Smarter Sample Preparation Method to improve Quality Control Efficiency in Electronic Industry

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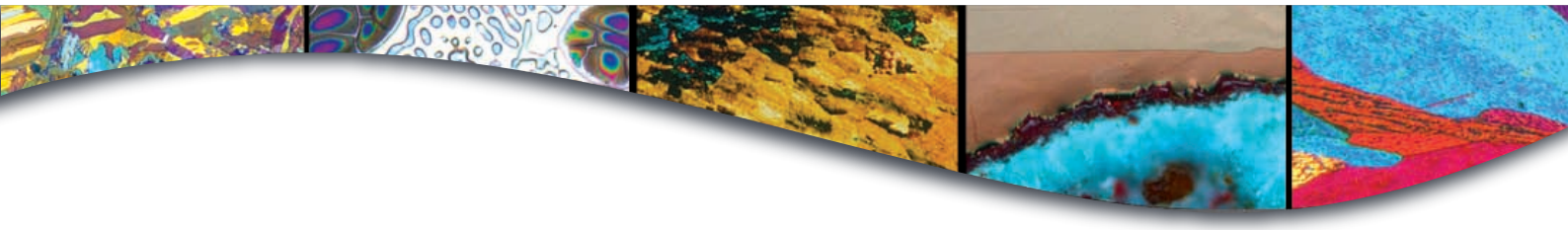

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Introduction

When the cross section must be conducted through a specific area or level in the sample, targeted micro-sectioning for microscope examination of samples is required. This is most often done in the electronics industry for failure analysis and quality control, but also for research and production control purposes.

Because the level of the feature(s) of interest varies from sample to sample, normally only one sample can be done at a time so the targeted micro-sectioning is done by hand. If the samples surfaces are flat enough or the features to be hit are on the similar plane, it is also possible to use an advanced micro-sectioning system which is able to handle multiple samples in high volume. As an example, Buehler PWB-Met system is designed to serve this specific purpose for quality control of through-plated holes.

A very common preparation procedure is to manually grind with SiC papers with successive finer grits visually inspecting the sample with a portable microscope or pocket magnifier to see when the level of interest has been reached. Then the sample is polished by two or three steps of alumina powders of different particles size. The outline of these methods is listed in Table 1

Table 1. Conventional Preparation Method

Cold-Mounting Accessories
25mm, 30mm, 32mm dia. or home-made mounting cup
Cold-Mounting Consumables
Acrylic, Polyester or Quick-cure epoxy

Grinding and Polishing Equipment		
Variable speed manual single or twin grinder/polisher		
Surface/Abrasive	**Base (rpm)**	**Time per Step (Min)**
*Plain backed SiC papers 120 (P120), 180(P180), 240(P280), 320(P3400), 600(P1200), 800(P1500),1200(P2500) **Sometimes only 3 steps*	150-300	3
MicroCloth MicroPolish Alumina Powders 1 µm, 0.3µm, 0.05 µm **Sometimes only 1 step*	150-200	4
	Total Time per sample	15-30

Figure 1. Metaserv 250 variable speed Twin Grinder-Polisher (L) and typical microsection (R) in the electronic industries

These conventional methods have been used for many years; but they still have several limitations:

1. Low sample throughput
2. Inconsistency in results due to difference behavior of operators
3. Cross-contamination due to the dry-out of the alumina on the polishing cloth
4. Smear which may hide features; e.g. micro-cracks, intermetallics, lagers or delamination
5. Relief problem from excessive polishing time and the use of soft cloth
6. Inconvenience of switch of SiC papers between steps

Making one sample at a time often means that preparation becomes a bottleneck. In quality control, production may wait for results which mean loss of money. Further, it means limited capacity, number of samples not sufficient to assure a proper statistical result and irregular sample quality causing false measurements and interpretations.

It is therefore evident that many users are interested in ways to improve the existing preparation method, speed up the procedure, improve quality and release operators from tedious work. This SumMet Note thus describes an improved method which is fairly simple and logical to bring targeted micro-sectioning a step further.

This improved method will be shown on three common types of samples from electronic industry: Chip Scale Package (CSP), PWB and wire bonding connections.

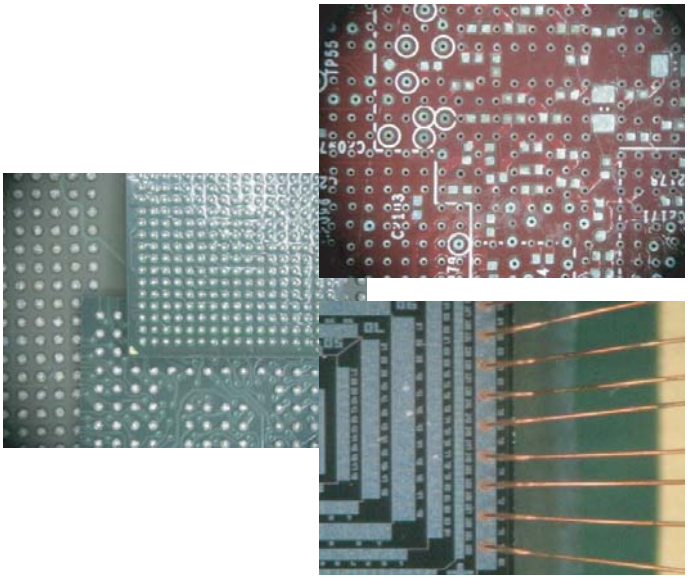

Figure 2. Common electronic samples: CSP, PWB & Wire bonding connections

The improved method follows a fairly direct way of preparation: define the "known distance" which is between the bottom of the mounted sample and the final level of interest. Then, simply start the manual grinding until it reaches a level in vicinity to the level of the interest, subsequently followed by automated polishing by using steps which material removal is controlled by the parameters set on the machine. The schematic drawing of this approach is illustrated in Figure 3.

