TECHNICAL NOTES

SEMICONDUCTOR DELAYERING USING THE PELCO® DIMPLER™

Product No. 84000

INTRODUCTION:

The PELCO® Dimpler™ is a useful tool for delayering semiconductor samples for SEM/optical inspection and/or preparation for TEM lift-out in failure analysis, process monitoring and competitor analysis. By using different PELCO® Dimpler™ tools and abrasives, one can selectively open broad or pinpoint areas of a die for further analysis. The advantages of the PELCO® Dimpler™ are its relative speed, low-cost of operation and reduced beam time for sample preparation.

MATERIALS:

PELCO® Dimpler™ (84000)

PELCO® Video Alignment Microscope (84050)

Large Platen Set (83042) or Large Area Magnetic Base (83007) *and* Pin Stub Platen for Large Area Tools (83043)

Large area tools (83011, 83036, 83037, 83038)

Repadding strips (83061, 83062, 83063) or your preferred polishing cloth cut to size (i.e. Final B (816-13))

Repadding Roller Tool Kit (83060)

Mounting adhesive (i.e. PELCO® Quickstick 135 (892-45))

Abrasive slurries/suspensions in various particle sizes of diamond, colloidal silica and alumina (i.e. PELCO® Diamond Suspension, Monocrystalline, 1µm (894-12) Polycrystalline Diamond Suspension 0.1µm (814-310), PELCO® Colloidal Silica Suspension CS2, 0.05µm (815-130), 1µm Alumina Suspension (895-58))

Wash bottle for water (19802)

Small bottles for abrasives (140-37) or clean Pasteur pipettes for each abrasive type (2262-17)

Gentle cleanser (i.e. 17391)

Binocular microscope (i.e. BA310MET (22570-10))

Low magnification/inspection microscope (i.e. SMZ-171BLED (2283-11))

Fine-tipped permanent marker (27174)

Razor blades (optional) (121-22)

PELCO® Sample Clamp (optional) (813-544 and/or 813-542)

Kapton® Tape (optional) (16092-12)

FACILITIES (OPTIONAL*):

Particle free/DI water

Particle free air/N2

*If facilities are not available, alternatives such as a compressed air duster and bottled DI water will be necessary

PROCEDURE:

This procedure is for decapsulated die and/or partially or fully-stacked wafers. Die decapsulation is not covered in this document. Knowing how many metal/interlayer dielectric (ILD) layers there are in your sample and their relative thicknesses is crucial to having a final surface free of scratches and defects at the Region of Interest (ROI). If stack information is unknown, it is advisable to make a small cross-section in the guard ring using a focused ion beam tool or cleave and image a cross-section to gather this data.

1. If using a Reactive Ion Etch (RIE) system to remove passivation (if present), do this first according to your standard process.
2. Mount a sample to the platen using the mounting adhesive of your choice, making sure the sample is as planar as possible (PELCO® Sample Clamps, shown in ***Figure 1*** below, can help with sample leveling while the adhesive is still pliable). Try to place the ROI as close to center of the platen as possible, even if the ROI is not at the center of the die.

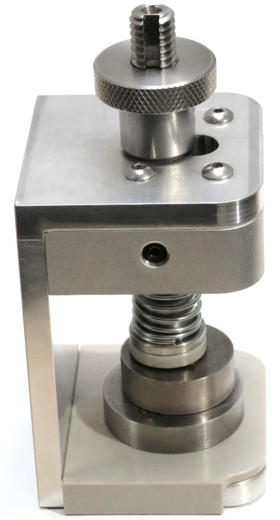

Figure 1*: Sample Mounted on Large Area Platen in Sample Clamp*

3. Locate the ROI using an inspection microscope and mark it with a fine-tipped permanent marker (***Figure 2***).

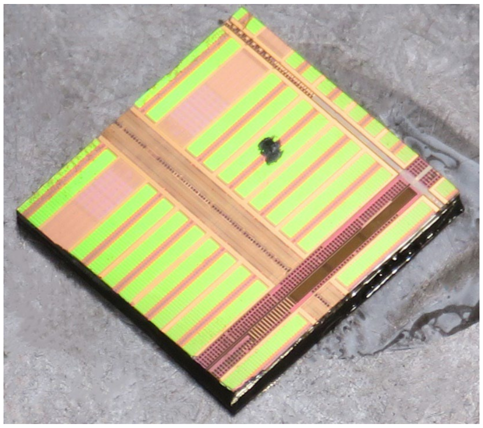

Figure 2*: Sample with ROI Marked in Black*

4. (Optional) If passivation is present and top metal is not the ROI, under an inspection microscope you may gently scrape the passivation in a circular motion using just the corner of a fresh razor blade (***Figure 3***). Keep the long edge of the blade nearly parallel to the sample (5-10°) and scrape the passivation gently to create a small hole at the ROI location. The size of this hole will partially dictate the overall opening area of the dimple and the speed of polishing, so learning what size opening is appropriate for your application while not damaging the layers below may require some practice.

