SAMPLE PREPARATION FOR REVERSE ENGINEERING – CHOOSING THE RIGHT TOOLSET

HARRIS REVERSE ENGINEERING WORKSHOP 2024

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ALLIED HIGH TECH

For over 40 years, Allied High Tech Products has provided the electronic failure analysis community with quality sample preparation products for microscopic evaluation. Allied designs and manufactures a complete line of state-of-the-art sectioning, mounting, milling, grinding & polishing equipment in our California and Oklahoma facilities. Allied's equipment is built in-house to specifications that deliver maximum performance and dependability.

MECHANICAL SAMPLE PREPARATION SOLUTIONS

Mechanical Milling/Grinding/Polishing

X-PREP®

Useful for:

Most everything

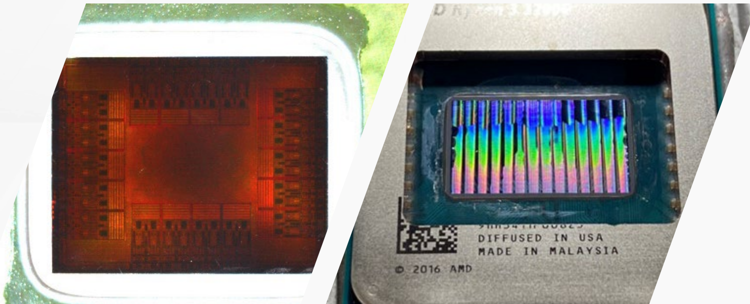
High Precision

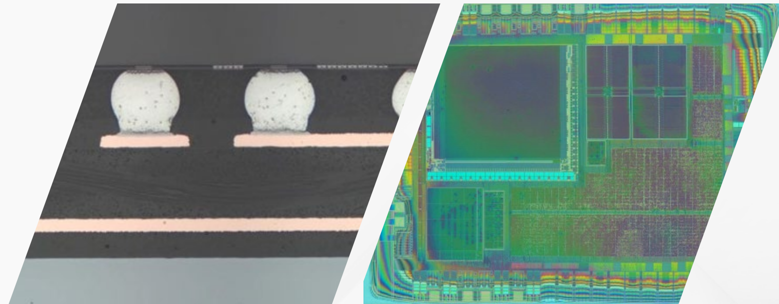
MULTIPREP™

Useful for:

Parallel Delayering

Cross-sectioning





MECHANICAL SAMPLE PREPARATION SOLUTIONS

Mechanical Milling/Grinding/Polishing

TECHCUT 5X™

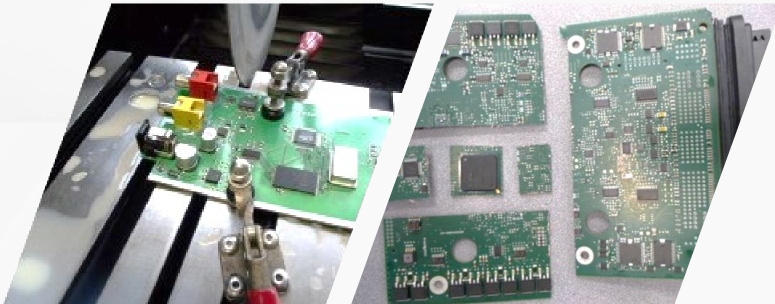
Useful For:

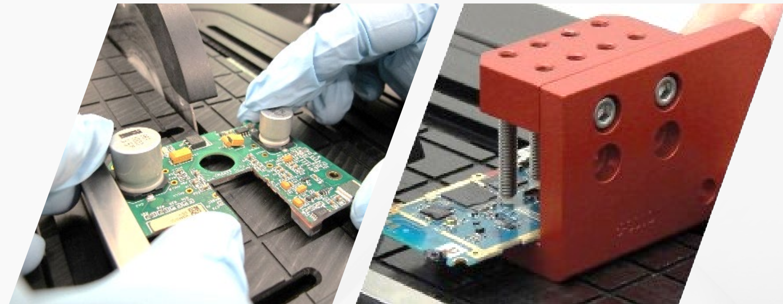
Semi-automated high precision cutting/dicing

TRIMSAW 2X™

Useful for:

Manual trimming/component extraction





REVERSE ENGINEERING

- Reverse engineering of semiconductor-based systems is not new/novel and a categorically has been well documented [1] :
  - Product teardowns – identify the product, package, internal boards, and components
  - System/Component level analysis – analyze operations, signal paths, and interconnections
  - Circuit extraction – delayer to transistor level, then extract interconnections and components to create schematics
  - Process analysis – examine the structure and materials to see how it is manufactured

➢ BUT WHAT TOOLSET SHOULD BE USED?

