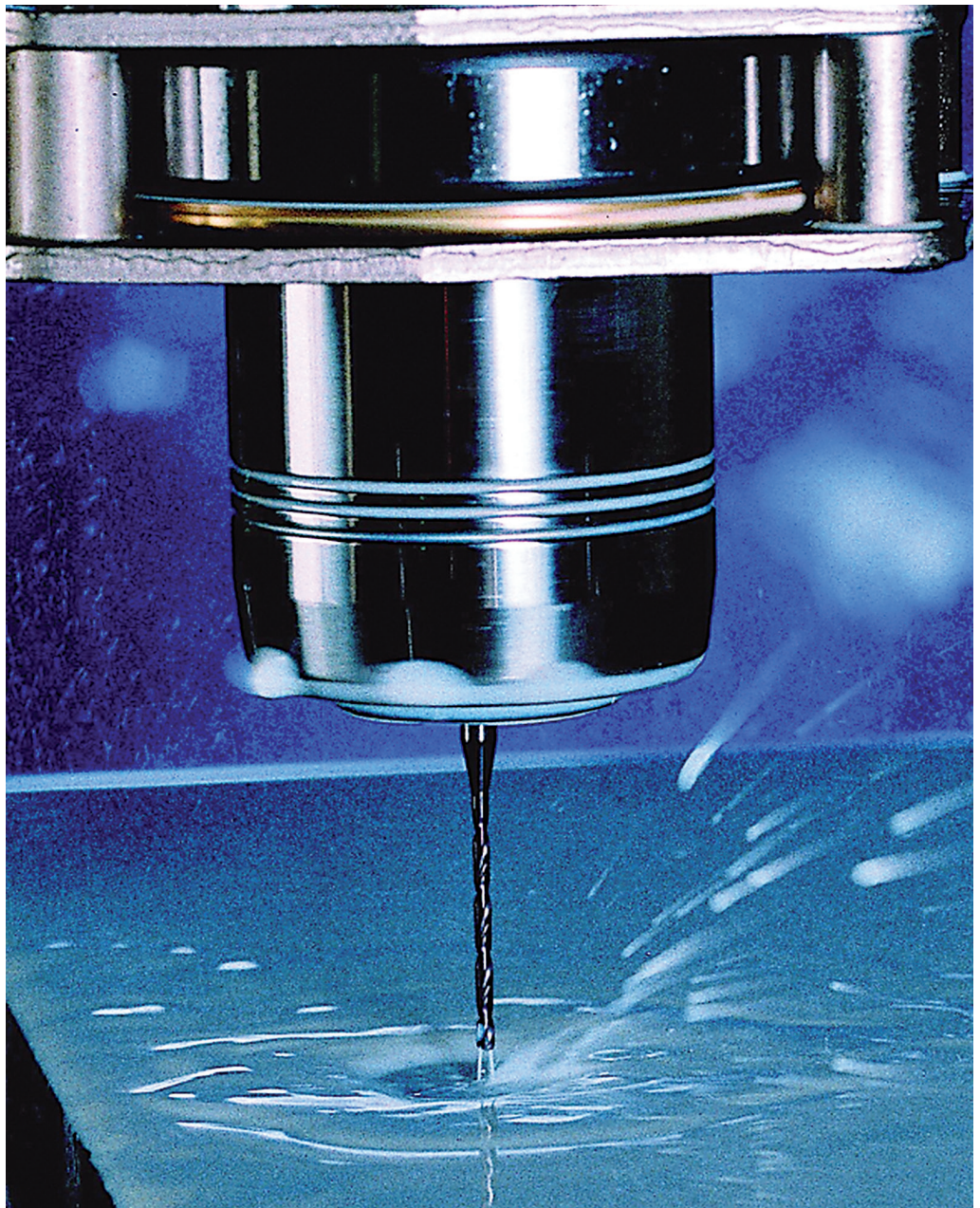
The elements of successful microdrilling

The term “microdrilling” typically refers to making holes smaller than 3mm in diameter. This includes the micron-range holes often encountered in the electronics industry, where many workpieces consist of wafer-thin material sometimes only a few tenths of a millimeter thick.

Holes this small are typically created by punching, laser cutting or EDMing, although

drilling and boring tools can produce holes as small as 30µm in diameter.

It's more common to find drills used on parts requiring 2mm- to 3mm-dia. holes. These applications include aerospace parts, molds and dies, medical devices and other machined components. Holes greater than 20 diameters deep are sometimes required. Examples of such applications include



All images: Walter USA

By Dr. Peter Müller
and Helmut Gschrey,
Walter USA

cooling, lubricating and venting holes.

Success factors

Successful microdrilling starts with the machine tool—specifically, one with a precise spindle and low runout. Similarly, the accuracy of a microdrilling operation will benefit from high-precision toolholders, typically hand-clamped to ensure against positioning errors that can be introduced by automatic toolchangers.

Regarding the tool itself, process engineers have generally chosen between two tool concepts when microdrilling: gundrills and helical twist drills. For many years, the classic gundrill, typically consisting of a solid-carbide head brazed to a steel shank, dominated these applications.

Twist drills, on the other hand, had to be made of high-speed steel (HSS) to have the required toughness to perform effectively in this application. As a result, with HSS twist drills, cutting speeds and feed rates were low, holes had to be continuously cleared of swarf, and process reliability left much to be desired.

However, the development of new carbide grades with high levels of toughness now permit the manufacture of long, thin twist drills capable of high speeds and feeds. The main advantage provided by the carbide twist drill is its two cutting edges. At a minimum, this allows the twist drill to run at a feed rate twice as fast in inches per minute (ipm) when run at the same cutting speed as a gundrill. Increasing the cutting speed of the twist drill further increases the feed rate. This new generation of solid-carbide twist drills have been racking up productivity rates superior to those of traditional gundrills.

Solid-carbide microdrills have several benefits. One is that they accommodate internal coolant channels. Fine coolant channels can wind their way through the helical body of these tools—all the

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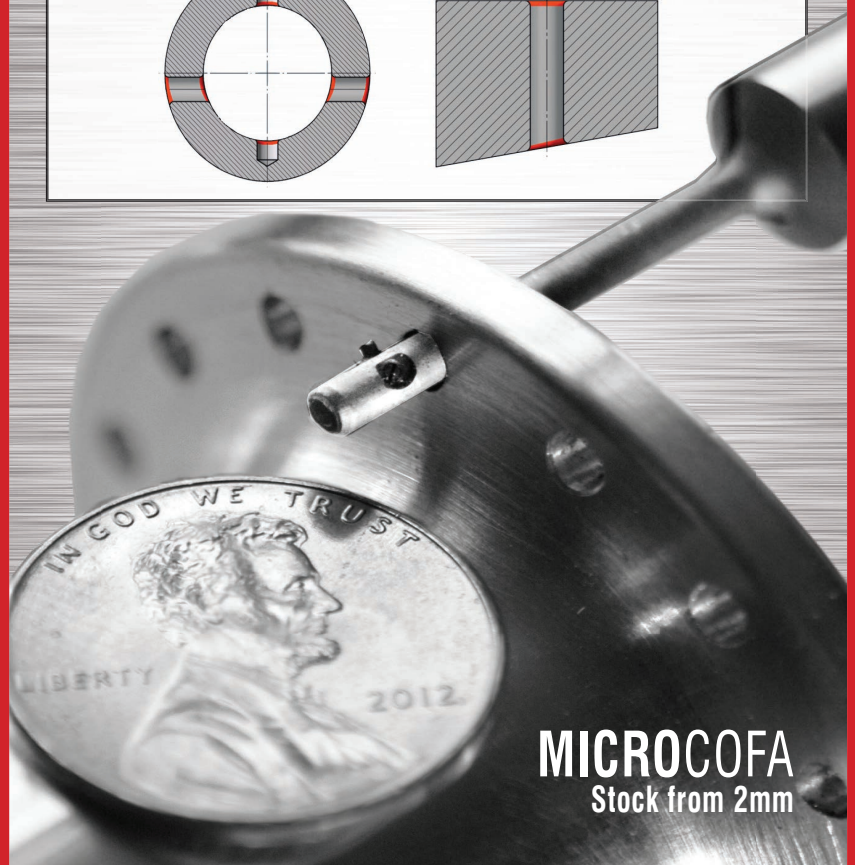
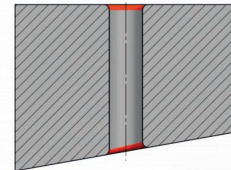
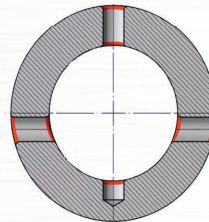
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way to the cutting edges—keeping the tools at the correct operating temperature. In addition:

- optimized point geometry with special edge preparation and flute geometry ensure proper chip formation;
- polished flutes support efficient chip evacuation;
- two lands keep the tools on course; and
- AlTiN coatings counteract wear and increase tool life.

Tools of this type are suitable for workpieces from the ISO material groups P (steel), K (cast iron), M (stainless steel), N (aluminum and other nonferrous metals), S (heat-resistant superalloys) and H (hardened steel). It is also possible to microdrill titanium workpieces.

Attention to detail

The smaller the tool, the more important the design considerations, including carbide grade, geometry, coolant channel, flute design and coating. Achieving the right interplay among these tool features can produce high-performance drills.

Using the proper drilling procedure is important as well. Drilling experts typically recommend the following sequence of operations.

1. Start the hole with a pilot drill, drilling to a depth equaling 1.5 times its diameter. (Pilot drilling can usually be omitted for hole depths of less than 12 times diameter.)

2. Enter the pilot hole with the primary drill at a low rpm (500 rpm is generally recommended).

3. Switch to the nominal speed after entry, then start flowing coolant through the drill to the required depth in one operation. A cooling lubricant pressure of 290 psi to 1,000 psi is generally recommended. This range ensures that chips are freely ejected from the hole. For cooling lubricants, emulsion

and cutting oil are both suitable, and the filter grade should be < 20µm.

4. After achieving the required depth, reduce the rpm and retract the tool.

No pecking

In view of the small hole diameter, would it be beneficial to stop the deep-drilling operation occasionally to peck the hole and clear it of chips? The answer is no. Restarting drilling means placing additional stress on the cutting



Newer solid-carbide microdrills, such as these from Walter Titex, are tougher than their predecessors.

tool, which should be avoided. Interrupting the process for pecking also brings an element of uncertainty into the sequence of operations.

The geometry of the drill is also important. With microdrills, geometry varies within a range of just a few microns, with cutting edges that are only 1mm or 1.5mm long. Accurate edge preparation, therefore, is vital in determining performance and tool life.

The microdrill manufacturer is best equipped to regrind the tool since it has the most knowledge of its tools' details. The same applies to the coating. Conventional regrinding of a micro-drill and applying a standard coating would significantly shorten tool life and reduce process reliability.

Finally, remember that with micro-drills close attention must be paid to wear indicators. Due to the tool body's low mass, heat absorption is minimal.

Thus, the price for overloading the tool is, frequently, total tool failure. This happens less often with today's solid-carbide helical microdrills than with conventional microdrills, but the laws of physics still apply, so closely monitor wear indicators.

Keeping these factors in mind and working with a toolmaker that offers sound application advice, correct cutting data and microdrill reconditioning services will help ensure successful microdrilling operations.

About the authors: Dr. Peter Müller is head of development for drilling and boring tools, and Helmut Gschrey is senior product manager for drilling at Walter AG, Tübingen, Germany, parent company of Walter USA LLC, Waukesha, Wis. For more information about the company's products, call (800) 945-5554 or visit www.walter-tools.com/en-us.



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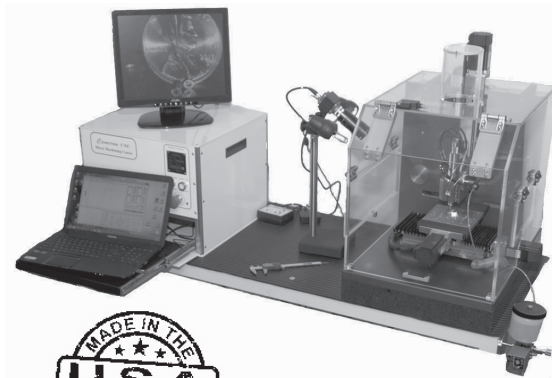
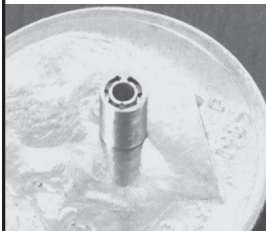
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Laser technique produces 3D models

Laser ablation tomography (LAT) is a process that allows the structural features of organic and inorganic samples to be viewed as high-contrast, full-color, 3D models.

A LAT system developed at Penn State University incorporates a nanosecond, Q-switched, pulsed ultraviolet laser, a camera and Avizo 3D analysis software. During operation, thin, successive layers of a specimen

virtually dissected.

A typical LAT setup is shown in Figure 1 (page 22). Samples are affixed to a cantilever, which connects to the travel axis of the laser's mechanical stage. Slice thickness is determined by incrementing a linear stage after each exposure. Resolution as fine as $1\mu\text{m}$ at 18 million voxels per slice is possible, providing a detailed image based on the data captured during the process. Data tables are created automatically and are immediately available for analysis (see table on page 22).

