FROM THE LAB

NEW!

The Microsection: A Work of Art (Part 2)

By Bob Neves

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In last month's column, I discussed PWB sample removal and encapsulation techniques. This month, the discussion will center around the abrasive techniques used for microsectional surface preparation.

The preparation of microsectional mounts has always been considered an "art" and, like art, there are good and had pieces of work. The "artists" who prepare microsections are called metallographers. No two metallographers will prepare a mount in exactly the same way, each adding their own flair and signature to the work.

A PWB microsectional mount contains various materials like glass, aramid fibers, kapton, copper, acrylic adhesive, epoxy, polvimide, tin/lead, etc. Each of these materials has a different relative hardness and, coupled with that of the mounting media (epoxy, acrylic, etc.), makes the PWB microsection one of the most difficult to complete. The difference in material hardness (see Fig. 1) equates to different removal rates during the grinding and polishing steps of the microsection process. This process is further complicated by the fact that when plated-through hole (PTH) analysis is required, it is essential to complete microsectional surface preparation in a plane within 10 percent of the hole's center. This is relatively easy on a 0.040" hole, but can be extremely difficult on a 0.006" hole (+/-10 percent is a 0.0012" target range).

If multiple PWB specimens are placed in the same mount, grinding and polishing must be accomplished so that the analysis area of all the specimens is aligned in the vertical plane. The use of tooling pins to align PWB specimens is popular because they ensure a common reference plane between all of the specimens. Although tooling pins add cost to the mount, they allow the ability to increase the amount of specimens per mount, along with adding thermal mass which helps distribute heat generated during encapsulation, grinding and polishing.

There are many resources for information, training and procedures about the microsectional process. Generic texts on metallography can be obtained from the American Society for Metals (ASM). The IPC supplies information on PWB metallography: IPC-TM-650 contains two test methods (2.1.1 and 2.1.1.2) for manual and automatic microsection preparation; IPC-VT-28 and -29 are instructional videos on manual and automatic microsectional preparation; and IPC-MS-810 provides guidelines and information on high volume microsectioning.

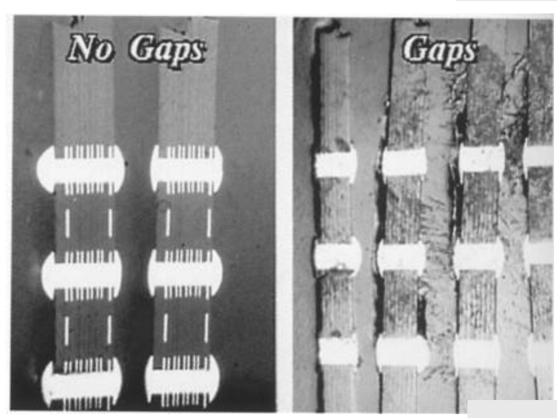
Manual vs. Automatic Systems

Manual operations require the metallographer to apply hand pressure to the mount in contact with a rotating wheel containing the abrasive. The uniformity of the pressure applied in contrast to the force wanting to rip the mount from the metallographer's hand requires a careful balance. A skilled metallographer will continuously interrupt the abrasive process and examine the mount surface to determine if the damage from the previous abrasive step has been removed, along with assessing the level and direction of abrasive attack. He will then rotate the mount to adjust for uneven abrasive wear and reapply appropriate force to the mount as it meets the rotating abrasive surface. The quality of the mount in the manual process is decided solely on the metallographer's skill in assuring that all the abrasive steps have been properly completed while arriving at the proper analysis plane.

Automatic systems apply a constant pressure to the mounts while continuously changing the direction of abrasive attack, limiting the chance for uneven wear. Most automatic systems use carbide-stops to limit the depth at which any given abrasive step will remove material from the mount. This allows the metallogra-

figure 1. Relative Hardness of Materials (HV).