Figure 3: *Removing the Passivation with a Razor Blade*

5. Place the platen on the magnetic base and then place onto the PELCO® Video Alignment Microscope (VAM). Align the platen on the magnetic base so the ROI is centered (***Figure 4***).

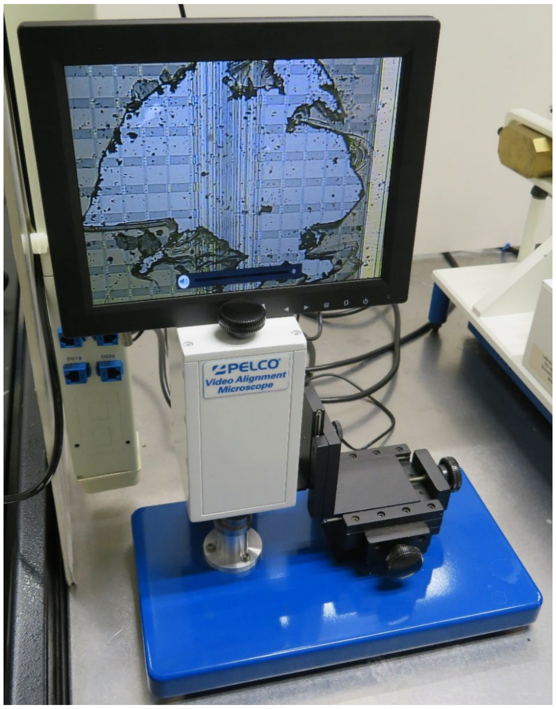

Figure 4: *Aligning the Sample on the VAM*

6. If the ROI is near the edge of the die, a sacrificial die or layers of tape can be used to keep the dimple from rolling off the edge of the sample (***Figure 5***). The sacrificial material should abut the sample closely and be of the same height. If sacrificial material is needed, it should be placed before dimpling begins. When handling wafer material rather than a singulated die, you may simply cleave a sample larger than the die itself to ensure the ROI is not at the sample edge.

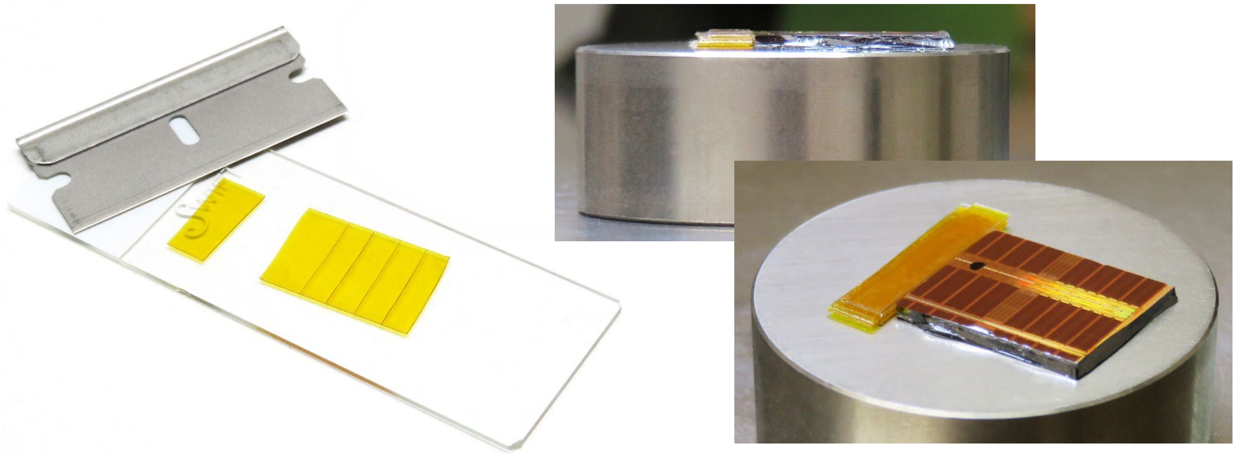

Figure 5*: Using Layers of Kapton® Tape to Protect the Die Edge*

7. Choose a tool for delayering—the ½” tool will open a larger area more slowly, the ⅛” tool will open a smaller area more quickly. The ¼” tool is the most popular tool for semiconductor delayering.
8. Referring to the instructions that come with the Repadding Roller Tool Kit, place fresh padding material on the tool you have chosen (shown in ***Figure 6*** below). Press firmly to ensure the pressure-sensitive adhesive makes a good connection to the tool, otherwise the corners may begin to lift as abrasive and water are applied. It may help to warm the Dimpler tool and/or the padding strip to ensure good adhesion between the two.

