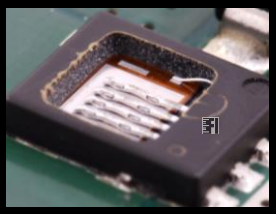
ELECTRONIC FAILURE INVESTIGATION

COUNTERING COUNTERFEITING IN THE ELECTRONICS INDUSTRY

Examples from a specialized Counterfeit Analysis Lab

Tamás Hurtony, PhD

www.efi-labs.com



EFI-LABS HISTORY

- 2003: founded at Budapest University of Technology and Economics, Department of Electronics Technology (BME-ETT)
- 2010: EFI-labs branding (BME university spin-off)
- 2015: over 1.500 projects per year
  - clients: failure analysis and process validation partner for the largest automotive electronics companies in Hungary
- 2018: accredited spin-off lab for Technical Cleanliness (particle-control.com)
- 2023: completion of accreditation of EFI-labs core activities

EFI-LABS FACTS

- Leading Failure Analysis and Process Validation lab for the automotive electronic companies in Hungary
  - Customers from India to Mexico
- 2000+ projects per year
- 22 full time employees
  - 10 MScs in electrical engineering, material science and physics, specialized in production
  - 2 PhDs related to electronic production technologies and analysis
  - Contribution in ESA space related projects

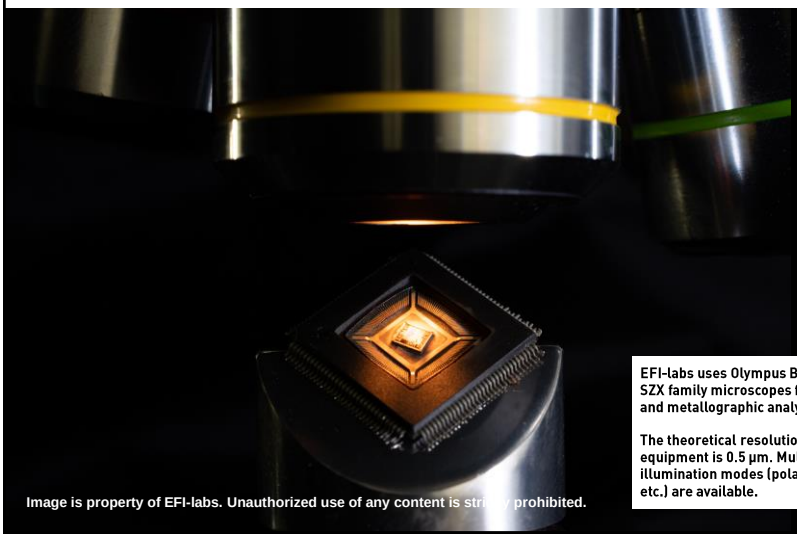
GLOBAL CHIP SHORTAGE

- Global
  - All market segments are involved
  - Every corner in the world
  - Acting against the problem needs cooperation
- Major causes
  - General cyclic nature of the demand-supply balance
  - Pandemic → forced shutdowns → disturbance in the supply chains (eg. raw material shortage, transportation issues)
  - Accumulation of resources, etc.
- Appearance of alternative sources
  - Genuine, but old batches
  - Unverifiable sources
  - **Counterfeiting**

REQUIREMENTS OF CF. ANALYSIS

- **Not only obsolete components are involved:**
  - Counterfeit analysis has a long history, but previously it was initiated in the case of obsolete components.
  - Any active or passive components could be involved
- **Short processing time:**
  - Hard to find components on the market, but the demand is huge, production is waiting
- **Huge number of analyses have to be carried out:**
  - Required quantities can only be provided from multiple source → repetitive and comparative analyses.

OPTICAL MICROSCOPY



EFI-labs uses Olympus BX family and SZX family microscopes for the optical and metallographic analysis.

The theoretical resolution of the equipment is 0.5 µm. Multiple illumination modes (polarization, DIC, UV etc.) are available.

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OPTICAL MICROSCOPY

Package analysis

- Dimensional analysis
- Labeling technology and font types
- Imprint verification
- Package dimensions
- Inspection of contaminations on the surface of the package or leads
- Signs of external mechanical damage

Genuine

Counterfeit

Top and bottom planes are parallel as expected.

The original labels had been likely ground off: the component height is lower, the top and bottom planes are not parallel Package is contaminated.