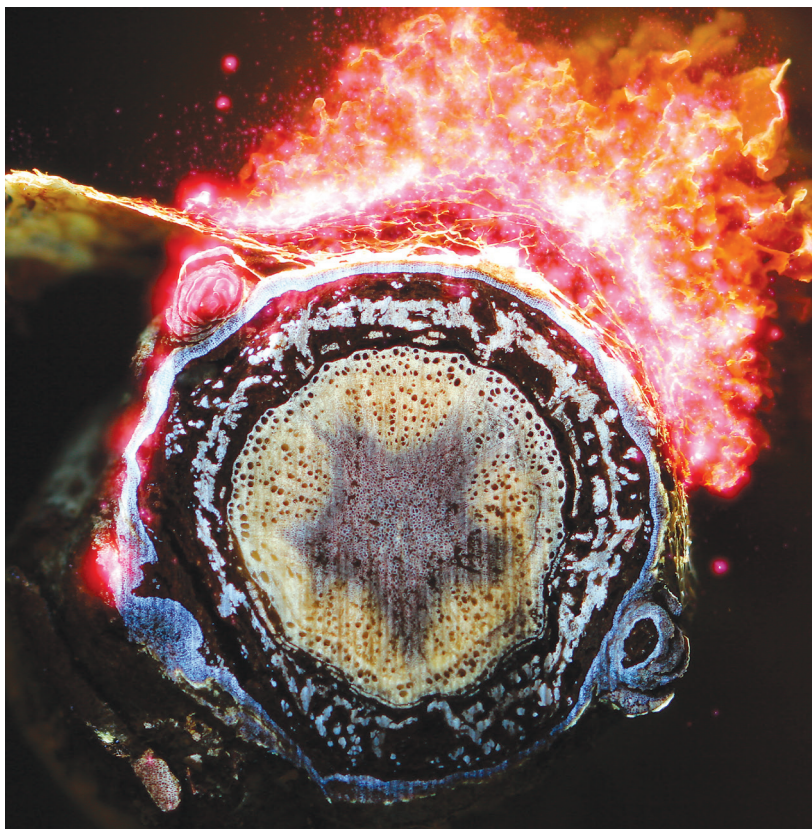
The LAT technique was invented by Benjamin Hall, a former student at Penn State and the co-author of this column; Dr. Jonathan Lynch, professor of plant nutrition at Penn State College of Agricultural Sciences; and Dr. Edward Reutzel, head of the Laser System Engineering and Integration Department at Penn State's Applied Research Laboratory.

Hall and a business partner, former Penn State graduate student Brian Reinhardt, have licensed the technology and founded a company called Lasers for Innovative Solutions LLC (LIS) to commercialize it. Prospective customers include companies involved in agricultural and horticultural research.

LAT vs. other approaches

Technologies such as X-ray and magnetic resonance imaging (MRI) have traditionally been used to obtain tomography data. They have distinct disadvantages. For example, they often require complex sample preparation, which frequently includes the use of heavy-metal contrasting agents and stains. These techniques often are affected by the sample's moisture content, density and composition.

The LAT process, on the other hand, requires virtually no sample preparation. The UV laser induces material-specific fluorescence, which facilitates detailed analysis because the fluorescent properties identify and discriminate among material structures at a level not possible by other means. Slices just a few hundred nanometers thick can be removed from a specimen, and the laser leaves a nearly parallel face on the sample.



All images: Lasers for Innovative Solutions

Laser ablation tomography can be used to create 3D models of organic samples, like this root.

are vaporized. Removal of the material only minimally affects the remainder of the specimen. A camera photographs the freshly ablated surface of the specimen after each laser pass. Data from the image is stored.

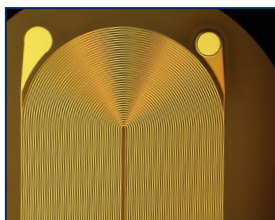
When all the data is gathered, the software processes and reconstructs a high-resolution 3D model of the specimen's interior and exterior that can be viewed, manipulated or



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The result is higher-resolution images than when using other processes to characterize biological samples, such as standard microtome sectioning (processes for slicing thin sections from specimens). LAT scans are also several orders of magnitude faster than microtome sectioning.

Figure 2 depicts a maize root captured with X-ray microtomography and a LAT scan. In the LAT scan, the fluoresced orange sections correspond to components with high lignin content, while the blue/white sections represent those with high cellulose content.

The LAT technique can be used to generate 3D models of things other than plants.

Lasers for Innovative Solutions is developing LAT technology to characterize the structure and composition of rock samples, such as shale, that are of interest to the oil and gas industry. LAT scans also could be used for MEMS-device and biomedical applications.

One drawback to LAT is that it's a destructive analytical technique, limiting its use to certain applications. However, for many applications, this is not an issue.

On the horizon

All of the work performed by LIS so far has been done with a 355nm, nanosecond laser, but other lasers could be

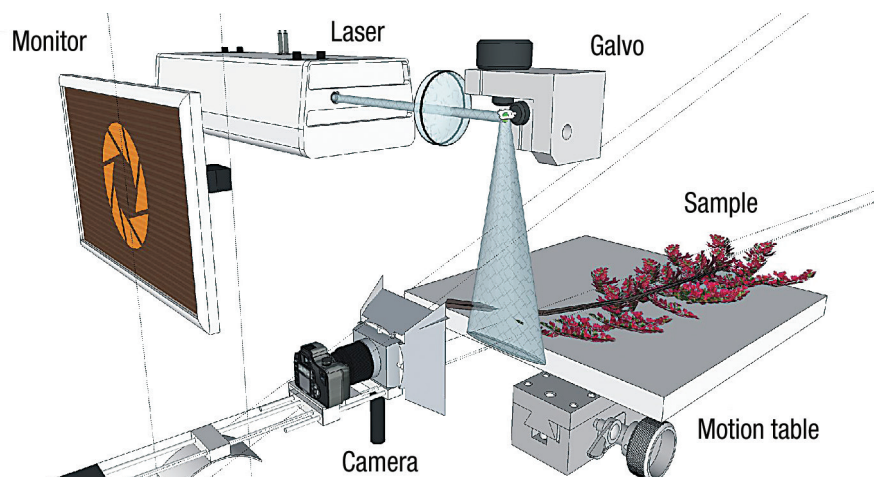


Figure 1: The LAT system consists of a laser, galvanometer, scanner, camera and table.

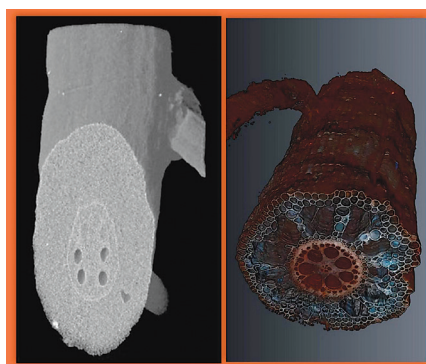


Figure 2: Comparison of a maize root captured with (left) X-ray microtomography and an LAT scan (right).

used to expand the power and utility of the technique. Potential candidates include shorter-wavelength (266nm) and shorter-pulse-length lasers, such as

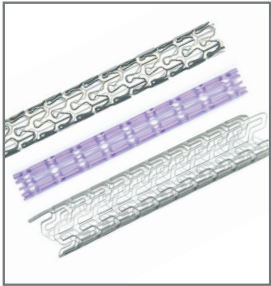
picosecond and femtosecond ones.

Though currently limited to examining samples, a more exciting prospect is to use the LAT technology to manufacture parts. Since digital information is created when performing LAT scans, the data could be transferred to a 3D printer to reconstruct the sample. This would allow the technology to be used to produce medical implants.

About the authors: Ronald D. Schaeffer, Ph.D., is CEO of PhotoMachining Inc., a high-precision laser job shop and systems integrator in Pelham, N.H. E-mail: rschaeffer@photomachining.com. Benjamin Hall is a founder of Lasers for Innovative Solutions, State College, Pa. Web: <http://l4is.com/>.

Root area	Root perimeter	Stele area	Stele perimeter	Aerenchyma area	Number of cortical cells	Average cortical cell area	Average xylem area
1.63	5.57	0.30	2.27	0.32	308.00	0.000948	0.0129
1.63	5.57	0.30	2.35	0.36	300.00	0.000929	0.0114
1.46	7.76	0.29	2.31	0.25	273.00	0.000895	0.0105
1.64	5.47	0.30	2.29	0.33	317.00	0.000894	0.0130
1.63	5.65	0.30	2.28	0.35	315.00	0.000883	0.0107
1.64	5.56	0.31	2.30	0.37	322.00	0.000884	0.0108
1.63	5.60	0.31	2.30	0.37	333.00	0.000882	0.0110

The LAT software automatically generates tables that compare different samples. Measurements are in millimeters.



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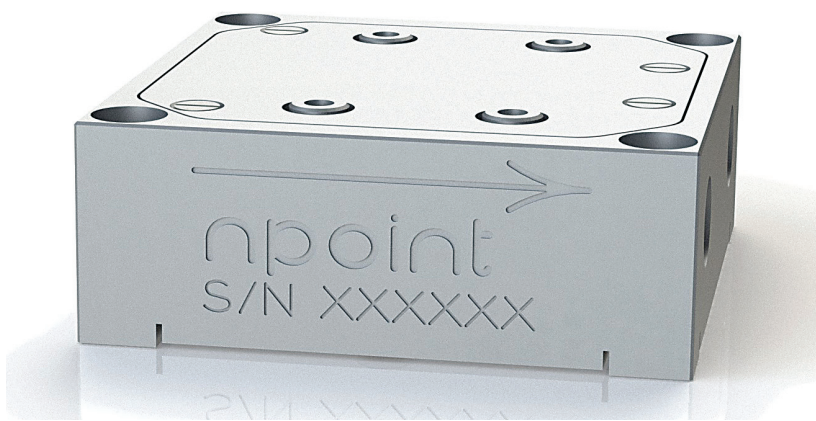
Motion systems bend to beat stiction

Piezoelectric stack actuators offer a way out of sticky situations that sometimes arise in microscale positioning applications.

The most commonly used material for stack actuators is a polycrystalline ceramic called lead zirconate titanate (PZT). The stacks consist of ceramic discs separated by thin metallic electrodes.

PZT is well-suited for micro positioning tasks because it responds to applied voltage with a minute, highly predictable linear dimensional change. Motion is caused by the reaction of a piezoelectric crystal to an electrical charge.

Piezo crystals change shape when exposed to an electric charge, and they give off an electric charge when mechanically deformed.



The nPX100 is a closed-loop nanopositioner with a 100 μ m scanning range and subnanometer resolution.

PZT stack actuators in closed-loop configurations can move in repeatable nanometer-size and even subnanometer-size steps because they have no conventional moving parts, which would be adversely impacted by friction.

Flexures add flexibility

When a motion-system application allows only nanometer-scale deviation from the ideal trajectory, stack actuators alone won't suffice. In addition, a compact motion package—i.e., one with a very short actuator—may be too small to

provide sufficient travel distance for a given application. For situations like these, a stack can be paired with a guidance device called a flexure.

Flexures connect a piezo actuator and the stage or platform being moved. Often made of steel or aluminum, these devices flex consistently and repeatedly without breaking. They can provide billions of cycles of maintenance-free service. Moreover,

For piezo-class devices, it becomes even more critical to manage stiction effects.

because flexures don't incorporate the rolling or sliding elements found in conventional motion systems, stiction—static friction that must be overcome to set a stationary object in motion—isn't an issue.

“For piezo-class devices, which are intended to go down into the nanometer range and below, it becomes even more critical to manage stiction effects,” noted Scott Jordan, director of NanoAutomation technologies for PI (Physik Instrumente) LP, Auburn, Mass.

With their ball bearings and granite tables, conventional motor-driven positioning systems are also relatively slow. “We speak of seconds when discussing the time it takes to position a sample with [conventional] systems,” said Klaus Pollak, an engineer with nPoint Inc., a Middleton, Wis., firm specializing in piezo-actuator-driven flexure stages. “But with a piezo stage, we can move parts in milliseconds.”

Flexures are not limited to single-axis stages. Thanks to technology called parallel kinematics, flexure-based systems with up to six degrees of freedom can be constructed.

What's not to like?

On the downside, flexures don't offer long travel distances.

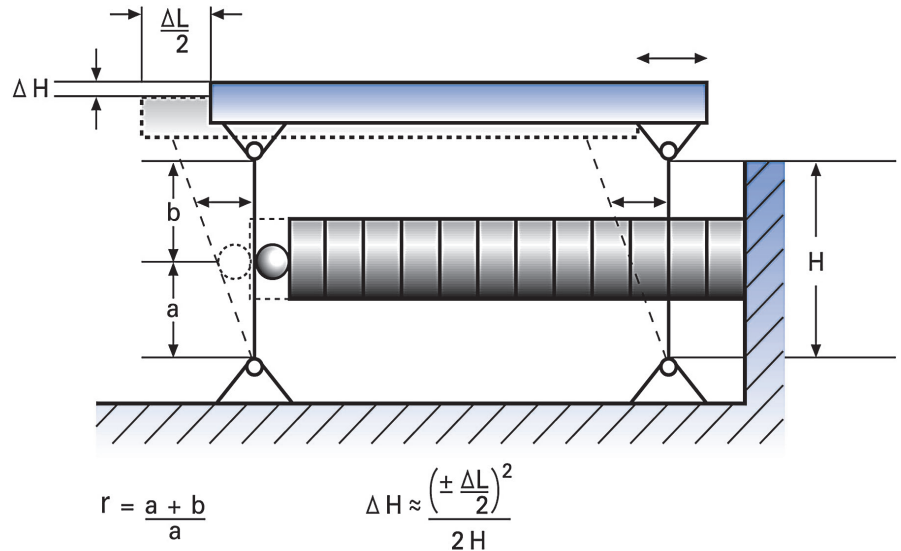
“If you need inches or meters of travel, flexures are not for you,” Jordan said.



Flexure movement is related to the travel of a stack actuator, which, in turn, is limited by the maximum strain achievable with the PZT material used. That typically is about 0.1 percent of the actuator length, according to Jordan. This means a piezo stack with a length of 100mm is capable of about 100µm of travel.

But a 100mm piezo stack is considered very long and would be “prohibitively expensive” for many applications, Jordan added.

An alternative to a long and expensive piezo stack is to amplify the motion of a shorter stack by having it push against a lever. PI claims flexure packages with lever-motion amplifiers can improve PZT displacement 20-fold, yielding travel ranges up to 2mm. One



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A flexure-based piezo actuator with a simple parallelogram flexure guiding system and motion amplifier. The amplification transmission ratio (r) is given by $(a+b)/a$.



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such PI package, the NanoCube, measures less than 50mm on a side but delivers 100µm of travel in three different directions, Jordan said.

Pollak pointed out that stack-actuated flexures that provide a lot of motion amplification can lose a good deal of their inherent speed and precision. Flexures offering a millimeter or two of travel may not have any advantage over conventional motor-driven stages, other than their smaller size, he said.

Another disadvantage of PZT stack-actuated flexures is that they're prone, in open-loop configurations, to hysteresis and creep. In closed-loop operations, however, a position sensor and controller working together can compensate for hysteresis and creep.

'It is a very exciting time in the field of motion control.'

