

ALTERNATIVE METHODS FOR CROSS-SECTIONING OF SMT AND PCB RELATED ARCHITECTURES

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ABSTRACT

The electronics industry has been using the epoxy puck for the processing of the vast majority of electronics micro-sections since the 1970s. Minimal advancements have been seen in the methods used for precision micro-sections of PCBs, PCBAs, and device packages. This paper will discuss different techniques and approaches in performing precision and analytical micro-sections, which fuse the techniques and materials common in preparation of silicon wafers and bulk materials. These techniques have not only been found to produce excellent optical results, but transfer effectively to SEM for high-magnification inspection and further analysis with minimal post-lapping preparation needed. Additionally, processing time is reduced primarily due to a significant reduction of bulk material removal earlier in the preparation, therefore needing less removal at later lapping steps compared to traditional sectioning methods. Additional techniques are introduced that mitigate some classic challenges experienced by technicians over the decades.

Key words: cross-section, preparation, micro-section, microscopes, epoxy, lapping, polishing

INTRODUCTION

This paper is primarily focused on alternative methods for analytical cross-section preparation techniques. The methods discussed here do not replace all current techniques but in some cases offer a quick, controlled way to look at assembly package related failures and PCB related anomalies. Some of these techniques utilize traditional material sets and some introduce new materials. In closing there will also be some commentary on imaging these types of specimens since they have a few advantages at times over the puck. This is not intended to be a how-to for cross-sectioning for the beginner but to show alternative means for experienced technicians to approach micro-sectioning when an analytical specimen is needed.

HOW WE GOT HERE

The Puck

The epoxy puck has been used for decades as a standard for cross-section preparation. Why? Because it worked! In many applications it is still the most effective way to produce compliance-based cross-section specimens for PCBs. The puck has been used for everything from encapsulating bulk metal specimens, bones, bullet fragments, and of course PCBs and PCBAs. Both thermal-

cure and room-temperature-cure epoxies have been used for years for this application. However, it can be somewhat limited in the preparation of analytical-based specimens where there is a need for distinct angles of attack and requirements for staying parallel to a datum plane.

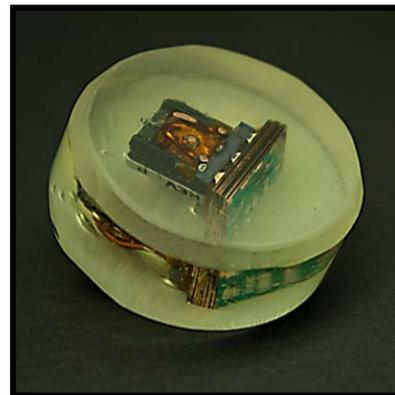


Figure 1. Traditional Puck Mounted Specimen

THE TRIPOD MICRO-SECTION TOOL

This apparatus was created well into the late 1980s but has primarily been used for silicon wafer analysis. Due to the ability for fine control, the hand tripod has been used for over a decade to produce Transmission Electron Microscope specimens as well as semiconductor sections. Considering the degree of control needed for wafer and die cross-sectioning, it was a natural migration to this method and an intuitive fine tuning to make a procedure for analytical SMT and PCB sections.

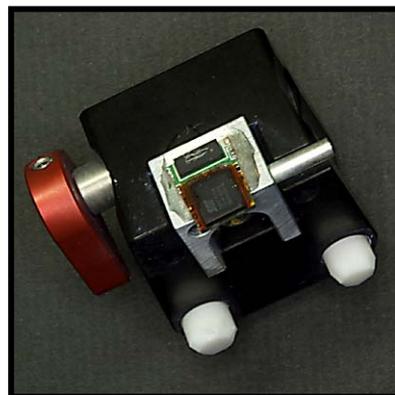


Figure 2. Micro BGA Tripod Mounted Specimen

PROS AND CONS OF THE TRIPOD PROCEDURE

Pros:

- Fine manipulation of positioning and attack angle for specimen alignment
- Ability to reposition easily if needed (using thermal melt glue)
- Reduction of bulk material translates to faster rate of removal and less processing time between lapping grits
- Lower grit and polish consumption
- Less chance of specimen compromise due to collateral bulk materials becoming mobile during lapping
- Lower waste streams of consumables
- Low obstruction of topside inspection due to minimal light distortion
- Easy transition to SEM for imaging
- Low volatile organic volume to contaminate a SEM environment
- Low charging mitigation (again due to low organic load)
- Multiple sections can be placed on a rotational stage and indexed for faster inspection
- Small size for easy preservation and filing

Cons:

- Specimen size is limited to approximately 0.75 inches in width
- Primarily a manual method and cannot utilize a multi-position power head
- Special considerations needed for inverted lens type microscopes
- Added cost of dedicating tripod fixtures for each specimen until the end of an analysis

THE QUESTION OF BULK REMOVAL

As any specimen is prepared it is necessary to understand the Area of Interest (AOI). With the tripod procedure this is still a major processing step but with different considerations. At times, accounting for materials and features other than the AOI can be the most challenging part of your specimen preparation. Dissimilar materials in large quantities can add difficulty and collateral damage to your specimen preparation and at times even destroy your AOI at the worst possible time as a result. The first part of the considerations for a tripod section is forethought of bulk removal. The closer to your AOI you begin, the shorter processing time will be, and generally improves the chance for success bearing all best lapping practices are followed. In some specimens this means you will need to clean and prepare your specimen prior to encapsulation. At times you will need to micro-encapsulate your AOI before you start bulk removal in order to maintain your AOI's integrity for analysis. The ability to micro-encapsulate is where the tripod method has a distinct advantage.

THOUGHTS OF PRE-ENCAPSULATING, MICRO-ENCAPSULATING, AND MINI-ENCASULATING

To accurately assess a failure or anomaly in its natural state without causing detriment or additional stress you may need to micro- or mini- encapsulate your specimen. This again brings a set of questions to the analyst: do you clean, do you encapsulate, do you cut, and if so when and in what order? As with any specimen preparation it is necessary to understand the Area of Interest (AOI).

For many reasons, including those listed above, it is suggested that pre-encapsulating be a focus for this technique. After your AOI is protected / pre-potted / pre-encapsulated, it can be handled and manipulated with a greater degree of ease without a high concern of damaging the AOI. At times with this method pre-encapsulating is the only encapsulating method necessary. This can be accomplished with as little as one drop of epoxy and a quartz cover-slide to small poly weighing boats. Aluminum is usually discouraged since it can alter or retard catalyst reactions and prevent epoxies from curing properly. See below images for examples of micro-encapsulating and results. A key element is to not limit creativity in your potting options. In many situations the PCBA is your ideal substrate.

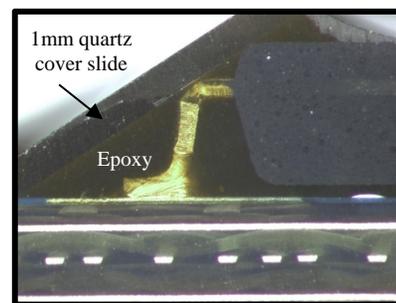


Figure 3. SOIC with Micro-Encapsulation
"The Lean-To"

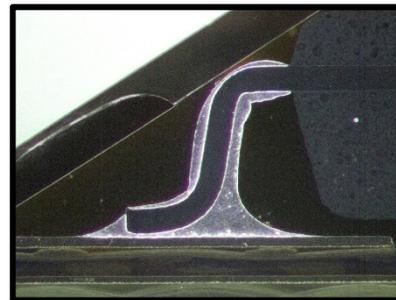


Figure 4. Same Section at 1µm Lapping

*Performed with 1 quartz cover slide, 3 drops of 10:1 thermal epoxy and 10 minute cure time at 95 °C
Total preparation time of 30 minutes*

A CONSIDERATION OF FLUX RESIDUES AND CONFORMAL COATINGS

With no-clean flux residues on a PCB you will first need to clean the specimen if your AOI is surrounded by no-clean

flux. This is a necessary consideration due to the hardness of no clean flux residue. The level of cure is dependent on the amount of cross-linking it received during the manufacturing process. Declining to clean the specimen may result in the flux residues harboring grit and debris from previous grinding/lapping steps and later releasing this material into your area of interest. If you decide to clean the specimen, consideration should be given to the AOI and if cleaning will compromise your specimen. Washing and cleaning considerations will depend on your specimen and is a subject for another conversation.