OPTICAL MICROSCOPY

Package analysis

- Labeling technology and font types
- Imprint verification
- Package dimensions
- Inspection of contaminations on the surface of the package or leads
- Signs of external mechanical exposure

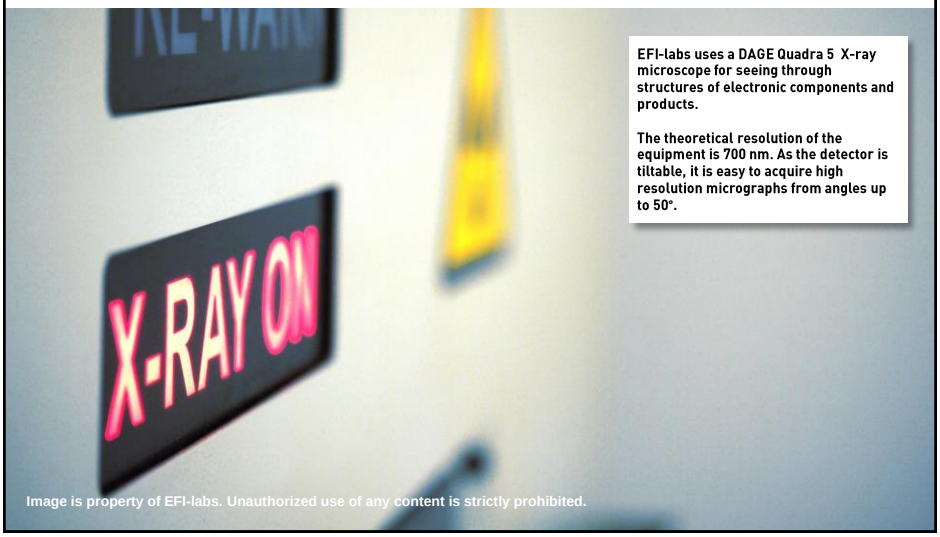
Genuine

Counterfeit

The surface finish layer is even and not contaminated.

The shape of the drain flag is different. The reflective properties of the surface finishes are also different.

X-RAY MICROSCOPY



EFI-labs uses a DAGE Quadra 5 X-ray microscope for seeing through structures of electronic components and products.

The theoretical resolution of the equipment is 700 nm. As the detector is tiltable, it is easy to acquire high resolution micrographs from angles up to 50°.

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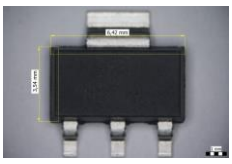
X-RAY MICROSCOPY

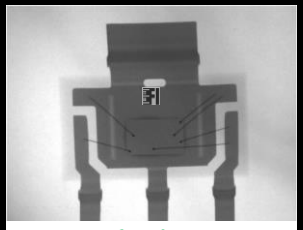


Analysis of internal structures

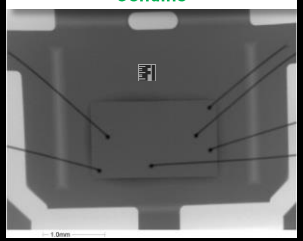
- Shape of the die paddle
- Integrity and trajectory of microwires
- Inspection of die attach
- Size and orientation of chip
- etc.

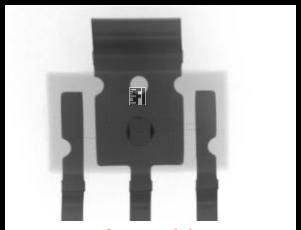
Example on voltage regulator IC:

- *different die paddle and chip size*
- *different microwires*

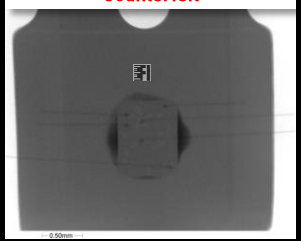


Genuine

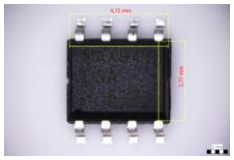




Counterfeit



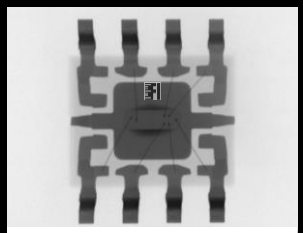
EXAMPLE 4
X-RAY MICROSCOPY



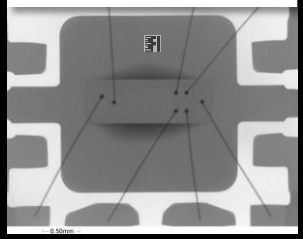
Analysis of internal structures

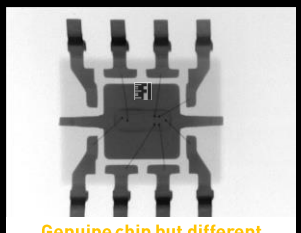
Example on Single-Supply Comparator IC:

- ***Same chip size***
- ***Same microwires (gold)***
- ***Different die paddle/lead frame***
- ***Might have been packaged in different production plant and/or at another time***