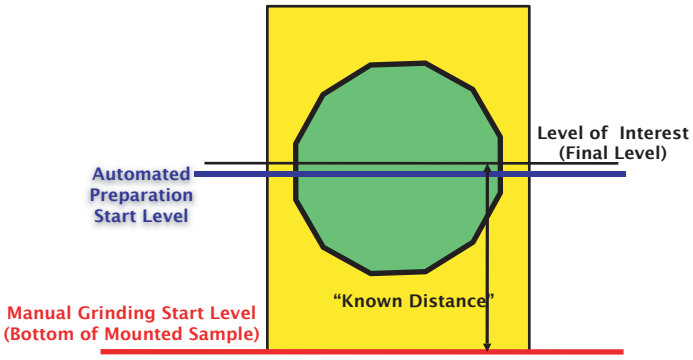

Figure 3. Preparation levels of the sample

Although the first step is still manual meaning only one sample at a time, the rest of the procedure is completed with multiple samples (using single force) automatically. Further, the first step is often fairly fast, whereas the rest is the time-consuming part of the preparation. In general, advantages of automated preparation are:

1. Total processing time per sample will be reduced
2. Sample quality and uniformity of the results will be improved considerably
3. The result is not affected by the operator's experience
4. The preparation capacity is considerably increased

Case 1 Solderball on the CSP

Preparation Procedures

1. For these samples, the length of the first manual step depends on the judgment of the operator. If the target is too far from the bottom of the mounted sample, either a coarser 180 (P180) or 240 (P280) grit CarbiMet 2 SiC paper will be used. If the "known distance" is comparatively short, 320 (P400) grit CarbiMet 2 SiC paper could be an alternative. The normal grinding time is around 2-3 minutes. The schematic drawing and overview of the sample are shown on Figure 4 & 5. When this level is reached, there will be distant mark of the "next row" on the current grinding plane which indicates that the target has been very close to be revealed. (see Figure 6).

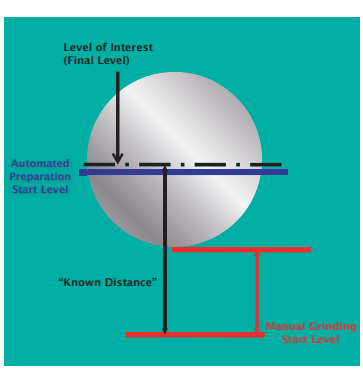

Figure 4. Schematic drawing of preparation levels of CSP-BGA

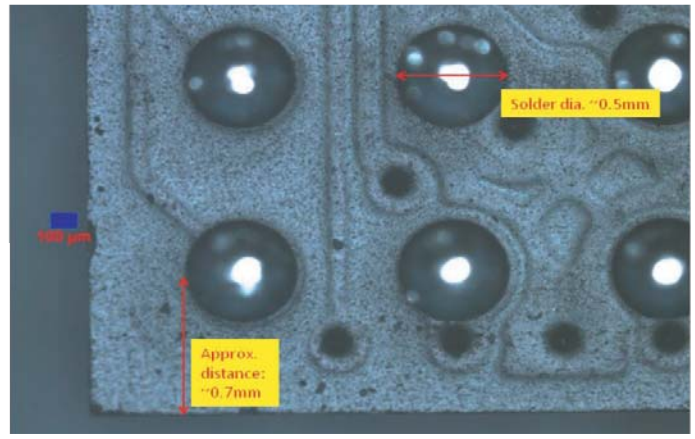

Figure 5. Overview of the sample. A known distance is shown on a CSP-BGA; best stopping level at the level of 0.7mm from the edge.

2. The 600(P1200) grit CarbiMet 2 is commonly used in semi-automated grinding with multi samples. Load four semi-finished samples (see Figure 7) in the single-force holder of the Metaserv 250/Vector grinder/polisher and start the grinding cycle. With the EcoMet/AutoMet 250/300, its six single-force fingers can prepare six samples at the same time by the way. Prolonged grinding time can result in loss of target. In this case, operating time depends on individual sample. The surface finishing is exhibited on Figure 8. The removal of materials is determined by grinding time and can easily be repeated for the next batch of samples because the parameters (e.g. pressure, speed) are fully controlled by the machine.
3. Perform the automated polishing with 3µm MetaDi Diamond Suspension (see Figure 9) on the VerduTex (or TriDent) cloth. Time is around 3 minutes.