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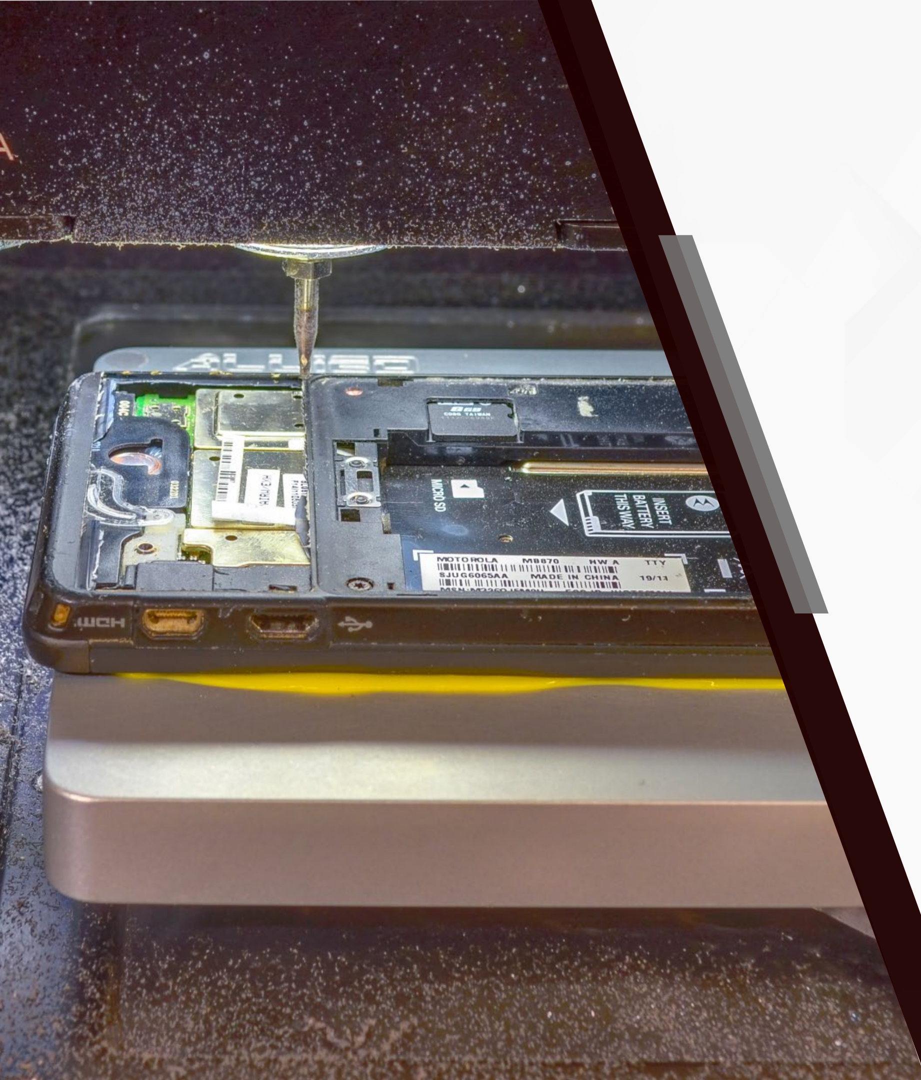
[1] R. Torrance, D. James; Reverse Engineering in the Semiconductor Industry; IEEE CICC, 2007



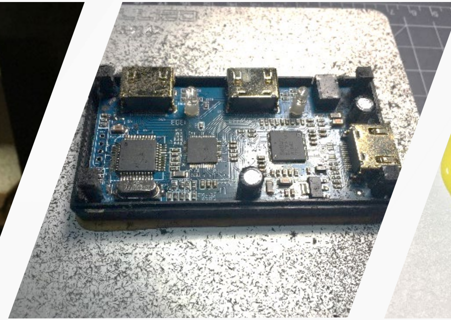
PRODUCT TEARDOWNS

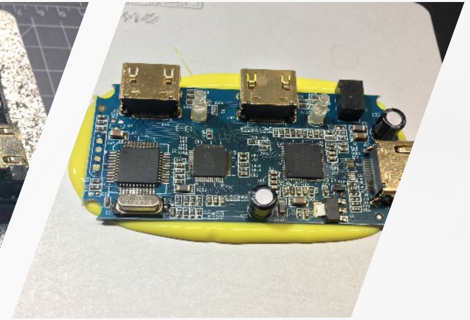
- ➢ Product teardowns can be simple, provided the system boards/ components are easy to access.
  - ❑ Toolsets might consist of the following:
    - o Screwdrivers
    - o Tweezers
    - o Scalpel/Razor blades
- ➢ Once exposed the boards and subassemblies can be photographed.

➢ WHAT IF PACKAGE CANNOT "BROKEN INTO" WITHOUT RISK OF BRUTE FORCE DAMAGE?

PRODUCT TEARDOWNS

Sometimes the package is not easily opened. → Toolset X-Prep





"BREAKING IN"

Mounting the part and leveling to make sure milling tool is perpendicular to cutting plane.

REDUCE RISK OF THERMAL DAMAGE

Matching the milling tool to the material being removed will allow for dry cutting without increased temperature risk.

PRECISION REMOVAL

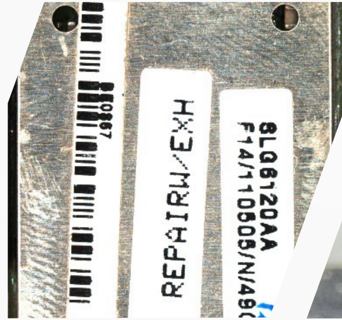
External package removed, board/component can be extracted.

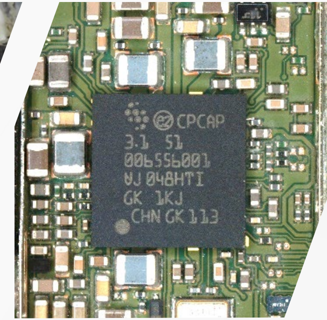
PHOTO DOCUMENTATION

Board removed and remounted for additional analysis/selective deconstruction.

PRODUCT TEARDOWNS

Carefully deconstruct the device to expose all components → Toolset X-Prep





SELECTIVE AREA DECONSTRUCTION

Utilizing a CNC based machine the sample is mounted for selective deconstruction.