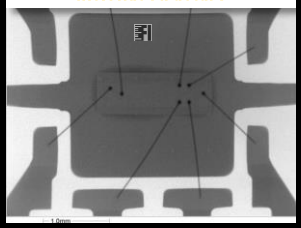


Genuine

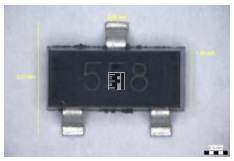




Genuine chip but different internal structure



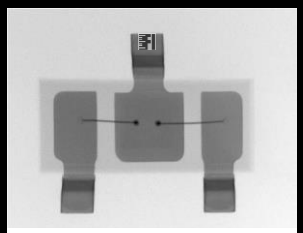
X-RAY MICROSCOPY



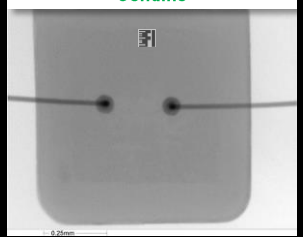
Analysis of internal structures

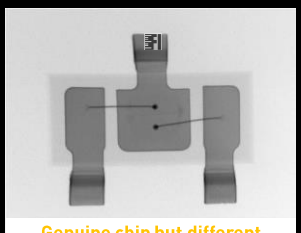
Example on Single-Supply Comparator IC:

- ***Same die paddle***
- ***Same chip size***
- ***Different chip orientation***
- ***Might have been packaged in different production plant and/or at another time***

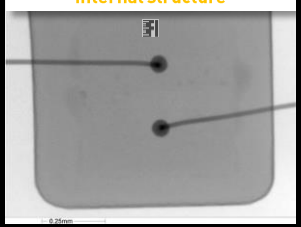


Genuine





Genuine chip but different internal structure



CROSS-SECTIONING

EFI-labs prepares dozens of cross-sections every day for many segments of the electronics industry.

EFI-labs uses embedding, grinding and polishing materials from many suppliers in order to research and optimize the cross-sectioning process.

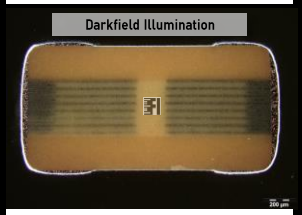
CROSS-SECTIONING

Analysis of internal structures

- *Shape of the cross-sectioned component.*
- *Geometry of internal layer structure.*
- *Color of ceramic body*

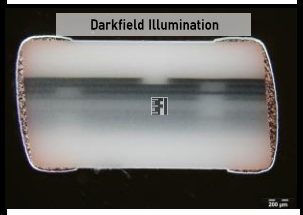
Example on MLCC component
- *Different color of ceramic*
- *Distorted cross-sectional area*

Genuine



Specific electrodes structure and ceramic type

Counterfeit



The electrodes structure and ceramic material are different

SCANNING ELECTRON MICROSCOPE (SEM)

EFI-labs is equipped with a FEI Inspect S50 scanning electron microscope.

This is a versatile equipment with high magnification, high depth-of-field and precise measuring capabilities.

Even though a magnification of 100 000 X can easily be achieved, a maximum of 10 000 X is usually sufficient for the analyses of electronic products. When required small features can be analyzed down to 10 nm.

The maximum sample size is approximately 50X50X20 mm. Non-conductive samples can be coated on site with a thin gold or carbon layer. Additionally a low vacuum mode is available to further reduce the charging of the specimen. Samples must withstand low pressure.

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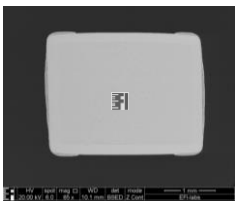
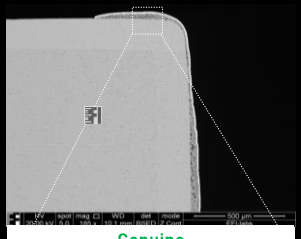
SEM ANALYSIS

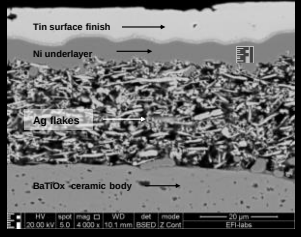


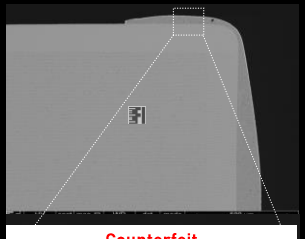
Analysis of terminal cap metallization structure

- *Evaluation of the terminal layer structure.*
- *Soft-terminated components have a flexible internal layer in the layer structure of the terminal metallization.*

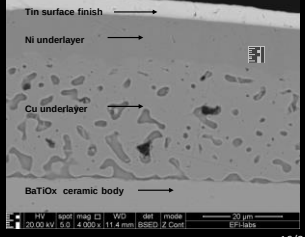


Genuine

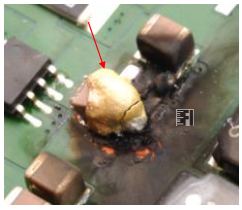




Counterfeit



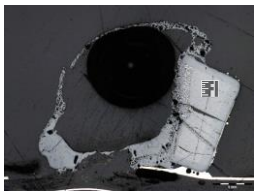
CONSEQUENCES

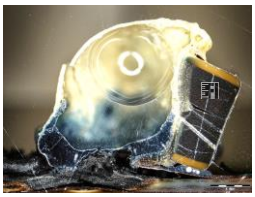


Field failure due to counterfeiting

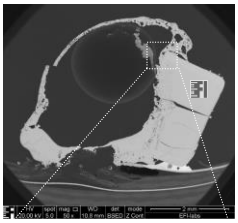
- *Not soft- terminated components instead of soft-terminated → flex crack*
- *Internal short of electrodes caused arcing*
- *Excessive heat caused significant thermal damage.*