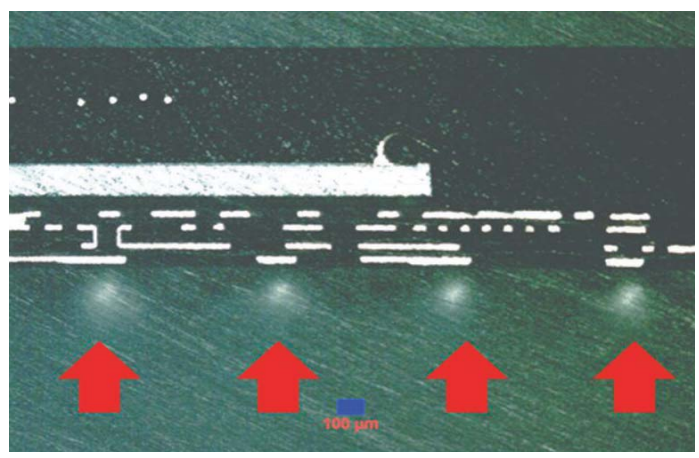

Figure 6. The target is almost revealed by 320 (P400) grit CarbiMet 2 SiC paper, a vague contour of the solderball is shown underneath the current grinding plane.

Figure 7. Four Semi-finished samples in single-force holder (L); automated grinding by Metaserv 250/Vector grinder/polisher (R).

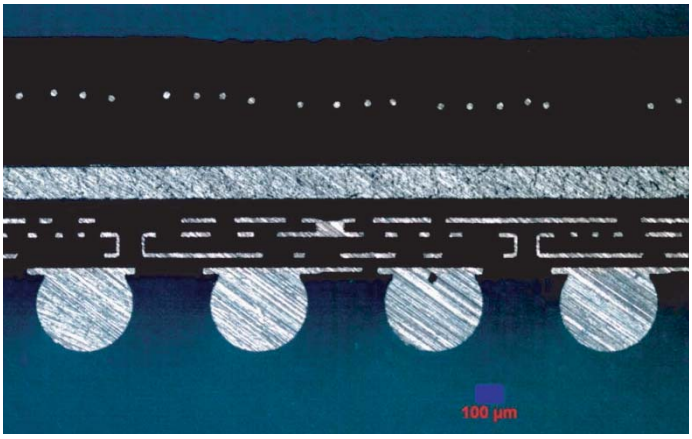

Figure 8. Decent scratches pattern from Grit 600/P1200 CarbiMet 2 SiC paper; 50x

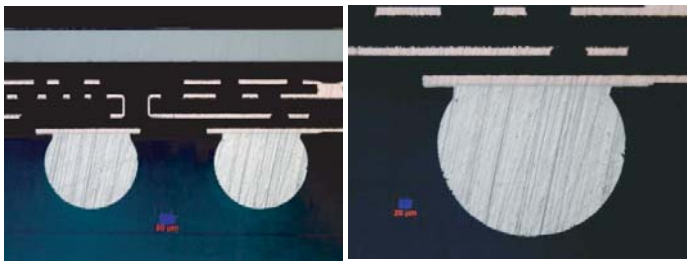

Figure 9. VerduTex 3um finishing: 100x(L); 200(R)

4. Perform the final polish with MasterPrep on a ChemoMet cloth. Polishing time should not be over 2 minutes (see Figure 10). The intermetallic layer is shown on Figure 11 & 12; in addition the complete sample preparation method and parameters is listed in Table 2.

Figure 10. Final Polishing with MasterPrep on ChemoMet (L) Final Polishing Result; 200x

