SWGDE Tech Notes regarding Chip-off via Material Removal Using a Lap and Polish Process

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1. Introduction

Removing flash memory chips from mobile devices to obtain forensic images not otherwise obtainable by commercial forensic tools is a proven and forensically-sound process. [1] [2] However, de-soldering the chip from the circuit board of the device carries certain risks. As the internal components of mobile devices become smaller and more powerful, advancements in the design, manufacturing, and assembly of printed circuit boards are creating new challenges to traditional chip removal via heat. Flash memory devices that are sensitive to heat and epoxy underfill that provides cushion and prevents thin integrated circuit packages from flexing on a printed circuit board, are two examples of the shift that is occurring in design, manufacturing, and assembly. As such, the traditional chip-off process via heated removal is becoming limited and much more difficult to perform.

An epoxy underfill is applied between the circuit board and flash memory chip during assembly. The underfill seals the bottom side of the chip and can sometimes be found covering the entire chip package. While this advancement creates better mechanical properties for the device, it creates a greater hurdle for heat-based removal as the underfill melts at a temperature much higher than the solder connecting the chip to the board. An examiner risks damaging the chip by exposing the chip to overheating (in an effort to cause the underfill to release from the board) or pulling pads from the chip while trying to pry the chip from the board. For this reason, new chip-removal techniques need to be introduced to, and vetted by, the digital forensics community to gain access to the information stored on the flash.

One new technique is the chip-off via material removal using a lap and polish process. This new process removes layers of circuit board and circuit board components from under the flash in order to access the chip's mechanical connection points, while minimizing the temperature escalation of the chip itself. This grinding and polishing process can be done effectively with any flat lapping and polishing machine with certain features. Required features include variable speed adjustments, the ability to change grinding and polishing grit surfaces, manual or automatic leveling adjustment, and manual or automatic pressure adjustment. As with any chip-off examination, all other processes should be evaluated prior to interacting with the device in a potentially destructive manner. Additionally, all examiners should consult with their legal counsel / prosecutor before attempting such a process.

This document explains the chip-off via material removal using a lap and polish process.

2. Chip-off via Material Removal Using a Lap and Polish Process

2.1 Remove the flash memory chip from the circuit board.

a. Device Disassembly.
   i. Disassemble the mobile device to access the printed circuit board.

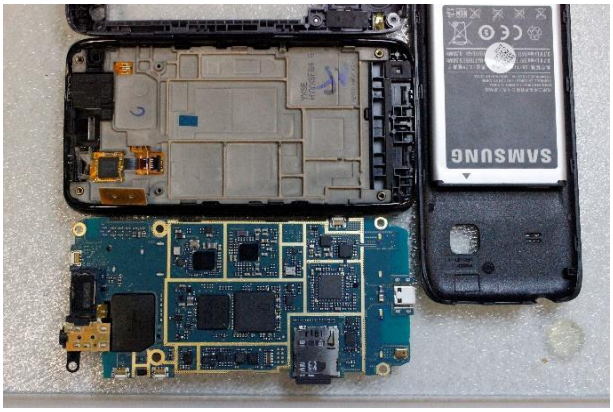

Figure 1 – Disassembled mobile phone

b. Cutting the circuit board.
   i. Using a cutting tool, cut the circuit board away from the flash memory chip. Leave enough perimeter around the flash memory chip to ensure the chip is not accidently damaged in the cutting process. Leave one-eight (1/8) to one-fourth (¼) inch of circuit board around the chip.
   ii. The perimeter material is only left on the chip to ensure the chip is not damaged when circuit board is cut away. The chip-off via material will be removed during the lap and polish process.