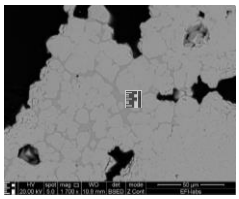
Optical microscopic images of cross-sectioned MLCC component



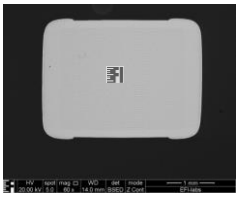


SEM micrographs of MLCC component (BSED images → Z contrast)





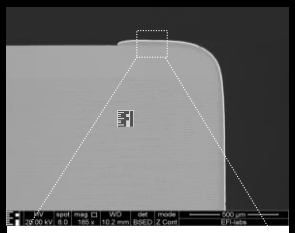
SEM ANALYSIS



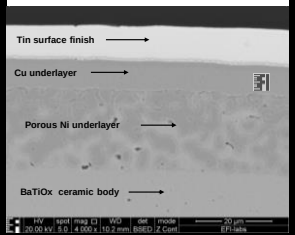
Analysis of terminal cap metallization structure

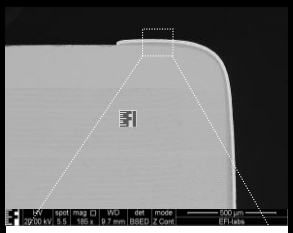
- *Detection of multiplated terminal layer structure:*

(In the case of MLCC components when the original surface finish layer becomes unsolderable a common method is to deposit an additional solderable layer on top of the original.)

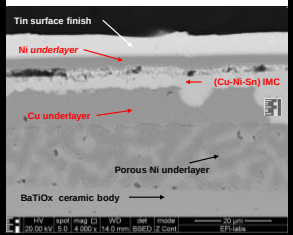


Genuine

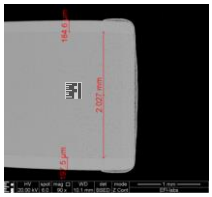




Counterfeit



SEM ANALYSIS



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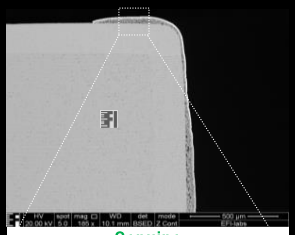
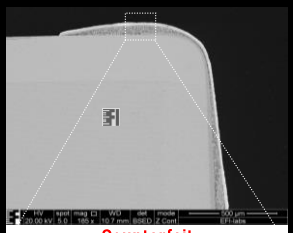
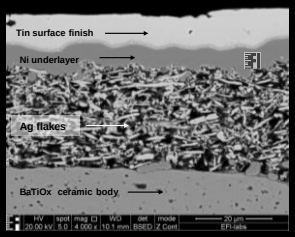
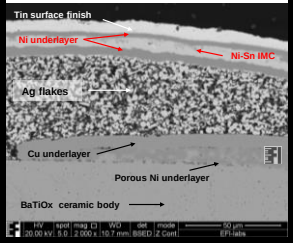


Genuine

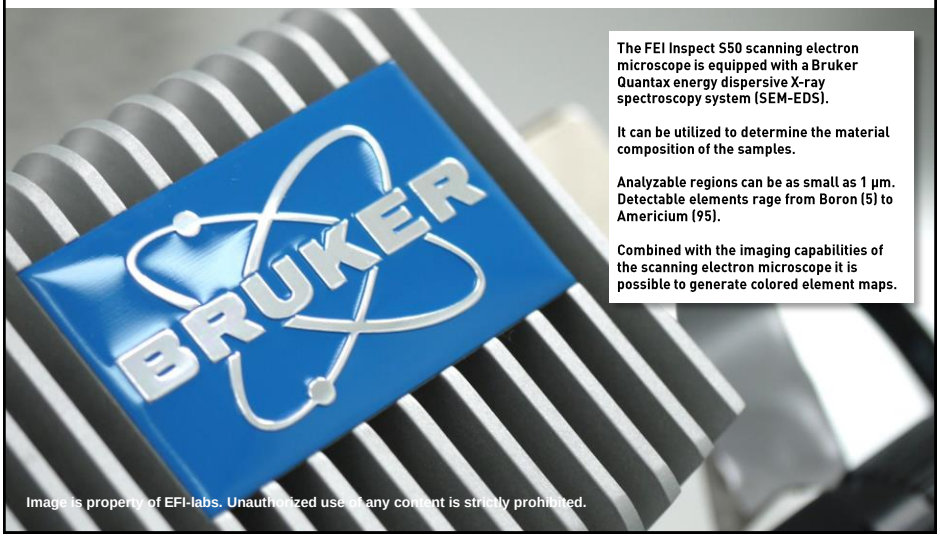


Counterfeit





SEM-EDS COMPOSITION ANALYSIS



The FEI Inspect S50 scanning electron microscope is equipped with a Bruker Quantax energy dispersive X-ray spectroscopy system (SEM-EDS).