REMOVAL OF SHIELDING

Record part/component markings, even include non specific labels.

PRECISION REMOVAL

End mill used to remove the shield (dry cut) while still preserving all circuitry/components under shield.

PHOTO DOCUMENTATION

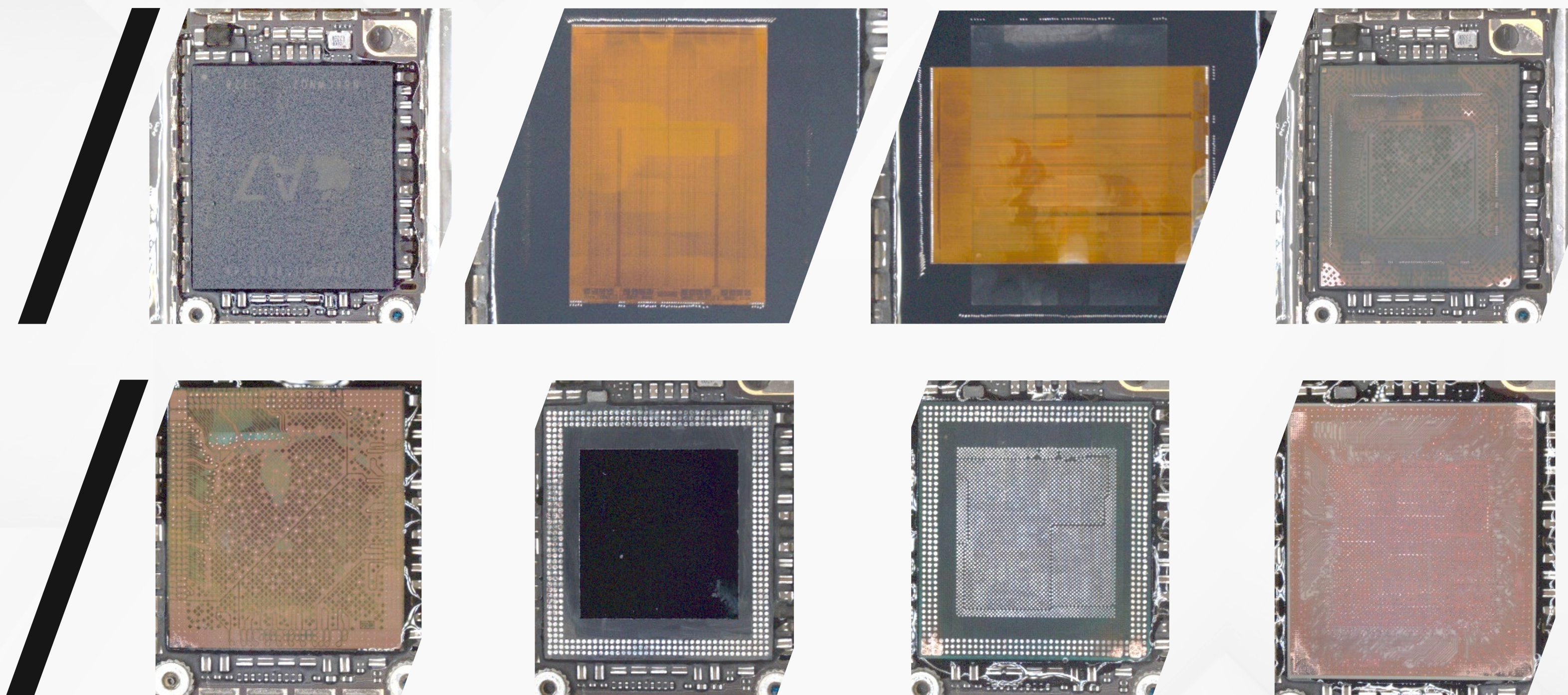
After shield is removed and device cleaned-up photo documentation can resume.

SYSTEM/COMPONENT LEVEL ANALYSIS

- Reverse engineering whether system level or component level is hierarchical analysis method.
  - Photo documentation and electrical analysis must be considered when selectively deconstructing.
  - Layer-by-layer analysis requires precision techniques and is not for the feint of heart.
  - Knowledge of the component is critical when deconstructing
    - Assistance of X-Ray and/or device cross-section is helpful

