ST-NXP Wireless

HAMAMATSU
THEMOS Mini Evaluation

Involved laboratories: CPG Agrate, RCCAL Rousset, Grenoble FA Lab

WMM, C&P Failure Analysis / GNB Failure Analysis Lab

EUFANET

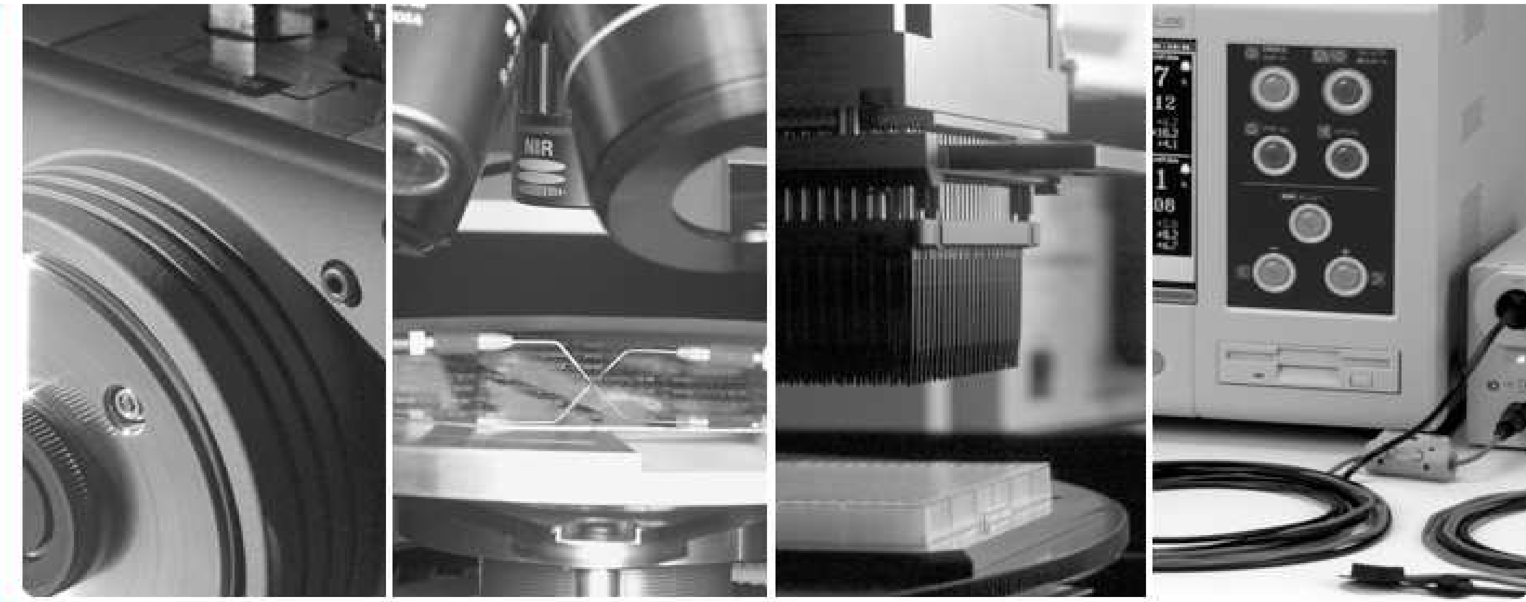
Optical Localization Techniques Workshop

26 & 27/01/09

Company Confidential / Jean Roux – Hamamatsu France

Outlines

- Introduction of thermal lockin
- Equipment short introduction
- Image Interpretation : Emissivity issue & Temperature calibration
- Casis studies on various processes , sample types and failures
- Summary : Thermal Imaging as a contribution to FA root cause extraction with EMMI and TLS.
- X ray & Thermal imaging combination.



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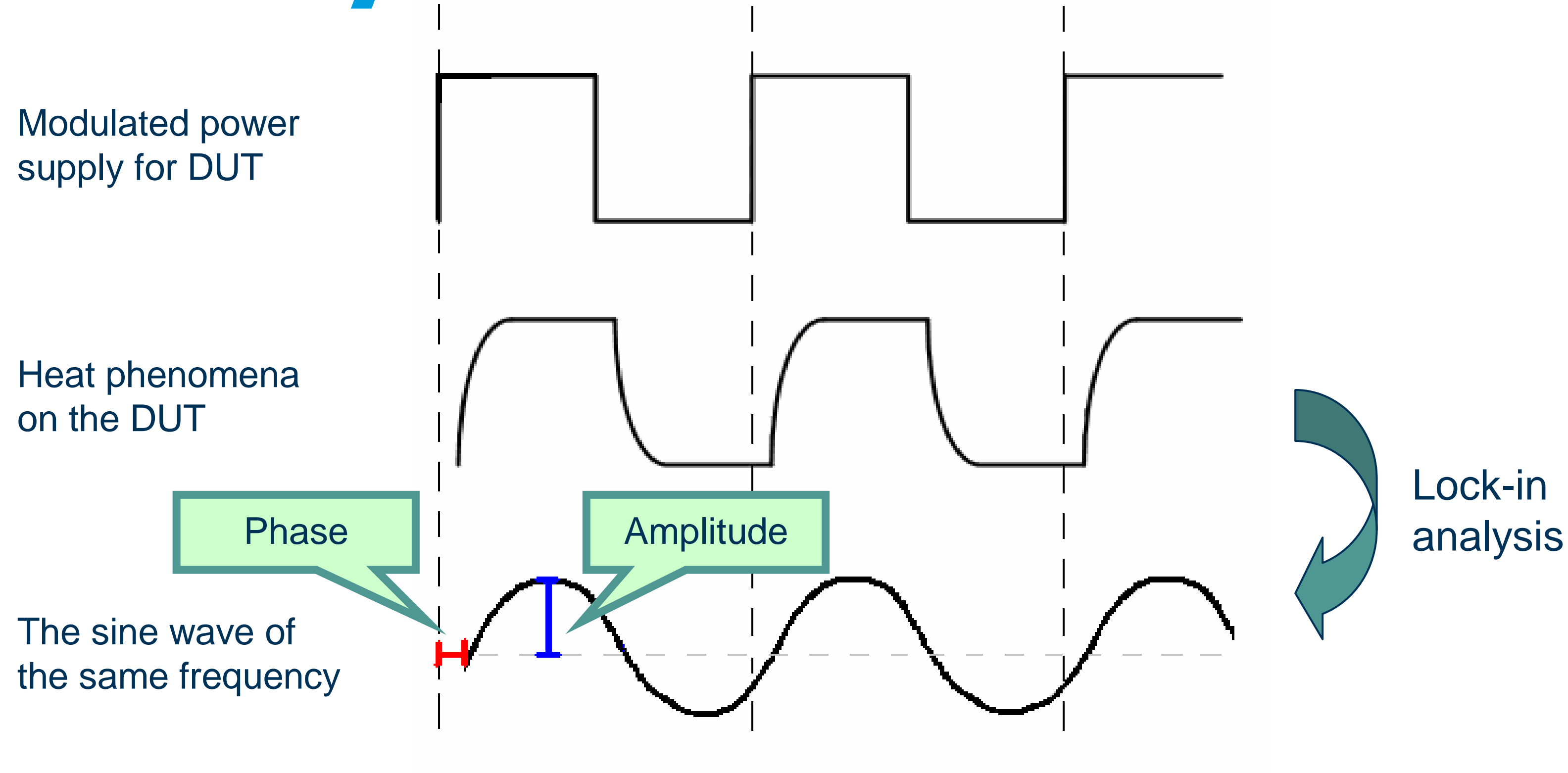
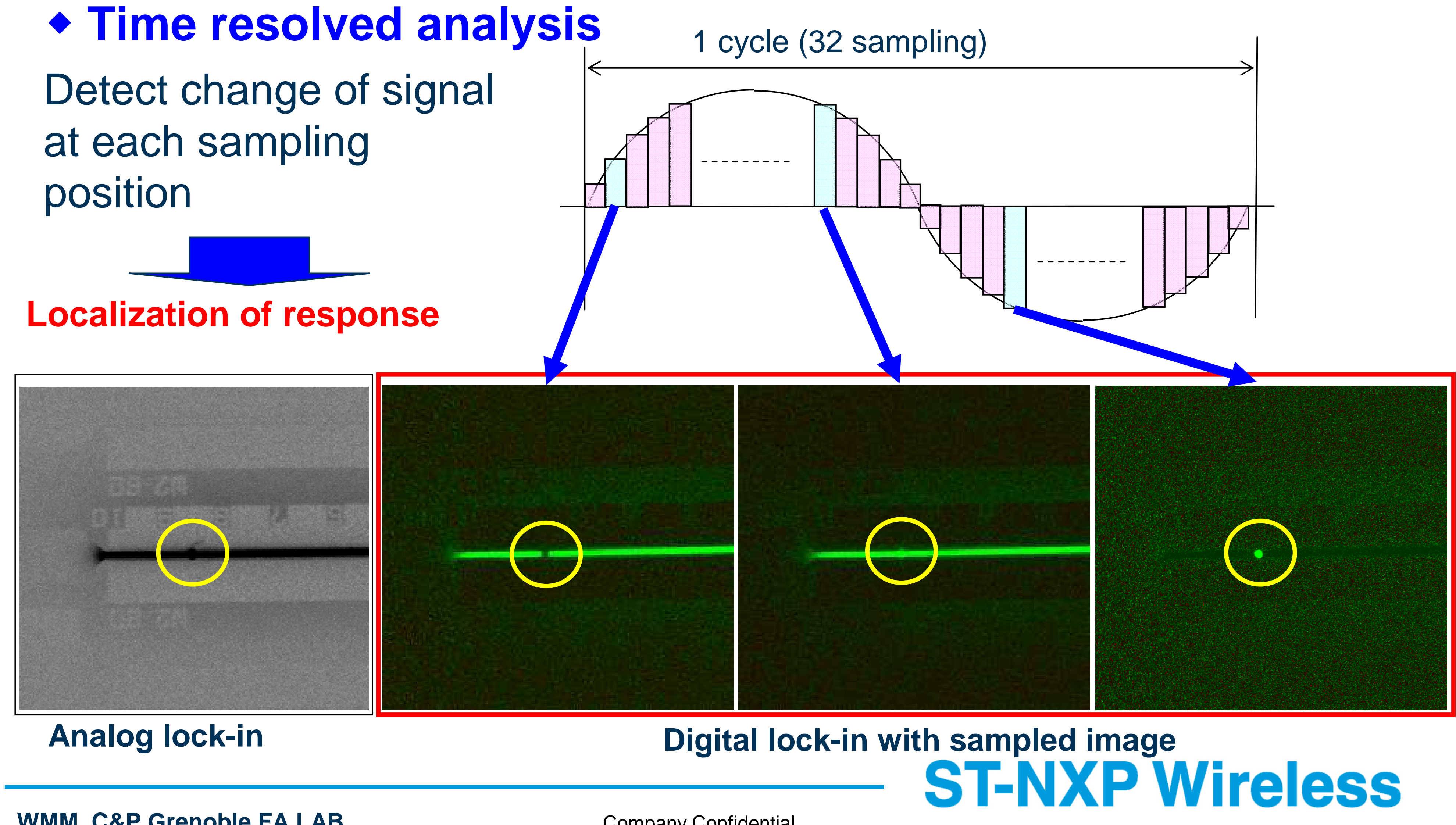
1. Principle of "Thermal Lock-in" analysis



An amplitude image and a phase image are built by conducting lock-in analysis spatially.