It can be utilized to determine the material composition of the samples.

Analyzable regions can be as small as 1 µm. Detectable elements rage from Boron (5) to Americium (95).

Combined with the imaging capabilities of the scanning electron microscope it is possible to generate colored element maps.

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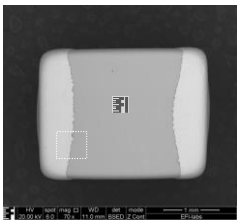
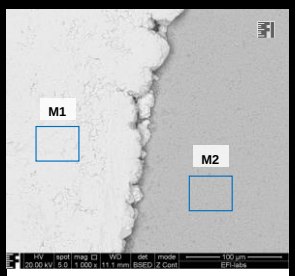
SEM ANALYSIS



Analysis of component body:

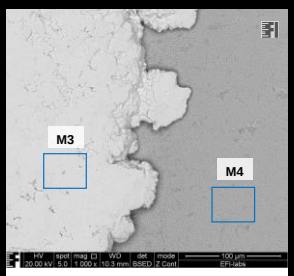
- *The material composition of the structures are measured with SEM-EDS*
- *The difference in the composition of any subsystem might be an indicator*
- *Typically the ceramic bodies are different.*



Genuine

M1 (terminal)		
Element	Wt %	At %
Sn	100.00	100.00
Sum:	100.00	100.00

M2 (Body)		
Element	Wt %	At %
O	21.47	56.84
Dy	3.25	0.85
Al	0.34	0.54
Ti	32.33	28.60
Sn	0.92	0.33
Ba	41.69	12.85
Sum:	100.00	100.00

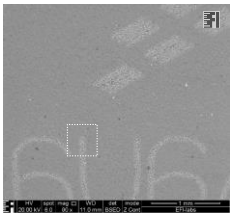


Counterfeit

M3 (terminal)		
Element	Wt %	At %
Ni	0.77	1.55
Sn	99.23	98.45
Sum:	100.00	100.00

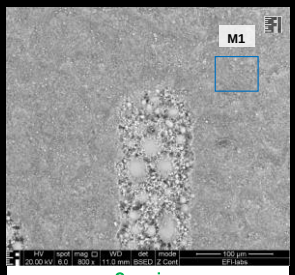
M4 (Body)		
Element	Wt %	At %
O	15.69	50.98
Ti	24.04	26.09
Sn	2.12	0.93
Ba	58.14	22.00
Sum:	100.00	100.00

SEM ANALYSIS



Analysis of component body

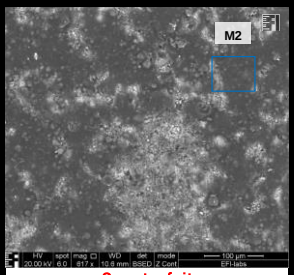
- *The material composition of the structures are measured with SEM-EDS*
- *Typically the packaging materials are different.*
- *Differences of the surface texture and the laser markings of the labeling.*



Genuine

M1 (Package)		
Element	Wt %	At %
C	33,71	45,34
O	37,98	38,35
Al	0,96	0,57
Si	27,35	15,73
Sum:	100,00	100,00

- The surface of the component package is relatively smooth
- The depth of the laser marks are uniform and even.
- Filler material is exposed and its composing element present in the spectrum (Al.Si)

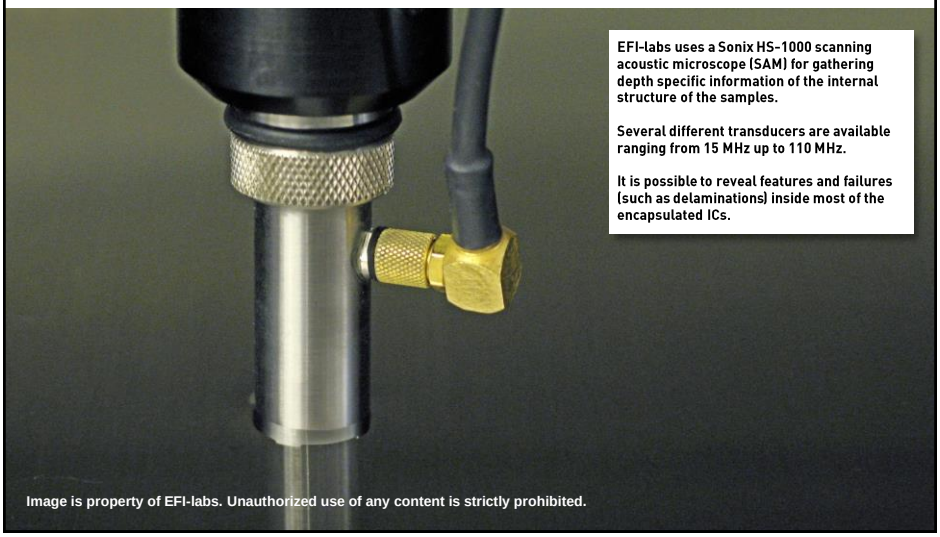


Counterfeit

M2 (Package)		
Element	Wt %	At %
C	71,59	80,07
O	17,53	14,72
Si	10,88	5,21
Sum:	100,00	100,00