PI offers multi-axis, closed-loop PZT-stack-actuated positioners that the company claims allow a point to be repeatedly located within a 1nm × 1nm × 1nm cube, depending on how well temperature and vibration in the surrounding environment are controlled.

Nanopositioner users concerned about hysteresis can



Physik Instrumente

A scanner, employing a flexure-based piezo actuator, used for imaging applications such as dithering, stabilization and pixel substepping (resolution enhancement).

also consider products from Israel-based Nanomotion Ltd. The company's systems feature piezo motors that operate in both a stack mode and an "ultrasonic resonant mode." In the latter, the piezo element deforms in two axes rather than just one, resulting in an elliptical motion at the tip that can be transmitted to another device.

One advantage of this mode is that it eliminates hysteresis when used to actuate a flexure, even in open-loop



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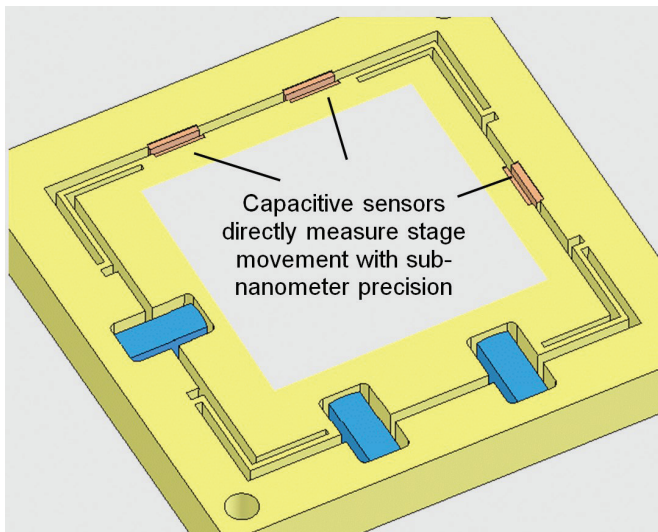
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configurations, according to Alan Feinstein, Nanomotion's vice president of sales and marketing.

In addition, Feinstein said this mode will hold a flexure in place once it has reached a certain position without

requiring additional power. By contrast, he said, a piezo stack would have to consume power continuously to hold a flexure in position.

Market success

Today, PZT/flexure actuator systems are available as off-the-shelf products and as specials. Applications for nPoint's piezo-driven flexure stages include semiconductor equipment and precision machining. Pollak also cited microscopy as a large and growing market. In addition to optical microscopes, nPoint flexure stages are used in AFMs (atomic force microscopes), where they may be called on to move distances less than the diameter of an atom.

The latest applications for PI's flexure-based actuators include the new field of silicon photonics, in which silicon is used as an optical medium, as well as microlithography, genomics and single-molecule biophysics.

With demand growing in these cutting-edge fields, Jordan calls it "a very exciting time in the field of motion control." ■

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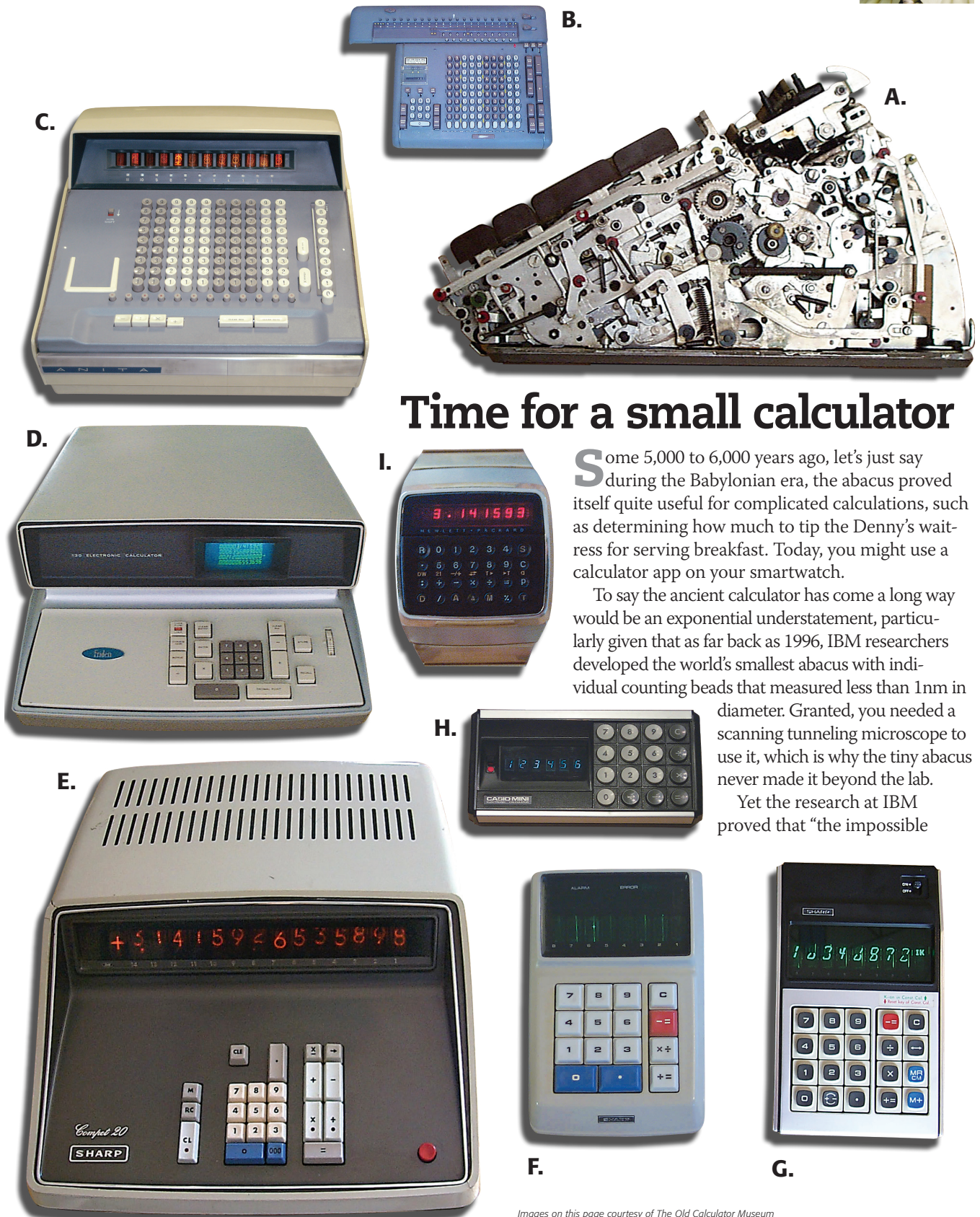
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Time for a small calculator

Some 5,000 to 6,000 years ago, let's just say during the Babylonian era, the abacus proved itself quite useful for complicated calculations, such as determining how much to tip the Denny's waitress for serving breakfast. Today, you might use a calculator app on your smartwatch.

To say the ancient calculator has come a long way would be an exponential understatement, particularly given that as far back as 1996, IBM researchers developed the world's smallest abacus with individual counting beads that measured less than 1nm in diameter. Granted, you needed a scanning tunneling microscope to use it, which is why the tiny abacus never made it beyond the lab.

Yet the research at IBM proved that "the impossible

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was possible,” noted Dr. James Gimzewski, who led the research team at IBM at the time. That sort of sets the tone

for the evolution of modern-era calculators, beginning nearly 50 years earlier than the breakthrough at IBM.

In 1949, the California-based Friden Calculating Machine Co. Inc. introduced the STW-10 Electro-Mechanical Calculator, which was typical of the electro-mechanical calculators of the

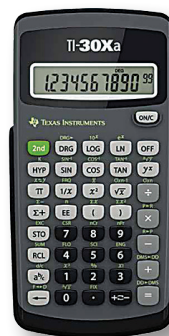
time. (See photos A and B on page 28, which show the inside and outside of the STW-10.)

Electromechanical calculators such

as the STW-10 remained popular through the 1950s and were produced until 1966, according to the Web site for The Old Calculator Museum (www.oldcalculatormuseum.com). Rick Bensene, a computing/network/telecommunications professional and “a fan of all kinds of technology,” created the site in 1997 and opened the museum near Oregon City, Ore., in 2005 to preserve, document and share the technology of desktop automatic calculating machines.

While Bensene acknowledged the museum’s Web pages “aren’t fancy,” the site more than makes up for it with a great deal of images and information available online to document the history of about 150 or so calculators. In all, the museum is home to about 175 old calculators.

Among the collection is the Sumlock Comptometer/Bell Punch ANITA



Texas Instruments



Casio USA

K.

L.

(photo C), which the museum cites as the first mass-produced, commercially available, all-electronic desktop calculator. Introduced in 1961, the calculator was seen as the death knell for electro-mechanical calculators. Though it was an all-electronic calculator, the Mark 7 and its immediate successor, the Mark 8, incorporated gas-filled vacuum tubes.

The vacuum tube technology didn’t last long, however, as Friden itself unveiled the EC-130 Electronic Calculator in 1963. Though generally recognized as the first all-transistor electronic calculator, the EC-130 (photo D) “used a magnetostrictive delay line for its register storage, which, technically, is not a solid-state device,” Bensene notes on the museum’s site.

For that reason, though, Sharp USA also lays claim to the first all-transistor electronic calculator, the Sharp Compet 10, which it introduced in 1964, and quickly followed up in 1965 with the Compet 20 (photo E).

Sharp is credited with introducing the first portable electronic calculator in 1971. But the Sharp EL-8 “Handheld” Electronic Calculator (photo F) was still too big to fit in a pocket. Plus, its size still proved somewhat impractical for traveling business people, according to the museum.

So just 18 months after introducing the EL-8, Sharp rolled out the EL-811 Electronic Calculator, which was smaller and lighter than its predecessor. The EL-811 (photo G) is considered to

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be "the first truly portable electronic calculator."

But another calculator captured headlines in 1972, the Casio Mini Handheld Calculator (photo H), which was among the first handheld calculators to use a single chip and the first to come with a price tag below \$100.

Rounding out the entries from the Old Calculator Museum is the HP-01 Calculator Wristwatch (photo I), which debuted in 1977 at a cost of \$795 for a gold-plated, stainless-steel wristband.

That's about as small as calculators have ever been made, aside from a calculator pen and some toy novelties. Interestingly, while the HP calculator watch has long been discontinued, Casio currently offers a calculator watch for about \$25 (photo J).

With calculators of all sizes and shapes and functionality available on the market today (photos K through N), the big news isn't necessarily how small or inexpensive they've become. Ultimately, it's about the user's needs, unless you account for the cool factor. In that case, you'll want to get yourself a smartwatch and play with a variety of calculator apps designed for the latest must-have gadget.

For more information about The Old Calculator Museum, which can be visited by appointment only, visit www.oldcalculatormuseum.com.

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Solid Growth

Sintering 3D parts from powdered metal is on the rise

By Kip Hanson, Contributing Editor



FineLine Prototyping

Cover Story

Acronyms abound: DMLS, MLS, SLS, SLM. All are used to describe technologies that convert powdered metal with the consistency of flour into most any shape imaginable—provided it's no bigger than a loaf of bread, that is.

The members of the ASTM F42 standards committee—those people who spend their days thinking about additive manufacturing—call it laser sintering (LS).

The term “sintering” is a bit of a misnomer, though. Many sintered parts rely on high forming pressures and temperatures slightly lower than the material's melting point. Laser sintering doesn't involve application of pressure.

Elevator ride

The first step in laser sintering is to electronically slice a 3D CAD model of the part to be fabricated into paper-thin 2D layers. The resultant file is then downloaded to an LS appa-

ratus, which consists of a build chamber fitted with an elevator system. A controller-guided, high-power laser and a scanner sit above the chamber. Powdered metal is placed on the build platform. The laser is then activated and moves such that its beam defines—draws—the outer edge of the part's bottom. When finished, the elevator lowers the part by the designated layer thickness, which ranges from 0.1mm down to a few microns. Then another layer of powdered metal is rolled across the work zone and the laser outlines that cross section of the part while fusing the second layer to the first. This process continues until the part—built from the bottom up, one layer at a time—is completed.

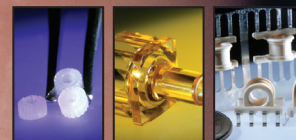
LS isn't new. In 1986, Dr. Carl Deckard of the University of Texas filed for the original patent, which describes the process of selective laser sintering (SLS) for powdered plastic, metal and

continued on page 35

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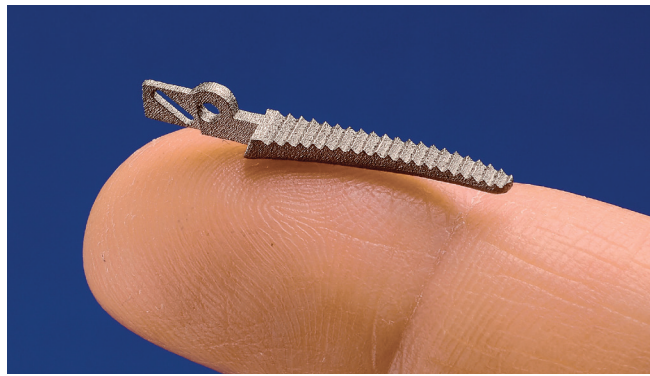
ceramic. He later founded a company that sold SLS machines.

Getting noticed

Metal LS has received a lot of attention from major manufacturers the past couple years.

"The larger companies, such as General Electric and Boeing, have recognized the competitive advantage this technology gives them," said Ed Tackett, director of the RapidTech Center at the University of California, Irvine's Samueli School of Engineering. "As a result, a number of AM equipment suppliers are now actively pursuing this market segment."

Tackett explained that laser sintering



FineLine Prototyping

A component for a surgical robot created by high-resolution metal laser sintering of 17-4PH stainless steel.

titanium, aluminum, stainless steel—the list goes on. This technology also opens the door to metals never before seen, according to Tackett. "By mixing different metallic compounds, it's possible to develop hybrid materials 'on the fly'

turning metal into powder since the time of the ancient Egyptians, but metal LS requires finer, more consistent particles than those used in traditional powder metallurgy. That's because layer thickness, and ultimately final product detail and accuracy, are determined in large part by particle size.