Digital Lock-in for laser and thermal scan application



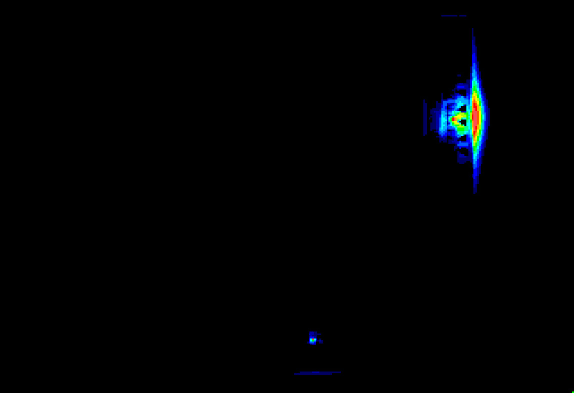
2. Features of the Lock-in method

- 1. Thermal lock-in analysis reduces noise and drastically improves the S/N ratio.
  - The kind of noise
    - Random noises, such as fluctuation of heat.
    - The background ingredient by the heat rise of the sample itself.
    - The pattern outline ingredient by vibration.
- 2. Pinpointing of an exothermic part is possible.
  - Predominance point
    - Solution of the equalization problem by diffusion of heat.
    - Solution of detection mistake problem by the difference of emissivity.
- 3. Domination of phase information
    - Improvement of weak thermal emission detection from feature that doesn't depend on thermal emission strength..
    - It is possible to extract thermal emission of target timing.
    - The response characteristic of thermal emission is understood.

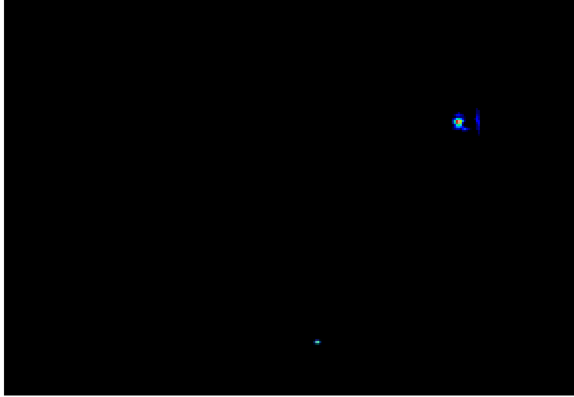
2-2-1. Specific of heat source points by removal of thermal diffusion.

Result of changing power supply modulation frequency.

Conventional method: 40seconds



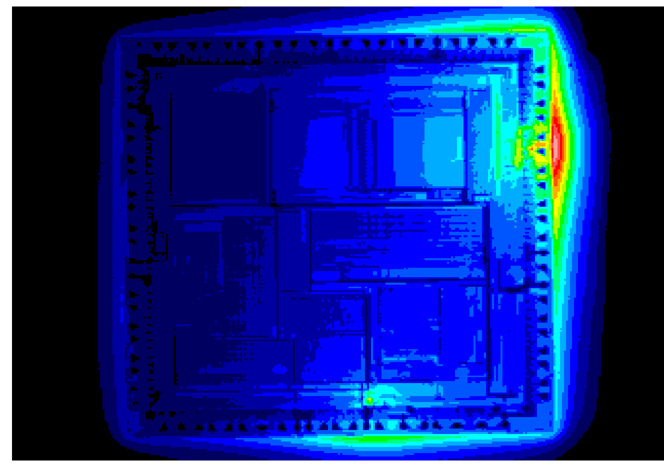
Thermal lock-in method: 1Hz



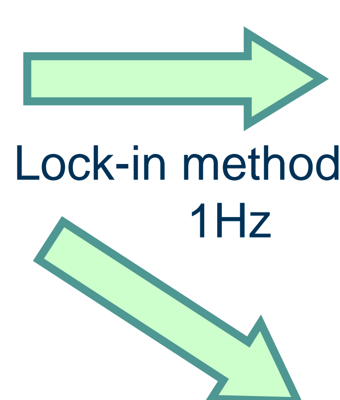
Thermal lock-in method: 20Hz

The dispersion of heat is suppressed by raising the modulation frequency, and the identification of the thermal source points is facilitated.

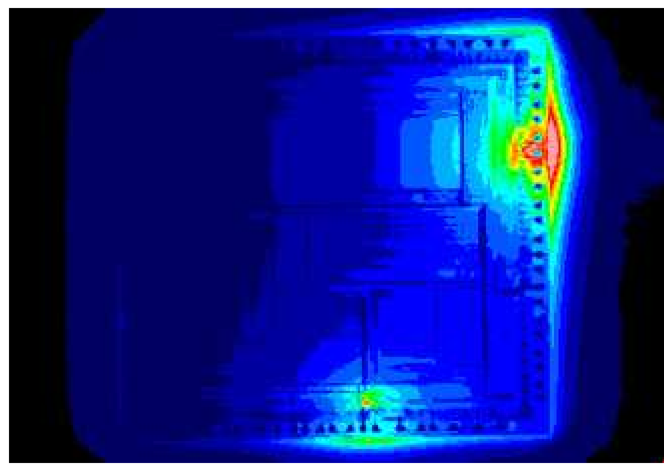
2-2-2. Even if emissivity is different, the thermal emission source points can be specified.



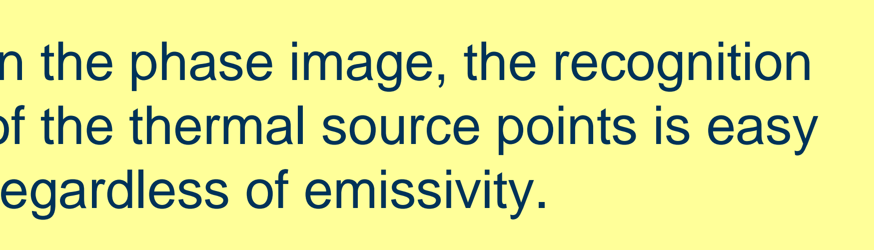
Conventional method



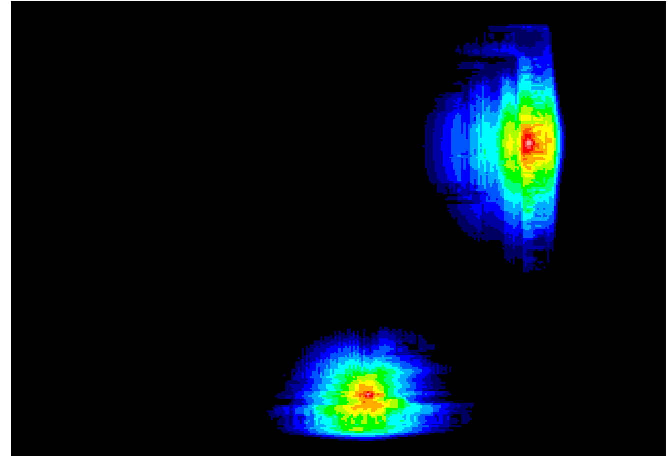
Lock-in method
1Hz



Amplitude

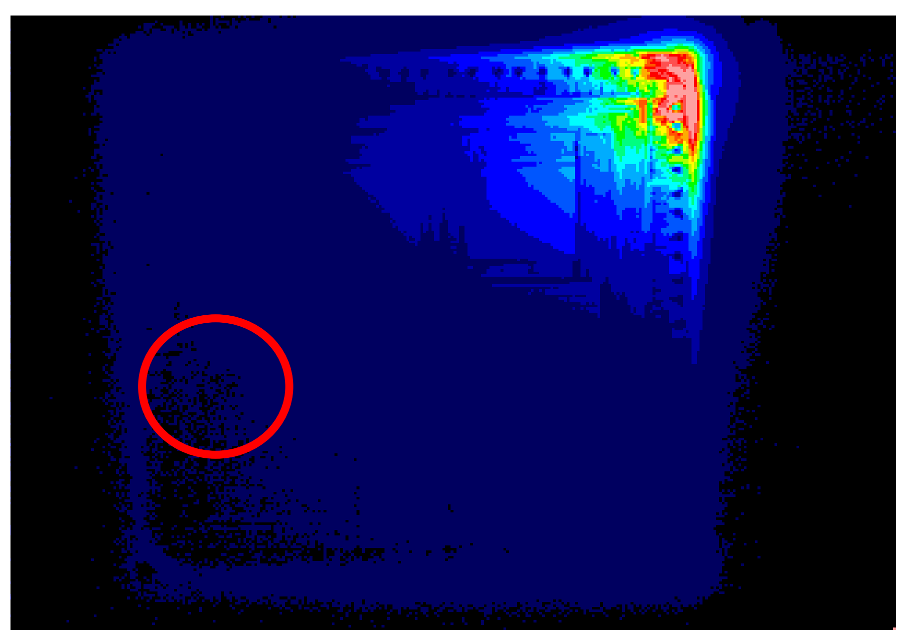


In the phase image, the recognition of the thermal source points is easy regardless of emissivity.



Phase

2-3-1. It becomes easy to detect week thermal emission by phase information.