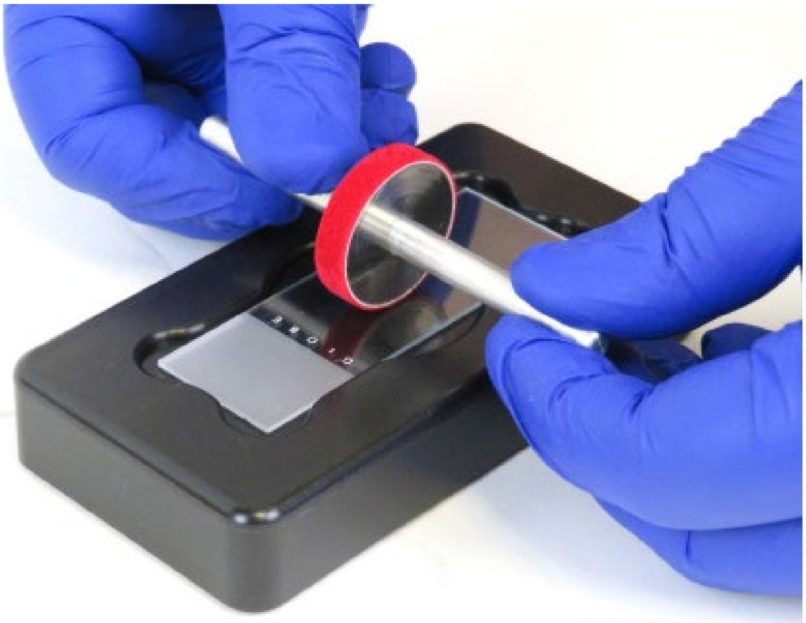

Figure 6*: Adhering Padding using the Repadding Roller Tool Kit*

9. Install the tool and place the platen with the sample on the PELCO® Dimpler™ (***Figure** 7*).

***Figure** 7: Platen and Tool on the PELCO® Dimpler™*

10. Wet the padding on the tool evenly with the first abrasive (***Figure 8***). Different processes will be better suited for different slurries, but a 1-3µm diamond or alumina is a good place to start for removing passivation, thick top metal, and/or thick ILD. 1µm diamond or smaller is recommended for thinner layers.

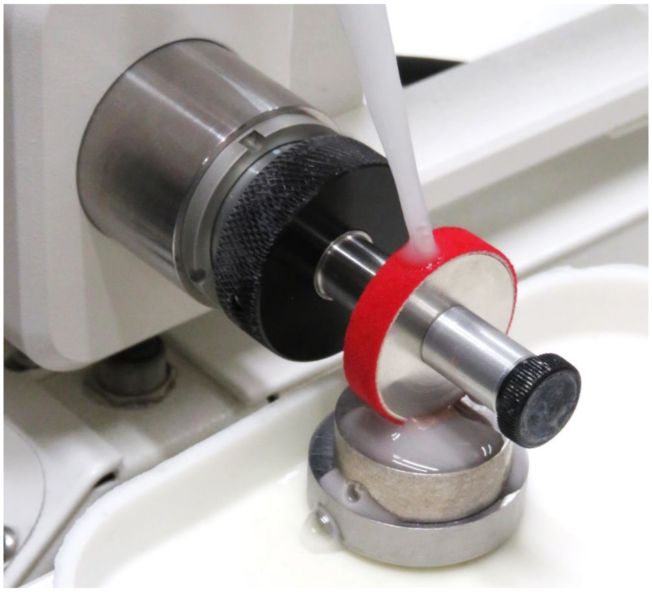

***Figure 8**: Adding Abrasive to the Padded Dimpler Tool*

11. Always keep in mind this rule of thumb—the particle size of the chosen abrasive may produce scratches, and working damage approximately 3 times the particle size, so care should be taken in choosing an abrasive according to the relative depth of the ROI to the current working depth.

12. Using the timer function on the PELCO® Dimpler™, set the tool to run for 5-10 minutes with "**FORCE SETPOINT**" set to 100 and "**TOOL SPEED**" set to 90 (***Figure 9***). These numbers are a rough suggestion and may change depending on individual samples and instruments.

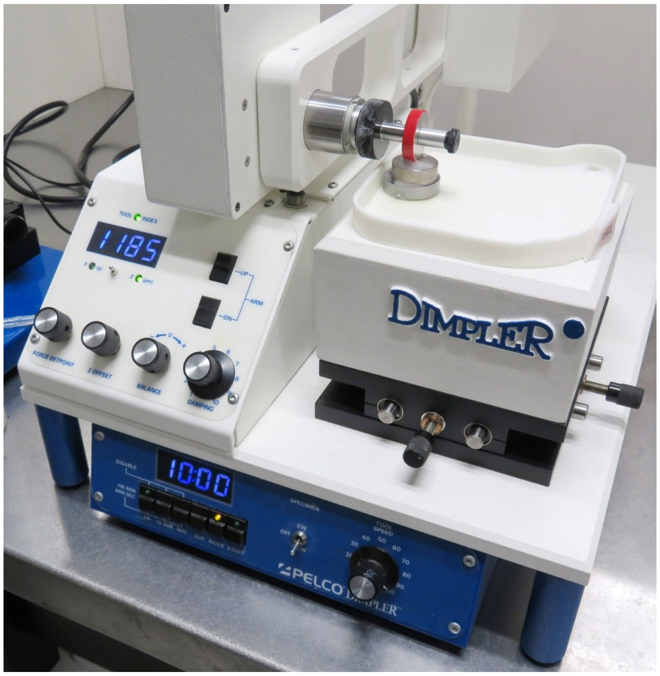

Figure 9: *Dimpling the Sample*

13. Inspect progress as necessary by stopping the PELCO® Dimpler™, removing the sample, platen, and base from the stage and rinsing the sample and platen assembly for at least 15 seconds under moving water. Use nitrogen gas or particle-free air to dry the sample. This is best achieved by directing the air in a single direction at about 5° above parallel to the sample. Once dry, you may inspect progress using the inspection or binocular microscope (***Figure 10***).