"You cannot simply buy this material on the street corner," said Joachim Göbner, CEO of 3D MicroPrint GmbH. "Our equipment creates layer thicknesses of less than 5µm, so the powder particles must measure less than that. Obviously, when you are working with layers this thin, you need a medium with the correct

"The larger companies, such as General Electric and Boeing, have recognized the competitive advantage this technology gives them."

machines have evolved to the point that the parts they produce exhibit physical characteristics as good as, and in some cases better than, equivalent cast or billet material. "The machines are very good now," he said. "You can create fully dense metal parts from a wide and growing variety of alloys."

Those alloys include cobalt chrome,

to meet specific mechanical or physical requirements. This gives engineers an unprecedented freedom of creation."

Overcoming obstacles

There are a few obstacles to metal LS, however. One of these is the actual feed stock—the metallic powder used in the sintering machine. People have been

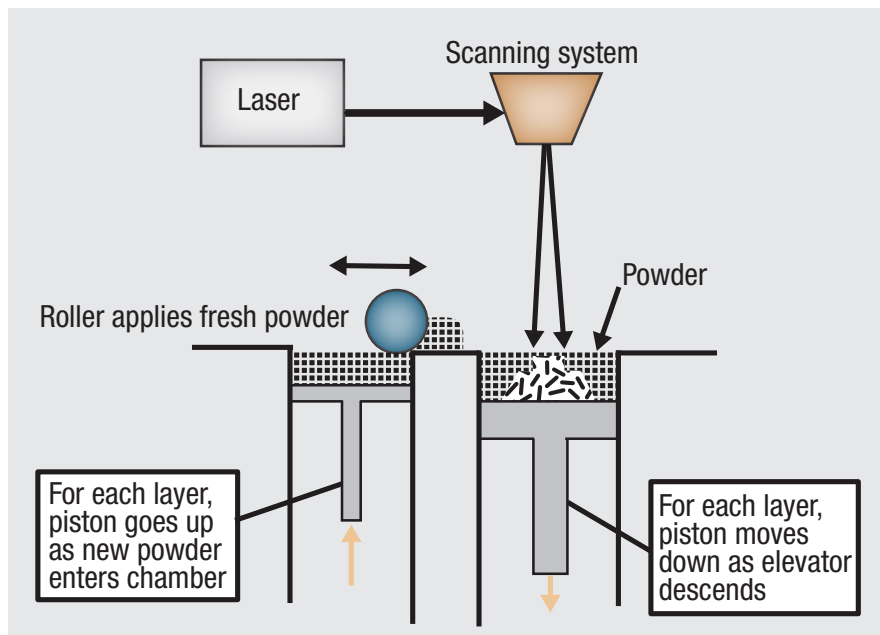


Figure 1: The laser sintering process.

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Solid Growth continued

properties and quality control—the better the powder, the more accurate the part.”

Based in Chemnitz, Germany, 3D Microprint was recently formed by 3D-Micromac AG, a Chemnitz-based builder of laser micromachining systems, and AM system builder EOS GmbH, Krailing, Germany. The company’s micro laser sintering (MLS) equipment currently has a work envelope 57mm in diameter and 30mm high, and boasts the finest resolution available in MLS equipment, said Göbner. The system has a laser focus diameter of $\leq 30\mu\text{m}$, he added, and can generate wall thicknesses down to $50\mu\text{m}$ and features measuring one to two times the maximum particle size. “This technology opens up new dimensions in additive manufacturing,” he said.

3D Systems also builds laser sintering equipment. The Rock Hill, S.C., company, which invented the stereolithography 3D-build process and bought the company Carl Deckard founded, calls its process direct metal sintering (DMS).

3D Systems Senior Vice President Kevin McAlea said: “Parts built in DMS can be used as functional prototypes, but, increas-



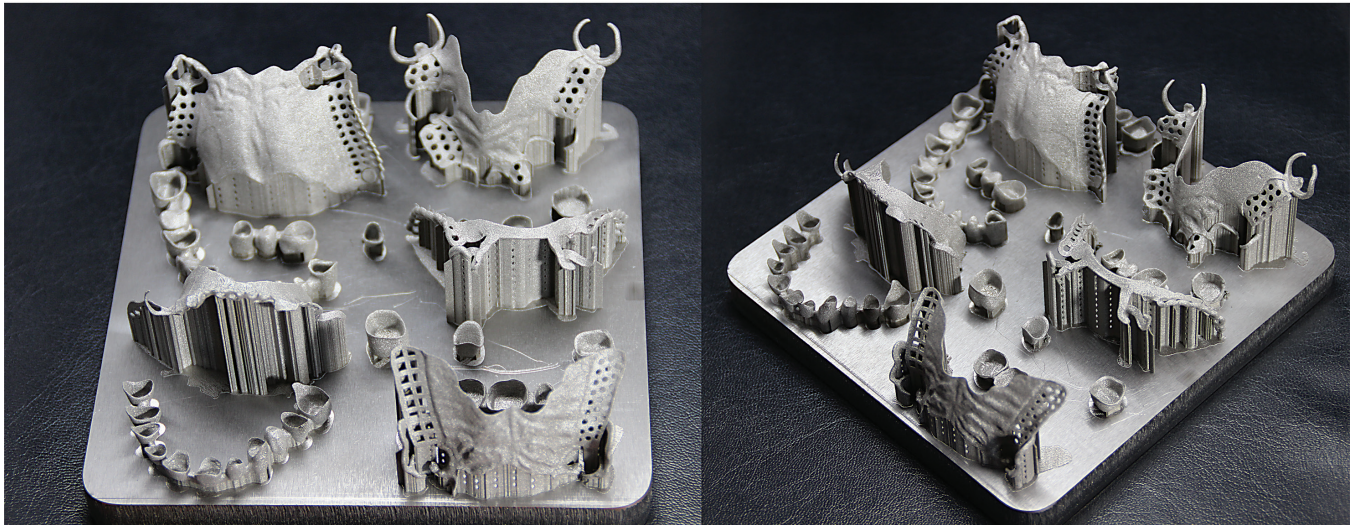
3D Systems

Top view of a dental prosthesis printed using 3D Systems’ ProX 100 dental metal 3D printing system.

ingly, customers are producing actual end-use parts or tools. Examples include tire molds, dental crowns and partial dentures, medical implants, jewelry and a variety of aerospace parts. Customers producing end-use parts and tools take advantage of our ability to produce complex, organic shapes economically, and to produce geometries that can’t be manufactured using conventional technologies. With 3D printing (the common term for DMS and other AM technologies), we say ‘complexity is free,’ and this message is taking hold in the design and engineering community.”

‘Free’ but not easy

Complexity might be free, but it’s not always easy. “This is by no means a plug-and-play process,” said Rob Connelly, president of FineLine Prototyping Inc., Raleigh, N.C. “A great deal



3D Systems

Dental prostheses, bridges and crowns made via direct metal sintering using 3D Systems' ProX 3D printer.

of experience has to be brought to bear in order to get the best part quality."

Connelly uses three metal laser sintering product lines made by Concept Laser GmbH. He explained that distortion is always a concern when laser sintering metal parts, and that great care must be taken when devising the build sequence and process.

"Support structures are critical," he said. "Significant internal stresses are generated during this process, and these structures help keep the part from moving. There are also a number of part-dependent orientation methodologies that we use to ensure that

distortion is minimized."

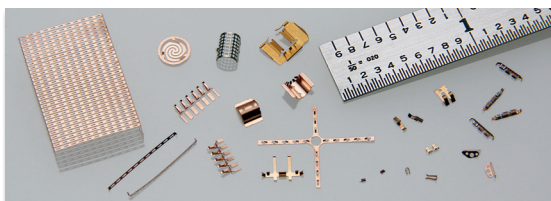
Chuck Alexander of Solid Concepts Inc. said that "because you're applying energy from one side, you get more melt on the top of the layer than you do on the [layer's] bottom." Alexander, AM product manager for the Valencia, Calif., contract manufacturer, said this thermal phenomenon causes the layers to "curl up" toward the laser.

Another laser sintering problem child is part cleanup. The support structures must be removed post-build. This means grinding or machining away the "hanging chad" from the actual

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workpiece, followed by a finishing process such as bead blasting or hand polishing. Because of the thermal stresses that arise when fusing thin layers of metal powder on top of one another, heat treatment after building is basically a given.

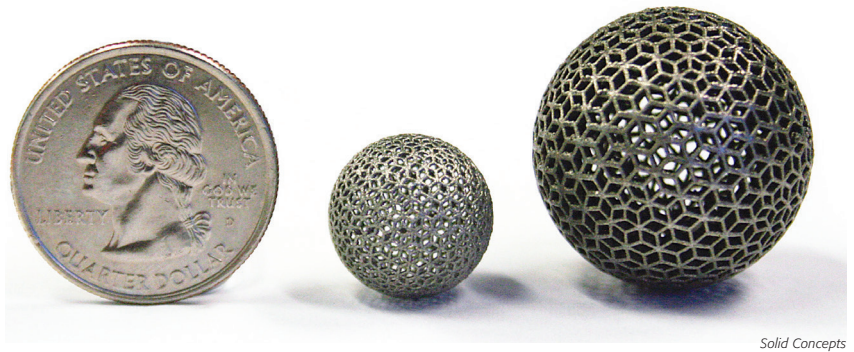
"It's these post-build processes, together with the capital cost of the equipment, that accounts for most of the expense with laser-sintered metal parts," Alexander said.

Big investment

With a ballpark price of \$500,000 and up, the machines aren't cheap. But if you're ready to get in the game, Scott Volk, director of metals-related additive manufacturing for Incodema Inc., an Ithaca, N.Y.-based prototyping company, pointed out some things to look for when buying a machine. Because laser sintering is basically a welding process, Volk explained, there is often slag and spatter associated with melting metal.

"That weld slag can go anywhere," he said. "When it falls back onto the build, it sticks, forming a hard, rough edge. Now the blade comes across to spread the next layer of powder and it can catch on that edge." That's when bad things happen to good parts.

The blade or the workpiece might be damaged, or the support structure may fail, toppling the build. To avoid this potential problem, some builders use rollers to spread the powder, or a lever-style blade that gives way under pressure. Better yet is



Metal laser sintering allows the use of hybrid materials that permit great design freedom.

layer-by-layer build verification.

"This process takes an image after every layer and compares it to the CAD file," Volk said. "If you're outside the tolerance, the machine pauses so you can fix the problem."

Every machine builder takes its own approach, said Volk, and each has pros and cons. This is one reason why Incodema has opted for acquiring multiple brands of machines and

'Support structures are critical. Significant internal stresses are generated during this process, and these structures help keep the part from moving.'

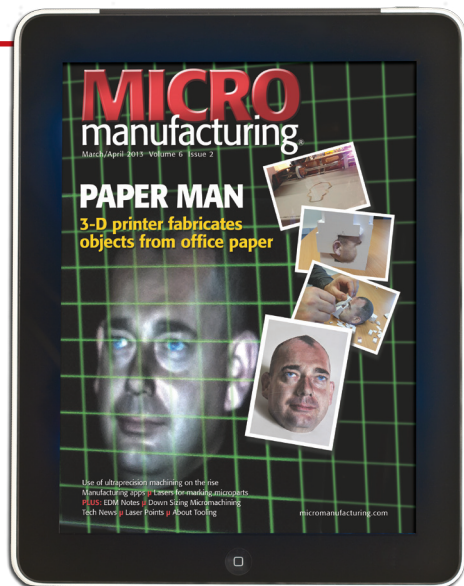
offering customers a variety of prototyping services, including machining, laser and waterjet cutting, stereolithography, FDM (fused deposition modeling), DMLS (direct metal laser sintering) and PCM (photochemical machining).

"The goal for us [is] to have at least one of each major technology," said Volk. "Each part is unique, and some build better on different systems."

According to Volk, there's plenty of prototyping work to be had, and that queries about sintering powdered-metal parts are rising. "People see this technology and they jump on it," he said. "And the big companies—Pratt & Whitney, Boeing, Orbital Science—they're all embracing the direct metal process because of what it's capable of doing. It's very exciting."

Whatever you call it, metal LS is here to stay. It produces functional parts in less time and with greater detail than ever before. Given the right powder and laser focus, extremely fine detail and accuracy is possible. And, with machine price tags comparable to those of other high-end machine tools, metal LS systems are within the reach of most shops.

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Swiss Fix

How a Swiss-style shop makes micro medical parts

By Larry Adams, Senior Editor



All photos in main article: L. Adams

The name of the machine shop, Roberts Swiss Inc., says it all: It does Swiss-style machining and only Swiss machining.

In business for more than 60 years, the Itasca, Ill., shop specializes in medical parts and, to enhance its capabilities, has continuously invested in new equipment throughout its history. And while Roberts Swiss has evolved over the years—the industries it serves, equipment it uses and its location—two constants remain: its approach to manufacturing parts and willingness to take on new challenges.

“We are a Swiss house, the entire scope of our business is Swiss,” said Fernando Ortiz, vice president and general manager. “We have just about every type of Swiss-based machine there is.” That ranges from cam-based escomatics for making components as small as 0.008" in diameter to 38mm multiaxis CNC machines.

New challenges have helped the shop hone its technical edge. Near its inception, the company invested in an escomatic to produce phonograph needles for a new client. Later, it acquired equipment to make defense-industry parts during the Vietnam War. About 30 years ago, a customer approached Roberts Swiss to make a square pin from round stock.

President John Makris Sr. and his machin-

ists didn't know how, but figured it out. Soon, medical device manufacturers came calling, and Roberts Swiss began machining micro medical parts, eventually making them by the millions.

“The bottom line is,” Makris said, “we don't say no to a job.”

There are, however, a couple caveats. The part has to be manufacturable on a Swiss machine and be profitable to make.

New and improved

Today, the ISO 9001:2008 company has about 90 Swiss-style machines, including a veritable army of multiaxis CNC machines that can machine extremely complex parts as small as 0.010" in diameter, achieve tolerances as tight as 0.0003" on diameter and impart fine finishes on metal and plastic parts. Roberts Swiss practices just-in-time manufacturing, zero defects, Kanban and lean manufacturing. It can shepherd new microparts from design and prototyping to full-run production.