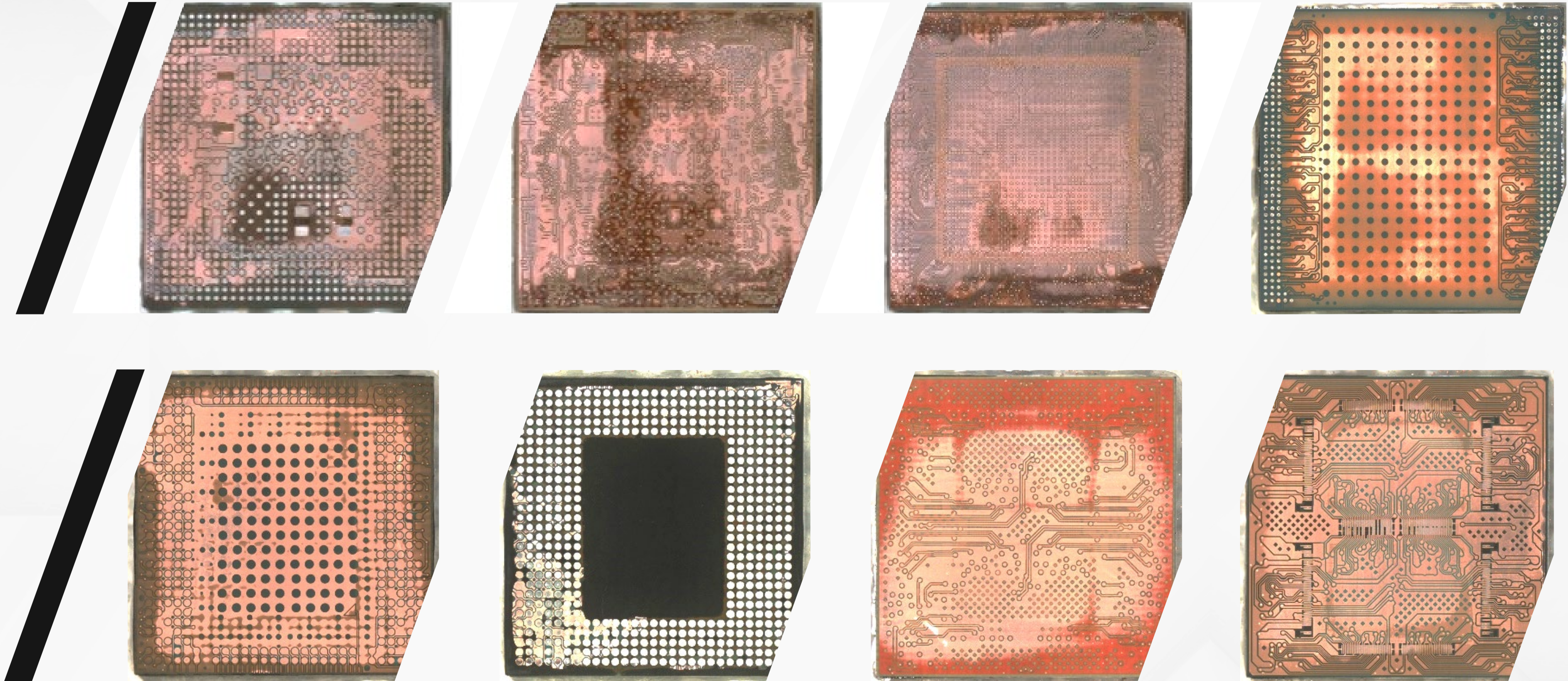
SYSTEM/COMPONENT LEVEL ANALYSIS

Component level deconstruction (not all layers shown) → Toolset X-Prep



SYSTEM/COMPONENT LEVEL ANALYSIS

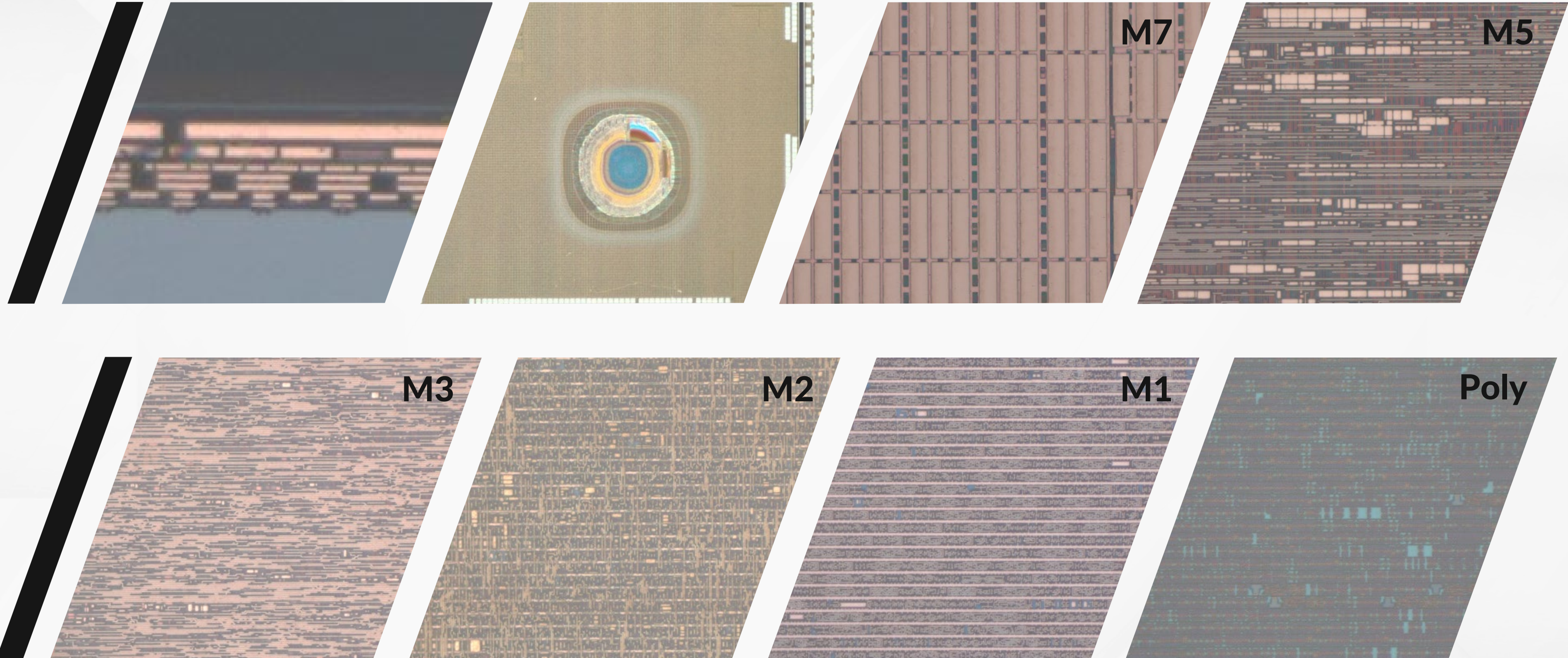
PCB Layer-by-Layer Analysis → Toolset X-Prep