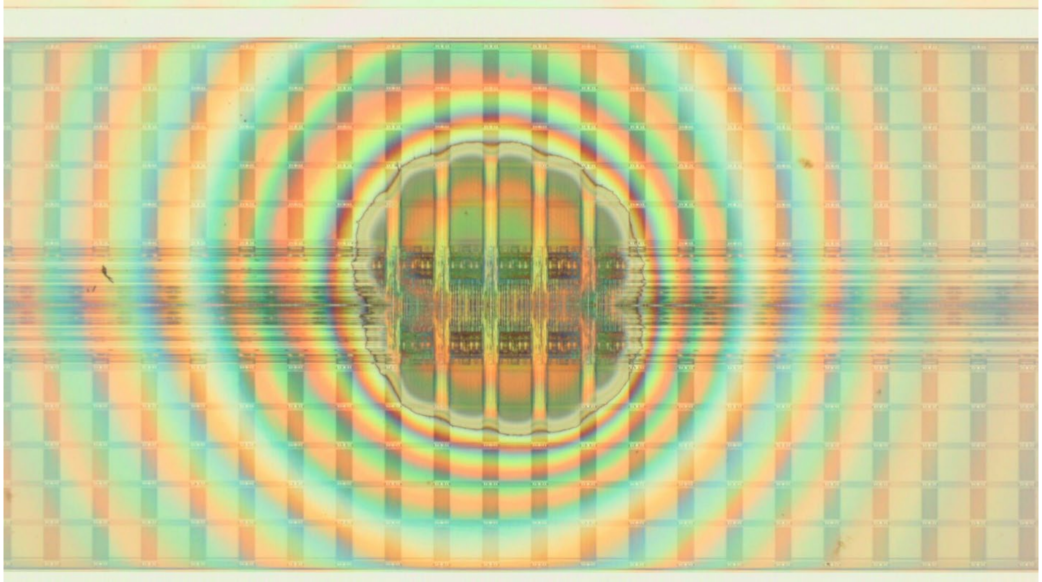

Figure 10: *Inspection Image shows Passivation and Top Metal Removed*

14. Depending on the composition of the ILD, it may be beneficial/faster to change slurries between metal layers and ILDs. If doing this, using separate tools or fresh padding for each type of abrasive is recommended. If this is not possible, take care to thoroughly rinse the previous abrasive from the padding of your tool.
15. After top metal is removed, for most modern semiconductor nodes the abrasive should be swapped to a 1µm particle size. Remember to either change the tool padding material or thoroughly rinse the padding and tool when switching abrasive type (diamond, silica, etc.) and particle size.
16. Repetitively dimple, clean and inspect your sample running the PELCO® Dimpler™ for 30 seconds to 1 minute at a time for smaller metal layers (***Figure 11***). This constant monitoring allows you to correct any issues if they arise (see the "**TROUBLESHOOTING**" section on page 10).