As the company has acquired new machinery and drawn new customers, it has expanded into larger facilities. The company started in the 1950s in a 5,000-sq.-ft. factory in Chicago, grew to 12,000 sq. ft. in the 1970s, and, then in 2005, moved into a 25,000-sq.-ft. building in

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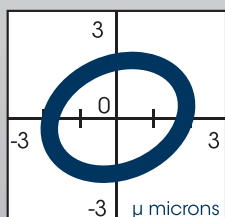
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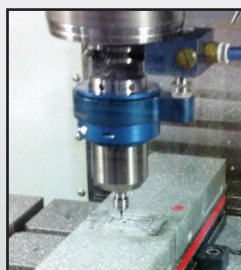
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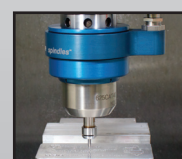
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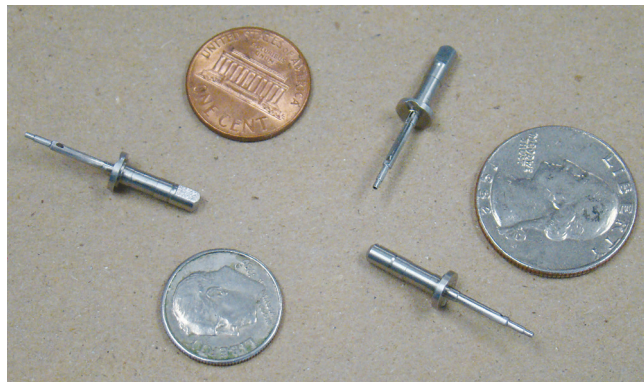
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Itasca. In 2011, it purchased an adjacent building, bringing its total square footage to 55,000 sq. ft.

The newest building houses row after row of Swiss-style CNC machines, lined up two wide the length of the production space. Reflecting its emphasis on servicing the medical industry, Ortiz had the walls, floor and ceiling painted white to give the facility a fresh, clean look. "We benchmarked [our customers] facilities because we wanted our clientele to feel comfortable in our facilities," he said.

The second building, across a driveway, holds the cam-based Swiss equipment used for tight-tolerance jobs that do not need as many dimensions machined as the parts run on the CNC machines. "We have, and use, the right machine for the job," Ortiz said. "We wouldn't put a simple pin on the CNCs because it just wouldn't be cost-effective."

All-in-all, the facility utilizes nearly 30 automatic, bar-fed, Star Swiss CNC machines, approximately 25 Strohm and Tornos automatic, bar-fed Swiss cam machines and approximately 35 escomatic automatic, coil-fed Swiss machines,



A small medical device with many features, including holes, slots and a taper, machined at Roberts Swiss on a multiaxis CNC Swiss machine.

including two CNC models.

The Swiss dance

While each machine has its purpose, the new multiaxis CNC Swiss-style equipment is something of which the company is clearly proud. Ortiz' description of the machines makes the machining process sound like performance art, with their sliding headstocks and guide bushings holding parts, moving and rotating them while simultaneously moving the cutting tools in and out of the material to craft precise features.

"These machines have live tools left and right, can simultaneously run three machining programs and work in up to 12 axes," Ortiz said, pronating and

supinating his wrists to describe the movement of the axis. "They can make very complex parts in one operation without having to move the part from machine to machine."

Makris appears no less excited about the equipment. "We produce [medical] components that can have five dimensions, as an example, and we can produce components that have more than 150 active dimensions on the drawings," he said. "The diversity in machining capability that we can achieve with our Swiss machines is what has made us successful, and the experience and capability that we bring to the table is what makes us competitive."

These machines opened new business

A guide to grinding guide wires

FOUNDED IN 1989, TRU TECH SYSTEMS INC., Mt. Clemens, Mich., is an ISO 9001:2008 grinding machine builder that also offers a wide array of grinding services, including microgrinding. Today, about 85 percent of its grinding services are for making guide wires for the medical industry.

Steve Smarsh is the company's vice president and its first employee. In 1991, then just 14 years old, he started working with his father, and company founder, also named Steve Smarsh. Over the years, he learned the equipment and how to grind complex parts and features.

The process can entail cutting, deburring, rounding, heat treating and cylindrical form grinding. Diameters range from 0.001" to 0.030", and Tru Tech has the capability to grind diameters, tapers and forms with virtually unlimited length.

"A typical guide wire may start at 0.020" in diameter by 100" in length and require the tip to be ground to 0.0020" in diameter," Smarsh said. Concentricity and roundness tolerances can be as tight as 0.000010" and diameter tolerances as tight as 0.000050".

Guide wires often feature multiple tapers and/or straight diameters, which are usually produced in one setup. Depending on wire length, part cycle times range from 30 seconds to 3 minutes.

At these diameters, workholding is critical and Tru Tech



Tru Tech Systems

Grinding wires requires matching the appropriate grinding wheel with the correct workpiece and wheel rpm.

developed the Perimetric workholding machine to accomplish this task. It uses a regulated roller to drive the workpiece, a work blade and an adjustable spring-tension roller to maintain solid contact.

The medical industry often specifies stainless steel and Nitinol work materials, which are considered difficult to grind. "With our years of experience," Smarsh said, "we can match the right grinding wheel, the right workpiece rpm and the right grinding wheel rpm."

—L. Adams

opportunities, and soon the company was making components it wasn't doing before, especially after CNC investments ratcheted up in 2008. The company's core competencies were small pins and similar parts for small hand-held medical devices such as staplers and cutters. While still making millions of these types of parts, Roberts Swiss' new multifeatured parts can be found in myriad devices, including the da Vinci robotic surgical system.

One recent medical part required the shop to broach a rod and perform several other machining processes. Previously, Roberts Swiss outsourced the broaching task until acquisition of the CNC machines, which provide adequate dimensional control. The control was needed because of the special relationships between the features.

"We broach [the base] and then cross-drill on the flat of the inside of a broach and then come in and tap a hole with very fine threads on it," Ortiz said. "The hole has to be at the exact location specified because it has relationships to other dimensions on the part. The newer CNC Swiss machines have the capability to control that."



An escomatic in operation at Roberts Swiss.

When examining some of Roberts Swiss' microparts, one wouldn't automatically think "Swiss" part. One example is a small, rather slender part. This description might sound like a traditional Swiss-machined part, except there is nothing round on the multifeatured part other than the diameter of the drilled hole.

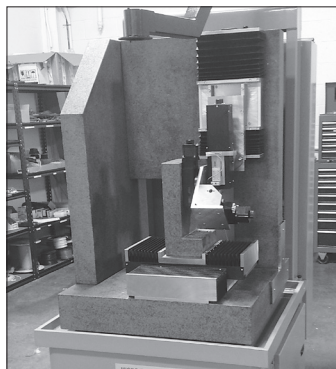
"Most people look at that product and wouldn't consider a Swiss machine

making it," Ortiz said. "But, we can make that part, and millions of parts similar to it. We mill at a faster rate than a VMC could, and we do it with continuous production."

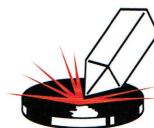
The company machines all types of materials, some of them proprietary and only available from a specific vendor. Some materials are unexpected, such as fiberglass, and some are simply difficult

A STEP BEYOND STANDARD EDM

Micro EDM Machine & Tool Co.'s latest entry to the Micro hole EDM machine line is the 5 axis nozzle master. It's built for high precision small hole production (.003 to .015 size range), and is very rigid with a solid welded and normalized base, granite table top and vertical uprights. The X-Y-Z slides are stainless steel and oversized for rigidity and accuracy.



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They make 'medical miracles'

PERIDOT CORP., PLEASANTON, CALIF., SAYS its employees may not be doctors, but the devices they make perform medical miracles. The company specifically targets the medical device sector.

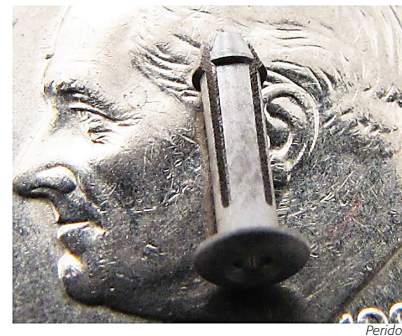
According to the company's owner, Patrick Pickerell, "[medical] is a much more profitable and stable market compared to electronics."

The company calls itself a "next-generation production partner" and offers more than 40 different machining services—including wire micro-EDMing and wireforming—to fabricate products such as cardiovascular and spinal implants, surgical devices and instruments. In recent years, the company has made a big push in laser processing. Its production facility includes nine CNC laser work centers that cut, weld, drill, ablate, and engrave and mark parts. Machines range from 1,500w machines and CO₂ sheet cutters with 4-sq.-ft. beds to pulsed YAG stent and tube cutters.

"We typically invest in only the newest and most advanced machining equipment," Pickerell said.

One focus is producing micro and miniature components, such as a device for cataract surgery. "We are laser welding 0.002"-dia. Nitinol wire to Nitinol tubing with 0.002"-thick walls," he said, adding that for this work, "we routinely hold tolerances of ± 0.0002 ."

—L. Adams



A titanium bone anchor Peridot turns on a CNC Swiss machine. It also wire-EDMs the 0.1mm-wide slots.

Swiss Fix continued

to machine, such as ToughMet, a copper-nickel alloy, and 300, 400 and 600 stainless.

The broached part with cross and angle milling, for instance, is made from 316 stainless steel bar stock, a difficult material to machine, especially at a high rpm, which could mar and create other problems with the part's surface finish.

Check it out

The new Swiss technology has led the company to invest in new testing equipment that improves part accuracy and turnaround, Ortiz said. "Everything today is about turnaround time and how fast you can do the job. We've got more equipment producing more products that are much more complex dimensionally. Our evolution is not just in the technology to make the products, but also in the way to measure and inspect them."

To ensure the material and parts meet specifications, the company uses a variety of metrology equipment, such as an X-ray fluorescence machine that checks final part accuracy and material makeup.

The company emphasizes using test, measurement and inspection for QC as well as process control. Machining parts accurately reduces expensive scrap, which reduces wasted time and money spent in putting work into parts that do not meet customer specifications.



A technician inspects a part using a laser-based measurement system.

The company's metrology capabilities have grown from relying on hand-held devices and optical comparators to sophisticated laser and vision machines that are used heavily in its two QC rooms, one in each building. For example, a new laser measurement system allows machine setup personnel to quickly check if a micro part is between the specified upper and lower control limits. With this data, they can determine if machine adjustments are needed to bring parts closer to spec.

"We can call up an inspection program, drop the part in and get all the dimensions tested in a few minutes instead of having to wait 30 minutes to test a micro part with 30 or 40 dimensions," Ortiz said.

In the second quality lab, a critical inspection device is an image dimension measuring system that allows automatic checking and measuring of up to 99 dimensions on a single part in a matter of

minutes, instead of having to check each dimension manually, Ortiz added.

The equipment is necessary because of customer demands. "We have a medical device client that requires zero defects for its parts that are used in a surgical device and the contract is for a couple-hundred-thousand parts," Makris said. "We had to check all of these microparts, and they all had to be perfect."

The project is a great example of what Makris previously said, that if the shop can make a part cost-effectively, "we don't say no to a job."

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Measuring the 'Unmeasurable'

Today's CMMs inspect parts once thought too small to measure

By Gary Hobart, Hexagon Metrology

Technological advancements have allowed the design and production of parts with geometrically complex features smaller than 10µm. Those features can be difficult, if not impossible, to measure with traditional inspection methods.

For example, machining centers are available that can precisely drill a 0.05mm-dia. hole. A

standard touch probe with a 0.3mm-dia. tip wouldn't fit into such a hole. A smaller-diameter, custom styli would be an option. But because its diameter must be smaller than its tip, the shaft could be overly flexible and deflect when contacting the workpiece. This would degrade accuracy.

And while resonance or inductance probes may have a place in measuring small parts, as their styli are typically smaller than other probes, problems can still arise. For example, when these styli enter a hole, the hole naturally becomes a cylindrical feature, by definition, and the walls and any contaminants can influence when the trigger is actuated and the quality of the data gathered.

These problems have created a quandary about how to maintain quality control. Frequently, a manufacturer will resort to measuring parts with devices it has traditionally employed, such as optical comparators or microscopes.

However, there is a solution to verifying the tolerances of features that are too small for traditional metrology instruments: a coordinate measuring machine with multiple sensors, including a sensor for optical measurement.

Compared to manual methods, CMMs allow manufacturers to inspect microparts to the GD&T (Geometric Dimensioning and Tolerance) standard. GD&T is a universal language that conveys design intent that's understandable to the global manufacturing community. This enables parts produced in one country to be utilized in assembly plants worldwide.



All images: Hexagon Metrology

Learn more about micro metrology

 To see video of a Hexagon Metrology multisensor CMM in action, scan the QR code on your smartphone or enter the following URL into your Web browser:
<http://micro.deliv.com/2sy4k>



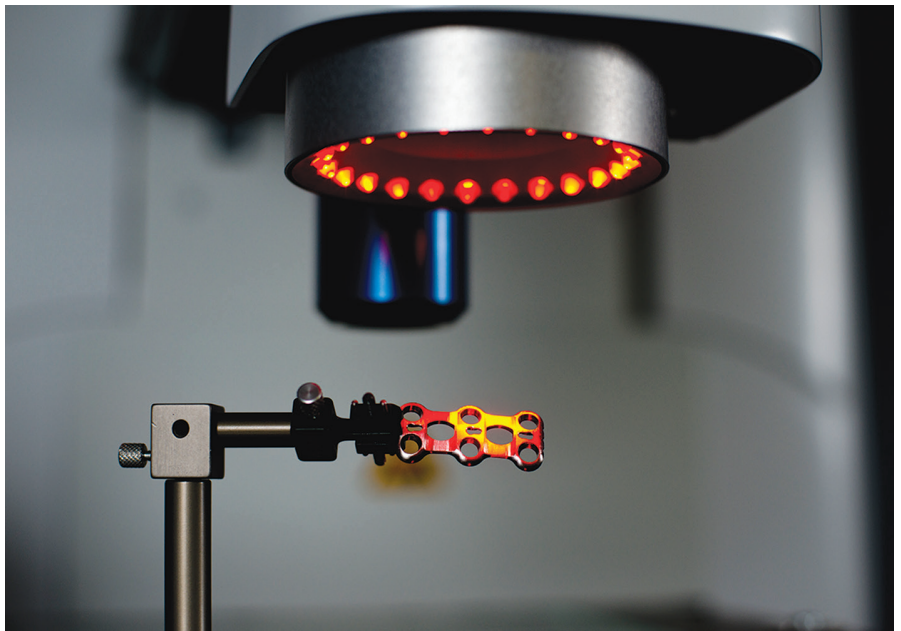
With GD&T, all parties involved—theoretically—measure parts the same way.