- Circuit extraction can be the most challenging as it might require a combination of methods such as mechanical polishing, plasma (dry) etching and wet etching.
- It is additionally complicated by technology size, metallization (Cu/Al and combinations), circuitry density, number of layers, etc.
  - Cross-sections can be helpful in obtaining this information.
- The challenge, should you choose to accept it, is edge-to-edge uniform deprocessing to allow for:
  - Imaging
  - Annotation
  - Schematic read-back
  - Analysis

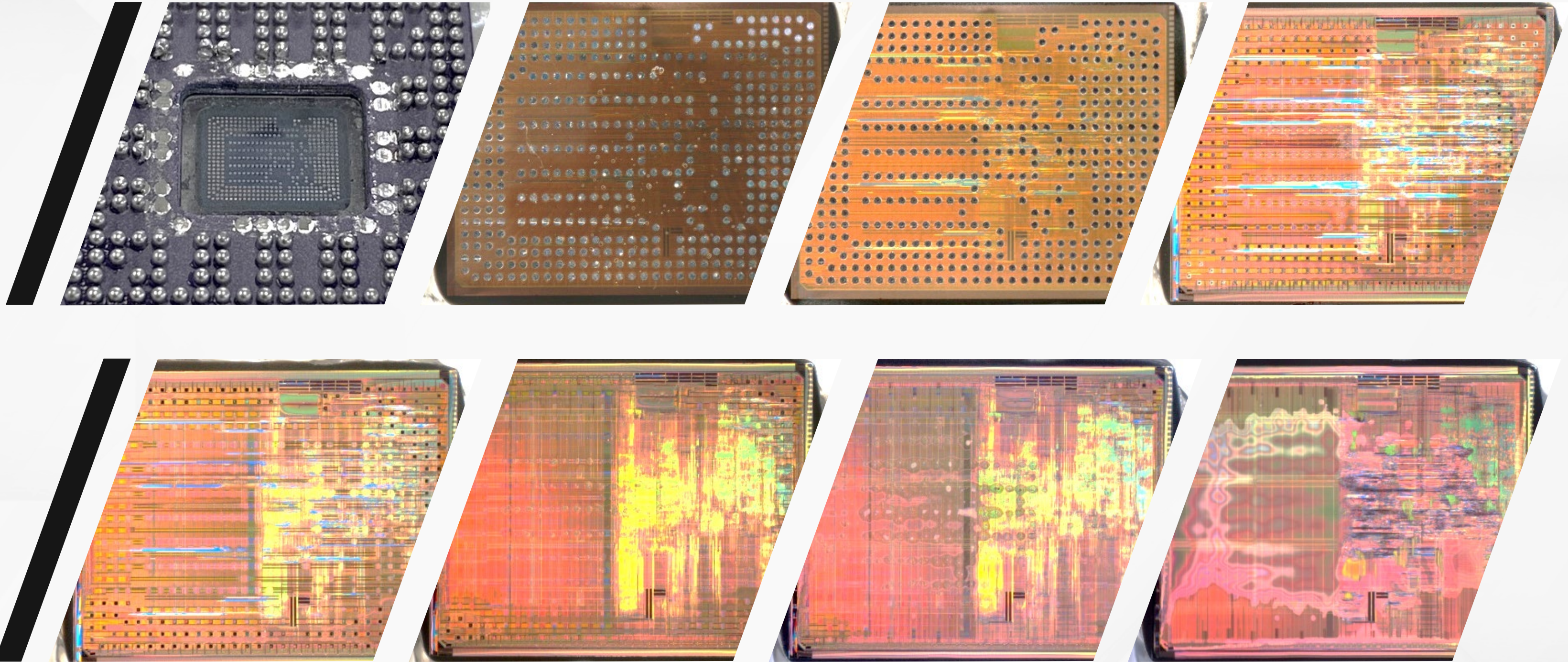
CIRCUIT EXTRACTION

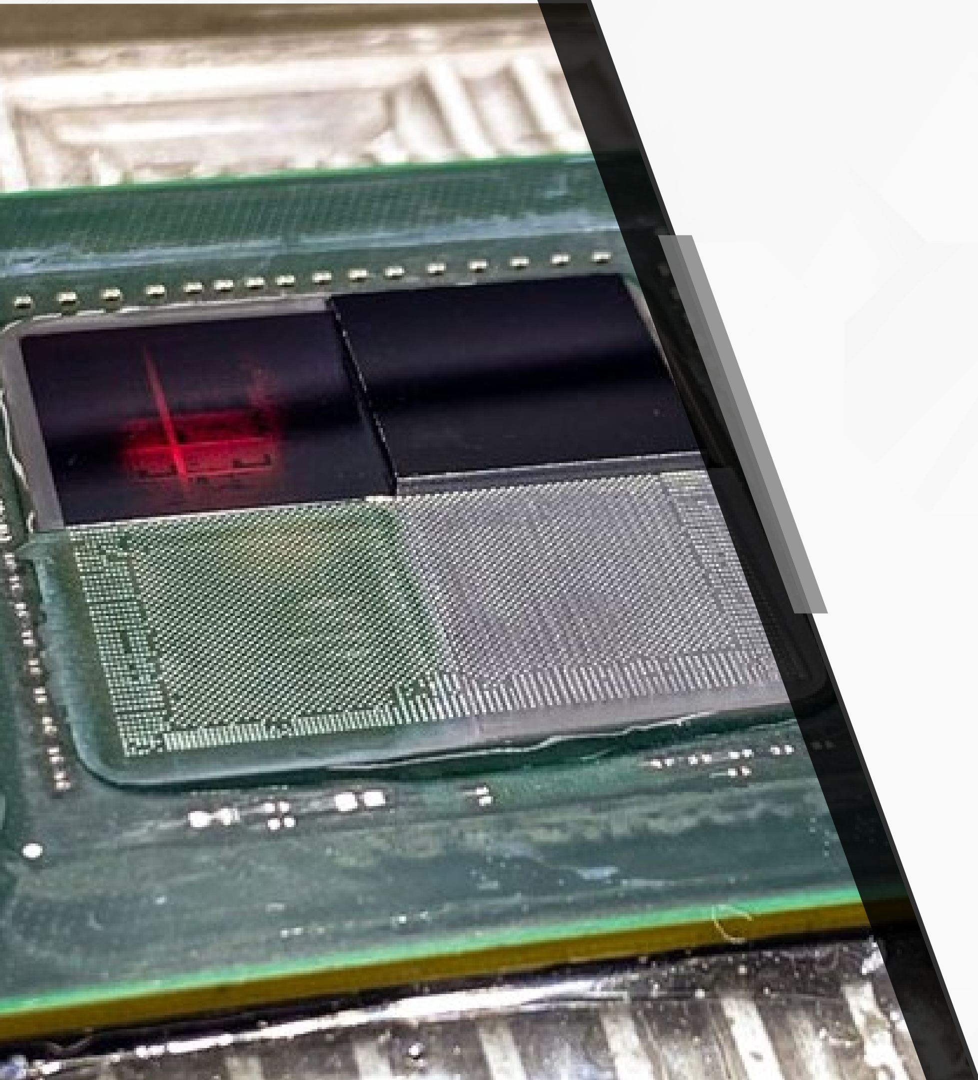
Area specific 2 mm x 2 mm region → Toolset X-Prep



CIRCUIT EXTRACTION

Edge-to-Edge extracted from ceramic package – Top 3 thick metal layers removed → Toolset X-Prep → Once extracted, Toolset MultiPrep



