



Union Tool's Carbon Coating Technique Innovates PCB Tools

Printed circuit board (PCB) machining has become increasingly harder, which necessitates the need to optimize high-performance PCB cutting tools, such as drills and routers, by improving the base material - the high-grade tungsten carbide - and the geometric design of the cutting edges and flute. In addition, the drilling spindles used on the computer numerical control (CNC) machines need ultra-high revolution per minute (RPM) capability to help reduce breakage, especially when using ultra-micro drills of $\leq \phi 0.1\text{mm}$ and routers at $< \phi 1.0\text{mm}$.

To achieve high performance, material-specific parameters are needed to compensate for the different laminate characteristics that can affect the result. By following these key points, it is possible to achieve process improvement in the drilling process. At the same time, demands on cost reduction require the stack height of PCBs to be increased and extend the tool's operating life. These factors have been the major drivers in PCB tool development.

To meet these continuing demands, Union Tool has developed a revolutionary, high performance, longer life tool that suits mass production by applying carbon coated technology. This is similar to Diamond-like carbon (DLC) coating and/or diamond coating of chemical vapor deposition (CVD) process to PCB tools.

Table 1: Kinds of carbon coat and their application

Type	ULF (DLC)	Diamond
Feature	High lubricant properties Low affinity with non-ferrous material	High hardness
Applicable Tool	PCB drill Non-Fe material routers	PCB router
Mechanism	<ul style="list-style-type: none"> Improve chip evacuation Non-adhesive to Cu, Al Reduce cutting torque Improves cutting performance 	Improves wear resistance
Main Effects	<ul style="list-style-type: none"> Improves breakage resistance for ultra-micro drill and high aspect ratio drills Improves HWQ Improves cutting performance and tool life for drills and routers for non FE material 	Enhanced longer life, high accuracy is also achieved due to reduced cutting edge wear

Effects of ULF Coating

With DLC, it is possible to obtain various mechanical characteristics using various coating formation methods. However, Union Tool succeeded in optimizing the DLC coat-forming method that has both durability and high lubricant properties, sustainable for use in PCB machining applications. This product is commercialized as the Uniontool Lubricant Film (ULF) coat.

Table 1 shows the carbon coating type and application to the PCB tool. The ULF coating contributes remarkably to the tool's improved performance, especially for applications using ultra-micro diameter drills, with an aspect ratio of more than 20:1. Router bits also improved in performance when routing non-ferrous materials.

Among the many positive effects of the ULF coated drill include greatly improved resistance to breakage on ultra-micro drills of around $\phi 0.1\text{mm}$.

Fig. 1 shows the comparison resistance to breakage of an uncoated drill and ULF coated drill ($\phi 0.1\text{mm}$). In this example, the geometry and the material of the drill are identical. In addition, the drilling is conducted with various spindle speeds under a constant chipload of $10\mu\text{m}/\text{min}$. The uncoated drill breaks easily at a low spindle speed due to the lack of appropriate surface velocity. This causes weaker chip evacuation, which increases the cutting torque. In contrast, the ULF coated drill resists breakage at this low spindle speed. This resistance is believed to come from the high lubricant properties of the ULF coating.

These lubricant properties of the ULF coating also resist material adhesion when machining non-ferrous materials as shown in Fig. 2. Although the cutting tool (router) is specifically designed to machine non-ferrous materials, serious adhesion can be observed on the cutting edges and in the flute of the uncoated router during the machining of aluminum panels. As the cut-

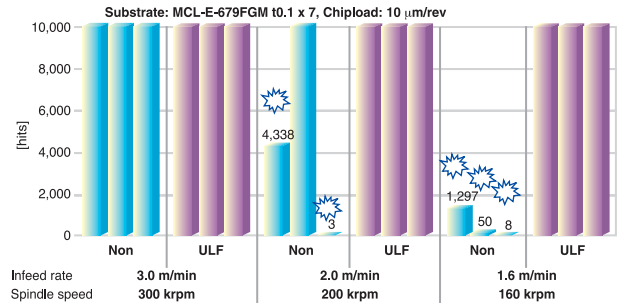
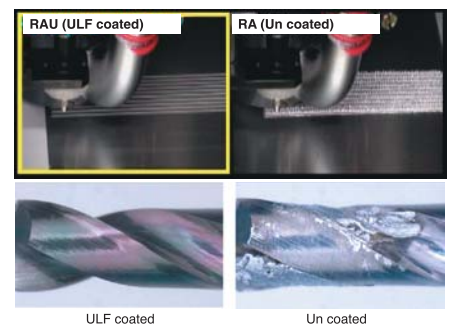


Fig. 1: Improvement of breakage resistance using the ULF coating $\phi 0.1\text{mm}$ drill