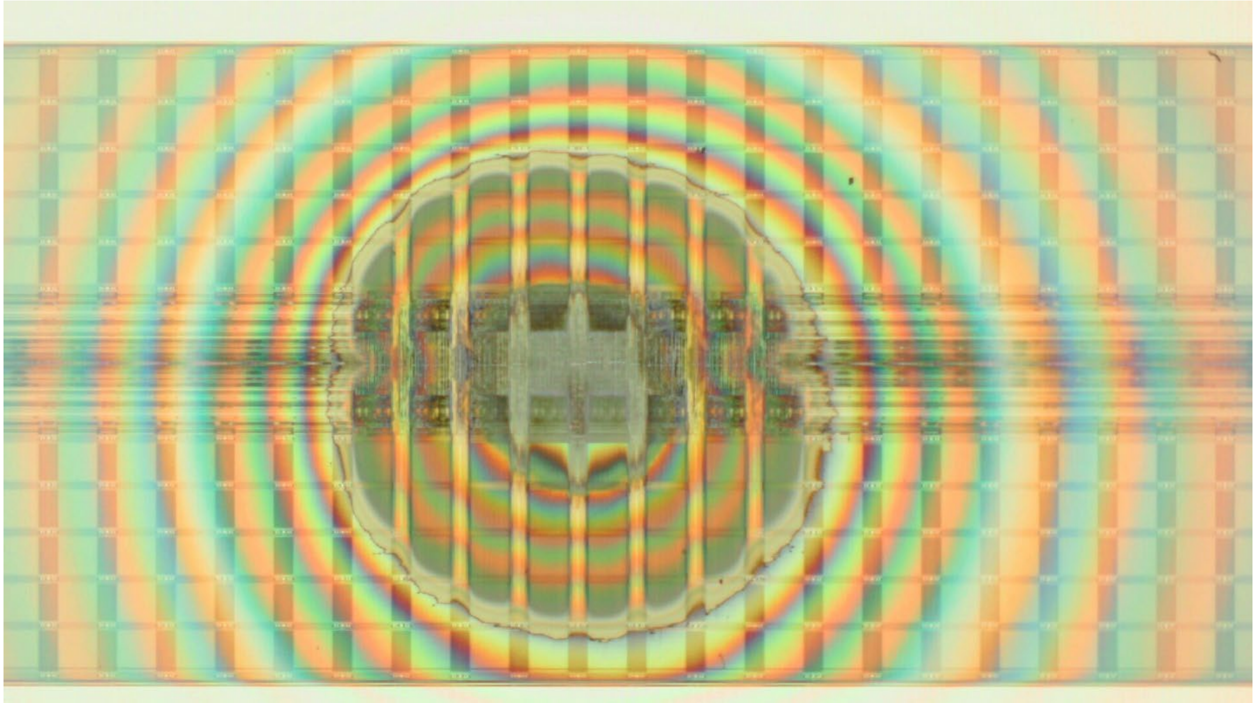

Figure 11: *Inspection Image shows Passivation, Top Metal and ILD Removed*

17. As you approach the ROI, switch to progressively smaller particle sizes and reduce force and speed to minimize damage.
18. In most cases, final polishing will be done with a very fine colloidal silica suspension (such as 815-140). The chemical-mechanical polishing effect of colloidal silica suspension leaves a very smooth surface if proper care was taken during sample preparation. However, do not allow the colloidal silica to dry on the surface of the sample as it becomes extremely hard to remove without polishing further into the sample.

19. Upon reaching the ROI (***Figure 12a*** and ***b***), instead of simply rinsing the surface with water, using a gentle cleanser such a Micro 90 with a gloved finger or very soft brush can help to remove very fine particles from the surface. Make sure to rinse the soap away for at least 30 seconds with running water. Dry the sample as normal.