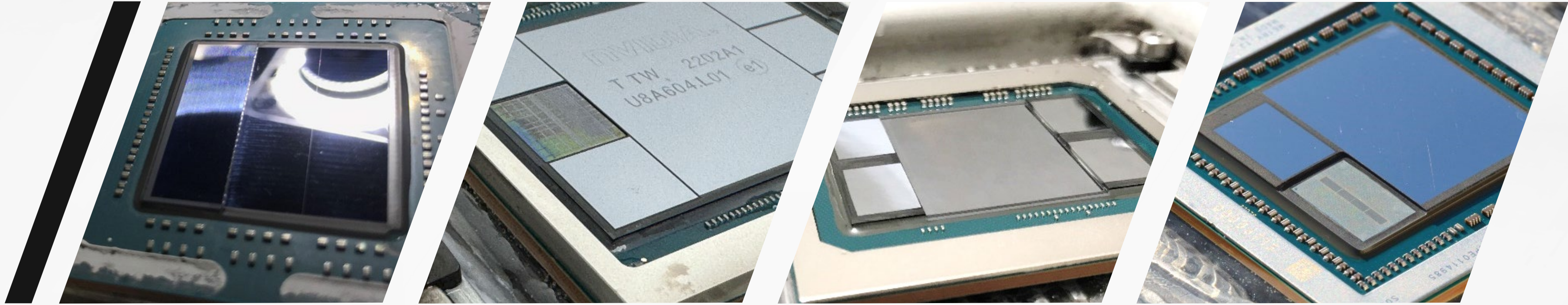


PROCESS ANALYSIS

- Process analysis of chips can entail a deep dive into a specific area of a chip which requires specific/precise deconstruction.
- Advanced packaging technology and heterogeneous packaging present different challenges when trying to keep the device electrically intact.

PROCESS ANALYSIS

Complex Heterogeneous packages may require different devices be analyzed. → Toolset X-Prep



HETEROGENEOUS PACKAGES

Removing top two of three memory chips in a stacked configuration

REMOVING SILICON TO EXPOSE CIRCUIT

Targeted thinning and polishing, just removed a silicon

THINNING TO SUB 5 MICRON

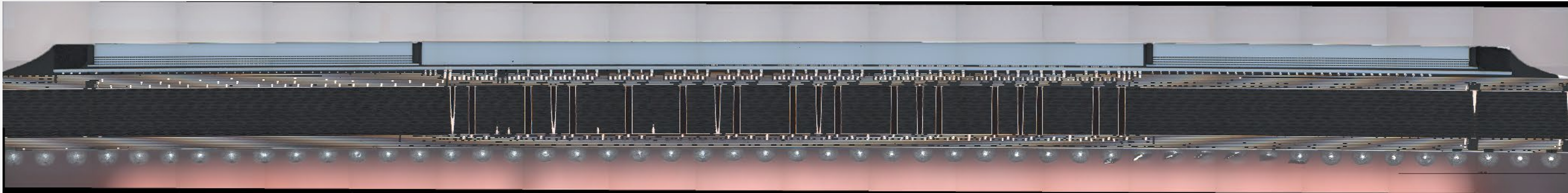
SOC thinned between HMB structures to allow for biased analysis