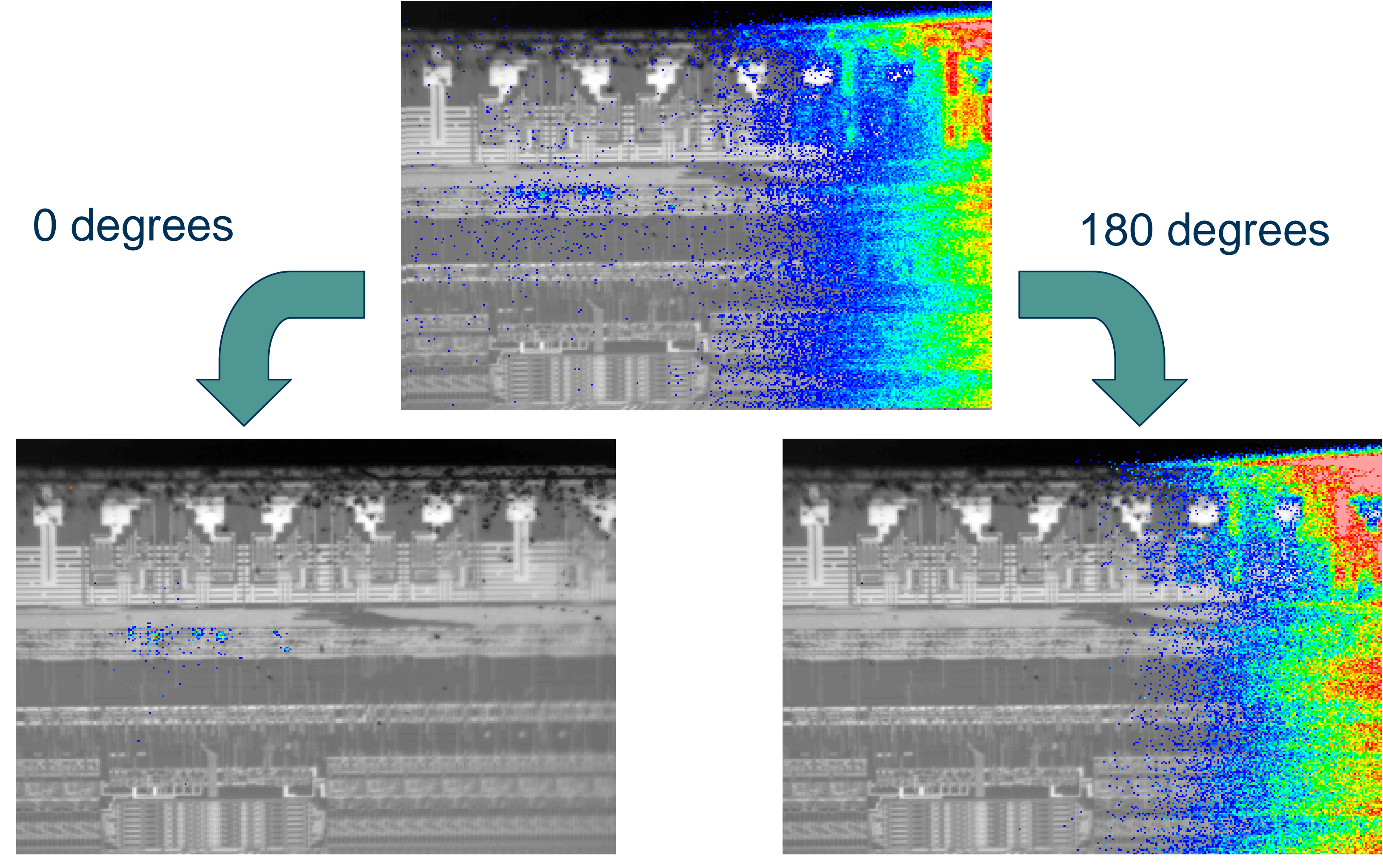


Thermal lock-in : Amplitude

Thermal lock-in : Phase

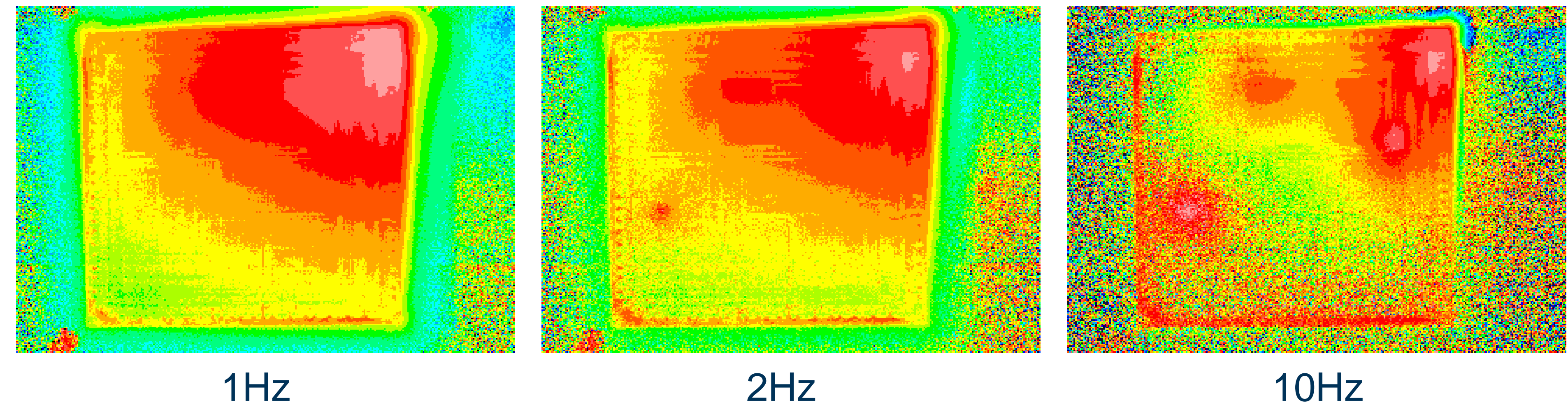
Week thermal emission was not able to be detected in the amplitude image, but it was able to be detected from the phase image.

2-3-2. Extraction of target data according to timing.



2-3-3. The response characteristic of thermal emission is understood.

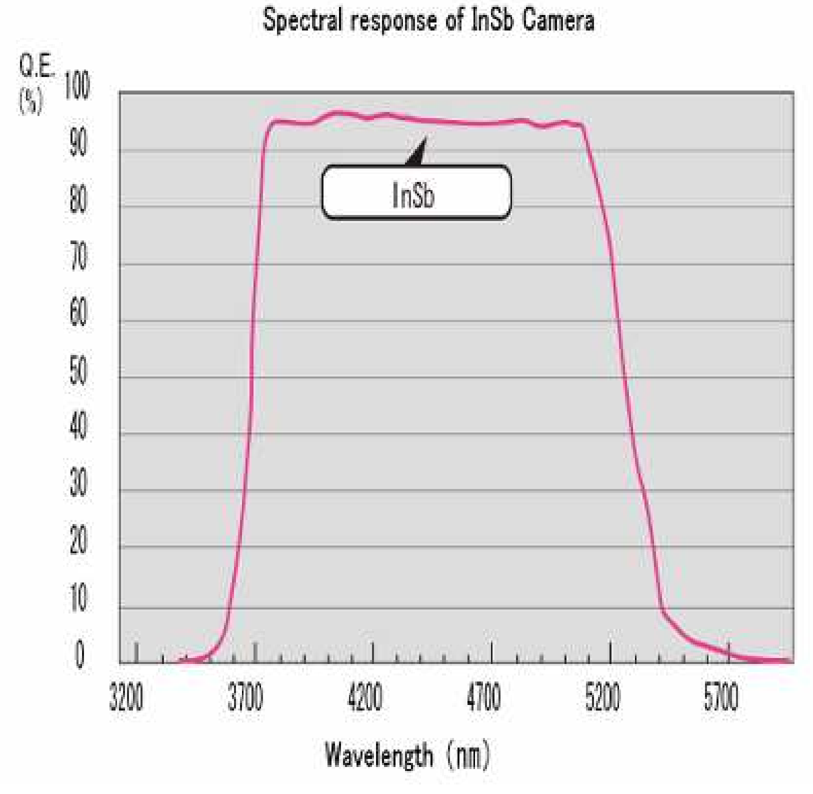
Thermal lock-in : phase image



The heat response characteristic can be recognized by changing the frequency of thermal lock-in.

1. Equipment Introduction

A. Mini THEMOS

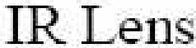


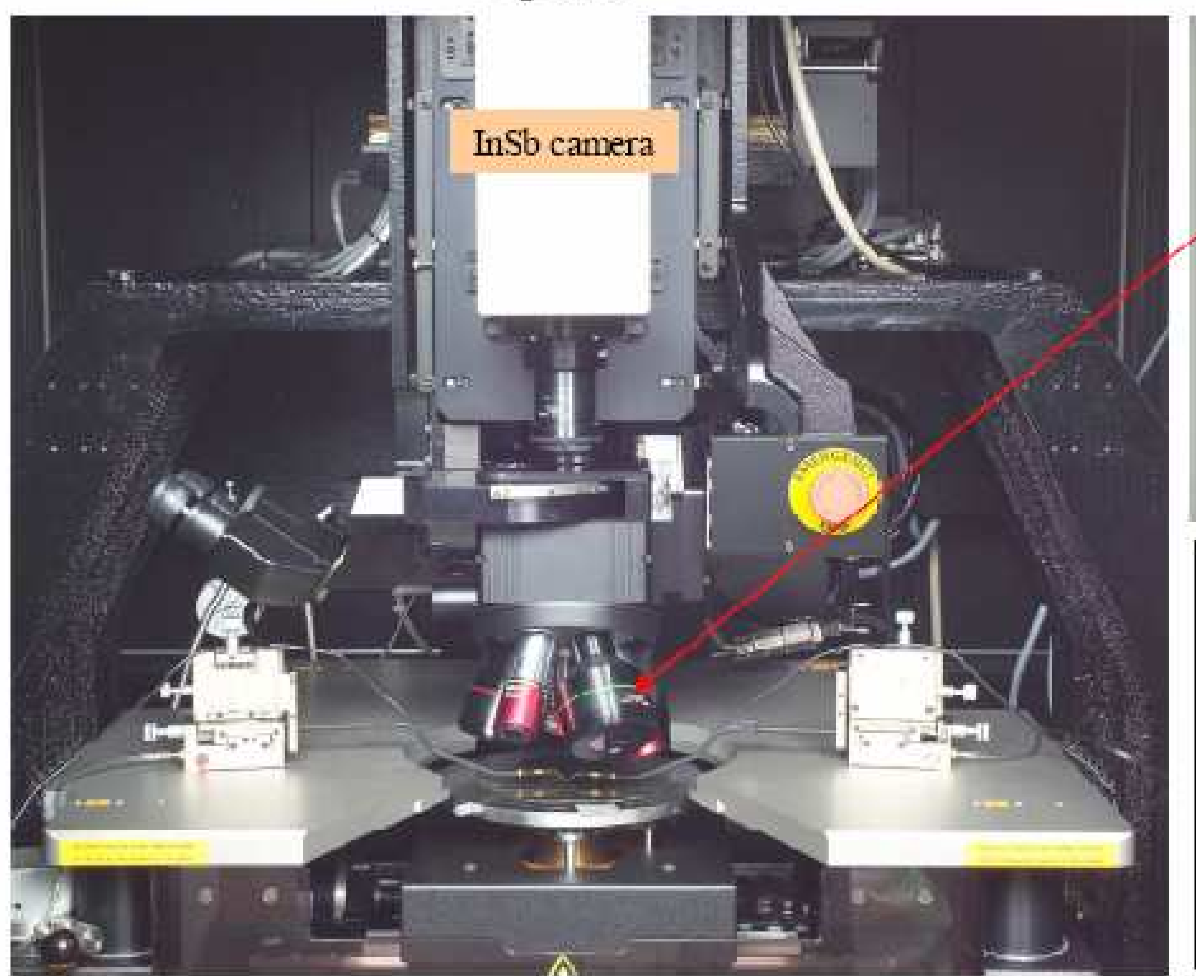
Main Characteristics:

InSb camera 320x240 pixels
Noise Equivalent Temperature Difference < 25 mK at 30°C (typ)
Resolution 0.8 μm (at 20x lens NA=0.4)
Manual revolver & xyz stage
MWIR lens 0.8x, 4x, 15x / Probing lens 5x
Illumination for probing
Vibration isolation table
Simplified HPK prober

B. Lenses description

Optics

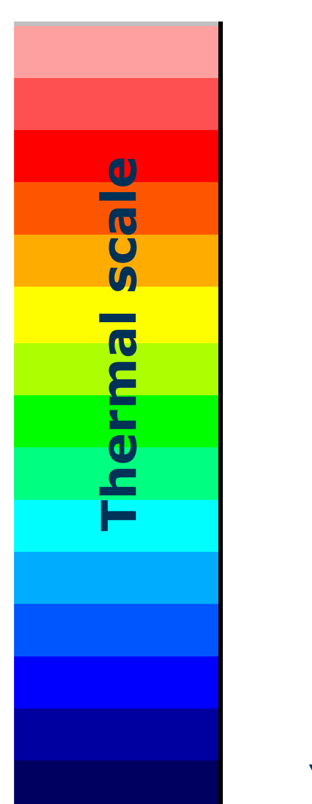


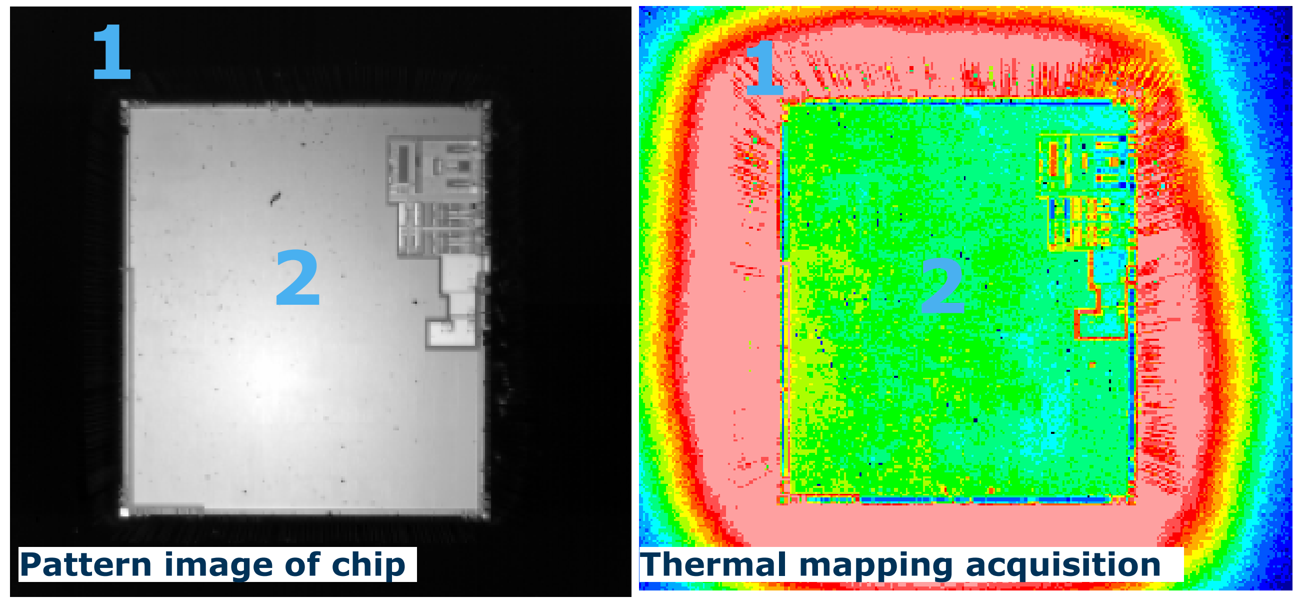


Mag.	NA	WD mm
0.8x	0.13	22
4x	0.52	25
15x	0.71	15

2. Image Interpretation

Higher to Lower Temperatures, BUT comparison is possible for materials with same emissivity.