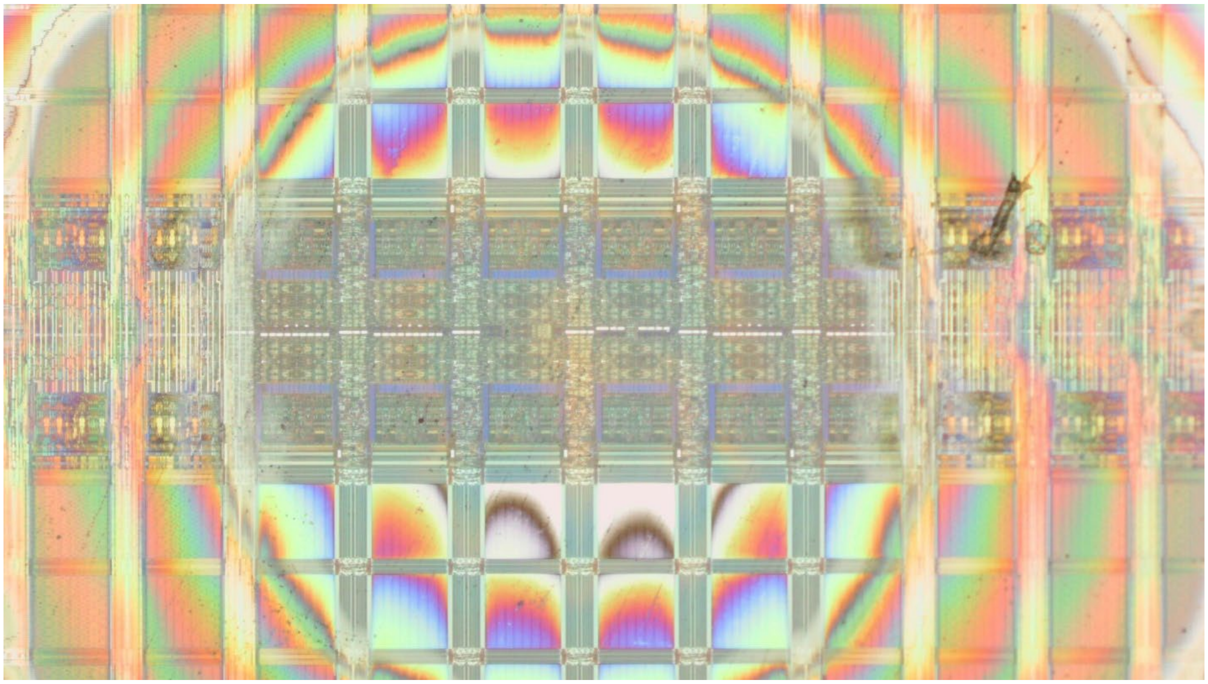

Figure 12a*: Optical Inspection Image Shows Final Dimple in the ROI*

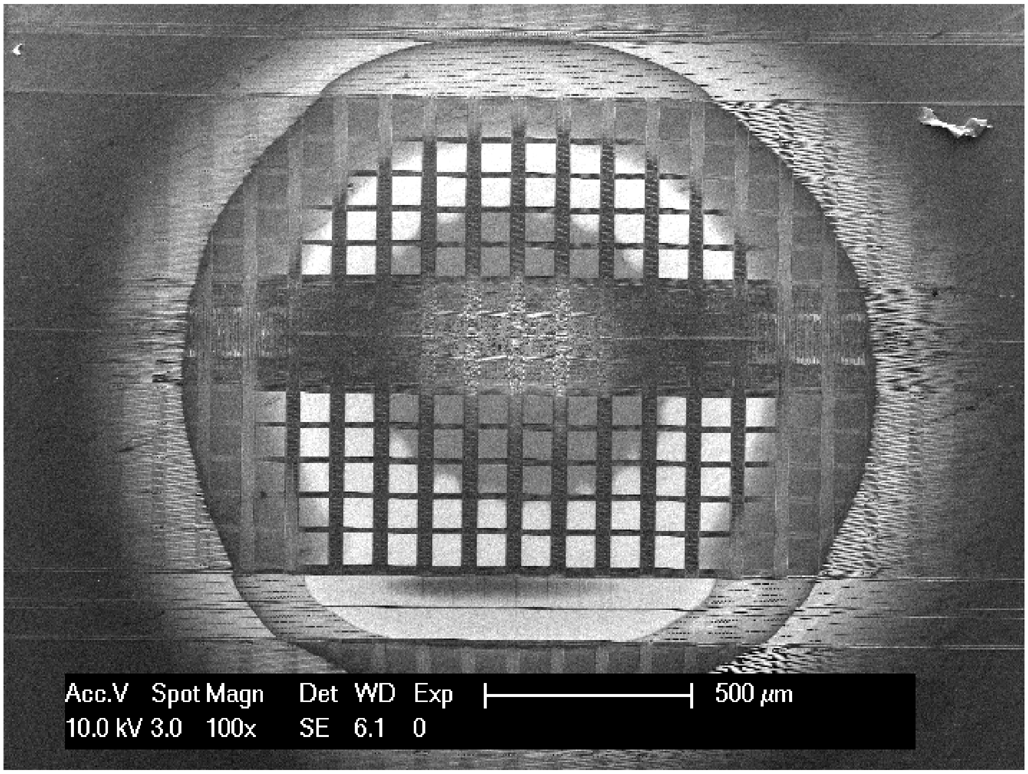

Figure 12b*: SEM Inspection Image Shows Final Dimple in the ROI*

20. Demount the sample from the platen (unless using the Pin Stub Platen). If adhesive contaminates the sample surface, sonicate in acetone or isopropanol for 5 minutes. Take final images of the ROI (***Figure 13a*** and ***b***).

