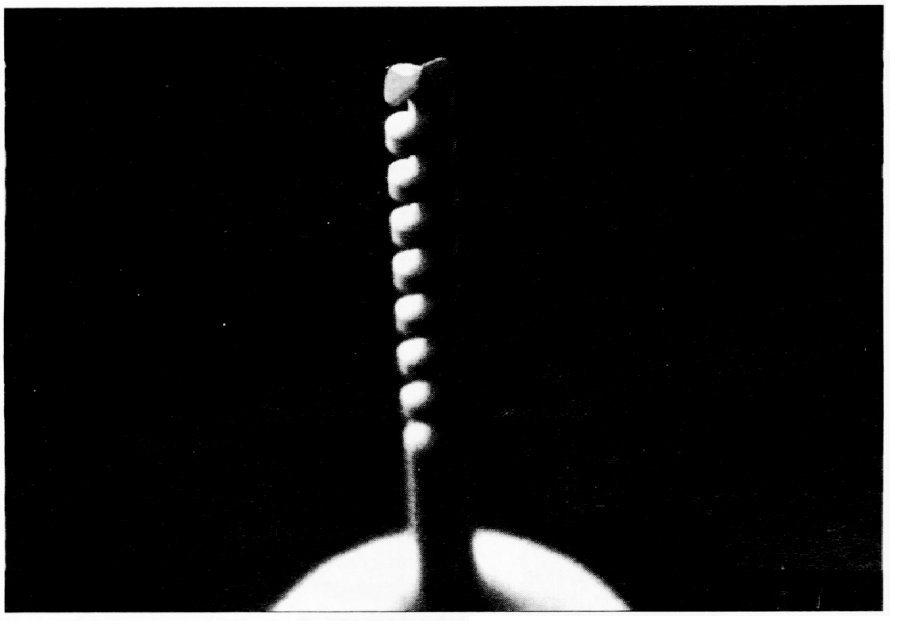
Small-Hole Technology: It Takes More Than a Drilling Machine

By Jerry Murray, West Coast Editor

Bits, backup, entry, and know-how.

How small can they go? A mystery tool maker in the Phoenix area, so it is said, continues to turn out l-roil circuit board drill bits in his garage, but nobody knows how he does it or what he does with his product. While this remains only a rumor, it raises the question of why anyone would want a drill bit so small. The answer might lie in one expert's theory that for each mil reduction in hole size, computer manufacturers can shrink their product by approximately 30%. Regardless of the theory's accuracy, people are **still making** some absurdly small drill bits.

Among several other manufacturers, M.A. Ford (Davenport, IA) has produced and sold a few hundred 2-mil bits for PCBs. According to M.A. Ford's Lee Schneider, these expensive, special-order bits are used primarily for developmental purposes. However, Schneider says, "We believe 2-mil bits can be used in an extension of normal practice. Runout and Z axis slop, which are disproportionately large for these very small drills, are the source of most small drill problems."



A 2-mil circuit board drill bit, manufactured by M. A. Ford. SEM photographic effects produce an apparently dull surface. When viewed through a magnifying glass, the tiny bit has the polished surface finish important for long bit life.

According to others I've talked with, breakage is the big problem with small bits, and staring too hard at a 2-mil bit can cause it to break. M.A. Ford produces 4-mil bits in limited quantity, with approximately the same bit geometry used in its larger bits. The company also produces 303 Series bits with variable helix geometry for longer life when used on difficult materials such as Kevlar.

Different manufacturers identify different problem areas, Mark McCullum of Precision Carbide (Niles, IL) says, "Bit makers have the problem of people wanting to push a bit further than they should, since it's cheaper to do that than it is to buy a new machine. So bit makers are caught between hole quality and bit breakage. If they produce a bit that makes better holes but breaks sooner, they can't sell it."