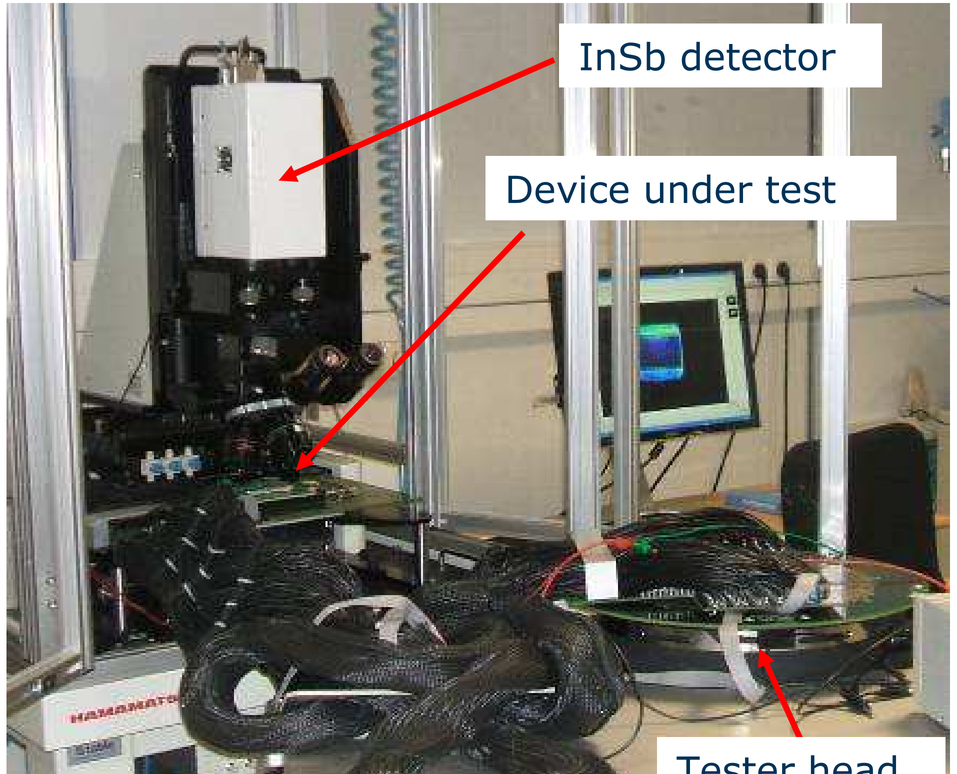


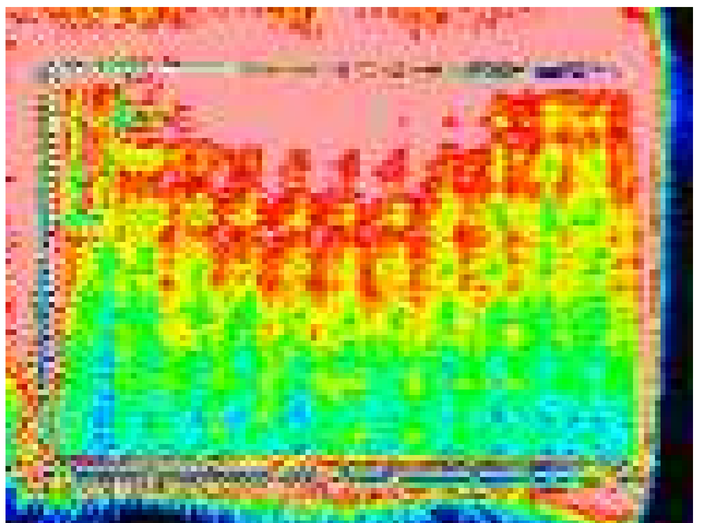
Example: area 1(wire bonding /gold + resin) cannot be compared to area 2(die / Cu, Al + SiO2) . We can't conclude that temperature in area 1 is higher than temperature in area 2.

3. Acquired Images

A. Thermal Mapping

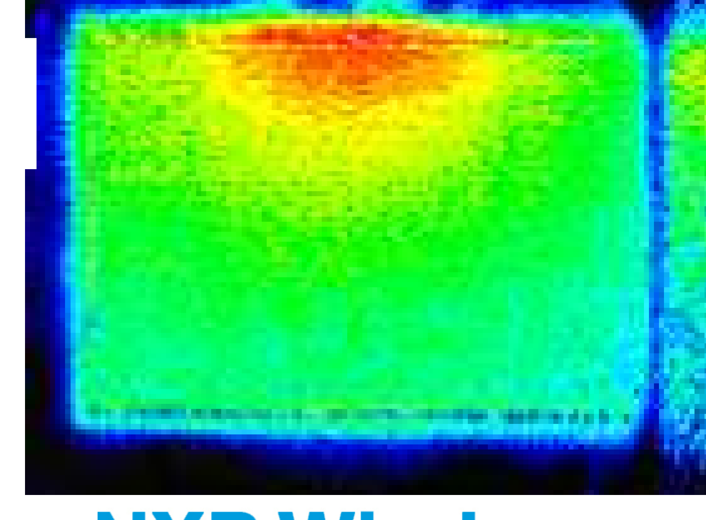
Techno : CMOS090





Lock in 0.4Hz

Amplitude



Lock in 0.4Hz

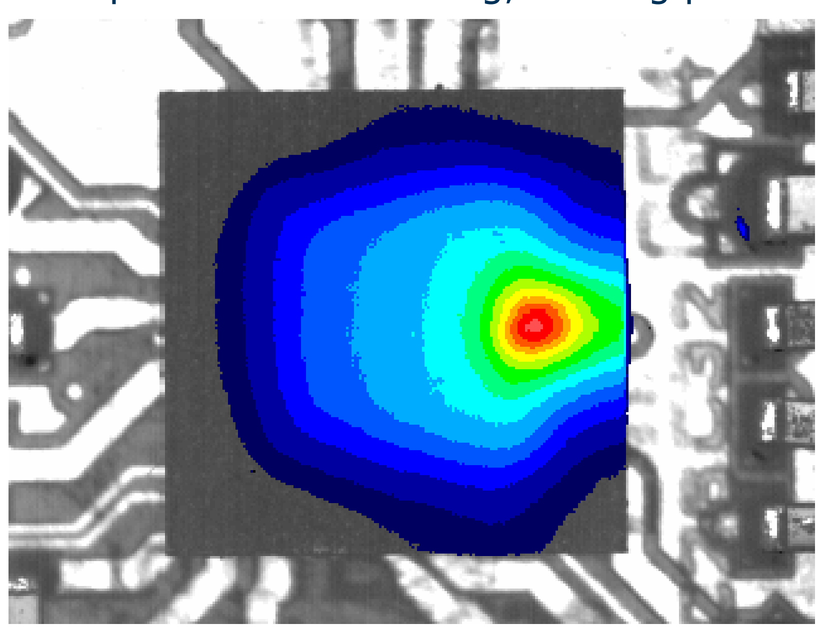
Phase

- A tester is used to loop a functional pattern during thermal acquisition.
- Temperature is higher on the edge of die close to areas from bandgap to PLL.
- Heat signature is almost the same between the 2 lots, just a little higher on fast lot.

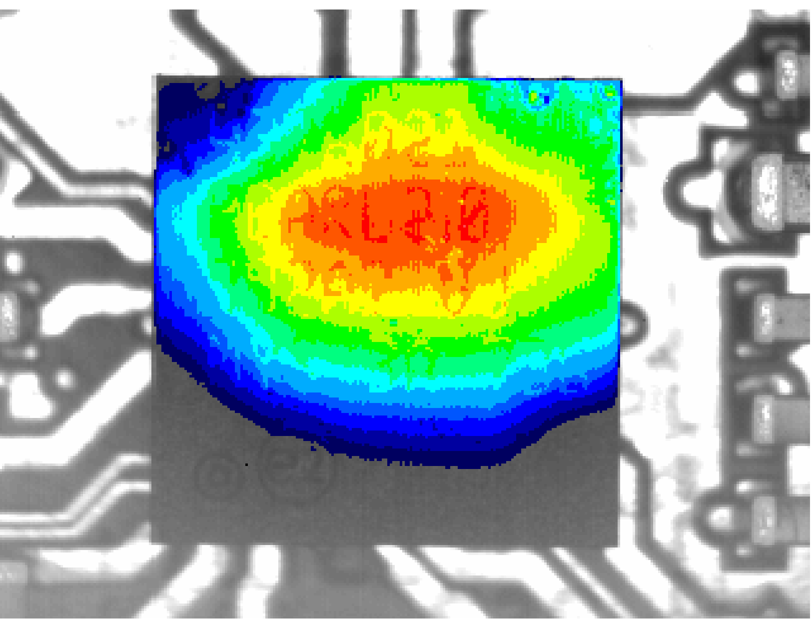
NXP Wireless

Techno : XXX

Sample 1: unit is running, heating phase



Sample 2: unit is stopped, cooling phase

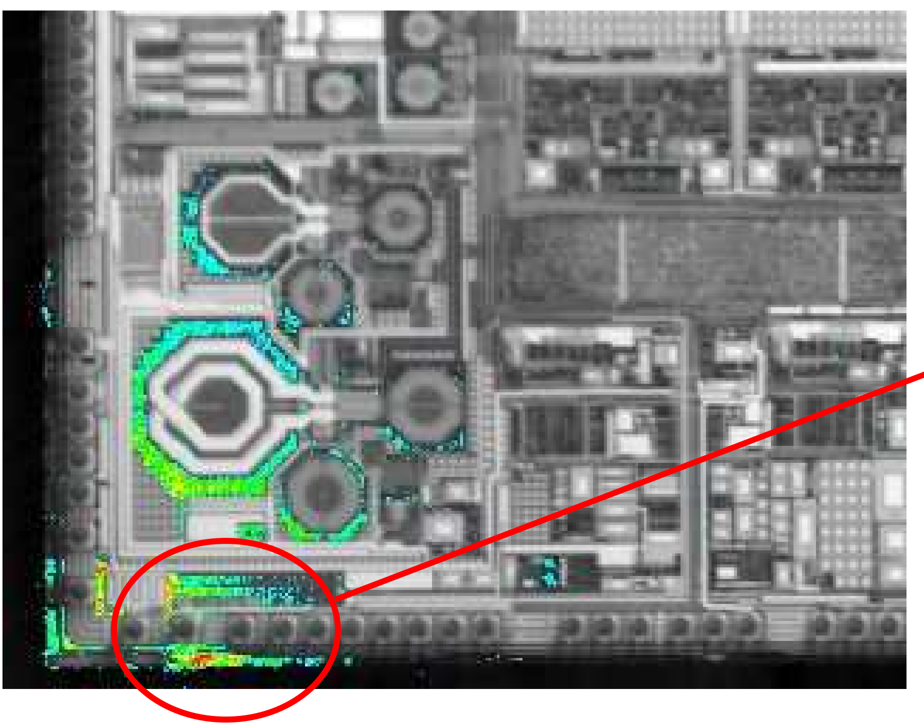


- Thermal mapping acquisition is done with an application board.
- Package is not decapsulated.