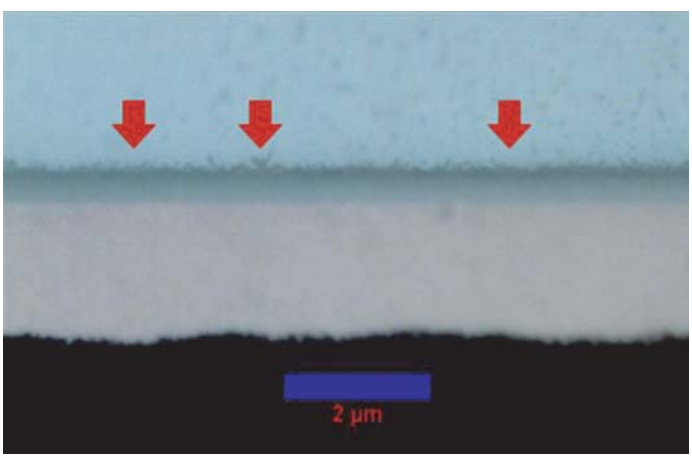

Figure 11. Intermetallic whiskers at the solder joint; 1000x

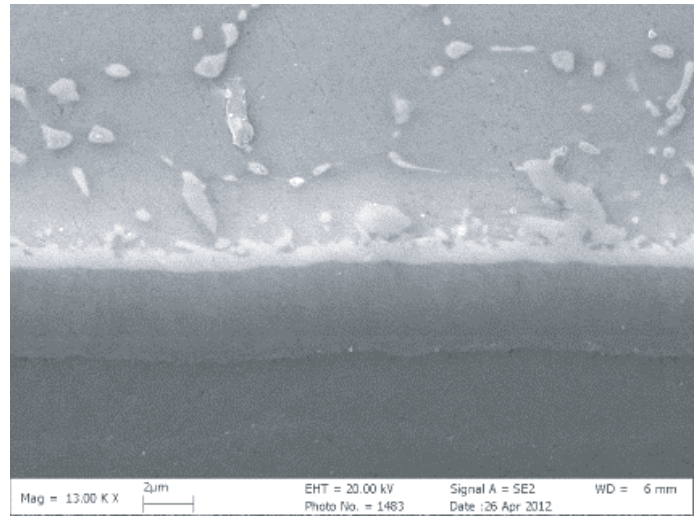

Figure 12. SEM Micrograph of intermetallic whiskers

Table 2. Preparation Method for CSP

Cold Mounting Consµmables & Accessories
EpoThin Epoxy & 25mm SamplKup
Polishing Equipment
Metaserv 250/Vector with Single Force Holder: 4 x 25mm & 10 ” platen

Surface/ Abrasive	Head/ Base (rpm)	Head Direction	Force (Lb)	Time per Step (Min)	Time per Sample* (Min)	**Time per Sample (Min)
320(P400) grit CarbiMet 2	150	NIL	NIL	3	3	3
600(P1200) grit CarbiMet 2	60/ 150	Comp	3	1.5	0.4	0.3
VerduTex 3µm Metadi Diamond suspension	60/ 150	Comp	5	3	0.8	0.5
ChemoMet 0.05µm MasterPrep polishing suspensions	60/ 150	Comp	2	2	0.5	0.3
			Total Time	10	>5	>4

*Vector single-force holder allows for auto preparation flexibility up to 4 samples
**AutoMet 250/300 grinder/polisher allows for auto preparation flexibility up to 6 samples

Case 2 Tested PWB with PbSn solder

Preparation Procedures

1. The time to reach the area close to the target based on the judgment of the operator. In this case, the target is the second row of the solder which is approximately 3mm away from the edge. One step of 320 (P400) grit CarbiMet 2 SiC paper is enough to get rid of the first row of solder and bring the target plane to the second row of solder. Manual grinding time is 2- 3 minutes. The target plan is shown on Figure 13 & 14. After this step, the target plane has been closed to the edge of the second row of solder. The vague mark of the “next row” can also been observed from current sectioned plane (see Figure 15).

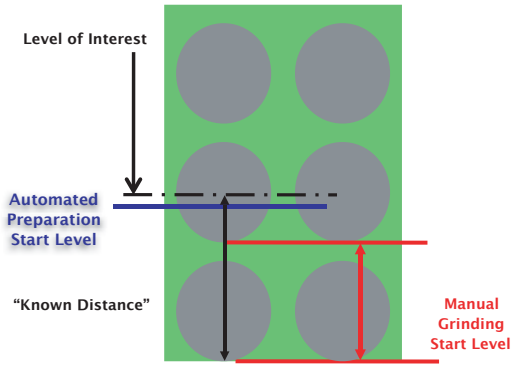

Figure 13. Schematic drawing of preparation levels of PWB

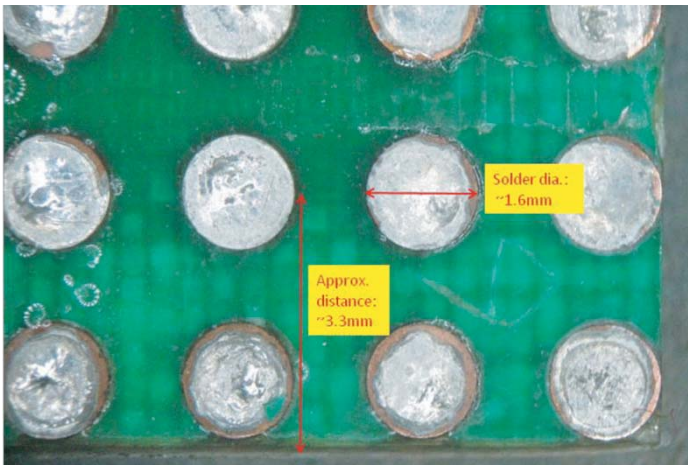

Figure 14. A known distance (~3.3mm) is shown on a PWB coupon

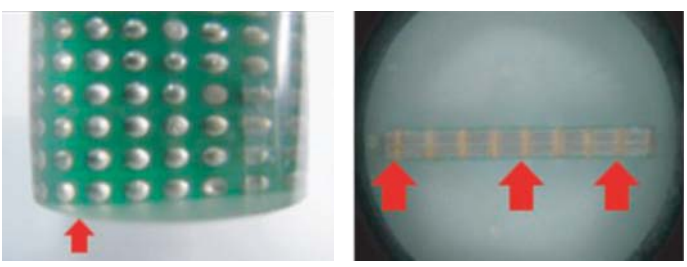

Figure 15.Current grinding plane is nearly touched the edge of second solder row (L); a unclear mark of second row contour is shown (L)

2. Load six semi-finished samples (see Figure 16) in the single-force holder of the AutoMet/EcoMet 250 grinder/polisher for automated grinding. Consumable to be used is 600(P1200) grit CarbiMet 2. In this case, the expected stopping level should be very close to the centre of the solder.