Multisensor CMM advantages

The benefits of multisensor CMM technology for inspecting microscale parts and features are numerous and compelling. One advantage is that a multisensor measurement system can seamlessly switch between sensors within its inspection program, seeking and then selecting the best measurement method for a particular feature's geometry, material and the specified accuracy requirements.

The parameters used to make these automated decisions are overwhelmingly based on feature orientation and methodology, similar to how a cutter is chosen for a machine tool. Depending on the application, some features are best measured using laser sensors or chromatic-white-light (CWL) sensors, while touch and scanning probes or vision systems prove more suitable for other features.

A touch probe is typically used to measure 3D features such as cylinders, spheres and planes, which are large enough for the stylus to touch in multiple



Hexagon's Optiv Classic is a multisensor measurement system that combines vision and touch probe inspection into one metrology platform. Used for diverse dimensional verification tasks, the scalable Optiv product line allows the user to configure a machine from "building block" component configurations: high-resolution cameras, TTL (through-the-lens) lasers, white-light-scanning sensors, analog scanning sensors and touch-trigger probes.

locations. Although the smallest standard conventional probe is 0.3mm in diameter, 0.5mm is more practical for everyday use as a contact device.

To inspect a part like a print head, which has micron-range feature and positional tolerances, it would be best to use a probe that incorporates a strain gage.

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Utilize CAD for inspections

A CAD MODEL REPRESENTS the ideal part and is the perfect reference for comparing a machined part to its original specifications. A multisensor CMM enables the operator to leverage CAD files to inspect a part by using a CAD-centric inspection software platform.

Metrology software is capable of programming and running inspection routines directly from native CAD files. Utilizing the original CAD file preserves the traceability of design intent from engineering to manufacturing to inspection. A CAD model with embedded GD&T data automatically communicates its design intent to drive inspection planning. The effective deployment of CAD with multisensor inspection systems yields faster and more-reliable programming, quantitative measurement results and shorter measurement cycle times.

Manual methods are qualitative by nature because they rely on the opinion of an inspector to confirm if a part meets specifications. This verification method has largely disappeared from many manufacturing industries. Using modern inspection systems, part features can be quantitatively evaluated. Any process that still relies on a human to qualitatively assess the

part is a candidate for replacement. This does not necessarily suggest an operator is unskilled, just that the results are less likely to be precise and repeatable.

Even with today's advanced programming software, mistakes are made. A frequent mistake is the establishment of the part's coordinate system per the ANSI standard. According to the standard, each datum, in order, should constrain as many degrees of freedom as possible.

For example, given three datums in the following order—a plane, line and hole—a common mistake is to level to the plane, rotate to the line and set the X-Y origin at the hole. The proper way to set the coordinate system in this example would be to level and zero to the plane, then rotate and offset to the line. The hole should only be used for the final translation.

To eliminate the potential for human error, it is best to remove the human from the equation. Besides using an automated multisensor CMM, sophisticated metrology software is a must for micromanufacturing operations.

—G. Hobart

Measuring the 'Unmeasurable' continued

Minimal force is needed to trigger a strain gage. This minimizes the deflection errors that result with traditional probes that are fitted with just an electronic switch, as well as the lobing effect.

Analog scanning probes that maintain contact with the part during scans increase accuracy because they gather a large amount of data in a short time.

Options, considerations

Vision sensors are recommended for measuring features too small for a touch probe and parts that require noncontact measurement, such as those that are flexible. Vision software examines an image to detect the gradation change in grayscale and automatically determines and digitizes the edges of a feature.

A variety of vision options are available that promote measurement accuracy, including motorized zoom cells that allow microparts to be viewed at various magnifications and fields of view. Another is a fixed optic that incorporates a microscope lens, which provides high part-feature magnification and high pixel counts.

Although vision sensors usually measure X- and Y-axis features, they also can measure submicron surface features.

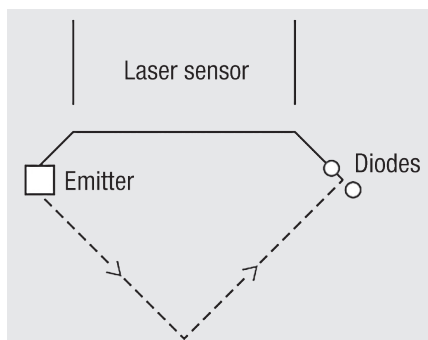


Figure 1: A laser sensor works via triangulation. The deflected light must pass between two diodes. If it doesn't, the part is moved up or down on the Z-axis.

A noncontact laser sensor is effective for measuring surfaces and contours. A laser measures the Z-height at a certain location via the process of triangulation (Figure 1). The laser beam on a multisensor CMM can capture single points or scan multiple points along a path.

High-end, ultrahigh-accuracy CMMs are differentiated primarily by their hardware.

Part material is a consideration with noncontact laser measurement. Shiny part surfaces can lead to reflective laser light that creates "noise" in the measurement data.

Part design can also cause problems.

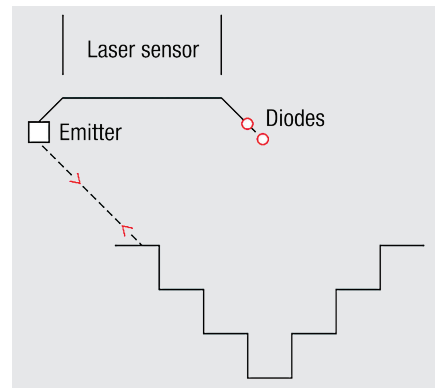


Figure 2: Holes with steps cannot be measured with lasers, because the light is not properly deflected to the diodes.

For example, when measuring a stepped hole, the edge of the hole may block the laser beam (Figure 2) and the image would appear as an ellipse.

When accuracy is higher than what a laser can deliver for noncontact inspection of surfaces and contours, a CWL sensor is the answer. The CWL sends white light through an optical probe, or lens, that corrects chromatic aberration by spreading the focal length over a discrete number of points, creating a full spectrum of light. Next, spectral analysis is used to determine the wavelength of the reflected light and calculate a precise measurement. The optical probe then determines the measurement range or focal depth of the spectrum.

CWL measures points on a surface

directly. That allows coordinate data to be acquired without Z-axis movement, which minimizes machine inaccuracy. This, in turn, increases measurement accuracy.

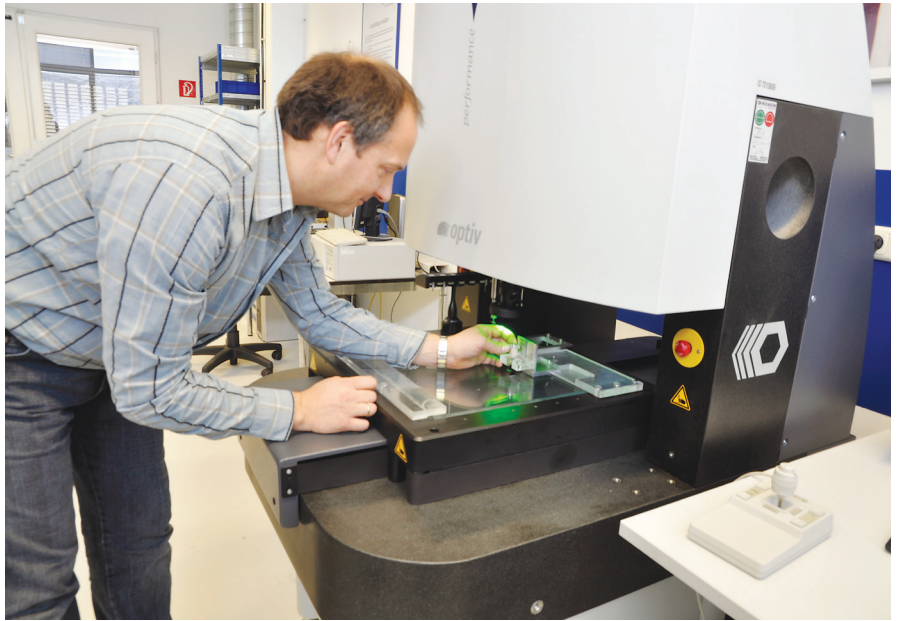
With CWL, it is possible to measure almost any surface, from highly reflective to transparent to matte black.

Hardware is critical

Sensor technology is only the starting point when it comes to overall inspection accuracy. A CWL with an accuracy of $1\mu\text{m}$ is practically obsolete if attached to a CMM with $5\mu\text{m}$ accuracy.

Most entry-level multisensor CMMs fall into the $2\mu\text{m}$ - to $3\mu\text{m}$ -accuracy range. These machines are typically mechanical-bearing machines with zoom optics that rely on computer algorithms to adjust for errors. The biggest differentiator among entry-level equipment is software.

High-end, ultrahigh-accuracy CMMs are differentiated primarily by their hardware. Obtaining an intelligent result when measuring a micropart requires a stable machine. Such machines have a granite-based fixed bridge and are fitted with



Multisensor CMMs allow precision measurements of tiny features that cannot be measured with conventional systems.

high-precision air bearings.

Controlling external influences, such as vibration and temperature fluctuations, contributes to measurement success. Vibration affects small parts more than big parts because small-part tolerances are often tighter. High-end CMMs are

built to dampen vibration and adjust to temperature variances that occur in manufacturing facilities.

Control the lighting

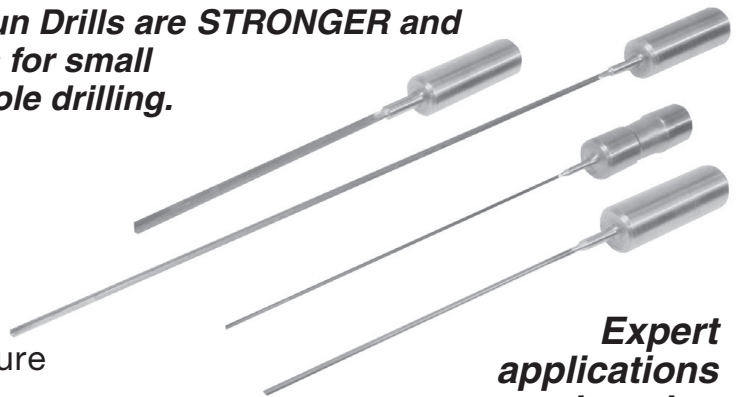
Vision technology relies on the detection and measurement of edges. In an

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application where edges are difficult to distinguish, such as a micropart feature, it may be tempting to increase the amount of light illuminating the workpiece. This is one of the worst mistakes an operator can make because light bends, and increasing backlighting will make a feature appear larger than it actually is.

Even a light directed from above the workpiece can lead to measurement error. Besides the distortion of features, a part that is flooded with light will lead to over-saturated pixels. This creates a "fringe" around the feature, resulting in the fringe being measured instead of the true edge.

Vision systems governed by advanced edge detection algorithms ensure that the appropriate amount of light illuminates the part being measured.

Outgrowing pains

The world of micromanufacturing, built upon improved machining and computing technologies, has not evolved without growing pains. Leaders in the metrology world were challenged by parts thought to be "unmeasurable" at



This multisensor system incorporates pallets that allow it to inspect 30 to 40 medical implants in one setup.

one time. They pioneered new solutions to overcome these inspection obstacles.

With the rise of GD&T inspection, quantitative part measurement is of the utmost importance. Using the tips discussed here, coupled with an understanding of what tools best suit an application, micropart manufacturers

can achieve optimal inspection results. ■

About the author: Gary Hobart is the national sales manager—vision products, at Hexagon Metrology, North Kingston, R.I. For more information about the company's metrology products, call (855) 443-9638 or visit www.hexagonmetrology.com.



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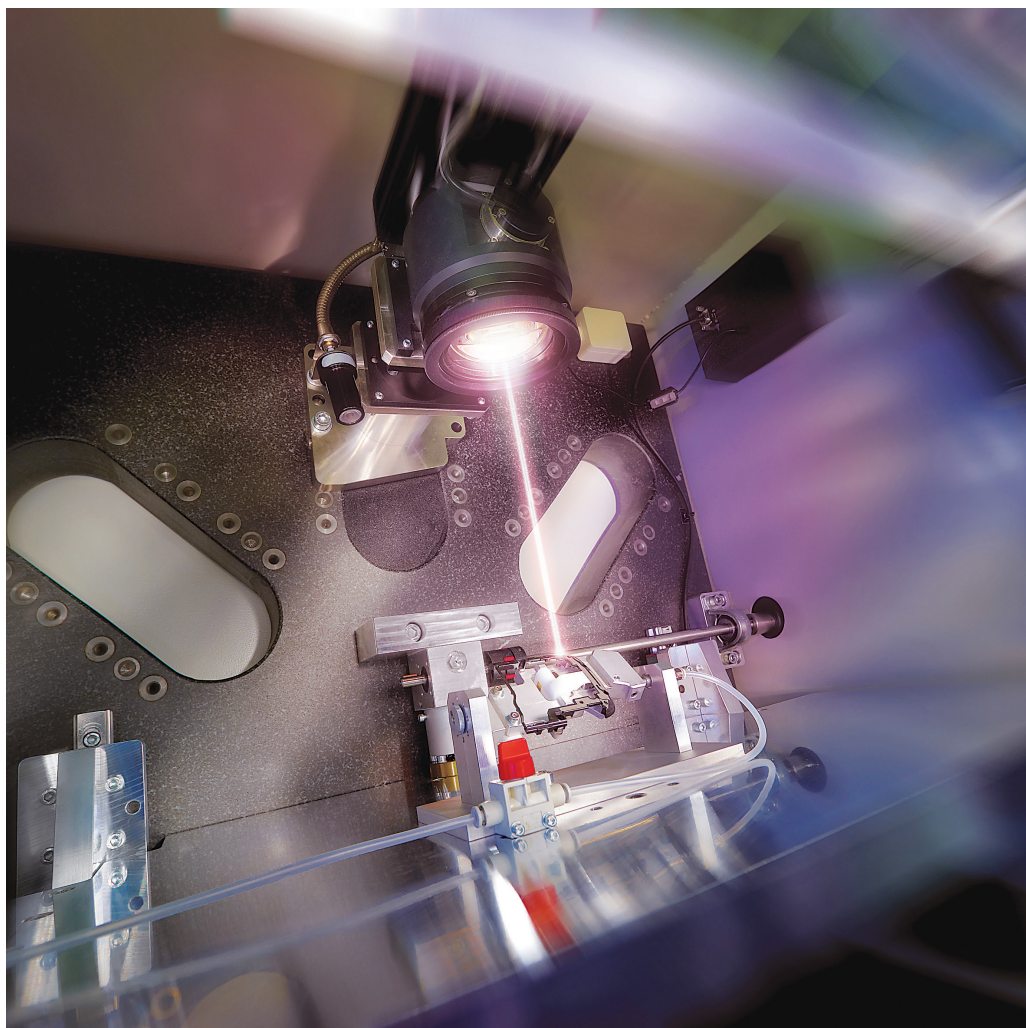
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Space Saver

Emerging technology adds traces that shrink assemblies

By William Leventon, Contributing Editor



LPKF Laser & Electronics

The laser direct structuring process makes it possible to produce circuit layouts on 3D structures.