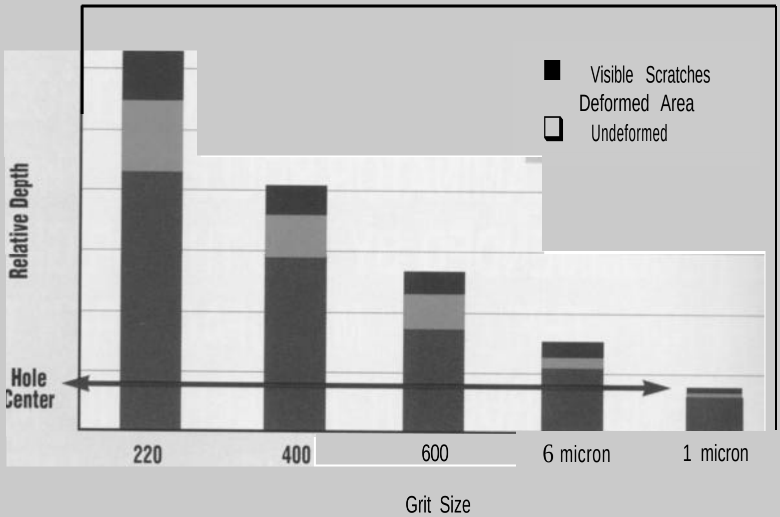
Acrylic	9	Glass Fibers	1000
Adhesive	–	Silicon	2500
Solder	13	Carbide	
Gold	22	Aluminum	2000
Copper	50	Oxide	
Nickel	260	Diamond	8000
Kapton	800	Polish	



pher to predict (with reasonable certainty) the degree of scratch and deformation removal achieved at any given abrasive step. Both the advantage and disadvantage of carbide-stops lie in their inherent material hardness (16OOHV). This hardness allows the stops to wear at a rate significantly less than that of the mount, providing for a stable termination plane when the carbide-stop meets the abrasive surface. That same inherent hardness causes the abrasive to fracture and break down quickly, giving it substantially less usable life than its manual method counterpart.

The increased use of automatic microsection preparation systems has allowed the metallographer to increase the repeatability and productivity of his work. However, it has not significantly reduced the skill level required by the metallographer since many decisions about the abrasive process must still be made (machine pressure, surface quality, abrasive life, carbide-stop height, etc.).

Figure2 Relative Grit Size vs Scratch *and Deformation Depth.*



Abrasives

There are four types of abrasive materials used for microsectional grinding and polishing.

1. Silicon Carbide: An artificial product made by the reaction between silica and carbon at extremely high temperatures. Silicon carbide is typically bonded to waterproof paper for practical use in abrasive grinding. The crystal structure of silicon carbide is hexagonal-rhombohedral, and its hardness is approximately 2500HV.

2. Diamond: The crystalline form of carbon available as an artificial or natural product. Diamond can be dispensed for abrasive grinding/polishing in sprays, suspensions and pastes. The crystal structure of diamond is cubic, with an approximate hardness of 8000HV.

3. Aluminum Oxide: Typically produced by fusing refined bauxite. Aluminum oxide is found in suspension or raw powder form. The crystal structure of aluminum oxide is hexagonal, with an approximate hardness of 2000HV.

4. Other Oxides: Silicon dioxide, chromic oxide, cerium oxide, colloidal silica, etc. Typically used in specialized applications-not for PWB microsections. The crystal structure and hardness vary with material type.

As with many things, the European system for rating abrasives is different from the U.S. system. The European abrasive rating system begins its grit designators with the letter "P" (i.e. P220, P400), which equates almost exactly to the U.S. system between 80 and 220 grit. After that, however, it diverges greatly to where a European grade Pl0OO is equivalent to the U.S. grit grade of 500. Be sure you're clear about which type of abrasive you order, as a European P400 grit grade will be virtually identical to a U.S. 320 grit grade. The grit sizes referenced in this column are U.S. sizes, and a chart has been provided to equate U.S. grit grade to actual abrasive particle size (see Fig. 3).

Abrasives have a limited life since fracturing of the cutting edges occurs during the abrasion process. Care must be taken to change or add abrasive at appropriate times during microsectional preparation so effective grinding and polishing can proceed. Continued use of worn-out abrasive may cause degraded grit particles to embed themselves in the sample surface, while also severely decreasing the abrasion rate on the sample.