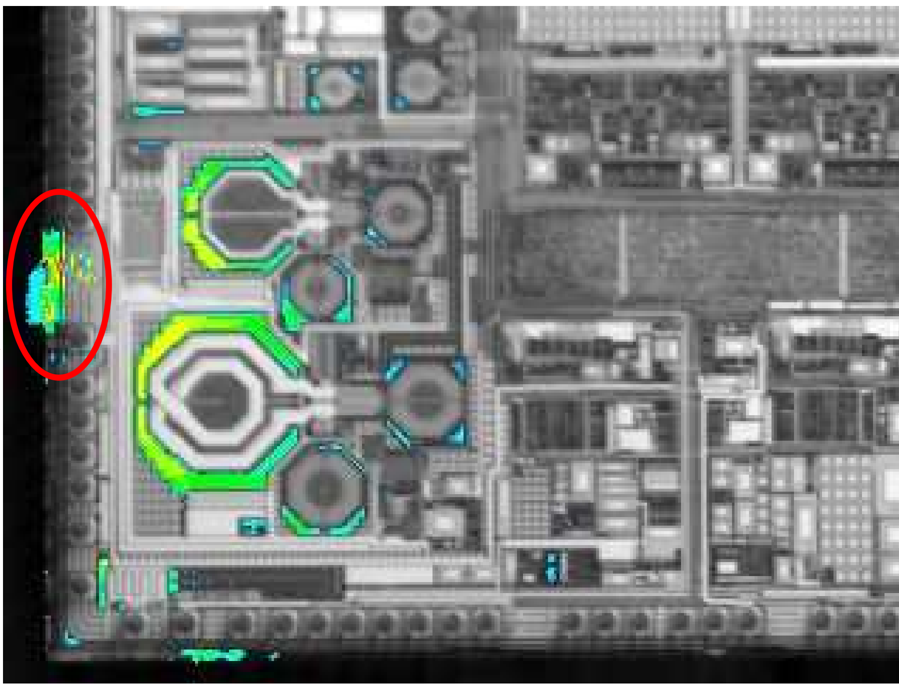
- Feedback from our internal requestor:
- There is no thermal camera matching our needs, temperature value measurement with an accuracy of +/- 5℃.
- Option available Q2/09

B. Latch-Up issue / Techno : XXX

No latch-up

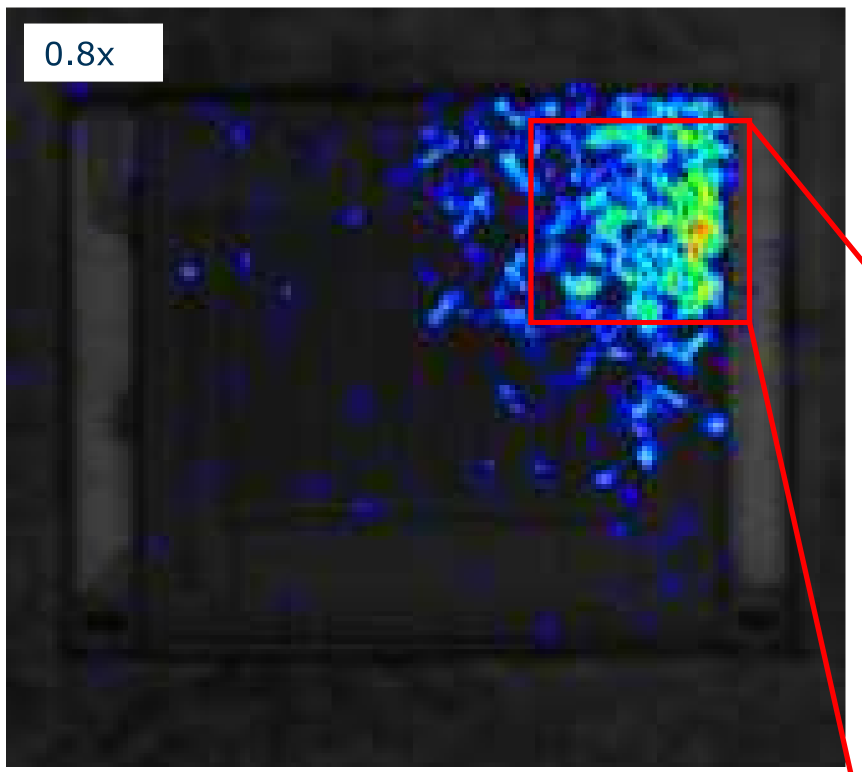


Latch-up – clamp 100mA

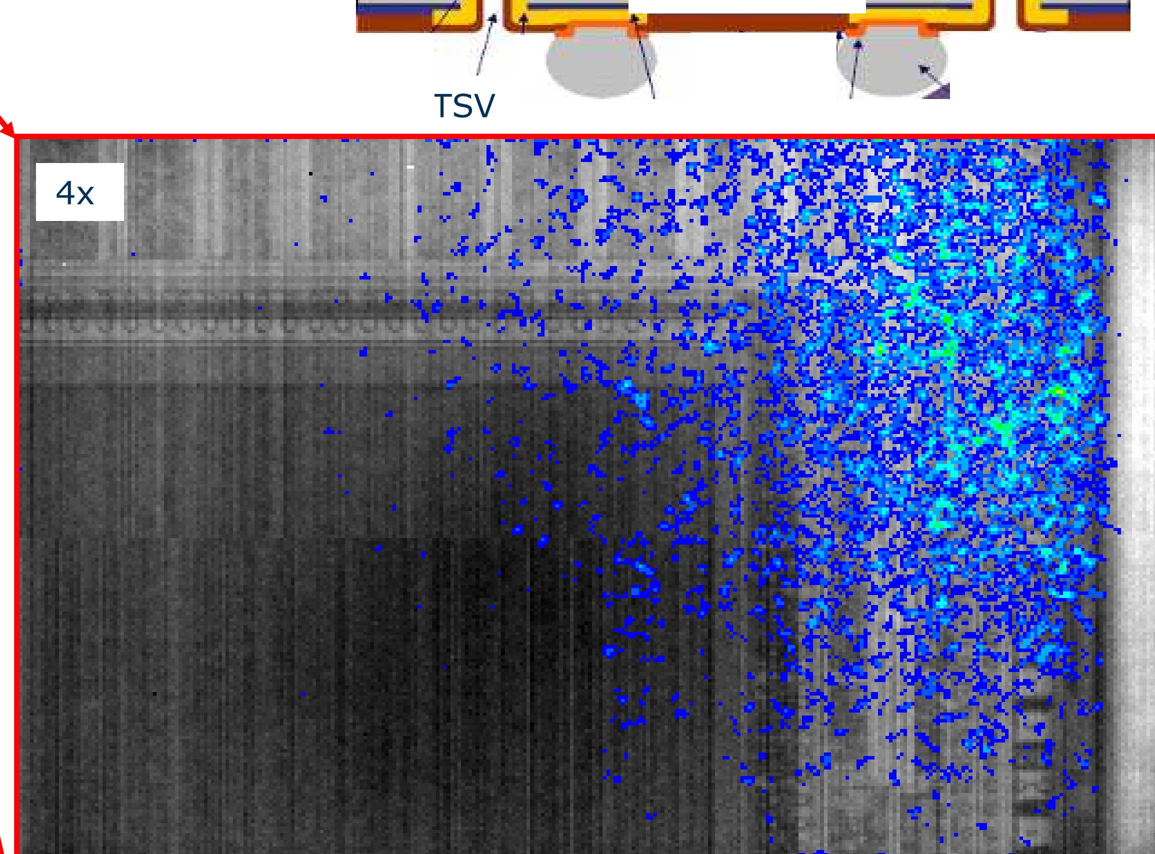


- Hot spot in a specific pad just before triggering the Latch Up (this pad is the source which delivers the current sunk on C1NI bloc). Then a very intense hot spot is detected on ESD protection structure once the LU is triggered.

C. Leakage issue / Techno : XXX



Through Silicon Vias (TSV) process overview



- Leakage on Vdig 10 µA vs 1 µA for a Ref.
- Obirch analysis done with no abnormal signature.
- Thermal analysis shows hot spots close to Vdd pads.

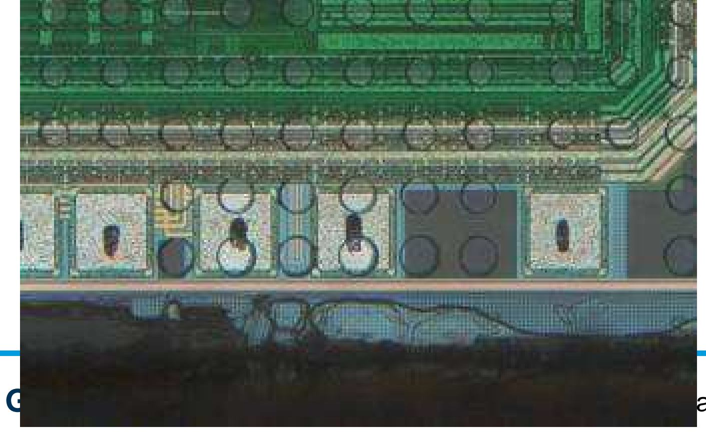
→ Damages are seen on die edge probably due to a bad sawing.

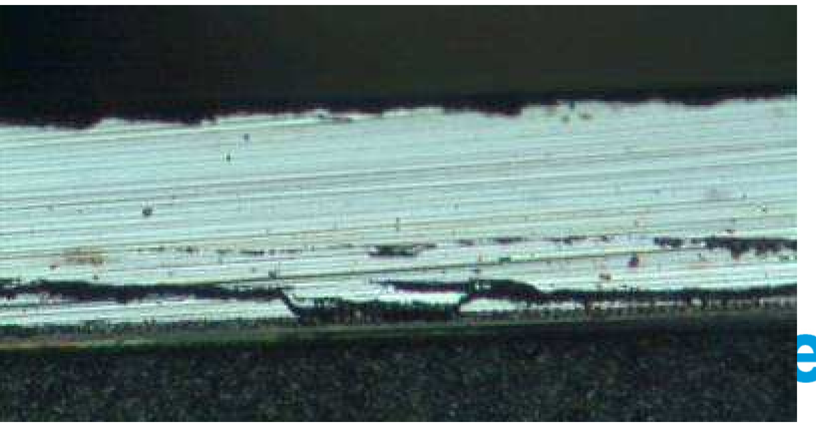
0.8x

4x

- Leakage on Vana 1 mA vs 1.5 µA for a Ref.
- Obirch analysis done with no abnormal signature.
- Thermal analysis shows hot spots at the bottom right corner of the die close to Vana pad.