Ever heard of 3D molded interconnect devices? Many manufacturers haven't, even though 3D MIDs have been around for decades and offer some major advantages in a variety of applications that require both molded and electronic components.

Lately, however, 3D MIDs have been popping up in a growing number of products that need to pack a lot of functionality into a small space. Because many companies and industries are now turning out such products, it seems unlikely that 3D MIDs will be mired in obscurity much longer.

Smaller, lighter devices

For those who aren't familiar with them, 3D

MIDs are injection-molded thermoplastic parts with integrated electronic circuit traces. Adding traces directly to an electronic housing or some other plastic part eliminates the need for separate circuit boards or lead-frame components, resulting in smaller, lighter devices with higher function density.

"We can use all the available real estate on a plastic part," said Stephan Schmidt, president of LPKF Laser & Electronics North America, Tualatin, Ore., whose German parent company is the developer of a leading 3D MID manufacturing process. Schmidt also pointed out that 3D MIDs can be molded into any 3D shape, allowing designers to use space more efficiently than those trying to bend circuit boards and other

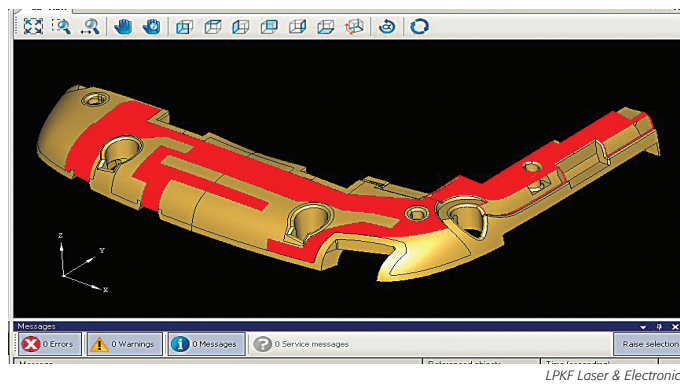
2D components into 3D configurations.

In addition, the reduction in parts made possible by 3D MID technology boosts device reliability, noted Richard Macary, president of Arlington Plating Co., Palatine, Ill., which is involved in 3D MID manufacturing.

Growing market

Though reliable data on the revenues of 3D MID manufacturers is not available, a growing market for the devices can be inferred from the significant increase in 3D MID applications in recent years, according to Thomas Kuhn, managing director of technology and science for 3-D MID e.V., a Nuremberg, Germany, research association that supports the introduction of 3D MID technology. Success stories can now be found in all markets for conventional electronic modules, according to Kuhn.

The technology scored its biggest success when it was adopted to make antennas for mobile phones. These antennas are integrated directly into phone housings, saving space and eliminating assembly steps. Today, more than half of all smartphones are equipped



The LDS process 'writes' circuits onto parts with a laser beam striking the molded part's plastic surface.

with antennas produced by 3D MID technology, according to Kuhn. The technology is also used to make antennas for other mobile devices in the consumer electronics market.

Other key 3D MID markets and applications include:

- **Telecommunications:** antennas, terminals and coaxial plugs.
- **Automotive:** sensors, switches, connection elements, remote controls, 3D circuit boards and radar for adaptive cruise control.
- **Medical:** circuit boards, switch elements, tweezers, LED carriers and hearing aid parts.

Hearing aid components are probably the most common medical application, according to Schmidt. "There's a need there to go three-dimensional to exploit the little space that's available to the maximum extent," he said. When used to make microphone carriers, for example, the technology allows microphones to be mounted in a way that maximizes sound capture, he explained.

Manufacturing options

3D MIDs can be manufactured in a variety of ways. One technique involves the use of two-shot molding. First, two different resins are shot into an injection

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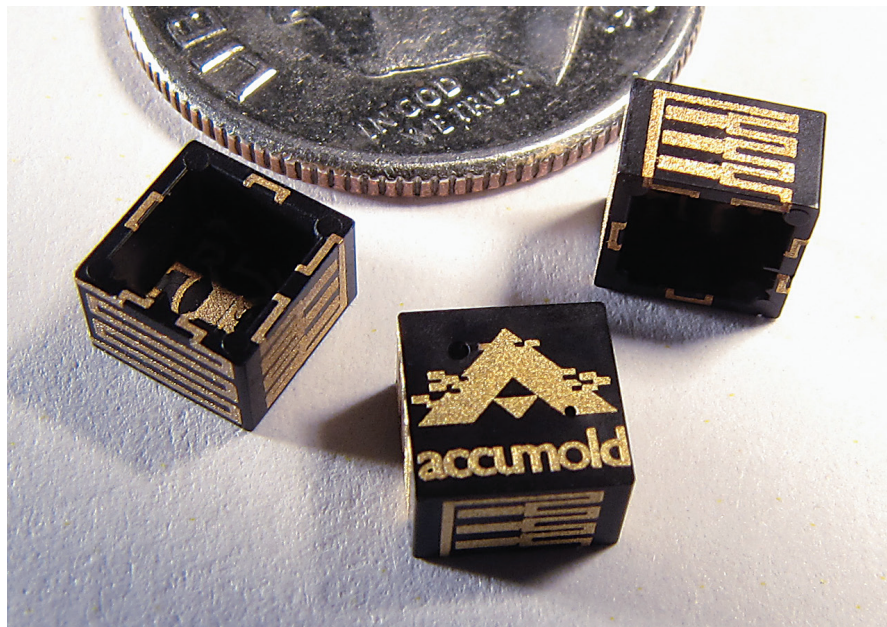
mold, one of which is platable. Traces are then created in an electroless plating process that produces a metal layer on the platable areas.

According to Schmidt, this process has some significant downsides. For one, he said, a "fairly complicated" injection mold is required to put a circuit pattern on a part. In addition, the process limits circuit design to the mold design.

Another option for making 3D MID is laser direct structuring (LDS), a process patented by LPKF Laser & Electronics. In LDS, the base material is doped with an additive containing chemically inactive metal cores that can only be activated by laser radiation. After a component is injection-molded in a standard mold, a laser "writes" the circuit traces on the part. Where the laser beam strikes the material, it activates the metal cores, forming a precise track with a roughened surface. The metal particles along this track form the nuclei for the metal coating that follows.

As in the two-shot molding process, metallization takes place in an electroless bath. Anchored in place by the roughened surface, conductor path layers grow on the tracks where the molding material has been activated by the laser. Successive layers of copper, nickel and gold finish can be produced in this manner. Traces with widths as narrow as 0.005" can be produced with good definition, according to Macary of Arlington Plating, whose firm handles the lasing and plating aspects of the process.

Because the laser puts the circuit pattern on the part after molding, circuit



Accumold

This sample part is approximately 1/4" square and is molded with a platable PC/ABS-blended resin. The parts were laser-treated on all six sides and are plated with a final gold finish.

design is separated from the design of the mold. Therefore, changes to the circuit don't require costly and time-consuming changes to the mold. All manufacturers have to do is transmit new control data to the laser.

LDS "allows part design creativity that extends beyond the limitations of an overmolded lead frame," said Aaron Johnson, marketing manager for Accumold, Ankeny, Iowa, which does both 3D MID and lead-frame molding. "You can trace on all sides of a part, because the plating will stick anywhere the laser strikes the plastic."

Still, Johnson sees 3D MIDs as complementing rather than supplanting overmolded lead frames. "There are distinct reasons why you would go one

Contributors

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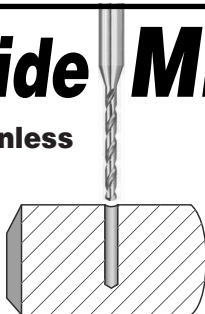
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way or another," he said. "It really depends on where you need the traces to go and what you're ultimately trying to accomplish."

Assembly issues

One possible reason for not choosing 3D MID technology over other options is the process that follows plating: the placement of electronic components on the part surface. The pick-and-place machines used in most assembly processes are designed for flat circuit boards. Therefore, "mounting components in a three-dimensional space usually requires specialized equipment, or at least a different approach," Schmidt noted. As a result, he said, 3D MID assembly is typically more costly and time-consuming than conventional assembly.

'It's amazing to see designers getting fired up about the opportunity to start doing something in three-dimensional space.'

Nevertheless, Macary advises those considering 3D MID technology to analyze whether it actually will be more expensive in the end. This is because the technology also cuts costs by eliminating conventional components and assembly operations from the manufacturing process. "You can rethink the way you're



3-D MID e.V.

This sample is meant to showcase and demonstrate 3D MID technology.

making a part and actually make it less expensive," he said.

In some cases, 3D MID assembly can be done using conductive adhesives or low-melting-point solders. To allow conventional soldering methods, however, higher-temperature materials are necessary. Here, 3D MIDs are at a disadvantage, Schmidt noted, because the temperature capabilities of injection-molded parts aren't quite as high as that of an FR4 circuit board.

On the bright side, Kuhn pointed out that new 3D MID materials include high-temperature thermoplastics, as well as thermally conductive plastics, thermosets and ceramics. Another new development is the appearance of colored LDS materials. In the past, LDS plastics were always black because that was the color of the additives. Now, however, pigments allow LDS materials to be adapted to a variety of color requirements.

In addition, it may soon be easier to prototype parts using LDS. Until now, Schmidt noted, the systems used to make 3D MIDs have been fairly complicated. To simplify things for designers, LPKF will be

coming out with a line of small-scale laser plating systems. These systems will allow designers to "kick around ideas and try 3D applications in the lab," Schmidt said.

No clue

As for what else might be holding back 3D MIDs, the biggest factor might simply be a general lack of knowledge about the technology. "We have been promoting it for 4 years, and we still find so many people who don't have a clue about it," Macary reported.

After designers learn about the technology, the next hurdle is changing their mindset. "Probably the biggest challenge is getting engineers to think 3D," Schmidt said. "Most electronics designers are raised in the two-dimensional world of the circuit board, where components are always mounted flat."

But for those promoting 3D MIDs, Schmidt has good news: "I've been to many presentations of this technology, and it's amazing to see designers getting fired up about the opportunity to start doing something in three-dimensional space."

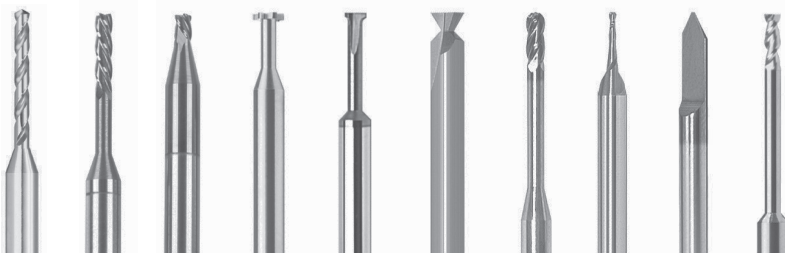
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MICRO DRILL PRESS. **Cameron Micro Drill Presses'** Model 214 drill press features a 1/2-hp, continuous-duty DC motor with a Bodine reversible-speed controller that creates more torque when loads are applied, even at low speeds, according to the company. It has a redesigned sleeved-spindle assembly with sealed bearings, which eliminate the need for lubrication. Runout is 0.0002" at the spindle taper, and, depending on chuck or collet size, the drill press can produce holes from 0.25" to 0.002" to the center of a 5" workpiece.

(800) 369-7769

www.cameronmicrodrillpress.com



QUICK-CHANGE PALLET SYSTEM. The quick-change pallet module VERO-S NSE mini from **Schunk Inc.** allows for direct clamping of small workpieces and machining of five sides. It features a drive with a fast stroke and a clamping stroke, according to the company. With a module diameter of 90mm and a clamping-pin diameter of 20mm, the NSE mini has pull-in forces of up to 1,500 N and is made entirely of stainless steel. The pallet module has small and variable gages for bore holes for workpiece and pallet clamping.

(919) 572-2705

www.us.schunk.com



MACHINING CENTER. The 701S machine from **Willemin-Macodel Inc.** is based on the dynamic control and rigidity offered by Delta-type kinematics. Designed for micromachining, the spindle fits seamlessly with the kinematics on the 701S machine. Tools are directly fixed on the powered spindle, with no need for toolholders, and the maximum spindle speed is 80,000 rpm. Utilizing the kinematics concept makes machining time two to five times quicker than conventional machining, according to the company.

(914) 345-3504

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HARDNESS MEASUREMENT SYSTEMS. **Fischer Technology Inc.'s** Fischerscope HM2000 and Picodentor HM500 are, respectively, micro- and nano-indentation measurement systems that can determine a coating's hardness in numerous scales in the micro and nano ranges. With its programmable X-Y stage and motorized Z-axis, the HM2000 is for automated measurement processes. The HM2000 S support-stand model is the entry-level version for easy-to-position specimens. The HM500 can determine a coating's Martens hardness, elastic characteristics and other material parameters in the nanometer range.

(860) 683-0781

www.fischer-technology.com



MICRODRILL ANALYZER. The Model MDGA microdrill analyzing microscope from **Titan Tool Supply Inc.** inspects the geometry, finish and accuracy of new and resharpened carbide drills down to 1/8" in diameter. It features a 30x magnification lens with a special reticle, two-position viewing and 360° rotation of the drill in a collet holder to allow complete inspection without refocusing or making other adjustments. Drills with shanks smaller than 1/8" in diameter can be inspected if a spacer, which is not provided, is used.