INTERPOSER INSPECTION

Top HBM removed to expose interposer between die

PROCESS ANALYSIS

Cross-sectioning of large device is best done mechanically – High Resolution auto stitched → Toolset MultiPrep



ADDITIONAL EXAMPLES

- Reverse engineering isn't always global, sometimes it can be very specific to a region
- Additional examples –Time Permitting

ADDITIONAL EXAMPLES

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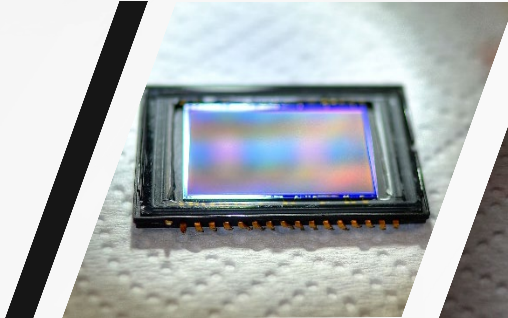
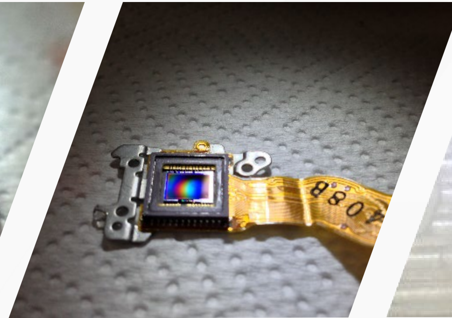
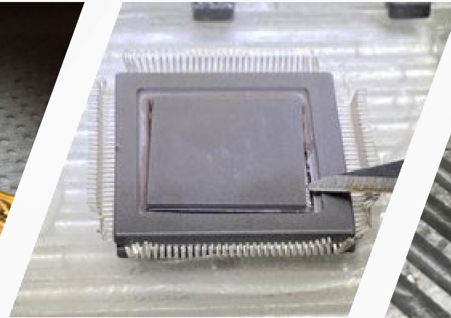
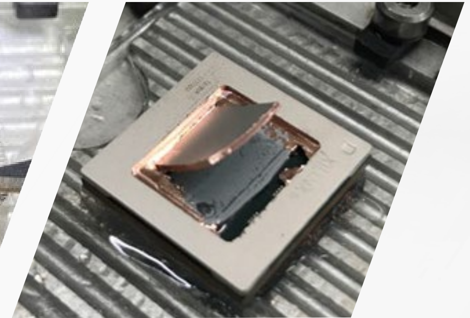








SENSORS

Removing the glass cover, without damage to the device

SENSOR ON FELX

Removing the glass cover, without damage to the device

CERAMIC

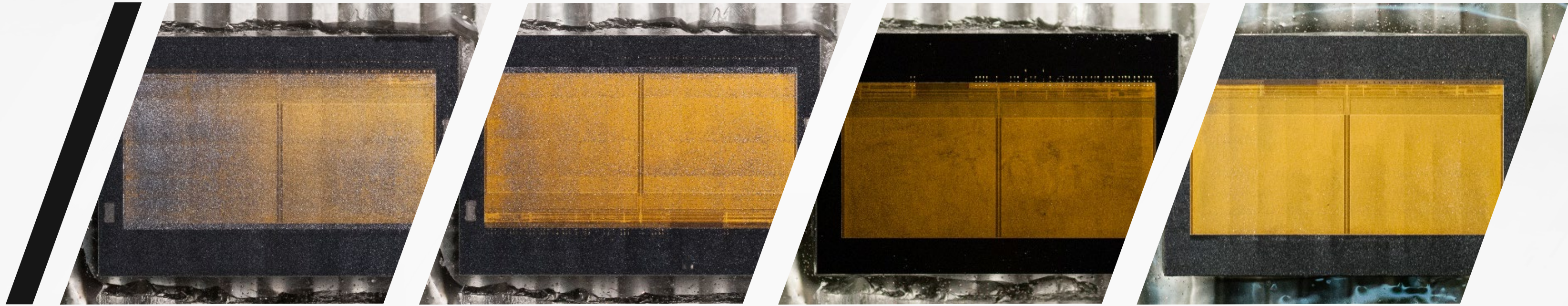
Removing ceramic lid without flooding cavity or damaging bondwires.

HEAT SPREADER

Easily Remove heat spreader leaving bulk of deice at full package thickness

ADDITIONAL EXAMPLES

Stacked Memory Die (8 devices)→ Toolset X-Prep

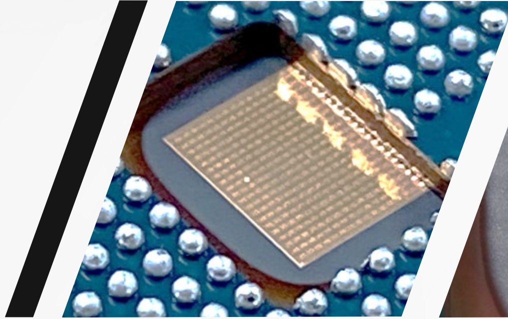


TOP DIE　　DIE 2　　DIE 3　　DIE 4

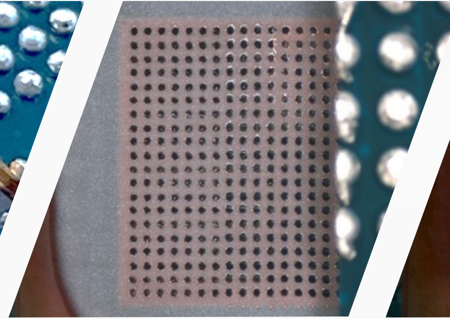
Die were removed in order to expose the 4th die in the stack. Stopping just above Die 4 DAF that can be removed chemically or with atmospheric plasma