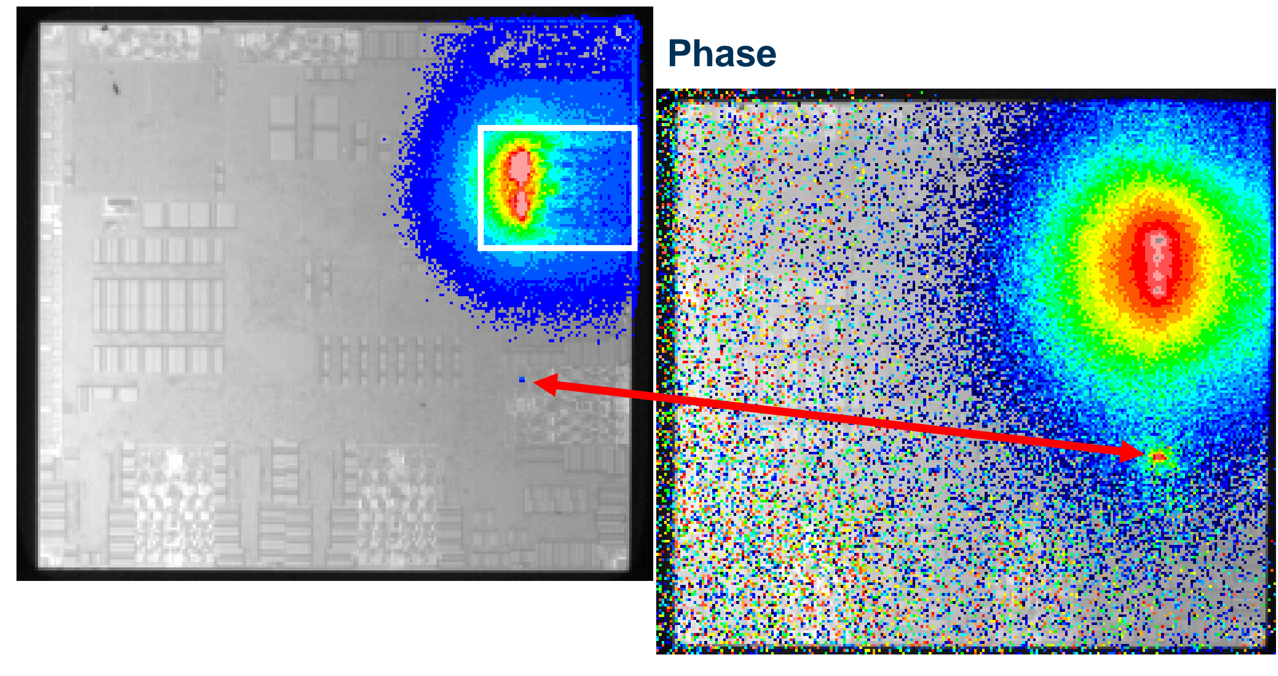
→ Damages are seen on die edge probably due to a bad sawing.



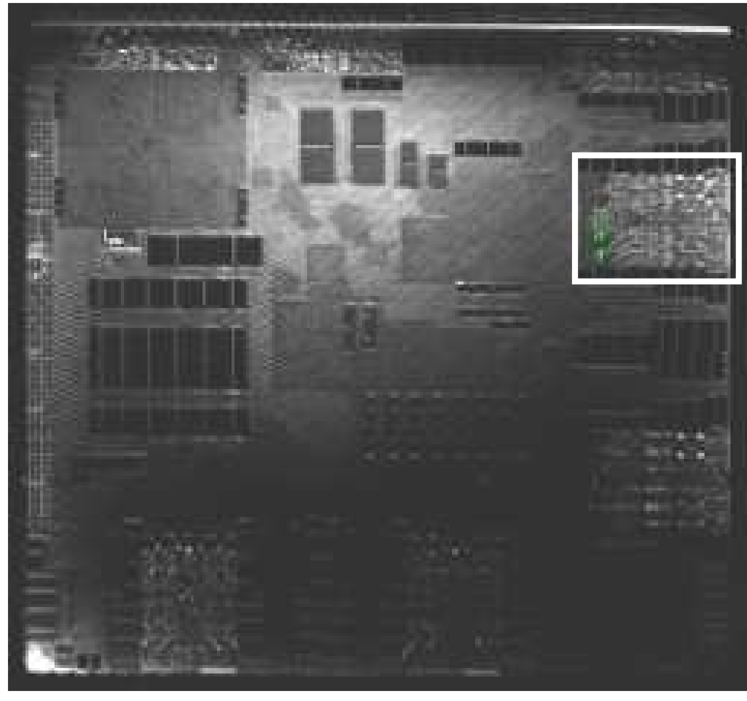


D. EOS reproduction / Techno : XXX

Amplitude

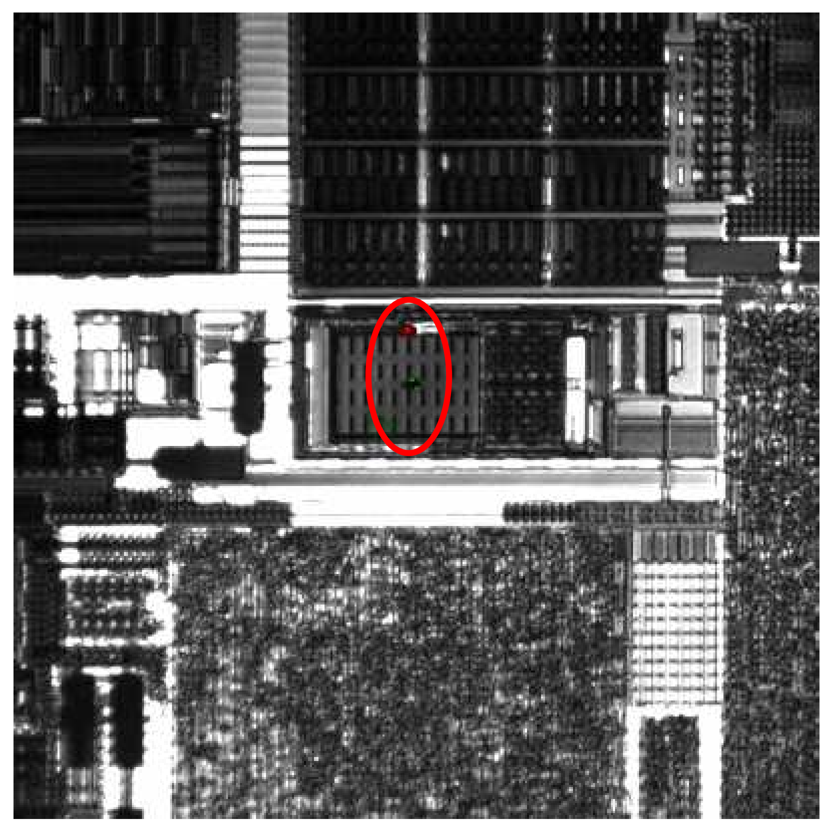


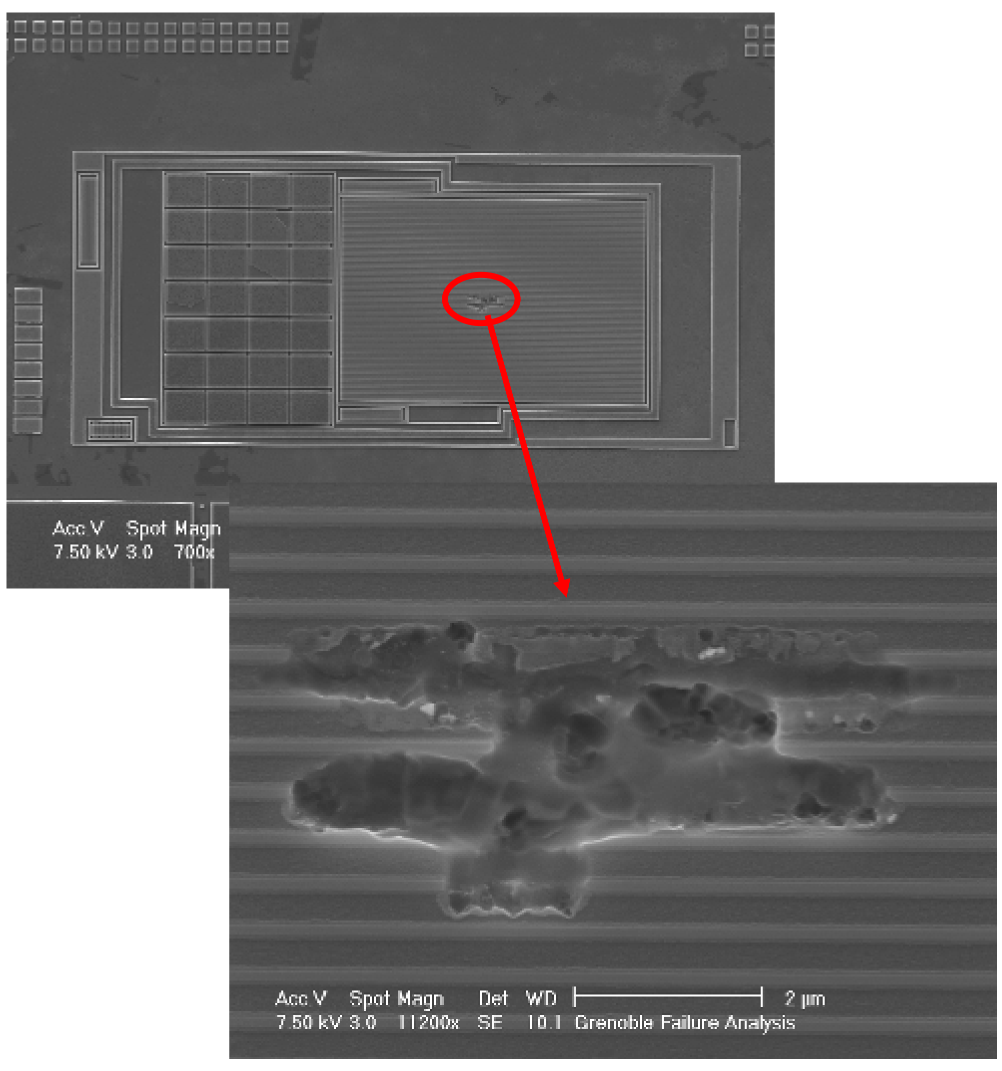
OBIRCH – 0.2V / 35mA



- Leakage 0.5V/100mA after stress.
- Localization with both OBIRCH & Thermal analyses.

- Interest of phase information, small spot is seen in amplitude but the area is heating at the same time compare to big spot area. → same cells damaged.





- The ‘CLAMP_1V0_ANA’ structures on VTT are damaged: silicon melting interconnect blow-up (contacts fused) and gate oxide breakdown.