- The surface of the component package is rougher
- The shallow laser marks
- Filler material is not exposed.
- Addional paint layer is visible

SCANNING ACOUSTIC MICROSCOPE (SAM)



EFI-labs uses a Sonix HS-1000 scanning acoustic microscope (SAM) for gathering depth specific information of the internal structure of the samples.

Several different transducers are available ranging from 15 MHz up to 110 MHz.

It is possible to reveal features and failures (such as delaminations) inside most of the encapsulated ICs.

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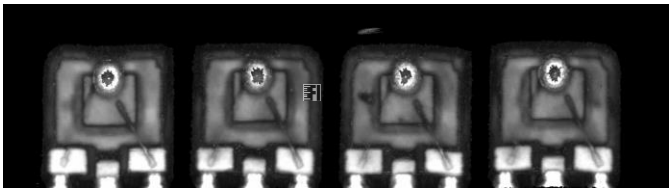
SAM ANALYSIS

Analysis of component body:

- *Non-destructive inspection of the internal structure.*
- *Delamination inside encapsulated IC.*

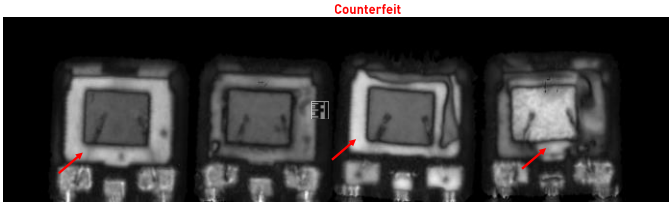
Genuine



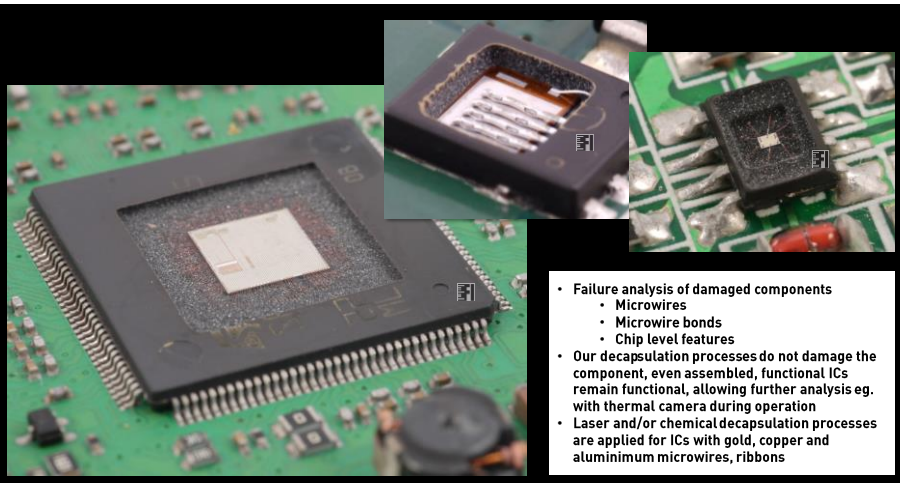
Example on MOSFET component:

- *Delamination was observed between the die paddle and the packaging material (marked by red arrows).*
- *The chip size is different*

Counterfeit



IC DECAPSULATION



- Failure analysis of damaged components
  - Microwires
  - Microwire bonds
  - Chip level features
- Our decapsulation processes do not damage the component, even assembled, functional ICs remain functional, allowing further analysis eg. with thermal camera during operation
- Laser and/or chemical decapsulation processes are applied for ICs with gold, copper and aluminimum microwires, ribbons

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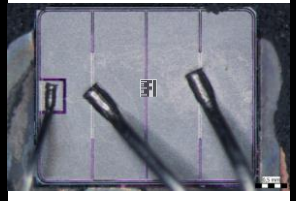
IC DECAPSULATION

Analysis of internal structure

- *The size and layout of the decapsulated IC is observed with SEM and/or optical microscopes.*
- *Imprints on the chip are located and compared.*