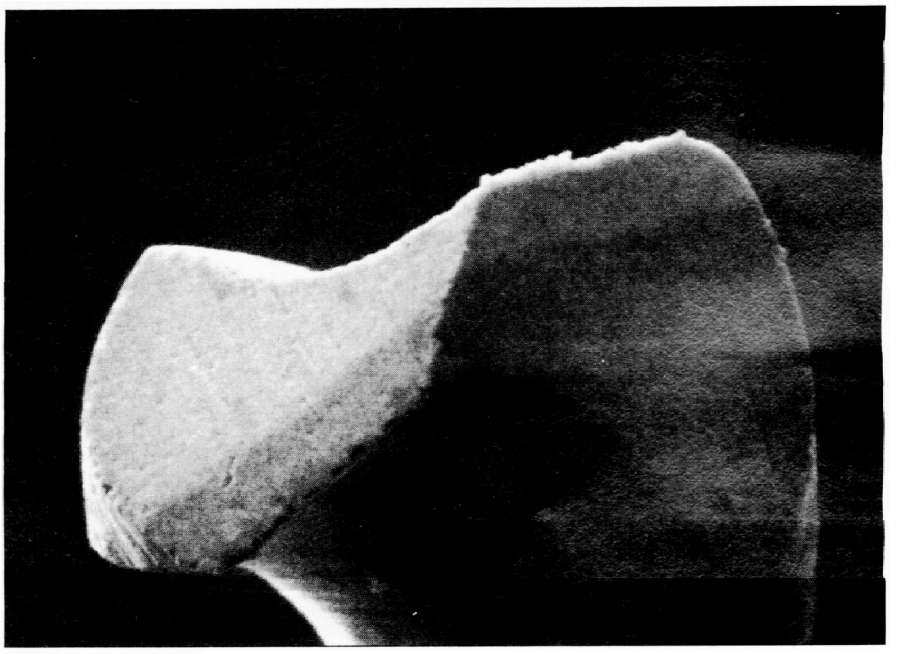
In the past, says McCullum, drilling machine technology surpassed metallurgical technology. Now that situation has reversed, especially in the case of poorly maintained eight to 10-year-old machines. If your drilling machine is in top shape, you can benefit further by using bits made of alloys that are 90% stronger than older ones. If you're trying to drill some really difficult boards, you can go all the way in materials and try some DIAEDGE diamond veined bits,

made by Precision Carbide Tool's subsidiary company, Precorp, Inc. A patented process inserts a polycrystalline vein at the right place in the carbide tip. The bits are made in sizes from 0.25mm to 9.6mm. The primary users of diamond bits are ceramic boards drillers, and these special bits are also used on polyamides and BT boards. A diamond bit, properly used, can purportedly drill a million holes in an FR-4 board.

Bob Schaeffer of Megatool (Buena Park, CA) says that as a company first starts to drill small-holes, problems appear in the form of shallower board stacking, more holes to be drilled, chip loads dropping from 3 to 1, and increased bit breakage. These problems can accumulate to cause an 80% drop in throughput. The most direct way to regain previous production levels is to increase the stack size. To this end, Megatool now manufactures ST-I, -2, and -3 bits in small sizes, and will soon introduce the ST-4, with the numbers in those notations signifying the stack height for which that bit was designed. Megatool produces these bits using a new carbide alloy, developed in Japan, which has a Young's modulus of elasticity 30% higher than that of older carbides. The bits which are made from this alloy are considerably more resistant to breakage from bending, and this property allows Megatool to extend flute length in the ST series for drilling through higher stacks, thus regaining productivity.

In developing its 503 series of drill bits, Tulon (Gardena, CA) learned that for optimum performance, bit geometry should be progressively altered with changing drill sizes. Tulon's Scott Henry said that geometric changes are particularly important as drill sizes decrease from 71 through 80. The complex changes essentially consist of optimizing each size bit for maximum drilling efficiency, greatest resistance to breakage, and minimum deflection when the bit is moving from its entry to its exit hole in a stack. Tulon manufactures its microdrills using a special carbide alloy, and particularly special equipment is used to machine and inspect the 503 series.