Conformal coatings, as with flux residues, need consideration in regards to the hardness of the coating and if there are no-clean flux residues beneath. In the case of soft conformal coating, it will require removal before encapsulating.

SOME WORDS ON BULK REMOVAL

Depending on your technique of bulk removal you may be adding stress to your AOI and even exacerbate its condition before you secure it with epoxy. There are many ways to remove or reduce bulk materials. These of course depend on what you are cutting and how complex the dissimilar materials are. For performing low stress removal at a reasonable cost, an option to consider is a wet band saw used in the leaded glass window crafts (see below).



Figure 5. Gryphon AquaSaw

These units are low cost, medium duty machines which can easily saw a PCBA with dissimilar materials and apply low stress to specimen (especially when micro or pre-encapsulated). They can be secondarily contained in sinks or placed in poly tubs for lab mobility. Suppliers of lapping consumables have a version of this machine which has been marketed to the sectioning community. They are an excellent alternative to higher priced models. These machines in no way remove the need for a round blade diamond saw but are a good addition to the section laboratory.

THE BASIC TRIPOD PROCESS

Not too unlike standard puck processing

- Cleaning? (if needed and appropriate)
- Pre micro-encapsulating? (to protect AOI)

- Vacuum if needed
- Bulk removal
- Micro-encapsulating (if needed –with epoxy of choice – vacuum if needed)
- Secondary bulk removal
- Mounting (thermal or instant glue)
- Lapping
- Polishing
- Wash and dry
- Imaging

MORE DETAILS ON GRINDING AND LAPPING:

Again, similar to standard puck processing

- Diamond plate grinding - 70µm
 - Water jet cleaning
- Diamond paste lapping on horizontal fiber cloth - 9 µm (key to micro-bulk removal and preventing large particle damage from affecting your specimen in subsequent steps)
 - Water jet cleaning
- Diamond paste on fiber felt cloth – 6µm
 - Water jet cleaning
- Diamond paste on fiber felt cloth – 3µm
 - Water jet cleaning
- Diamond paste on fiber felt cloth – 1µm
 - Water jet cleaning
 - IPA or methanol rinse
 - Hot-air forced drying (hair dryer)

Using the above material set, emphasis is to be put on the 9 µm diamond paste step. Removing the majority of the damage from earlier bulk removal is done at this step. The properties of using a poly orientation diamond paste with a horizontal fixed fiber pad give an aggressive removal condition which reduces embedded particles and damage with very little applied hand force.

One key benefit of this procedure is its ability to make ideal specimens for SEM inspection. Using a variable pressure (E-SEM or equivalent) in backscatter mode will allow the technician to stop polishing at a grit of 1µm (diamond paste). This produces a section with a degree of optical occlusions but will not be visible in backscatter mode. This shortens the work time allowing skipping the 0.05 µm –0.02 µm polishing step and proceeding to specimen clean-up, dry, and into the SEM.

MICRO WATER-JET CLEANING:

Micro water-jet cleaning is the use of low- to medium-pressure air in combination with low water flow to produce a highly aggressive micro-power washer. This technique is highly effective at removing particles from specimens as well as the section hand tool assembly.

CONSIDERATIONS OF SEM IMAGING AND WHY THIS METHOD HAS ADVANTAGES:

When imaging a cross-section specimen a technician will use an optical microscope numerous times between steps to

assure proper specimen finish at the correct grit steps. The ability to achieve an optical image with the focus and contrast to show many package, PCB, and metallurgical anomalies can be done with great efficiency in a SEM at low power magnification. Since this procedure makes "SEM friendly" specimens there is little material to charge and off-gas. Pump down times are optimum and specimen exchange is efficient due to the specimen holder (Chuck) being a standard 1/8" stud mount.