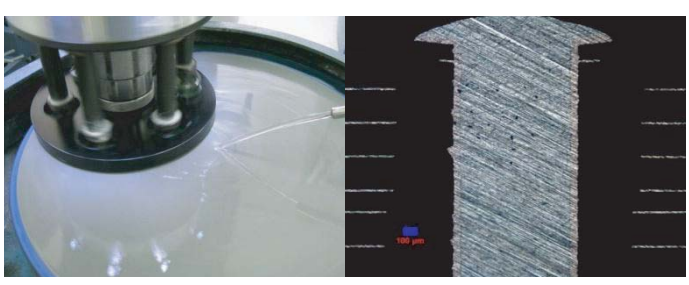

Figure 16. Automated grinding by AutoMet/EcoMet 250 (L) Proper scratches from Grit 600/P1200 CarbiMet 2 SiC paper; 50x

3. When the 600(P1200) grit CarbiMet 2 step is finished, the next few polishing steps are removing the deformed material on the surface and uncovering the real microstructure. Perform the automated polishing with 9µm MetaDi Diamond Suspension (see Figure 17) on the TriDent cloth. This hard cloth usually gives better flatness on very soft materials polishing due to the low resilience. Polishing time is around 3 minutes.

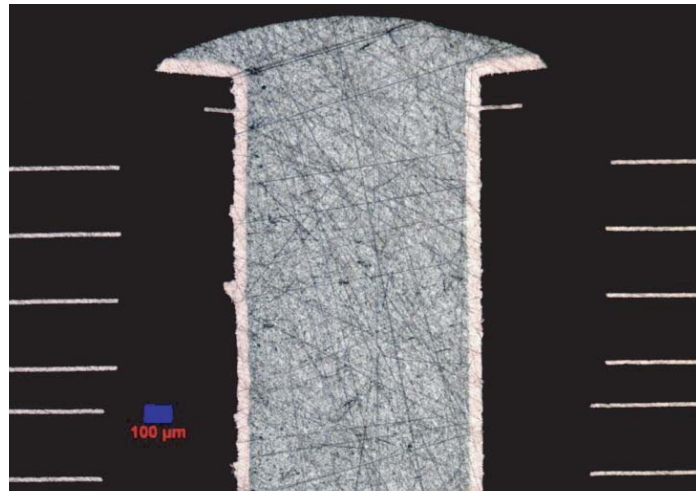

Figure 17. Coarse polishing scratches from TriDent 9µm polishing; 50x

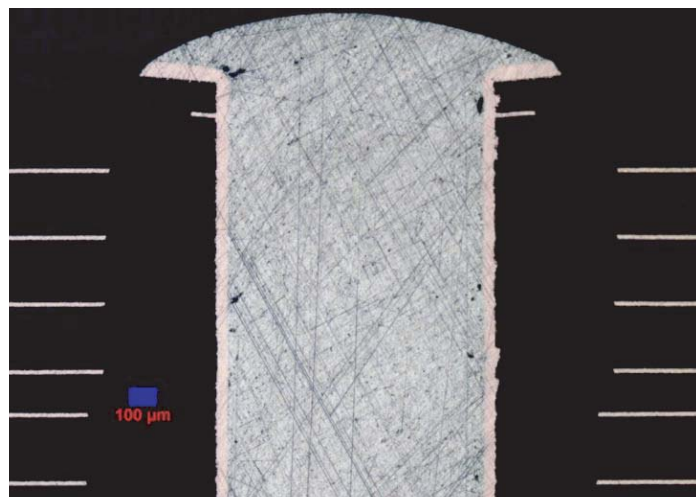

Figure 18. TriDent 3µm Diamond Finishing ;50x

4. Soft and smear material (e.g. Sn-based solder or copper plating) usually requires diamond polishing steps to remove the preparation deformation. In this case, the 3µm polishing is the initial polishing step (see Figure 18). The conventional alumina powders polishing tend to produce only lustrous surface and smeared material sometimes unfortunately covers the materials defect (e.g. pores or crack). Diamond abrasive therefore considers as the best cutting alternative due to the sharp cutting edge to reveal the real microstructure. If certain tiny defects cannot be exposed after 3µm polishing, an optional TriDent 1µm diamond polishing step would be a solution.
5. Perform the final polish in general with MasterPrep on a ChemoMet cloth; nevertheless, the polishing time should not be over 1.5 minutes. The finished microstructure is shown on Figure 19; a plating crack defect is exposed after the complete sample preparation (see Figure 20). The developed method with test parameters is shown on Table 3.