Tulon uses nine-axis Kobayashi grinding machines to flute, relieve, and point its bits. These grinding machines provide consistent products, each of which is subsequently inspected with a rather remarkable video AOI machine engineered and produced by Tulon. Fully automated and CNC operated, the machine auto-



Precision Carbide's DIAEDGE bit, incorporating polycrystalline diamond within the cutting surfaces of the drill, can extend small bit life by as much as 100X.

loads and orients every bit. It focuses a camera array on the product and then inspects with a repeatability of 0.00001 5". As it packages the bits that pass inspection, the AOI system generates a quality spreadsheet for Tulon's process control.

Tycom (Santa Ana, CA) claims small-hole drilling is its forte and takes quite a comprehensive approach in dealing with its expanding customer base. Says Tycom's Scott Yardley, "Because circuit boards are such diverse products, and because there are so many different kinds of customers in so many stages of their small-hole drilling program, we customize our involvement in bit design, application engineering, and problem solving to specifically fit the needs of our different customers."

"The way a board is assembled before drilling is a factor in establishing a drilling program. Hole quality requirements can vary greatly. Pad size, registration requirements, the age of the drilling equipment, and the customer's criterion for successful drilling — all these are considerations when our applications engineers enter a customer's plant. We have a staff of eight engineers, all of whom have a circuit board manufacturing background. With these engineers," explains Yardley, "Tycom is trying to provide engineering to a customer base that isn't capable by itself of reengineering its drilling process to accommodate small-holes. Most board makers are under tremendous day-to-day pressures, and this makes it difficult to allocate resources to long-range engineering projects. We have the ability to come in and achieve that goal." The California-based company now has two engineers working out of Minneapolis and a successful oper-

Regarding the double-barreled issue of small bit breakage and good hole quality, Jon Smith of Carbide International, located in Chicago, IL, says that "recent advancement in tungsten carbide materials has resulted in drills with both higher transverse rupture strength factor and greater resistance to wear. This allows for designs that offer better cutting and chip removal characteristics. These new materials have been fully tested and are being implemented where they are applicable."

According to Smith, "Our step shank design was developed to reduce drill breakage in small diameter drill bits. This design offers a means to more effectively distribute the stresses that lead to drill breakage. The high stress zone at the end of a conventional fluted design is reduced and partially displaced by the second shank diameter transition. In addition, recent grinding developments have allowed for a very high polish finish on the outside diameter and within the flutes. These finishes facilitate reduced heat generation, provide a sharper cutting edge and offer increased drill bit life."

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BACKUP AND ENTRY

LCOA's laminates have been the industry's standard for many years, and have probably the most frequent backup and entry (BU/E) material sandwiched around circuit boards. In the company's Research Center **in** Escondido, CA, LCOA's technical staff performs comprehensive drilling studies and conducts classes for customers. Nearby in Garden Grove, CA, an elaborate machine designed by LCOA president Jim Block laminates aluminum foil on sheets of specialized cellulose for distribution throughout the world.

EO+ and Micro EO+ are LCOA's entry materials. The former is intended for general use and the latter for holes under 20-mils, or when aspect ratio is a problem. EO + consists of 2-mils of 3003 H-19 900 aluminum foil on each side of a 14-mil cellulose core; Micro EO+ has 1.5-mils of the alloy on each side of a 3.5-mil core. Their laminated construction causes the materials to lay very flat. The alloy's softness allows for easy and accurate

bit penetration. The bit impact is therefore softened and top to bottom stack registration is accurate because of the cushioning effect of the cellulose core,

LCOA's backup material, known as Series 3000, consists of 2-mils of the same aluminum alloy on both sides of a special wood core. The material is available in thicknesses of 0.062", 0.093", and 0.125". The special wood core is nonabrasive for easy and cool drilling, and is low in salts and resin content, which, in combination with the aluminum outerlayers, prevents moisture absorption that can lead to warping and twisting of a material that must be flat for accurate drilling. LCOA's materials, specifically designed for the PCB industry, are extensively used in Europe and are experiencing widespread acceptance in Asia.

More exacting and stringent comparison test controls are responsible for the increasing use of phenolic materials in many PCB shops.