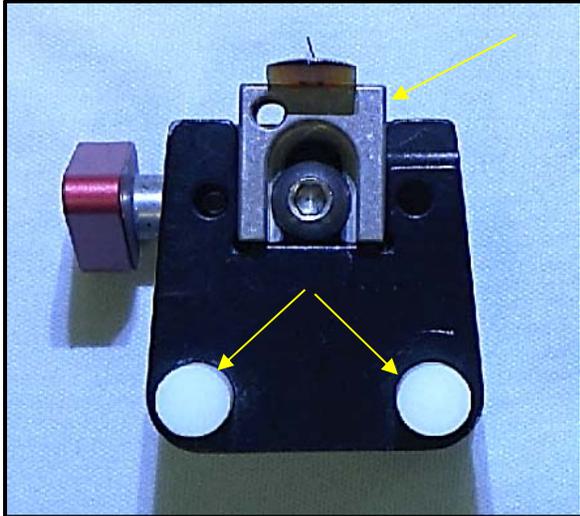


Figure 6. Allied High Tech Hand Tool
Note Specimen Chuck and Adjustable Feet

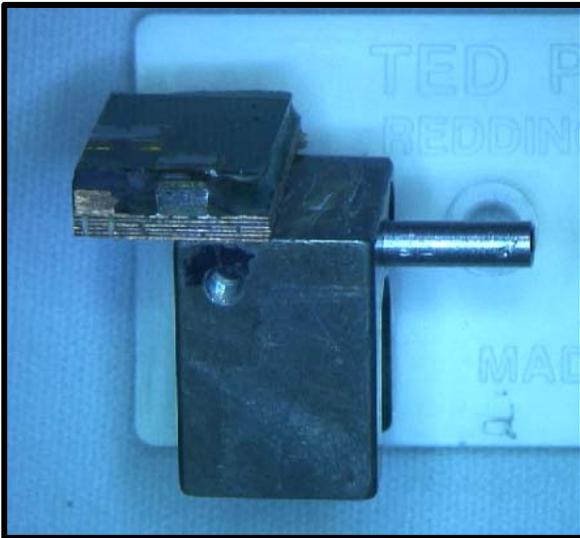


Figure 7. Specimen Chuck with Standard 1/8" Stud

CONCLUSIONS:

- The tripod method of cross-section has a number of distinct advantages for imaging and analyzing SMT and PCB related architectures. One large advantage is the ability to create low bulk material specimens which easily transfer to SEM analysis.
- These advantages allow for stable imaging and other electron beam related analyses with minimal preparation after lapping and polishing.

- This method does not eliminate the usefulness of puck specimens in all situations or needs. It allows a stable, alternative method when performing analytical cross-sections.

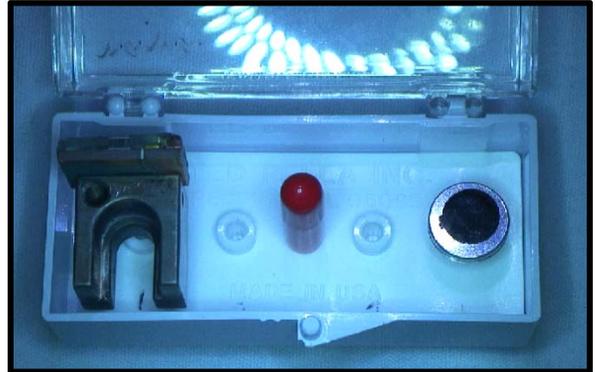


Figure 8. Specimen Chuck in 1/8" Tray
Considerable Size Difference versus Puck Specimen

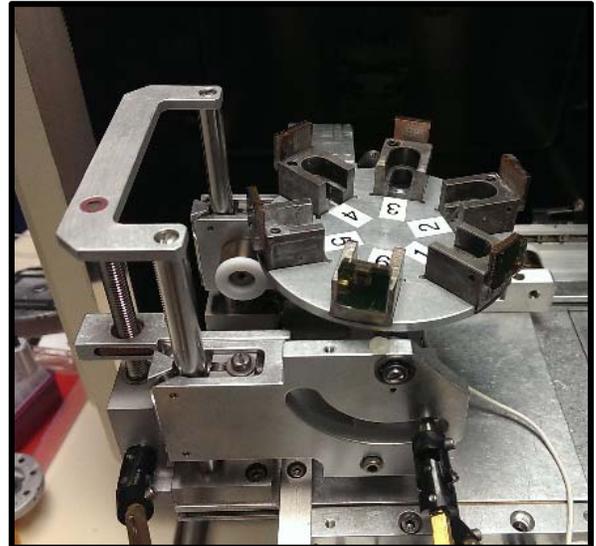


Figure 9. SEM Stage with Specimen Holder
Considerable Size Difference vs Puck Specimen