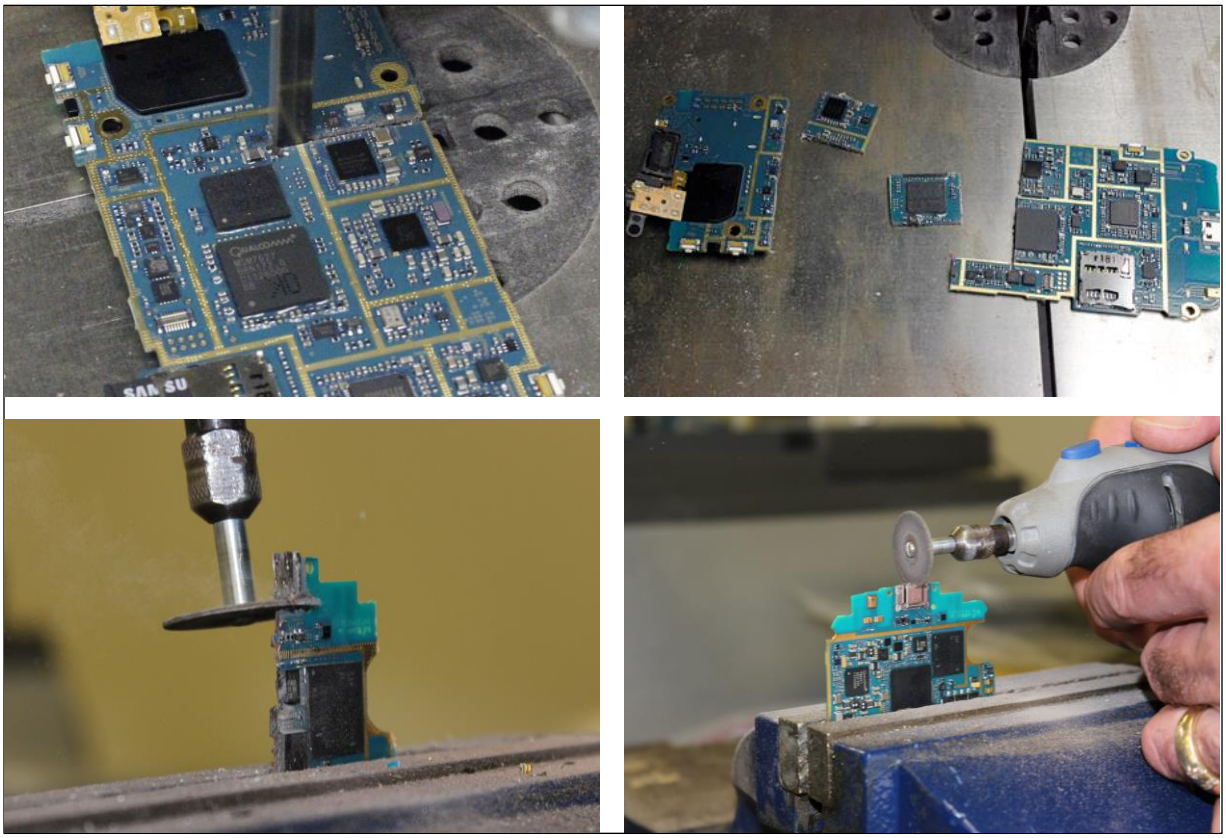

Figure 2 – Methods for cutting flash memory from a circuit board

2.2 Prepare the lap and polishing wheel with the appropriate materials.

a. Attach a lapping disc to the lap and polish wheel.
   i. Basic rule of thumb, start with a more abrasive level of lapping disc then move to a less abrasive polishing disc as you get near the metal soldering-point balls of the ball grid array (BGA) on the memory chip.
   ii. For the recent example (**Figure 2**), an 80 grit disc was used to start then a 600 grit disc was used to finish the process.

b. Ensure that the required liquid is available in the lap and polishing machine to act as a coolant for the lap and polishing process.

2.3 Attach the flash memory chip to the holder provided by the lap and polishing machine manufacturer.

a. Adhere the chip to the device provided by the manufacturer that holds the chip. For the purposes of this process description, we refer to that device as the "chip holder."
   i. To adhere the chip to the chip holder, most manufacturers recommend using a wax specified by the manufacturer.
   ii. Some examples of the name for the "chip holder," by the various lap and polish manufacturers, include a platen, stub, stub holder, jig, puck, or, material holder.