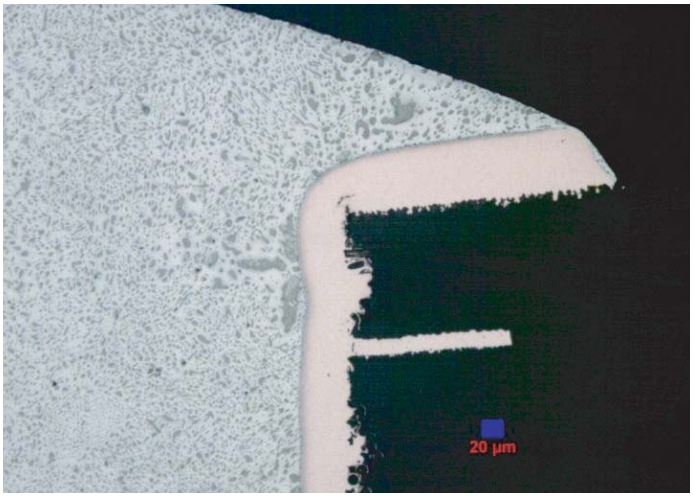

Figure 19. Final polishing by 0.05µm Al2O3 suspension; 200x

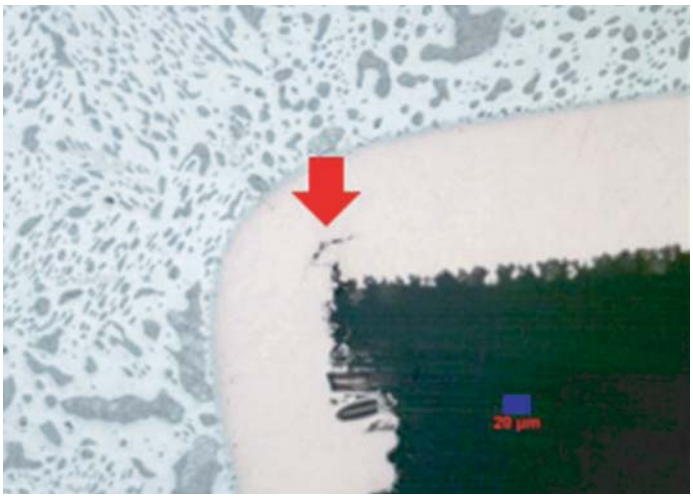

Figure 20. A plating crack on the copper plating; 500x

Table 3. Preparation Method for PWB with PbSn solder

Cold Mounting Consµmables & Accessories
EpoThin Epoxy & 25mm SamplKup
Polishing Equipment
AutoMet/EcoMet 250 with Single Force Holder: 6 x 25mm & 10 ” platen

Surface/ Abrasive	Head/ Base (rpm)	Head Direction	Force (Lb)	Time per Step (Min)	Time per Sample (Min)
320(P400) grit CarbiMet 2	150	NIL	NIL	3	3
600(P1200) grit CarbiMet 2	60/ 150	Comp	3	3	0.5
TriDent 9µm Metadi Diamond suspension	60/ 150	Comp	3	3	0.5
*TriDent 3µm Metadi Diamond suspension	60/ 150	Comp	3	3	0.5
ChemoMet 0.05µm MasterPrep polishing suspensions	60/ 150	Comp	1.5	2	~0.3
			Total Time	14	~5

*An optional TriDent 1µm is required if the 3µm polishing result is not fully satisfied.

Case 3 Copper wire bonding connection

Preparation Procedures

1. Since the “known distance” is just 0.3mm in this instance (see Figure 21 & 22), the grit size of the SiC paper for this first manual can be fine. The ordinary SiC paper is 600(P1200) grit CarbiMet 2 which gives acceptable damages on silicon wafer or the copper bump. With the coarse P240 or P180 SiC paper, the fragile silicon wafer will crack in general. The best level of this first step should just contact the edge of the copper bump or reveal the 40-60% area of the copper bump (see Figure 23). The processing time is around 30 seconds to 1 minute, another closer view of this grinding position is shown on Figure 24.

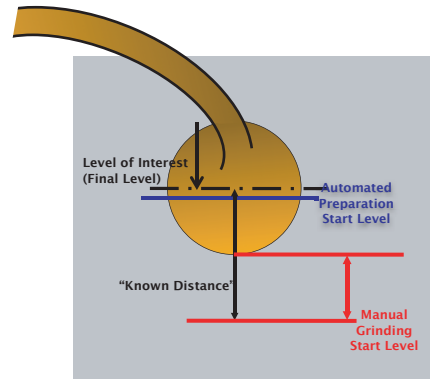

Figure 21. Schematic drawing of preparation levels of wire bonding connection

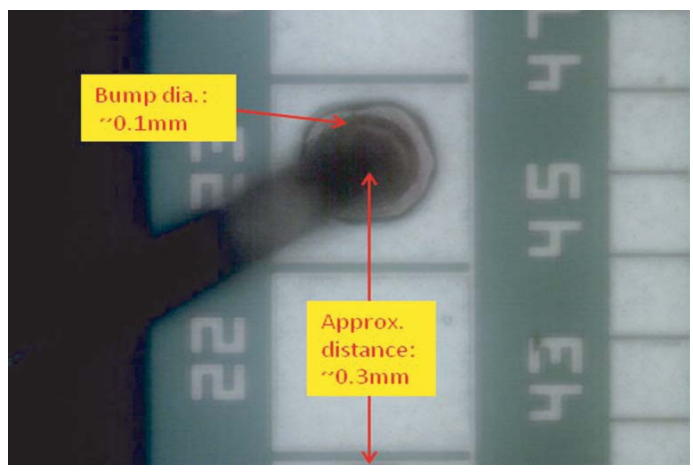

Figure 22. A known distance (~0.3mm) is shown on a wire-bonding connection

2. Load six semi-finished samples in the single-force holder of the AutoMet/EcoMet 250 grinder/polisher for automated polishing. With the high pressure, the 3 µm diamond suspension on the TriDent cloth is able to get rid of all the previous preparation damages and obtain a fairly good polishing result (see Figure 25 & 26).
3. Mix 98ml of MasterMet with 1ml hydrogen peroxide & 1ml ammonium hydroxide as the specialized final polishing fluid on the ChemoMet cloth. MasterMet itself has the chemical polishing effect on non-ferrous materials whereas the addition of the other chemicals would properly enhance the whole chemical polishing process. The polishing result is shown on Figure 27-30. The complete sample preparation method and parameters is listed in Table 3.