E. Shorts / Techno : XXX

Amplitude

0.8x

4x

OBIRCH

1x

20x

Si substrate

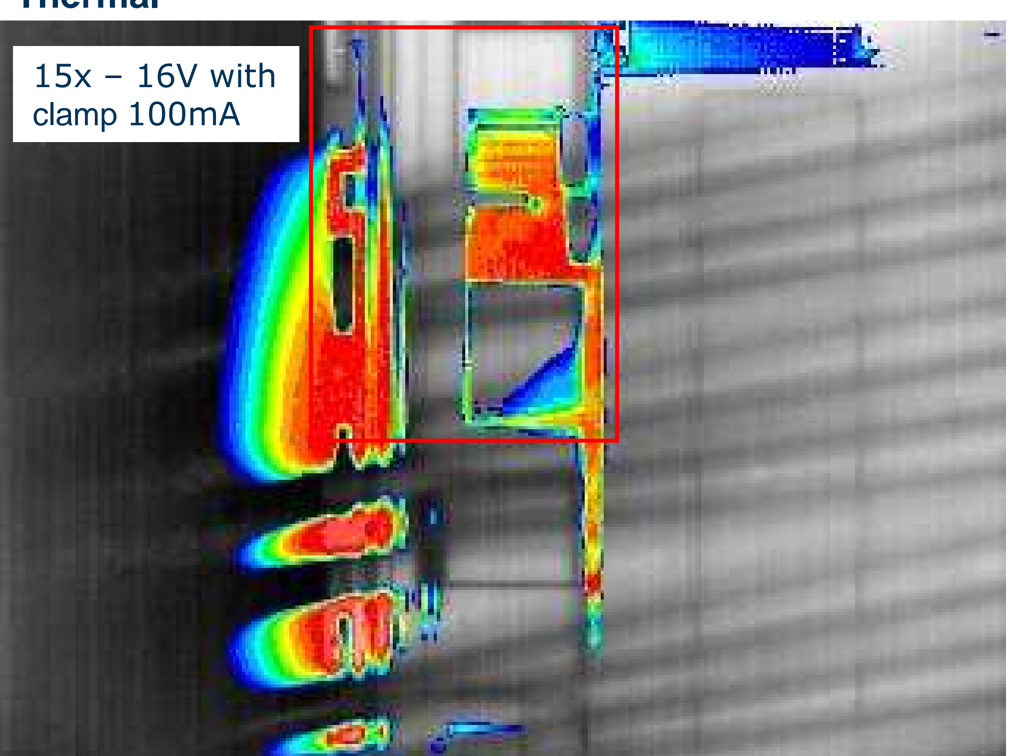
void

Copper pad on PCB

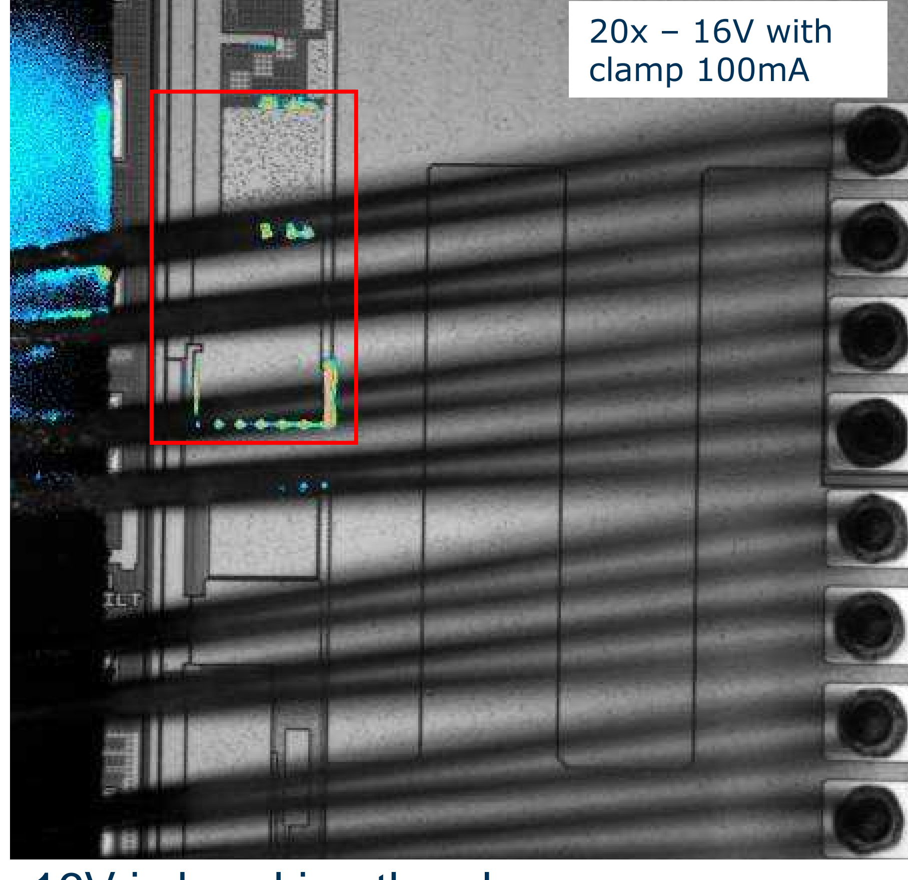
- OBIRCH & Thermal signatures are not localized in a “specific” structure and are quite diffuse: an issue under the active area of the die is suspected (back-end / bump level).
- The failure modes observed are voids in underfill, a solder extrusion and a metal migration in bump.

F. Design issue / Techno : XXX

Thermal



Emission

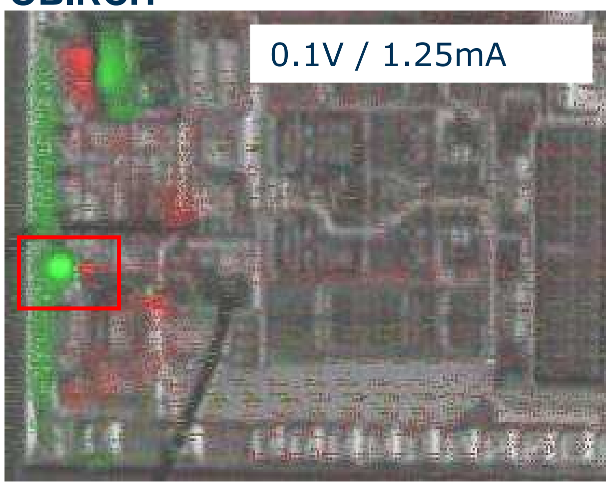


- Charger issue: fast charger connection up to 16V is breaking the phones.
- The movie capability of Themos mini was used to locate easily the failure. Then photos are generated when the fail is triggered.
- Emission localization was performed and emission is found above the driftswitch when the current is latched.

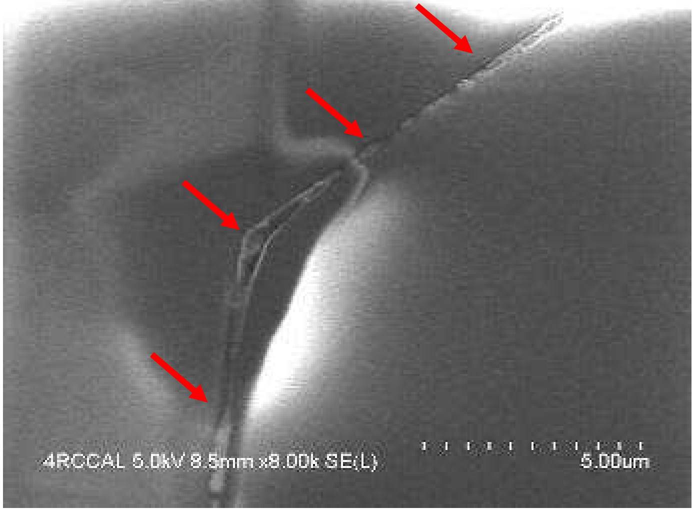
G. Short - M5 M4 suspected / Techno : XXX

Amplitude

OBIRCH



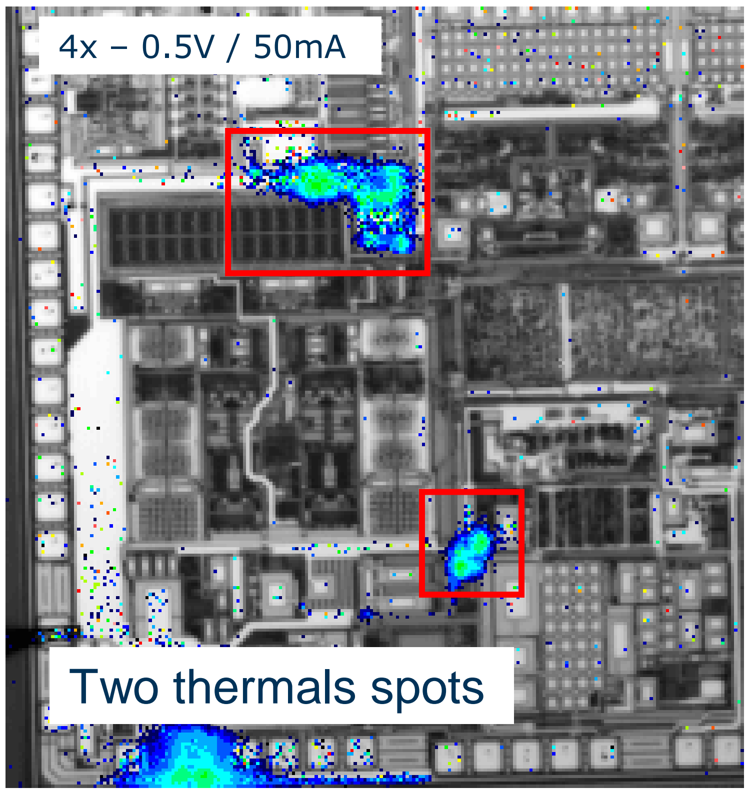
SEM view: Parasitic trench filled with with metal.



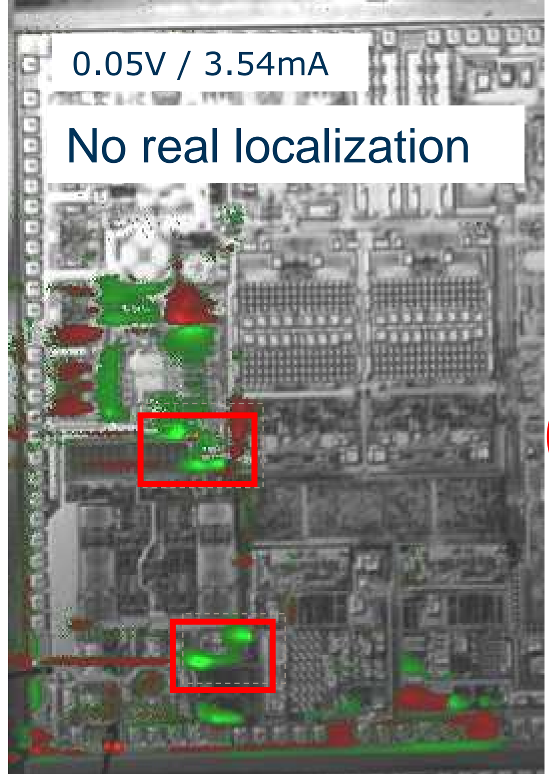
- Short 0.1V / 1.25mA.
- Good result BS vs FS (0.8x & 4x), Better FS result @ 15x (Top layer level issue suspected)
- Two thermal spots localized, less noised than OBIRCh signature.
- Parasitic trench filled with metal creating a short between M5 & M4 layers.

H. Short - CMP M5 suspected / Tecno : XXX

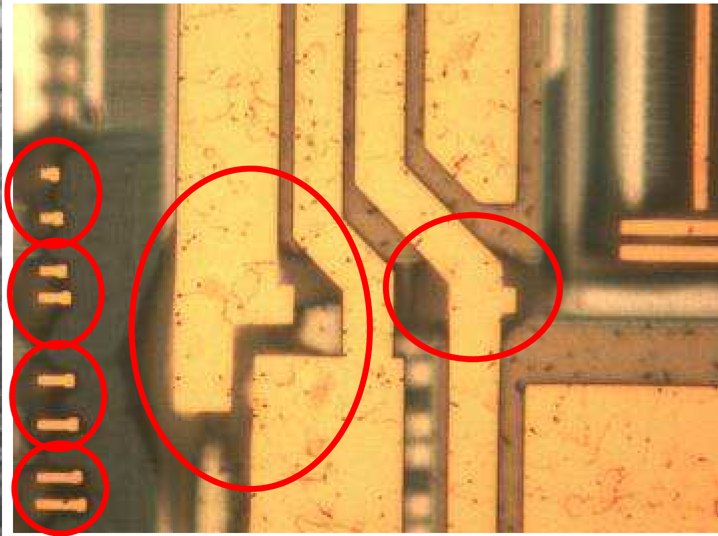
Amplitude



OBIRCH



Optical view: CMP issue confirmed @ top layer.