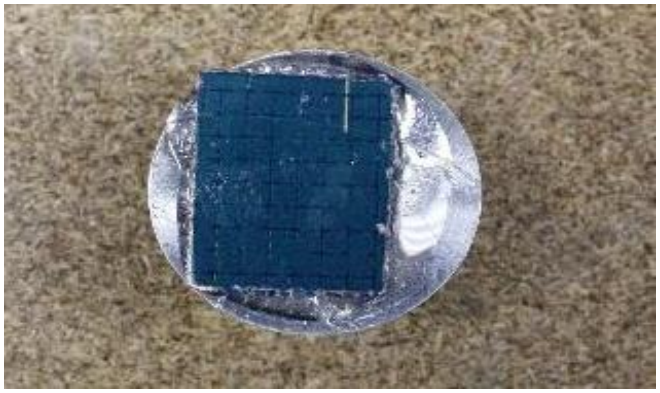

Figure 3 – NAND flash memory chip with circuit board intact attached to holder

b. Place the recommended amount of wax on a chip holder, place the chip holder on the hot plate, and, heat to the temperature defined by the manufacturer.
   i. To adhere the flash to the chip holder, place a few pieces of wax on the chip holder or rub the solid wax and place this on a hot plate at the melting temperature and wait for it to completely melt. ***Note:*** *Only use enough wax to get the flash to stick to the holder. Too much wax can create extra work when cleaning the flash.*
   ii. Use the lowest temperature required by the wax manufacturer to melt the wax. This will ensure the chip is exposed to the lowest amount of heat required to melt the wax.

Figure 4 – Melt wax on the holder to temperature recommended by wax manufacturer

c. When the wax is liquid and tacky, place the flat, non-circuit-board side onto the wax.

2.4 Remove the lap and polish holder from the heat so the wax can begin to set.

a. Ensure the flash memory is level to the surface of the lap and polish holder.

b. Apply pressure or use a small weight to ensure the chip stays level and adheres to the wax while it cools.

Figure 5 – Example of weight pressing the memory chip to a holder

2.5 Attach the holder to which the chip is adhered to on the polishing arm of the lap and polishing machine.

a. Secure the locking mechanism.

2.6 Level the holder.

a. Use the leveling mechanism and techniques defined by the manufacturer of the equipment.

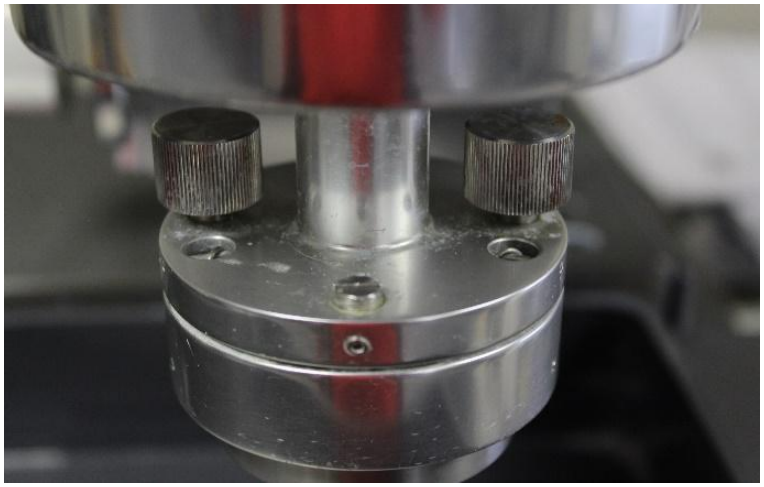

Figure 6 – Example of leveling thumbscrews on a lap and polishing machine

2.7 Begin the lap and polish process.

Process information:

- Load pressure refers to the downward pressure of the material against the polishing wheel. Manufacturers' instructions may refer to this pressure as z-axis and load pressure. It is most often measured in grams of pressure. RPM refers to the defined speed at which the lapping and polishing disc is spinning.
- The chip examples represented in this document used the following load and RPM parameters:
  (1) Once the chip is confirmed level, increase the load pressure to as much as 20 grams of pressure for several 15-20 second intervals. Next back the pressure down to 10 grams of pressure for lapping intervals then as low as 5 grams of pressure after switching to fine grit polishing discs.
  (2) 125 RPM worked consistently throughout the lap and polish process.

a. Lower the polishing arm down until it is resting against the polishing wheel.
   i. Following the manufacturer's instruction, set the pressure at which the polishing arm pushes down to 0. This will allow fine control on the amount of pressure being exerted on the chip against the lap and polishing wheel.