The Abrasive Process

The abrasive process is segregated into generic process groups called grinding and polishing. The abrasive process removes material from the mount surface to expose the desired plane for analvsis. This is accomplished by placing 'the mount against rotating surfaces containing successively finer abrasive grit sizes. This process removes material, including the scratches and deformation left by the previous abrasive step, while moving the mount's outer-surface closer to the required plane for analysis.

An often overlooked step in the abrasive process is mount cleaning between steps. Cleaning off the mount surface between abrasive steps is important because abrasive particles that are transferred from one step to the next will contaminate the new abrasive surface with larger particles, causing surface scratches and deformation that cannot be removed by the new grit size. Gaps, bubbles and unfilled PTHs will promote entrapment of abrasive particles and make the particles more difficult to clean away. Any gaps & bubbles in the mount surface that are adjacent to a specimen edge will cause the abrasive process to round and deform the unsupported specimen edge. In extreme cases when the gap is within the PTH, the plating may collapse, thereby destroying the hole.

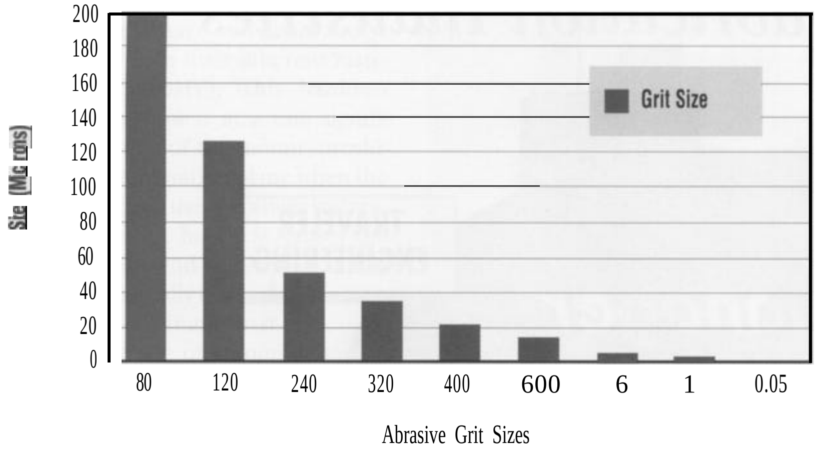
Each abrasive step leaves both visible and invisible damage to the mount surface. The visible damage is easily distinguished by surface scratches, but the invisible material deformation extends well into the mount surface (see Fig. 2), and can extend as much as 25 times the depth of the visibly apparent scratches. This unseen deformed area can be both distorted and smeared; it is extremely important that it be removed by successive abrasive steps or incorrect analysis may result.

Grinding

The grinding process comprises steps which remove the majority of material between the mount surface and the analyses plane. The grinding process steps typically center around abrasive grit sizes in the 80 to 600 range. The lower the grit number, the larger the actual abrasive particle size (see Fig. 3). Silicon carbide, bonded abrasive paper is typically used for the PWB microsectional grinding process.

When the mount and rotating abrasive paper meet, both heat and debris are generated. During the grinding process, a lubricant (typically water) is required in

Figure 3. Relative Grit Size vs. Abrasive Grit Grade.



sufficient quantity to cool the mount surface and remove debris build-up. Heat build-up can deform the mount surface, leading to incorrect analysis, while excessive debris build-up will cause ineffective grinding, severe surface deformation and premature failure of the abrasive grit. "More is better" is the key concept to grinding lubrication.

Polishing

Many people view the polishing process as a way to fix all of the scratches left by the grinding process. That philosophy applies if the only apparent scratches and deformation are created by the final grinding step. The polishing process removes an insignificant amount of material and will not remove scratches and deformation from early grinding steps. At this stage, the mount surface should be ground very near the analysis plane. Polishing procedures are typically a two- or three-step process using diamond and/or various oxides. Polishing abrasives are typically rated by actual abrasive particle size and not by grit size like grinding abrasives. Polishing abrasives range from 6 to 0.03 micron in size, and are not typically bonded to the surface of the carrier like grinding abrasives. Polishing abrasives are applied to the carrier by the metallographer and come in a variety of forms (spray, paste, suspension, etc.).