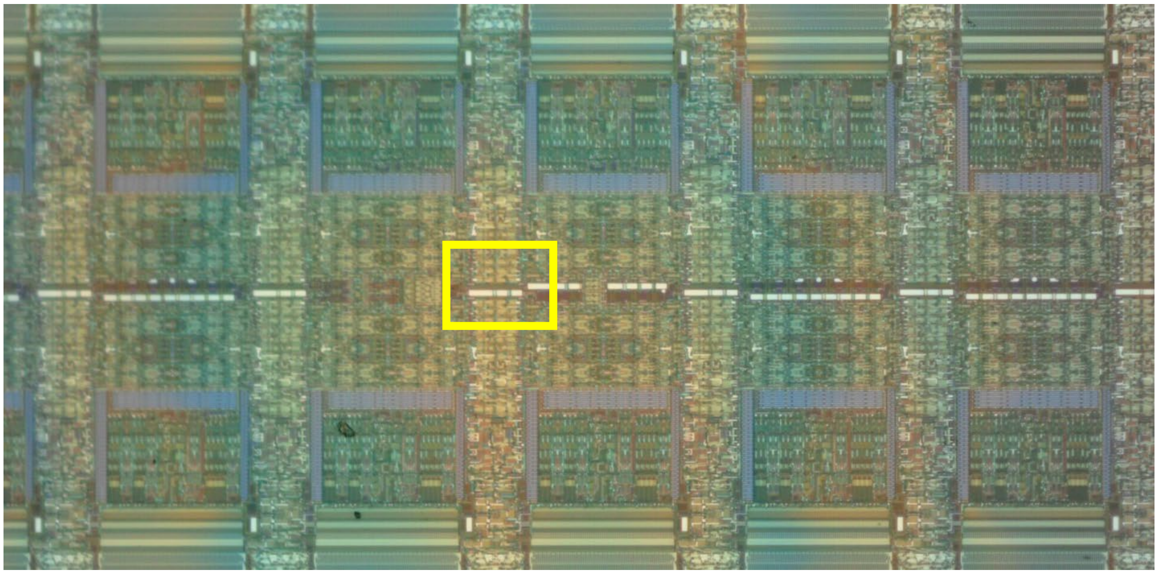

Figure 13a*: Highlighted Area Shows Location of SEM Image Shown Below*

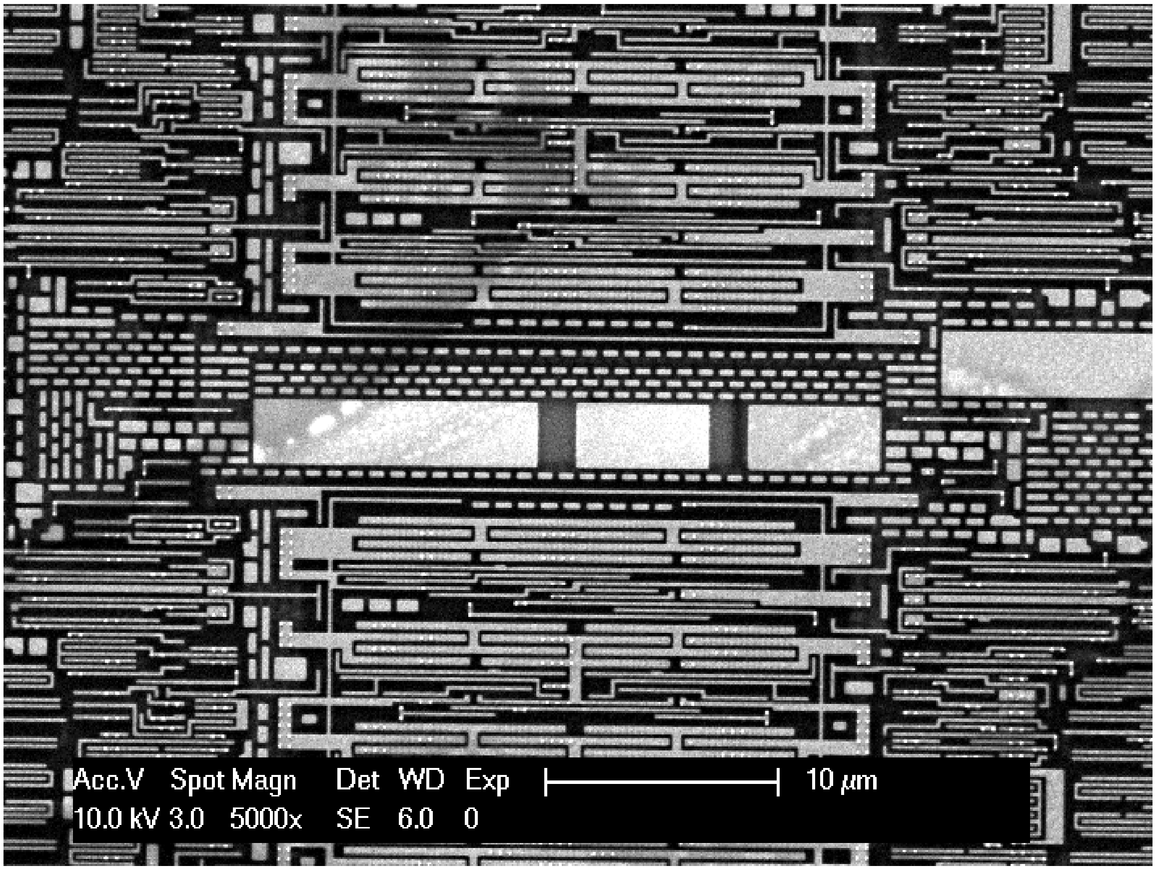

Figure 13b*: SEM Inspection Image Shows Final Dimple in the ROI*

TROUBLESHOOTING:

1. Dimple appears as a donut or off center.
    a. Go through the arm balancing and stage centering procedures in the PELCO® Dimpler™ manual.