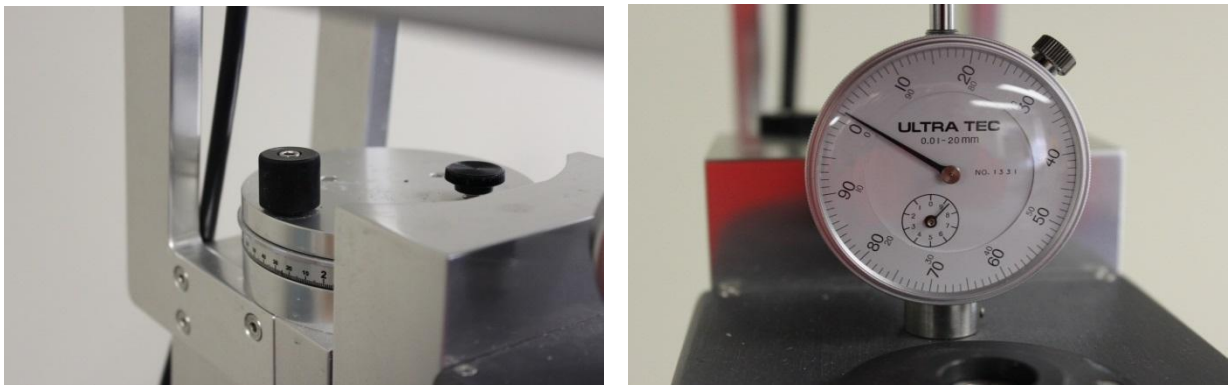

Figure 7 - Example of controls on a polishing arm and measurement dial for load pressure

b. Turn on the lap and polishing wheel.
c. Turn on the recirculating coolant.

Figure 8 – Example of polishing wheel powered on and coolant circulating

d. Let the machine run for 15-20 seconds, then stop the machine and remove the holder to check the chip.
    i. At this first check, inspect whether the material is being removed in an even and level fashion.
e. Replace the holder and continue the lap and polish process.

2.8 Checking the chip for material removal.

a. The chip should be visibly inspected every 15-20 seconds to determine the (1) amount of material that has been removed, and, (2) the even, level removal of material.
b. At any point in the lap and polish process, if the printed circuit board layers appear to be removing in an uneven fashion, the process should be stopped and the X-Y axis of the holder levelled according to the manufacturer's instructions.

2.9 Switching to polishing disc to finish removal.

a. When the green or blue of the solder mask of the circuit board becomes visible, switch to a finer grit polishing disc.
b. In the example below (**Figure 9**), the solder balls start to be visible as a visual cue of when to switch to the finer grit.
c. Once the solder mask layer is removed, it is possible to remove the printed circuit board layers until only the chip and exposed leads remain.

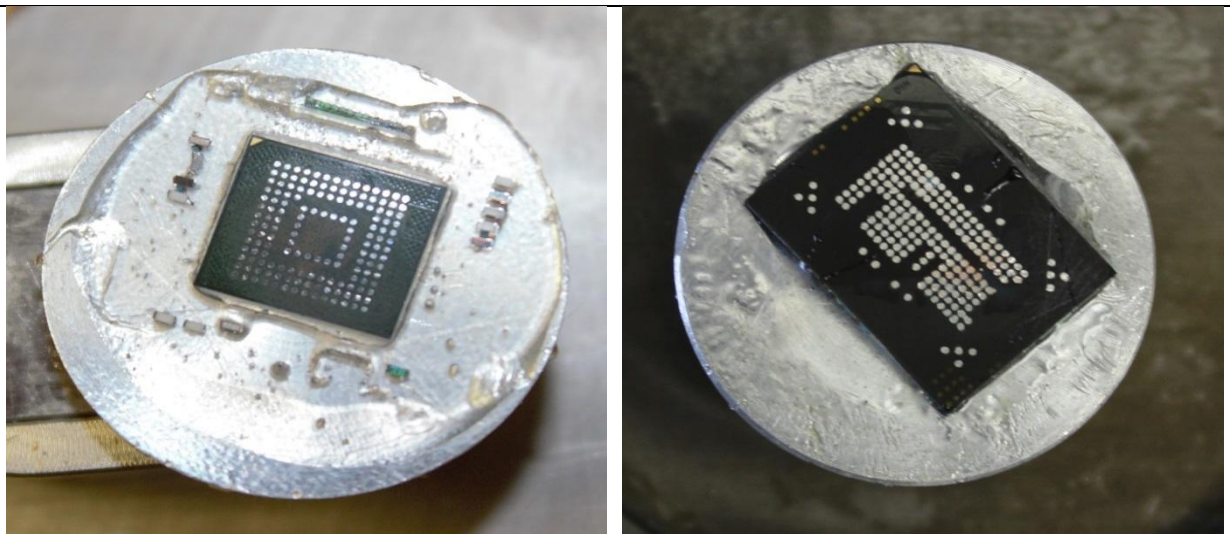

Figure 9 – Example of circuit board and solder mask removed

2.10 Inspecting the chip under a microscope.

a. Before removing the chip from the holder, it is recommended to inspect the chip under a microscope to ensure even clean exposure of the chip connections.