Genuine

Counterfeit



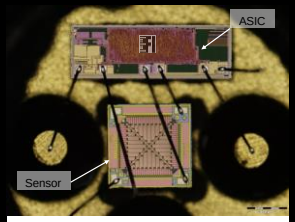
Silicon chip of the reference component

Different Silicon chip and different microwires

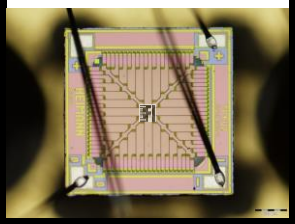
IC DECAPSULATION

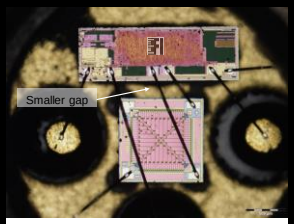
Analysis of internal structure

- *The ASIC and the sensor components are slightly closer to each other, but both components are considered Genuine*

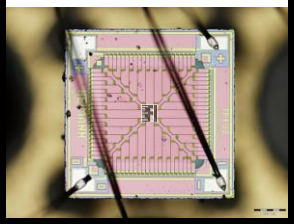


Genuine (reference)





Genuine (from Broker)



DEVICE SURFACE TEST

Device surface tests in accordance with IDEA-STB-1010:

- **Device marking test**
- **Device surface**
- **Scrape test**

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SCRAPE TEST

Analysis of component package

- *Scraping the top side of the component package*
- *If the surface starts to flake the component may fail the test.*
- *If the component was counterfeited by molding an additional layer of packaging material it likely to flake of during scrape test.*

MCU component

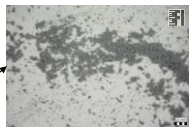
After scraping with scalpel

Genuine

Counterfeit

Evaluation of scrape test:

- *The flakes are rather small and lighter → PASSED*



- *The flakes are larger and darker in color or an underlaying labeling is revealed → FAILED*

Scraped plastic flakes

FT-IR COMPOSITION ANALYSIS

EFI-labs uses a Bruker TENSOR II FT-IR spectroscope equipped with diamond and Ge ATR accessories.

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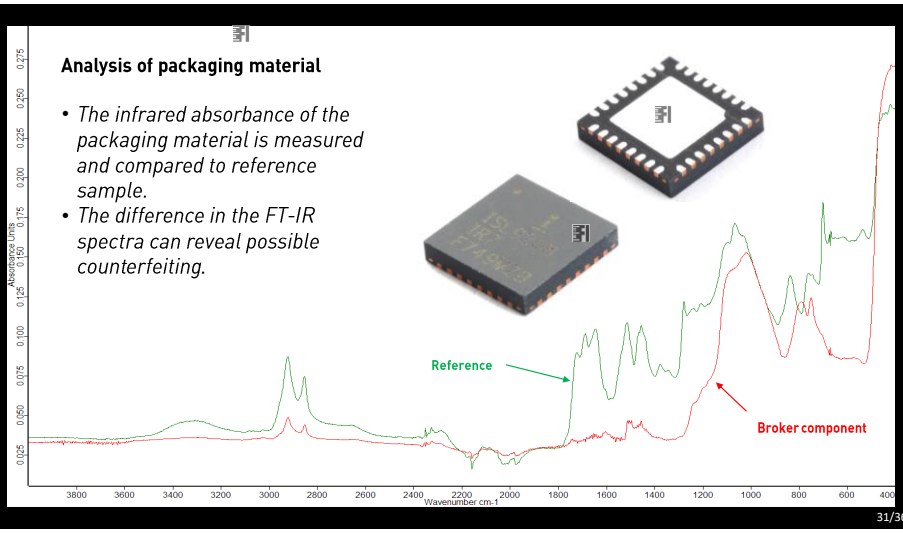
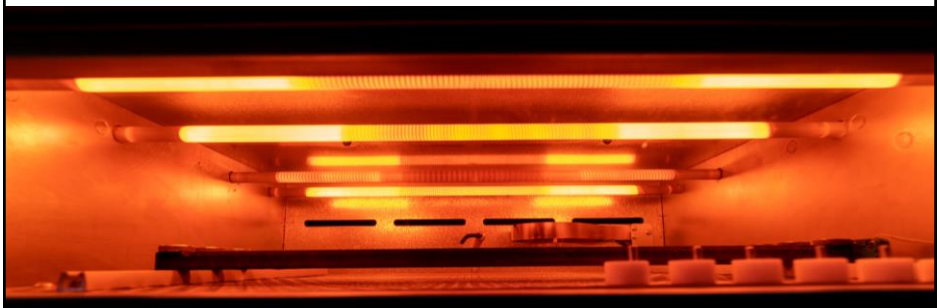
FT-IR ANALYSIS

Analysis of packaging material

- *The infrared absorbance of the packaging material is measured and compared to reference sample.*
- *The difference in the FT-IR spectra can reveal possible counterfeiting.*



SOLDERABILITY TEST



EFI-labs uses IR reflow oven/VPS for solderability tests with variable temperature profiles