There are many different types of polishing carriers on which the polishing abrasive can be applied. They are made from cloth, paper and a variety of synthetic polymers. The aggressiveness of the polishing surface relates to carrier material composition, knapp height and the interaction of the abrasive/lubricant combination with the carrier. "Knapp" is the term used to describe carrier fibers which are normal to the surface plane. The higher the knapp, the more aggressive the abrasive process will be.

Lubrication is critical to the polishing steps, but unlike the grinding steps does not remove debris from the polishing surface. The lubricant is used to disperse the abrasive evenlv across the carrier surface, while distribuhng the heat generated during abrasion. The lubricant used for diamond polishing abrasives is either alcohol- or oil-based, and too much or too little can be detrimental to the polishing process. The lubricant used for alumina is typically water-based and is usually mixed by the metallographer with alumina powder to form a liquid suspension. Added water containing particles larger than the alumina particle size will leave scratches on the sample surface which will not be removed by subsequent polishing steps. Many abrasive manufacturers supply premixed abrasive/lubricant combinations, and it has been my experience that these pre-mixes typically provide more consistent polishing materials.

Aggressive polishing of the PWB mount can be attractive to the metallographer who has done a poor job of grinding, but has some severe drawbacks. The variety of materials present in the PWB mount (see Fig. l), combined with an aggressive, high-knapp abrasive surface causes the softer materials (solder, epoxy, acrylic adhesive, etc.) to be removed from the surface significantly faster than hard materials (glass, kapton, etc.). This can leave the surface looking like a rough patch of ground with tree stumps sticking up. These fabricated features will make accurate metallurgical analysis of the PWB virtually impossible as defects can be obscured or created. The general rule of thumb is to use a surface with no knapp for intermediate polishing steps, and a low-knapp surface for limited time (less than 30 seconds) for the final polishing step. The pressure level applied during polishing should always be less than that applied during the grinding steps.

The Work of Art

A correctly prepared PWB microsection is a work of art. The surface is smooth and free of scratches. Rounding and smearing of surface materials is not evident, and the surface finish is like that of a newly purchased car. This work of art will allow the accurate evaluation and assessment of the PMB specimen evaluation plane without ambiguity.

There are certain tests for microsection preparation quality that even the casual observer can make. One simple test is to take your thumbnail and run it over a newly polished microsection surface. Your nail should not stop or catch on any surface feature, and if you close your eyes, you should not be able to feel where the PWB specimen is within the mount. If your metallurgist has heart failure over the thought of your thumbnail producing scratches, hold the sample at an angle against a bright light and view it with a small magnifier as you would a diamond or other gemstone, again looking for surface flaws and inconsistencies. If a PTH is desired for analysis, this "diamond buyer" technique can also let you distinguish whether the holes are at +/-10 percent of center from top to bottom. Holes that are not flat and within a 10 percent plane of the center will cause plating/coating thickness measurements to be inaccurate.

Another simple test is to place the sample under the microscope and look for the sharp definition of metal edges between the mount material, tin/lead, copper and laminate material. If the joining edge is fuzzy or not well defined, the surface metals are probably smearing and may be obscuring features which should be evaluated.

Practice and experimentation are the only way to come up with the right microsectional preparation procedure(s) for your lab. Manufacturers are constantly developing new polishing carriers, abrasives and lubricants to make that task eas ier. Keep your eyes and ears open-experiment! Careful preparation techniques will give you your work of art.

Next month, "The Microsection: A Work of Art (Part 3), Evaluation."

Reference:

"Metallographic Polishing by Mechanical Methods," Leonard E. Samuals, American Society for Metals (ASM). IPC-TM-650, methods 2.1.1 & 2.1.1.2,