**EXAMPLES OF RESULTS:
Micro-Encapsulation**

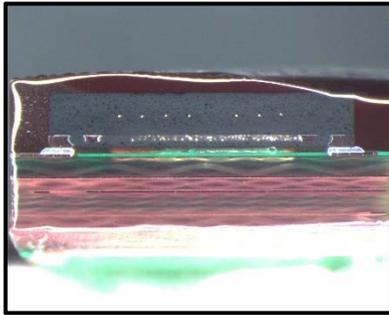


Figure 10. PQFN in Micro-Encapsulation
Quartz Cover Slide Technique
at Beginning of Section Process

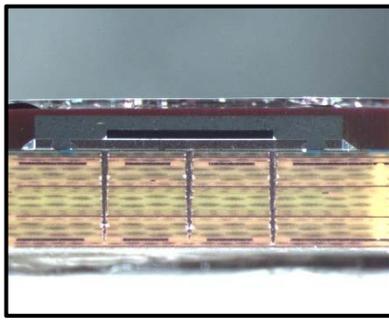


Figure 11. PQFN in Micro-Encapsulation
Beginning Entry into Thermal Vias



Figure 12. PQFN in Micro-Encapsulation
Silicon Surface Condition

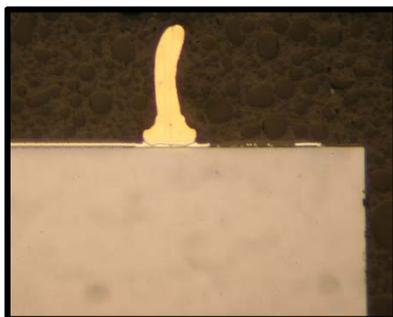


Figure 13. PQFN in Micro-Encapsulation
Gold Bond on Aluminum

**EXAMPLES OF RESULTS:
Mini-Encapsulation**

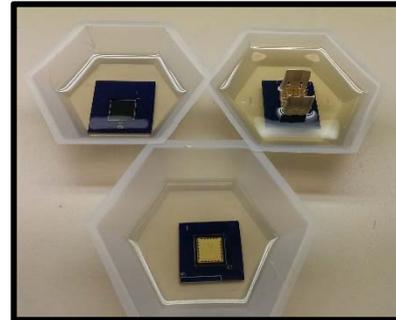


Figure 14. Shallow Non-Puck Potting

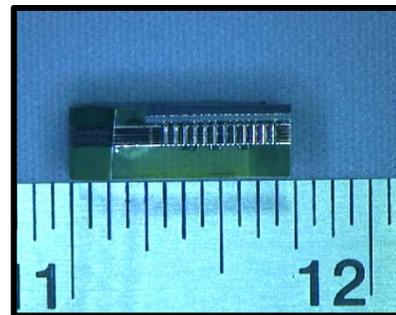


Figure 15. Ideal specimen Size Mini-Encapsulated after
Secondary Bulk Removal ~ 0.75"

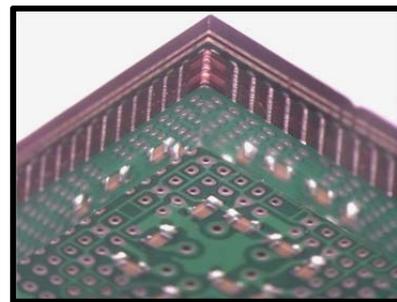


Figure 16. Micro-Encapsulated Specimen after
Secondary Bulk Removal

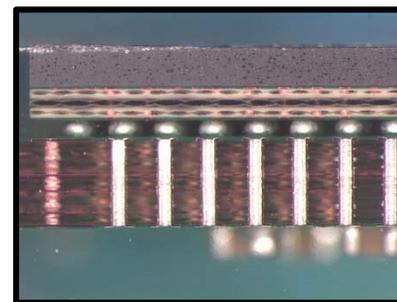


Figure 17. Optical Results of Micro-Encapsulated Tripod
Section. Note Via Planarity