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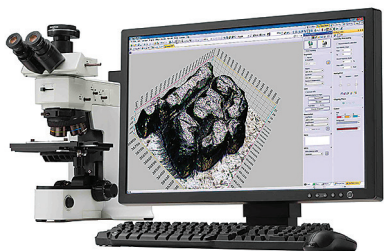
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BORING HEAD. **BIG Kaiser Precision Tool Inc.'s** EWN 04-7 series precision finish boring heads are for use on micromilling machines with high-speed spindles, such as HSK-E25, -E32 and -E40. The boring heads have an adjustment accuracy of 0.0005"/diameter when used without the accompanying Vernier scale, and 0.0001"/diameter when used with the Vernier scale. The boring heads have a diameter range of 0.016" to 0.276". The product is available with the Kaiser KA1 modular connection or a 10mm-dia. straight shank and accepts boring bars with 4mm-dia. shanks. The maximum through-tool coolant pressure is 300 psi.

(847) 228-7660

www.bigkaiser.com



MICROIMAGING SOFTWARE. The Stream 1.9 microimaging software from **Olympus Corp.** allows users of industrial microscopes to acquire, process and measure images, and use this information to analyze data and create reports. The software enables automatic measurement to detect edges and recognize patterns and measure distances, circle diameters and angles between two lines. The coating-thickness feature measures the thickness of prints created using the Calotest method.

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www.olympus-ims.com/en/microscope



MINIATURE SCISSORS. Xuron Corp.'s 440 Mini Scissors is an ultraprecise tool for cutting fine or delicate items with a clean, square edge, according to the company. It features a user-friendly design that includes a return spring and eliminates finger loops for increased precision and control. It is rated for cutting soft metals up to 0.005" thick.

(207) 283-1401

www.xuron.com



AM MATERIALS. EOS of North America Inc. has introduced new plastic and metal materials for its 3D printers. The plastics include PrimePart ST, a soft, flexible and elastic material, and PrimePart FR, a flame-retardant Polyamide 12. In terms of metals, the EOS NickelAlloy HX is a heat- and corrosion-resistant nickel-chrome-iron-molybdenum alloy for applications where temperatures reach 1,200° C (2,192° F).

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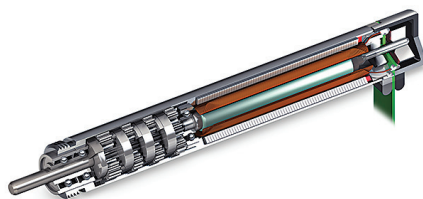
www.eos.info



MOLDING MACHINE. The M3 microinjection molding machine from **MHS** can produce runnerless plastic parts. The machine is optimized for clean-room operation, making it ideal for medical device and component manufacturing, according to the company. The M3 operates using four compact modular inserts, each containing eight microcavities that can produce a total of 32 plastic parts with shot weights of less than 10mg every 5 seconds. The machine has a 4-ton magnetic clamping force.

(905) 873-1954

www.moldhotrunnersolutions.com



MICROMOTOR. maxon precision motors inc.'s EC4 is a 4mm-dia., brushless DC motor and gearhead that features a new winding technology and powerful magnets that reportedly increase power output. It is available in a short version with 0.5w nominal power or a long version with 1.0w nominal power. According to the company, it incorporates a gearhead to ensure optimal continuous running, and ceramics for the gearhead carrier make the motor capable of high input speeds and drive torques. The speed/torque gradient is 50,000 rpm mNm-1 with a continuous torque of 0.4 mNm.

(508) 677-0520

www.maxonmotorusa.com



MICROWELDER. Miyachi Unitek Corp.'s DC29 linear DC microwelder for small resistance-welding jobs features a 200A to 4,000A output. The output makes the DC29 suited for applications where closed-loop feedback control, fast response times and a controlled and precise energy waveform are required, claims Miyachi. Featuring single-phase input, a compact size and dual-pulse schedules, the DC29 offers a controlled, repeatable waveform and a rise time of less than 200µm/sec. Other features include side-mounted bus bars with threaded inserts for mounting weld cables and simplified rear-panel input/output connections.

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manufacturers have struggled to see it as anything other than a promising prototyping tool. That will begin to change in 2014 as large manufacturers invest in and find new ways to apply the technology. GE, for one, is driving the evolution of 3D printing with major investments. And Siemens recently said it is doing likewise, with a goal of using 3D printers to produce spare parts for gas-turbine engines. Those investments will drive a new generation of 3D printers capable of working with a wider range of materials and introducing a new model of distributed manufacturing.

6. Drones and smarter robots will emerge. 2013 was the year that Apple and Internet giants Google and Amazon got really interested in robots and even commercial drones. As a result, 2014 will be the year that manufacturers start thinking about such devices. The expectation is that

Increasingly, manufactured products are being outfitted with sensors and Internet connectivity that allow them to broadcast back to manufacturers data on how they're being used.

investments by these behemoths could lead to a new generation of smart, learning-capable, location-aware machines capable of transforming distribution and manufacturing facilities.

7. The 'Industrial Internet' will flourish. If you think the data generated by today's back office, MES (manufacturing execution systems), control, supply chain and warehouse management software systems is overwhelming, just wait. Increasingly, manufactured products are being

outfitted with sensors and Internet connectivity that allow them to broadcast back to manufacturers data on how they're being used, why they broke and when they need to be serviced. By 2020, in fact, 40 percent of all data generated may come from such sensors. GE calls this trend the Industrial Internet and estimates that it will add between \$10 trillion and \$15 trillion to global GDP in coming years. Manufacturers will need to manage and analyze more data faster than ever before.

8. Workplace safety will become more of a public issue. On April 24, 2013, an eight-story plant in Savar, Bangladesh, known to be unstable, collapsed, killing 1,129. It was one of a series of disasters that occurred in low-cost contract manufacturing plants. Considered to be the largest garment manufacturing disaster in history, the Rana Plaza plant collapse attracted attention in publications and on social networks around the world. Suddenly, manufacturers that contracted with that plant and retailers that sold garments made there were under the kind of intense scrutiny that can bring permanent damage to brands. Some companies, such as PVH, responded

by offering to pay for fire safety and structural improvements. Recently, four other companies agreed to create a \$40 million compensation fund for the victims. In 2014, manufacturers are on notice that responsibility for insuring the safety of the workers who make its products cannot be outsourced.

9. Cyber vulnerability will increase. The current surge in connectivity in manufacturing—between people, machines, processes and global partners—is increasing every manufacturer's vulnerability to

The current surge in connectivity in manufacturing is increasing every manufacturer's vulnerability to cyber attack.

cyber attack. The dangers of operational disruption, competitive espionage or the theft of intellectual assets are rising. But while the latest connectivity technologies may be more security-aware, legacy manufacturing control systems, such as SCADA or ICS, remain a potential Achilles heel.

10. New organizational forms will be tested. As mobile and social technologies change how manufacturers work and interact with employees, customers and partners, manufacturers will continue to experiment with more collaborative organizational structures, seeking to strike what has already proven to be a difficult balance between efficient decision making and inclusiveness. The Manufacturing Leadership Council's September 2013 survey on Next-Generation Leadership showed, for example, that 56 percent of manufacturers expect to employ a collaborative organizational model within the next 5 years, but the finding was considerably below the prior year's finding of 72 percent. The new year will test whether the collaborative movement has solid legs, whether manufacturers will revert to command-and-control structures or whether they will attempt to devise some sort of organizational compromise to reap the benefits of both collaboration and fast-but-efficient decision making. ■

About the author: Jeff Moad is research director at the Manufacturing Leadership Community, Mountain View, Calif. Part of Frost & Sullivan, the organization works with senior executives to plan for the future of their companies and their industries. Telephone: (510) 531-3456. E-mail: jeffrey.moad@frost.com.



Manufacturing trends to watch in 2014

Note: Reprinted with permission from the Manufacturing Leadership Community, a unit of Frost & Sullivan that includes the Manufacturing Leadership Council.

For 2014, the Manufacturing Leadership Community's editorial department offers 10 issues that should be top of mind for manufacturers.

1. Manufacturing growth will continue in the U.S. and globally. Since 2010, U.S. manufacturers have added 665,000 jobs. That's still far short of replacing the nearly 7 million manufacturing jobs lost over the past 30 years. But all indications are that the positive trend will continue, at least into 2015. Manufacturing markets in the U.S., U.K., other parts of Europe and developing countries such as Mexico are also on the upswing.

It appears that manufacturers are continuing to rethink past offshoring decisions made in the pursuit of low-cost labor.

2. Reshoring will slowly gain momentum, but the global production trend will continue. Contributing to the modest increase in U.S. manufacturing jobs has been a reshoring trend that is expected to slowly build. Driven by the desire to produce closer to where they innovate and sell, rising wage costs in China, rising transportation costs and increasing concerns with quality and intellectual property protection, high-profile manufacturers such as GE, Whirlpool, Caterpillar and Ford have reshored some production. And, based on conversations among members of the Manufacturing Leadership Council, it appears that manufacturers are continuing to rethink past offshoring decisions made in the pursuit of low-cost labor. Of course, reshoring/offshoring is a two-way street. Even as

they consider reshoring some products, manufacturers such as Ford are making large investments to enable production in growing consumer markets such as China.

3. The skills gap will grow. As manufacturing grows, so do concerns about the availability of enough people with the skill sets needed to support that growth. In particular, manufacturing executives in 2014 will be increasingly challenged to attract talented young people to manufacturing. A recent Manufacturing Leadership Council survey, "The Manufacturing Workforce: A Deepening Crisis," found that 27 percent of manufacturers are already experiencing a high degree of difficulty finding the production and operations workers they need in North America. Moreover, almost 36 percent expect to run into a high degree of difficulty finding such workers in North America over the next 5 to 10 years. Manufacturers in North America had the gravest concerns about workforce availability, compared to counterparts in other parts of the world.

4. Manufacturing advocacy will accelerate as U.S. elections near. In his 2013 State of the Union Address, President Obama made manufacturing a high-profile priority, promising a \$1 billion investment in a series of manufacturing innovation institutes as well as business tax code reforms and stepped up enforcement of fair trade laws. The elevation of manufacturing as a public policy issue will only intensify in 2014 in the U.S. and globally. In the U.S., with the arrival of the mid-term elections, politicians will strive to be perceived as enhancing job growth by supporting manufacturing. The challenge for manufacturers will be to see those promises translated into action.

5. Additive manufacturing will gain production applications. Many mainstream manufacturers have been decidedly more ambivalent about the revolutionary potential of AM, or 3D printing, than advocates of the so-called "maker" movement. While the makers see 3D printing transforming the production of physical goods, many

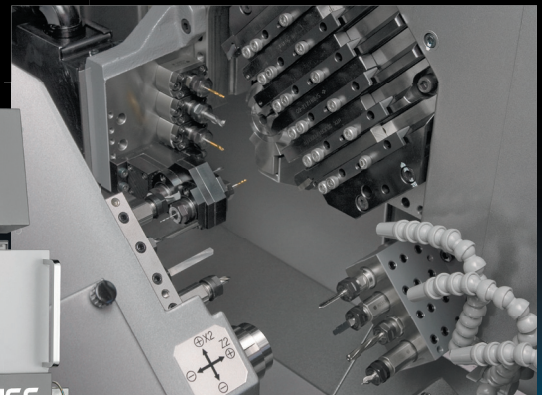
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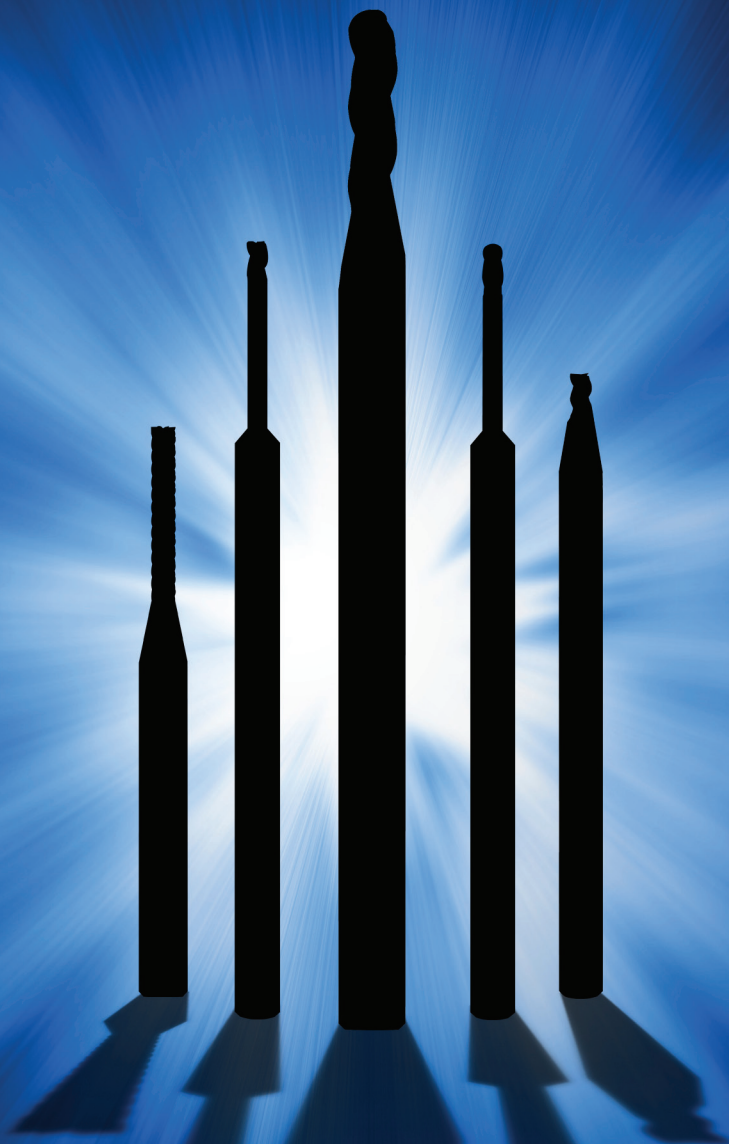
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