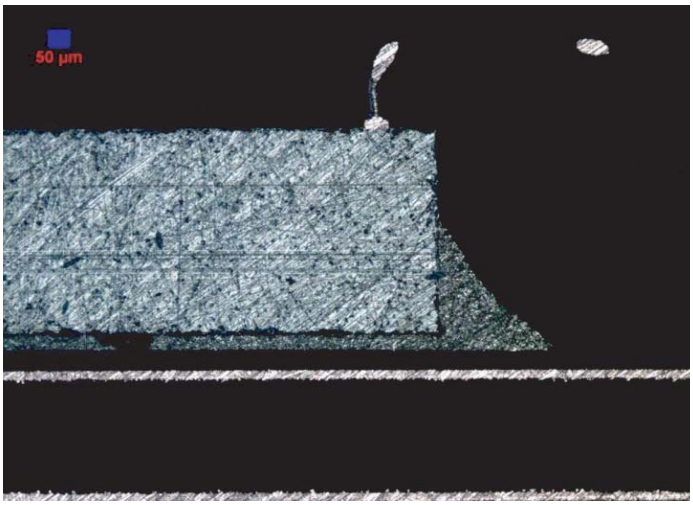

Figure 23. Surface finishing of 600(P1200) grit CarbiMet 2; 100x

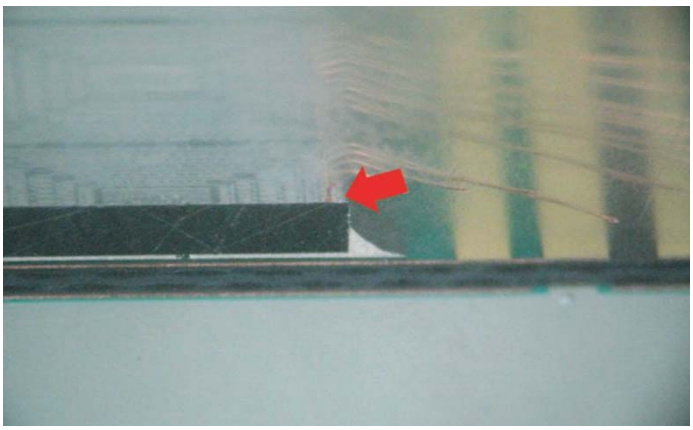

Figure 24. Position of the targeted copper bump seen through the mounting resin

Figure 25. Six Semi-finished samples in single-force holder (L); automated grinding by AutoMet/EcoMet 250 grinder/polisher®

Figure 26. Automated polishing (L); TriDent 3µm Diamond Finishing; 200x (R)

Table 4. Preparation Method for copper wire bonding connection

Cold Mounting Consµmables & Accessories
EpoThin Epoxy & 32mm SamplKup
Polishing Equipment
AutoMet/EcoMet 250 with Single Force Holder: 6 x 32mm & 10 ” platen

Surface/ Abrasive	Head/ Base (rpm)	Head Direction	Force (Lb)	Time per Step (Min)	Time per Sample (Min)
600(P1200) grit CarbiMet 2	150	NIL	NIL	1	1
TriDent 3µm Metadi Diamond suspension	60/ 150	Comp	5	5	~1
98ml MasterMet 0.06µm polishing suspension + 1ml Hydrogen peroxide +1ml ammonia hydroxide solution	60/ 150	Comp	2	2	~0.3
			Total Time	~8	~2.5