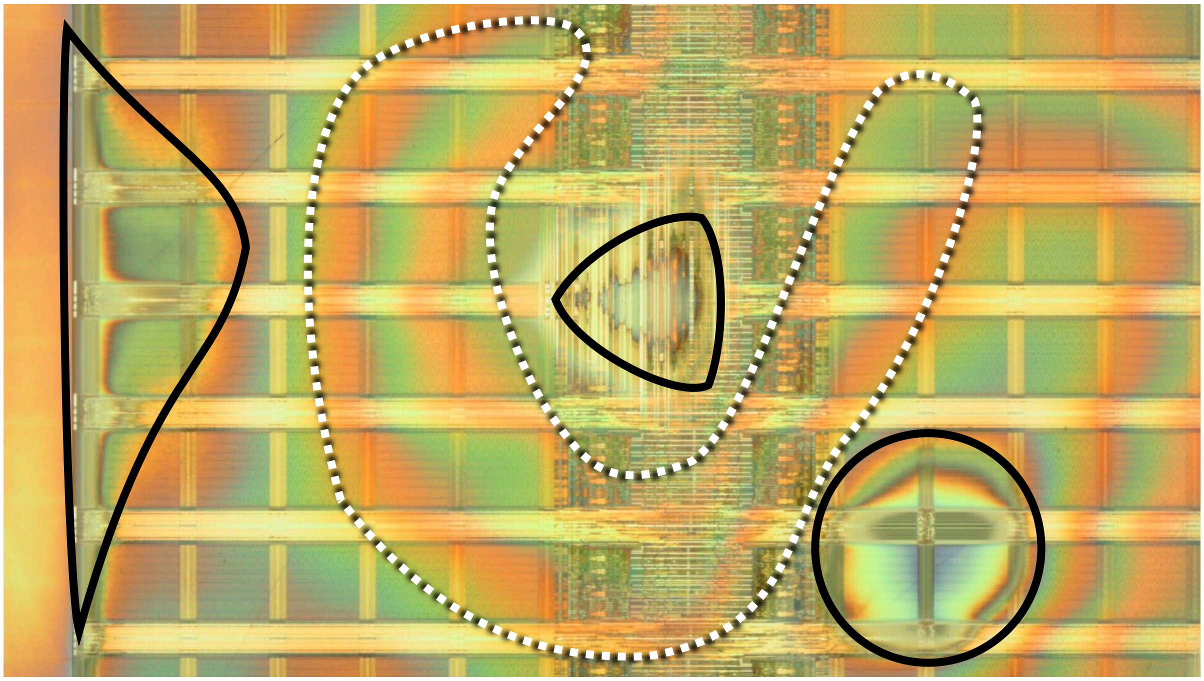

Figure 14: *An Asymmetrical Dimple Caused by a Misaligned X-Y stage: low areas are highlighted in black, high area in dashed white*

2. ROI was misidentified/is slightly off-center.
    a. Method 1. Dimple migration. Compensate for location error by overcorrecting in the direction of the true ROI, especially if you are already close to the target layer of the ROI. A good rule of thumb is to go past the ROI (away from the center of the incorrect dimple) at least 50% of the distance between the ROI and center of the dimple. See example below in ***Figure 15***:

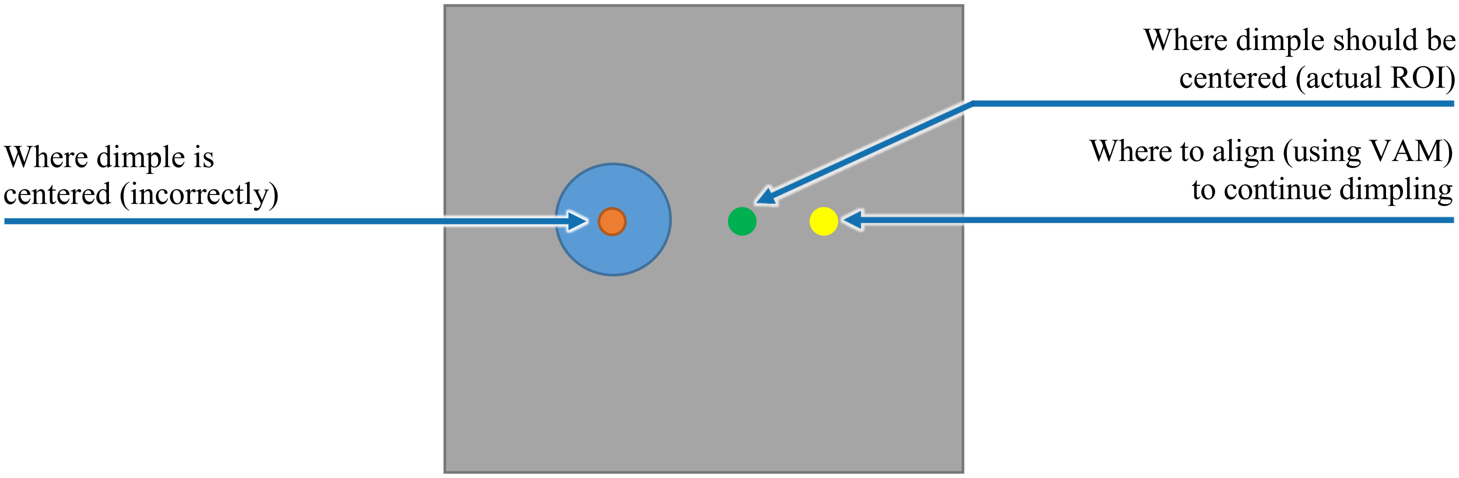

Figure 15: *Illustrating How to Re-Align a Dimple that Missed the ROI*

b. Method 2. Dimple masking and redimpling. If the error cannot be corrected by attempting to migrate the dimple (for instance, the dimple is already at the target layer and that whole layer needs to be preserved), the current (errant) dimple can be masked off using Kapton® tape (or similar) and a new dimple started nearby. Note that the tape will need to be cut to custom shape/size appropriate to the dimple.

   Polish in the adjusted ROI area until reaching the same layer as the errant dimple. Remove the Kapton® tape and re-center the whole dimple. Do a short (5 second) final polish with small particle size colloidal silica or diamond, then do final soap wash and rinse (as in step 19).