ADDITIONAL EXAMPLES

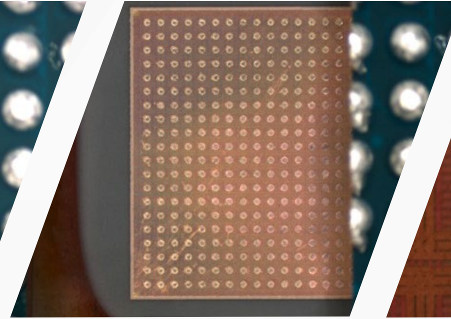
Selective exposure of Cu Pillars 6 mm x 4 mm window → Toolset X-Prep



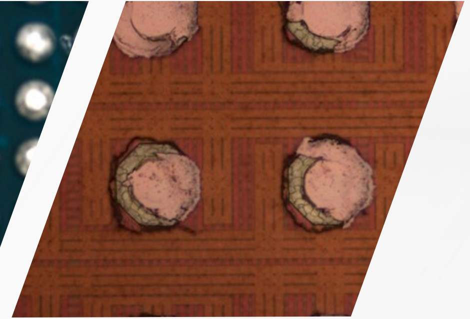
FINISHED DEVICE



APPROACHING DIE SURFACE



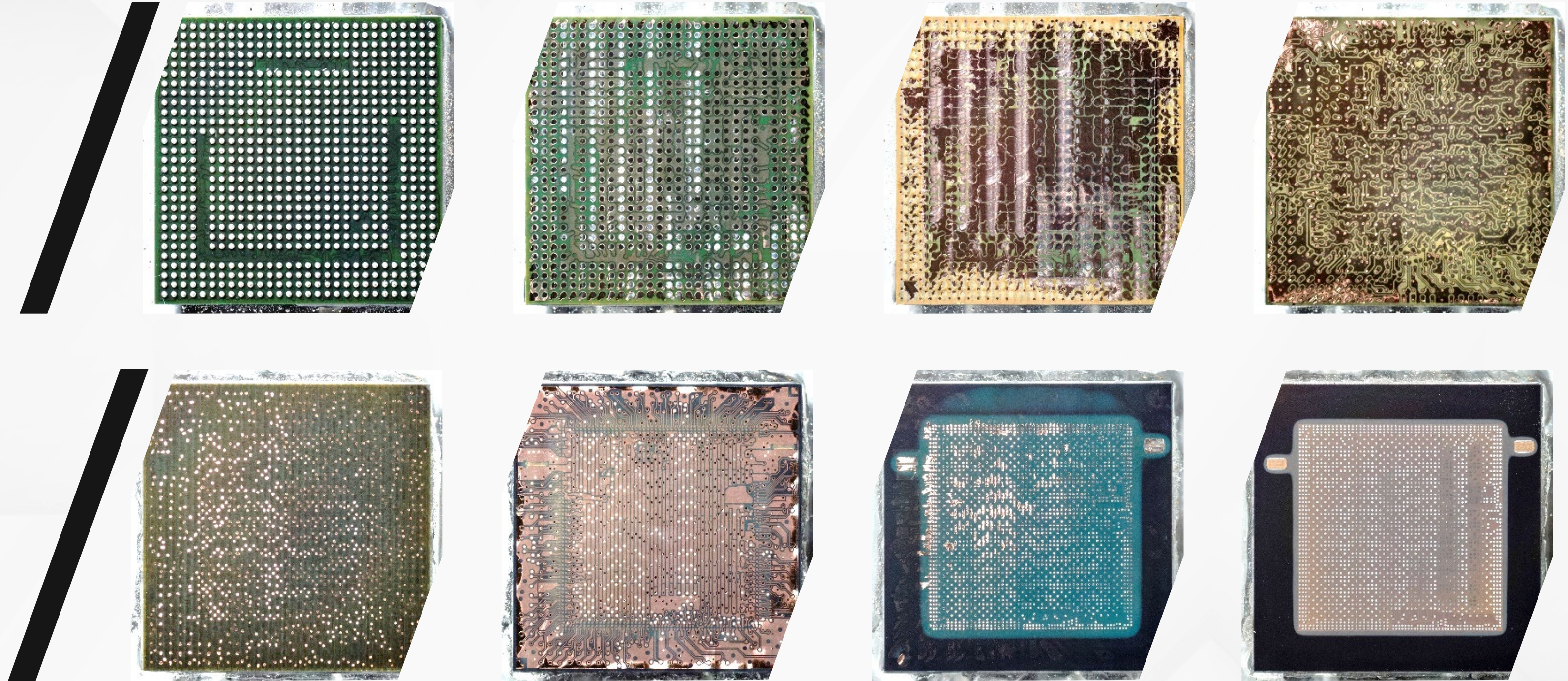
5 MICRONS



500X IMAGE

ADDITIONAL EXAMPLES

PCB Layer-by-Layer Analysis → Toolset X-Prep



THANK YOU

QUESTIONS?

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