RE Service Co. (Sunnyvale, CA) offers improved phenolic paper-based BU/E materials. Earlier materials of this type had gritty resins and paper containing too much pulp, which resulted in drill bit chipping. By achieving more precise control of the resin, the paper, and the manufacturing process, RE Service's Bob Norman claims that the company has gained control of the bulk of today's phenolic BU/E market. According to Norman, more exacting and stringent comparison test controls are responsible for the increasing use of phenolic materials in many prestigious PCB shops. "The industry is getting tougher," says Norman, "and it's about time. People are getting more concerned with the details of processing, which can lead to increased yields. They are finding that proper experimentation in evaluating new materials is cost-effective. "

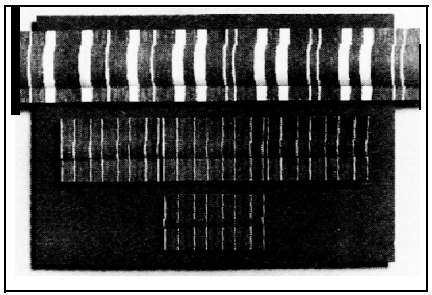
RE Service's entry materials are offered at 12- and 18-mils, and its backup material is available in three thicknesses. Cray Research uses the company's 24-mil material in its

small-hole drilling process. On the other end of the scale, many shops prefer RE Service's 60-mil backup material because of cost savings achieved by flipping the backup and using both sides.

Lamination Systems (Industry, CA) laminates phenolic paper to a cellulose core to produce its Gold System BU/E materials. The company offers any thickness of entry material from 10-mils for micro drilling to 24-mil maximum thickness. Gold System backup materials are available in thicknesses of 50-mils to 93-mils. A very tight product thickness control is exercised to produce a flatness of 3 mils variation across a 48" panel in the company's current batch lamination process. This process will soon be further improved when Lamination Systems cranks up a Burkle press to turn out its product.

Lamination System's Bill Protzman says the Gold System is in use in some of the alphabet shops (IBM and AT&T) because of product quality, company service, and establishing partnerships with customers.

Buckeye Pacific (Portland, OR) developed BU/E materials called System 2. Says the company's Bill Streeter,



Backup and entry materials should minimize drilling debris in holes.

"The average driller penetrates the backup material 20- or 30-mils. Our backup material is 30-mils thick. Operators put a piece of it on the **drilling table and leave it there.** They then pin another piece to the bottom of the stack in the conventional way, and place the stack directly on top of the backup material on the table. The drill depth is set to go 20- or 30mils past the bottom board, and when the **stack has** been drilled, operators can see that the bit hasn't entered the backup on the table. For the first time, the drillers will know if they are going too deep."

The System 2 and Buckeye Pacific's nine other more conventional BU/Es are made of phenolic paper saturated with a new phenolic resin system that is less moisture sensitive, more stable, stays flat, and, according

to Streeter, "... turns into dust when it's hit by the drill bit. It powders up instantly, almost explodes, allowing vacuum systems to efficiently get rid of the dust and debris."

LASERS?

Yes, people are still using lasers to drill holes in printed circuitry. Lumonics (Camarillo, CA) produces an excimer laser that bores very neat holes in thin materials, such as 0.003" polyimide. Excimer lasers are based on a nonthermal ablative process, which is markedly different from the thermal processes of other lasers, which melt and vaporize their way through materials. Lumonics also manufactures specialized lasers for marking circuit boards.

George Zahaykevich of Advanced Laser Technology (Boston, MA), whose company invested much time and money in PCB drilling research, says the technology is in place to laser-drill small-holes in a pretty big way. The secret, he says, lies in the use of two different laser beams for each little hole. "If you need to drill a lot of small-holes," says Zahaykevich, "the dual laser is the way to go. The answer for industry is alternating CO2 and ruby lasers. The CO2 cleans out the epoxy and doesn't touch the copper, and then the ruby laser comes on to peck through the copper. With both laser beams on the same axis and a computer keeping them in focus and alternately firing them at the right times, you can drill a million holes, very nice ones, one every second, with no maintenance problems for five or so years." Zahaykevich says the concurrent laser drilling process is patented, a prototype model sits on a shelf in a large computer company's high-tech lab, and Advanced Laser Technology specialists are sitting by the phones. •

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