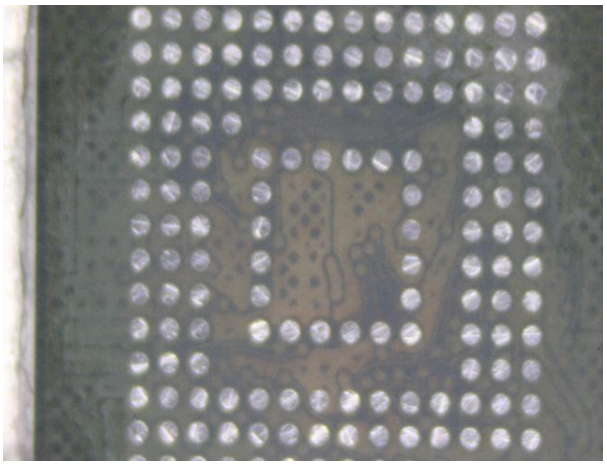

Figure 10 – Example of BGA package under microscope that was removed by the lap and polish process

b. Look for BGA leads that (1) still have solder mask covering the lead and (2) solder that may be bridging two or leads together.
   i. In some instances, it may be required to gently use a fine grit polishing medium to remove the final imperfections to make the chip ready.

2.11 After the lap and polish process is complete;

a. Remove the chip from the lap and polishing holder.
b. Expose the lap and polishing holder to heat to melt the wax.
    i. Use the lowest temperature required by the wax manufacturer to melt the wax. This will ensure the chip is exposed to the lowest amount of heat required to melt the wax.
    ii. Gently remove the chip from the wax.
    iii. While the wax is still cooling, gently wipe and remove the excess wax with a paper towel.
        - Use a cleaner recommended by the wax manufacturer to remove any remaining wax on the chip.
        - In our example, acetone was the cleaner recommended by the manufacturer for removal of the wax.

2.12 Read the chip for data acquisition.

a. Normal procedures for reading the chip after chip removal can be utilized at this point.

Figure 11 – Example of NAND flash memory chip that was removed from the circuit board via Lap and Polish Process ready to be read in a chip reader

3. Final Note

This document outlines the lap and polish process utilizing a mechanical arm and chip holder as designed by the manufacturers. Many manufacturers offer precise leveling with these mechanical arm, chip holders, and built-in leveling mechanisms to hold the chip exactly parallel to the rotating wheel. Some efforts have been underway to test holding the chip by hand to the rotating wheel as a means of completing the material removal.

Extreme caution should be used with a handheld exposure of the chip to the rotating wheel as the precise leveling of the chip parallel to the surface of the wheel is dependent on the ability and precision of the end user. The chip should be checked more frequently to ensure too much material is not being removed and the material removal is occurring consistently and evenly across the face of the chip.

4. Conclusion

Chip-off via material removal using a lap and polish process provides a valid alternative to traditional chip-off via thermal-removal processes. The lap and polish process allows the thermal exposure to the chip to be controlled via revolutions per minute (RPM) of the polishing wheel along with the use of liquid coolants being applied during the removal process.

Special attention must be paid to ensure the chip is level during the lap and polish process and that material removal does not exceed the external boundaries of the chip package.

5. References

[1] Scientific Working Group on Digital Evidence, "SWGDE Best Practices for Chip-Off,". [Online]. https://www.swgde.org/documents/Current%20Documents

[2] S. Willassen, *Advances in Digital Forensics*, M. M. Pollitt and S. Shenoi, Eds. Orlando: Springer, 2005.

6. Manufacturers of lap and polish machines.

The industry currently has many offerings for lap and polishing machines. Prices vary from a few thousand dollars to over one hundred thousand dollars. By searching for “lap and polish machines” online, a variety of vendors and price ranges can be identified.

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History

Revision	Issue Date	Section	History
1.0 DRAFT	2016-10-26	All	Initial draft created and SWGDE voted to release as a Draft for Public Comment.
1.0 DRAFT	2016-11-09	All	Forensics Committee voted to submit the draft to SWGDE for review and a vote to release as a Draft for Public Comment. Formatting and tech edit completed.
1.0 DRAFT	2016-11-16	All	SWGDE voted to publish as a Draft for Public Comment. Formatting and technical edit performed.
1.0	2017-01-12	2.4.b/ Figure 5	Changed the image in Figure 5 to show a level weight. SWGDE voted to publish as an Approved document (Version 1.0).
1.0	2017-02-21	Formatting	Formatted and published as Approved Version 1.0.