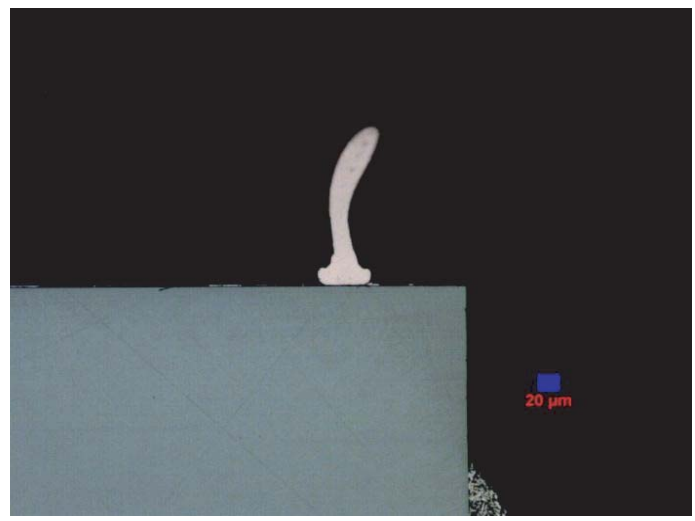

Figure 27. Final polishing result; 200x

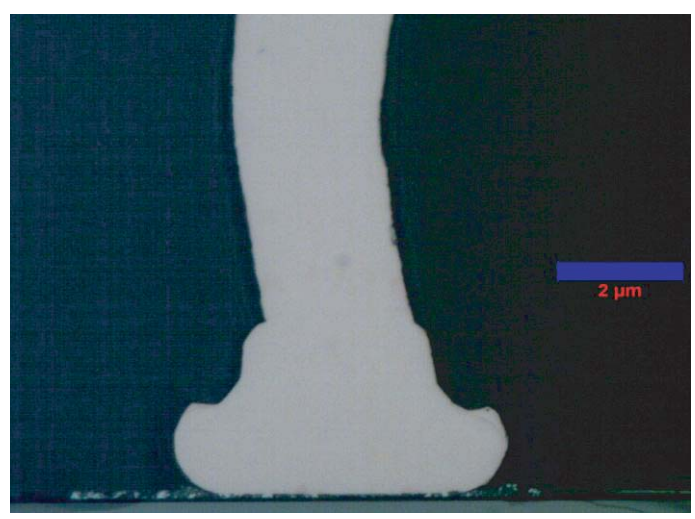

Figure 28. Final polishing result; 500x (L); 1000x (R)

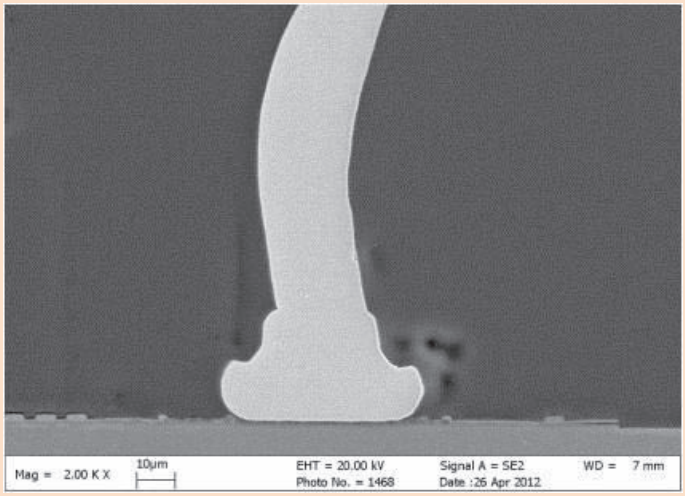

Figure 29. SEM Micrograph of copper bump; overview

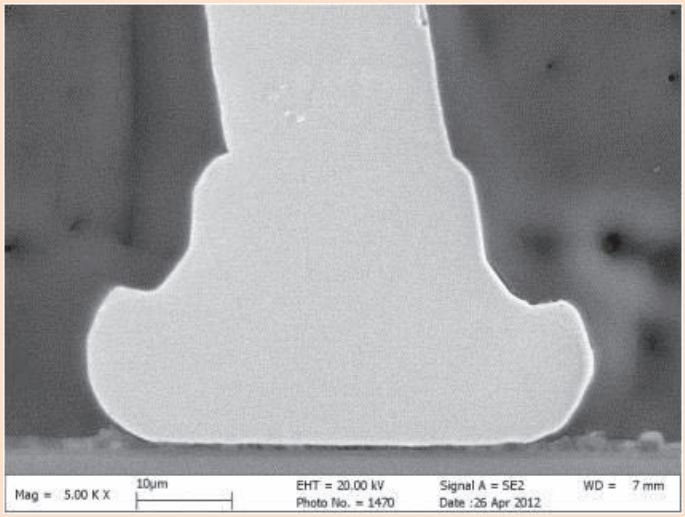

Figure 30. SEM Micrograph of copper bump;, closer view

Conclusion

Reviewing the methods from above cases, the first step undoubtedly requires some practices to achieve the known distance before developing a full successful recipe. It also requires experience to decide the appropriate grit size of the grinding paper for this step depending on the type and size of the sample and the distance to the target level.

In general, if the known distance is more than 100µm; a 320 (P400) grit CarbiMet 2 with 2-3 minutes grinding should be able to quickly bring the grinding level close to the analytical point. If the known distance is less than 60µm, the 600(P1200) grit CarbiMet 2 most properly is the secure choice even its removing rate is relatively slow. If any known distance is shorter than foregoing range, the targeting has to be conducted with caution to avoid overgrinding. If the device contains some very fragile materials (e.g. GaAs), a finer SiC paper would be an alternative to reduce catastrophic damages. Having a regular check under optical microscope on the grinding level in every 10 seconds is always a safe exercise.

Following the first step, the rest of the procedure is completed automatically. It will requires some initial work to find out the correct parameters, but the fact that the single-force mode allows the operator to stop the places and inspect the samples and makes this more easily. And once done, the procedure can be easily be repeated. The result then is time-saving of at least 10 minutes per sample is possible and in addition samples will be more uniform capacity increased and costs reduced.

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