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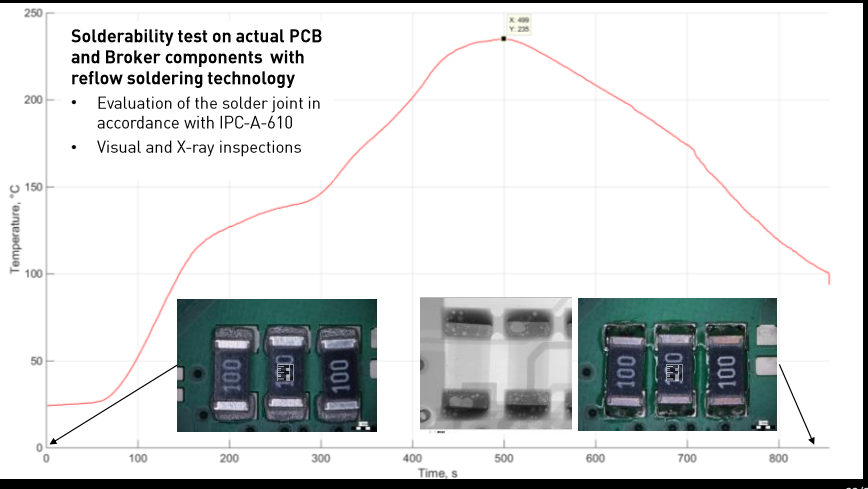
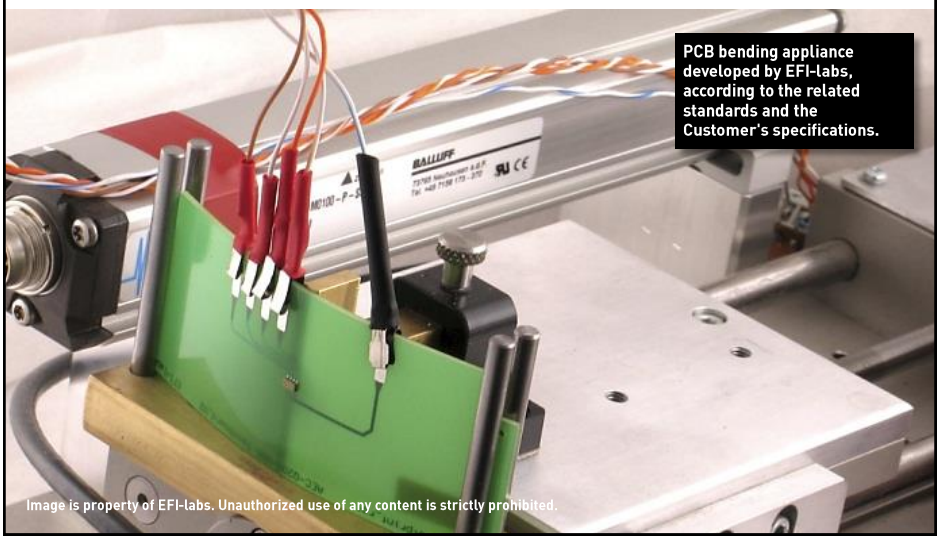
SOLDERABILITY TEST

Solderability test on actual PCB and Broker components with reflow soldering technology

- Evaluation of the solder joint in accordance with IPC-A-610
- Visual and X-ray inspections



CUSTOMER SPECIFIC TEST



PCB bending appliance developed by EFI-labs, according to the related standards and the Customer's specifications.

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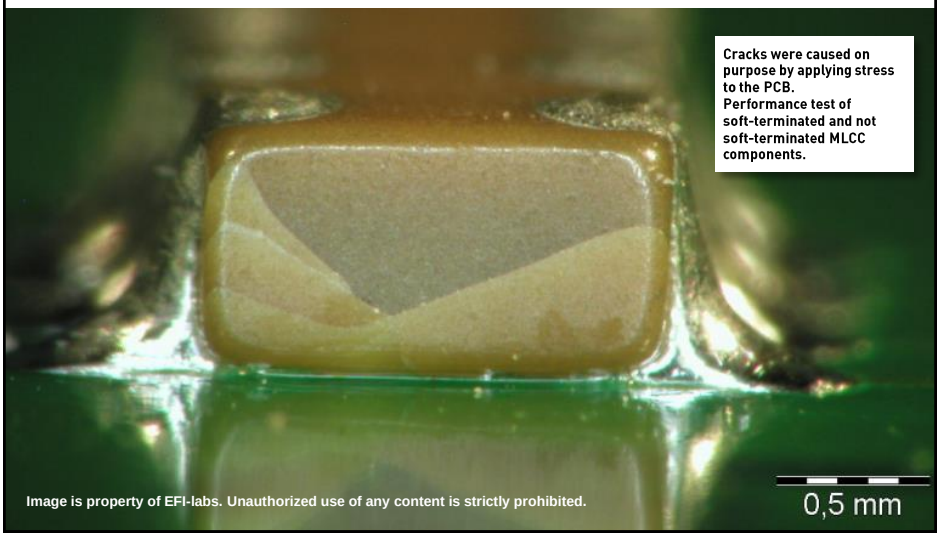
CUSTOMER SPECIFIC TEST



EFI-LABS CONTACT

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  - **tamas.hurtony@efi-labs.com**

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