Work: Aluminum t1.0 x 1, Spindle speed: 28 krpm, Feed rate: 0.4 m/min

Fig. 2. Reduced material adhesion using the ULF coating when machining aluminum material ($\phi 2.0\text{mm}$ router)

ting edge is effectively blunted by the build-up of material, a burr is generated on the edges of the slot. The photograph of the slot is taken after 2.0m of routing. Clearly, the lifecycle of the tool ends as the level of burring is beyond the acceptable specifications. When a ULF coated tool is used, there is almost no material adhesion of the aluminum material, enabling much longer tool life, as the tool remains sharp and unclogged even after 10m of routing. This non-adhesion effect is also significant when machining copper, which is also non-ferrous. Fig. 3 shows the high-speed camera image of $\phi 0.25\text{mm}$ drilling on a $t0.5\text{mm}$ thick copper panel. The un-coated drill broke at the first hit, whereas the ULF coated drill achieved 2,000 hits without breaking. Here, the non-adhesion effect of ULF coating is shown for the drill breakage resistivity. This non-adhesion effect, therefore also improves the machining performance on PCBs made of copper layers, as well as the chip evacuation. It can be concluded that this significantly influences

the drill breakage resistance and improved hole wall roughness on PCBs.

ULF Coating Application

As an example, in Fig. 4, a high aspect ratio drilling application on a t0.4mm substrate stacked 6 high, using a $\phi 0.20 \times 4$ mm drill (aspect ratio 20:1), is a typical application for a ULF coated drill. With this kind of increased stack height, the total quality requirement, including hole registration accuracy and hole wall roughness, is difficult to improve using an uncoated drill. Increasing the rigidity of the drill may improve the hole registration accuracy, how-

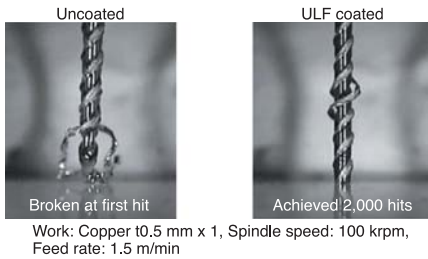


Fig. 3: Breakage resistant effect of ULF coating on machining of copper panel ($\phi 0.25$ mm drill)

ever, on the other hand, the chip evacuation gets worse leading to bad hole wall roughness. To target this kind of high precision machining with a high aspect ratio, the technique of applying the ULF coating to a highly rigid drill design enables improved chip evacuation that gives good hole wall roughness. Therefore, the ULF coating makes it possible to do high precision machining that was difficult to achieve with an uncoated drill on the stack heights.

Together, the examples above clearly show that the application of the ULF coating on to a PCB drill, at around $\phi 0.1$ mm, can be a commercial success and is proving so as a product for package substrate machining. Union Tool's customers have already verified at mass production the advantage of improved resistance to breakage when drilling ultra-micro holes as shown in Fig. 1.

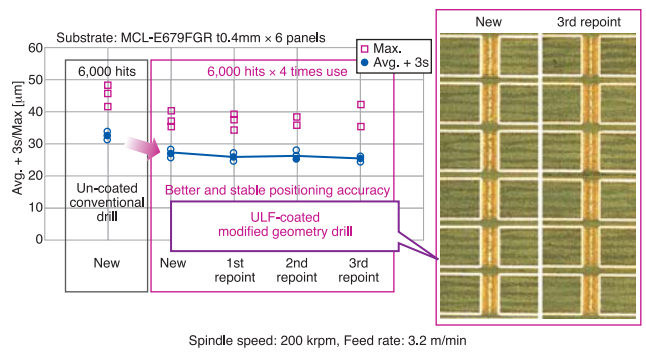


Fig. 4: $\phi 0.2 \times 4$ mm ULF coated high-rigidity drill performance [left: hole registration accuracy; right: HWR (around the 6,000th hit)]

Future Prospects

The revolutionary ULF coating is proven effective in the following applications: ultra-micro drilling below $\phi 0.1$ mm for package substrate; high-precision machining for higher stack heights at $\phi 0.15$ to 0.25 mm; drilling flexible PCBs; high copper-layer multilayer PCBs; and drilling and routing of aluminum radiator panel for LED technology; high current, thick copper panels. □

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| 台灣佑能工具股份有限公司
TEL: +886-3-354-3111
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| 佑能工具新加坡有限公司
TEL: +65-6846-9309 | UNION TOOL SINGAPORE
FAX: +65-6846-0197 |
| 東莞佑能工具有限公司
TEL: +86-769-8884-8901 | DONGGUAN UNION TOOL
FAX: +86-769-8884-8296 |
| 優能工具(上海)有限公司
TEL: +86-21-5762-8577 | UNION TOOL WAIGAOQIAO SHANGHAI
FAX: +86-21-5762-8436 |

總公司 **UNION TOOL CO.**
 日本 140-0013 東京都品川區南大井 4-15-8
 TEL: +81-3-5493-1008 FAX: +81-3-5493-1019
<http://www.uniontool.co.jp>