**EXAMPLES OF RESULTS:
Micro-Encapsulation in SEM**

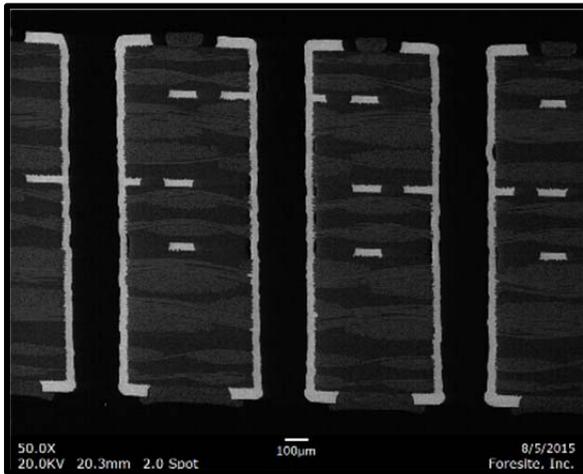


Figure 18. SEM Micrograph of PCB PTH Vias

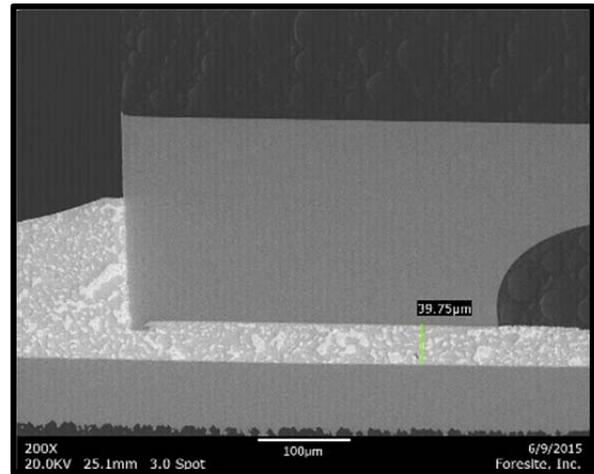


Figure 20. SEM Backscatter Image of PQFN Termination

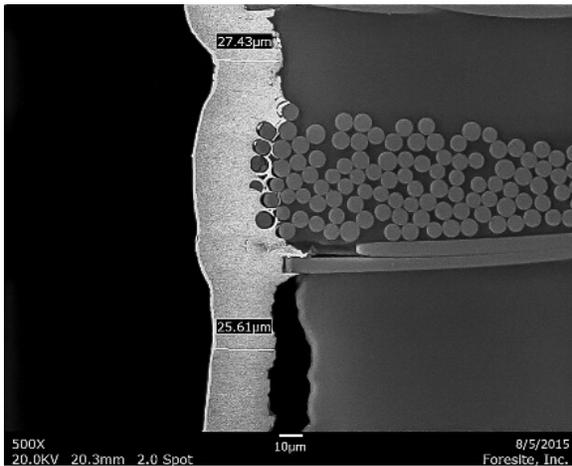


Figure 19. SEM Backscatter Image of PCB PTH Via

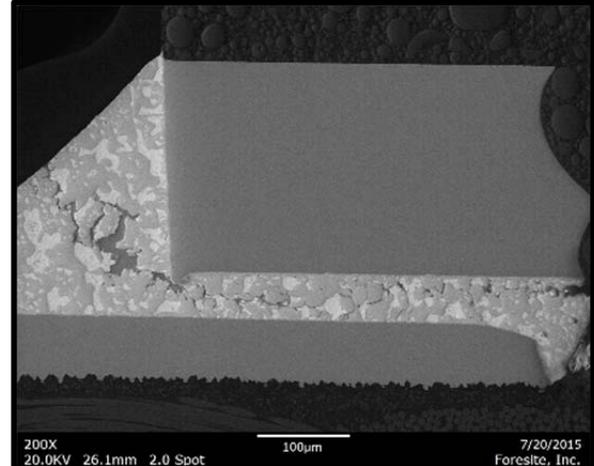


Figure 21. SEM Backscatter Image of PQFN Termination

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