- Short 0.05V / 3.54mA.
- Good result BS vs FS (@ 0.8x => 15x)
- Lock-In has a real impact on localization
- Two thermal spots localized in comparison of OBIRCh signature.
- CMP issue is confirmed.

I. Short / Techno : XXX

Amplitude

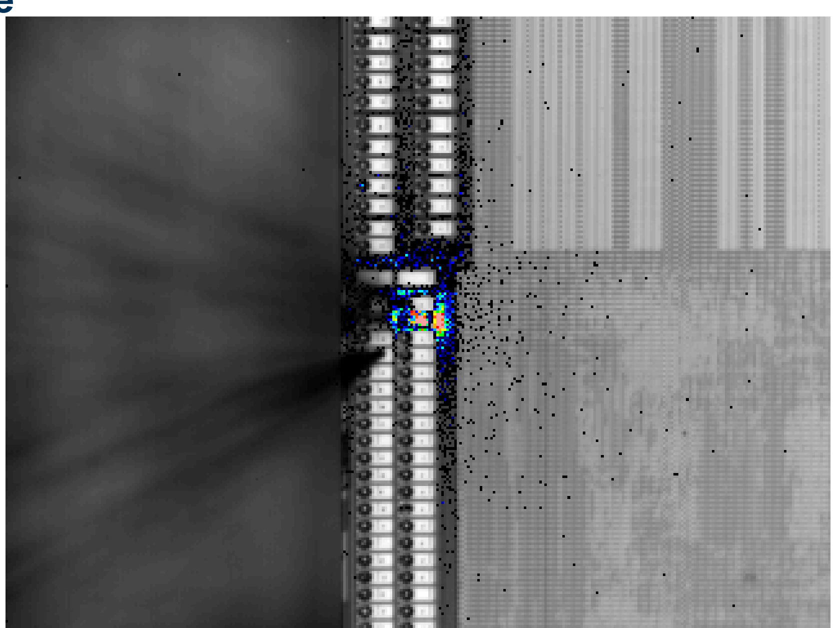
4x – 0.2V / 30mA

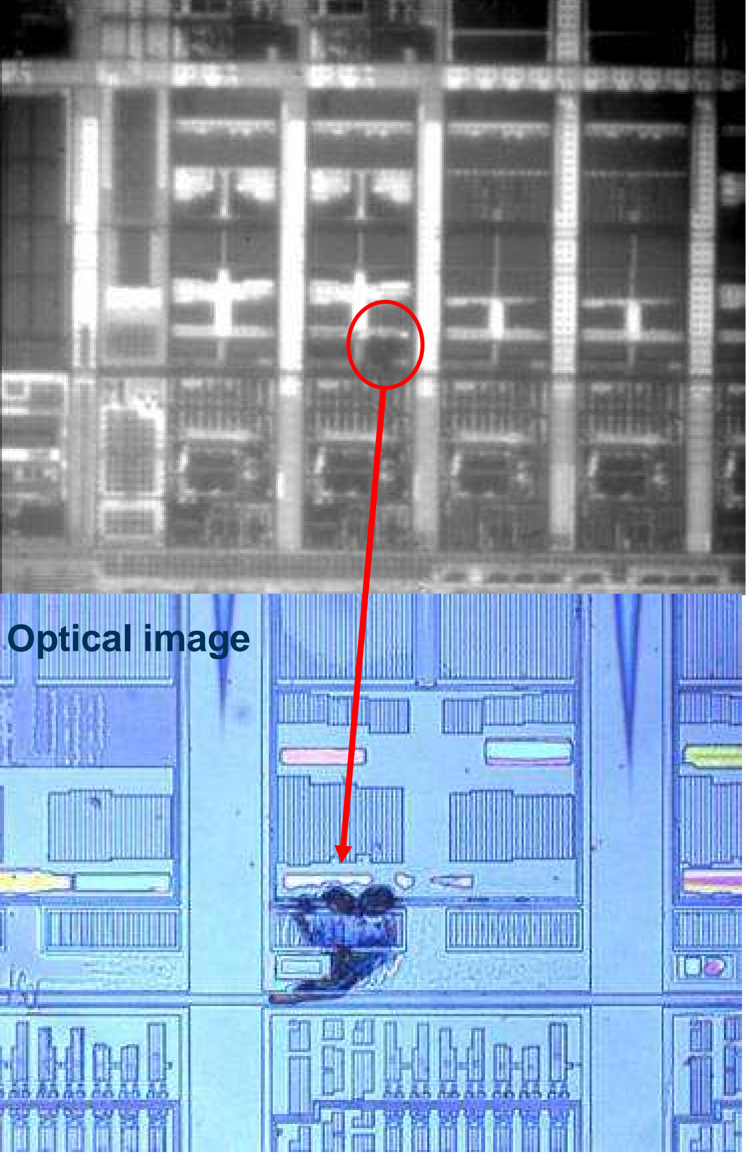
0.05V / 5.57mA

OBIRCH

- Short 0.05V / 5.57mA.
- Good result BS vs FS (@ 0.8x => 15x)
- Lock-In has a good impact on localization
- One thermal spots localized in comparison of OBIRCh signature.

J. Short / Techno : XXX





- Even if no spot was visible either with OBIRCH or EMMI, an accurate backside visual inspection performed with InGaAs EMMI detector showed a burning on the active area in the failing pad.
- By thermal camera equipment we managed to see an anomalous dissipation of power in the area of the failing pad.
- We then proceeded by quick de-processing to reach the active area, finding out the final confirmation of the presence of the burning.

4. Summary

Process	Sample type	Problem	EMMI	OBIRCH	THERMAL
XXX	Package	Good	NA	NA	Mapping
XXX	Package	Good	NA	NA	Mapping
XXX	Package	Latch-up	No (too many spots)	No	Yes
XXX	Package	Leakage	No	No – Yes (on previous analysis)	Yes
XXX	Package	Leakage	Yes	Yes	Yes
XXX	Package	Leakage	NA	Yes	Yes
XXX	Package		Yes	NA	Yes
XXX	Package	Short	NA	Yes	Yes (+)
XXX	Package	Short	NA	Yes	Yes (+)
XXX	Package	Short	NA	Yes – No	Yes (+)
XXX	Die	Leakage	No	No	Yes

Summary

- Improvement of SNR by lock-in amplifier is demonstrated by separating signal and noise.
- Digital lock-in is confirmed to be useful for stability, accuracy, flexibility, better signal quality as well as time resolved imaging
- Further possibility using phase information for new physical information such as layer information
- Thermal lock-in is demonstrated being useful tool to improve SNR and higher sensitivity on Themos system.
- Localize real heat source using phase information

X ray and Thermal imaging approach

- **Package analysis using Thermal emission microscope**
- **(Themos mini)**
- 2009/01/16 reported by Yoshiyuki Yokoyama @HPD
- This experiment is done at HPD to investigate the Themos capability to detect signal at package level without opening a device.
- First steps for stacked devices analysis ?...

X ray and Thermal imaging approach

- **Equipment**
- THEMOS mini with Lock-In
- IC polisher
- Xray- micro focus system L9631
- Flat panel sensor for X-ray C7921-09

- **Sample**
- Microprocessor (HITACHI H8)
- Front side / Chip size 30mmx30mm)
- 5V apply at line

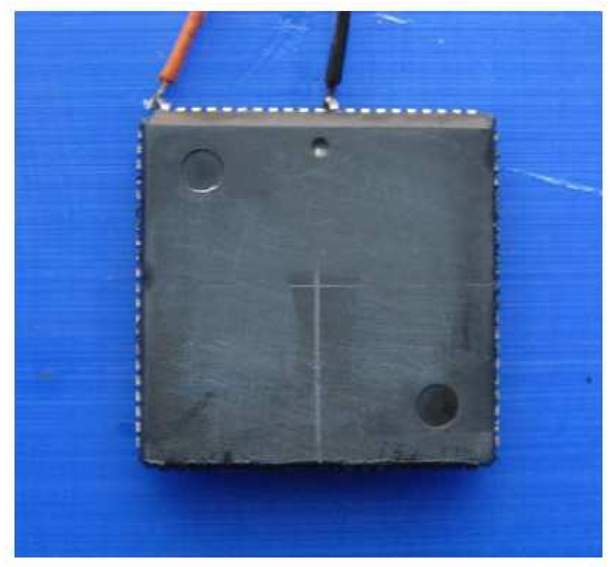
X ray and Thermal imaging approach

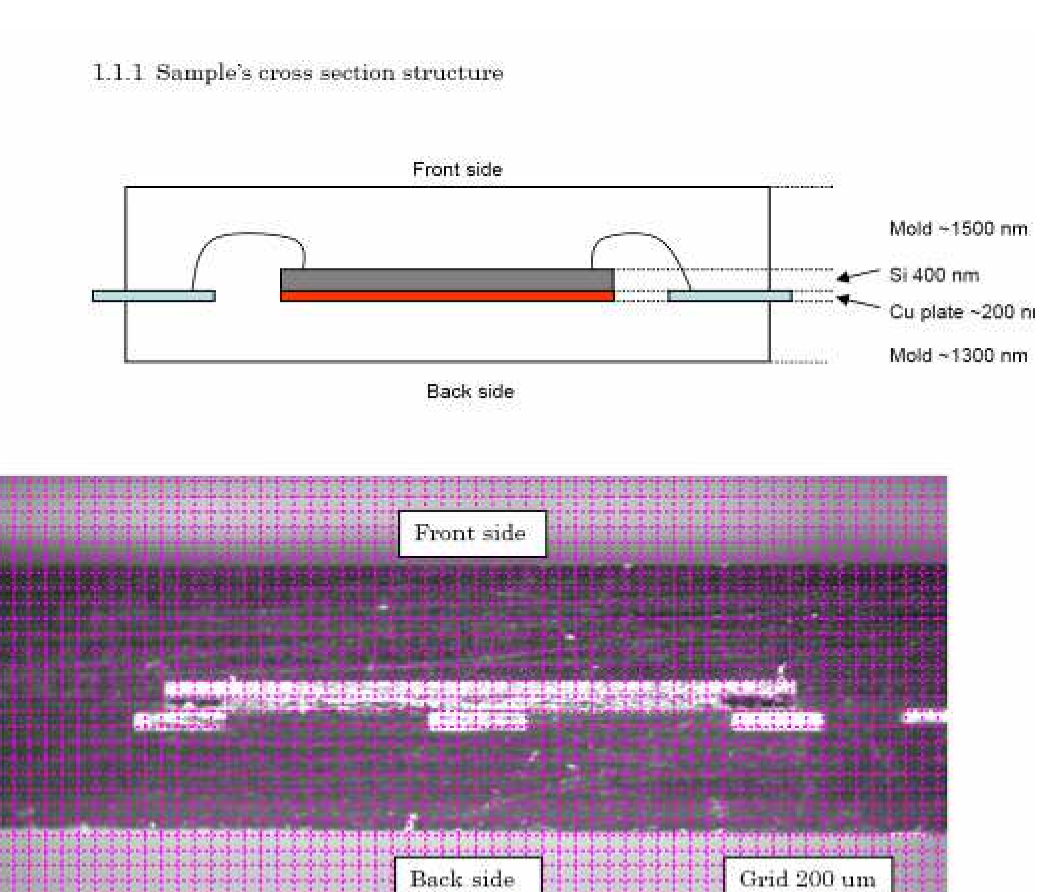
Sample

Microprocessor (HITACHI H8)

Front side / Chip size 30mmx30mm)

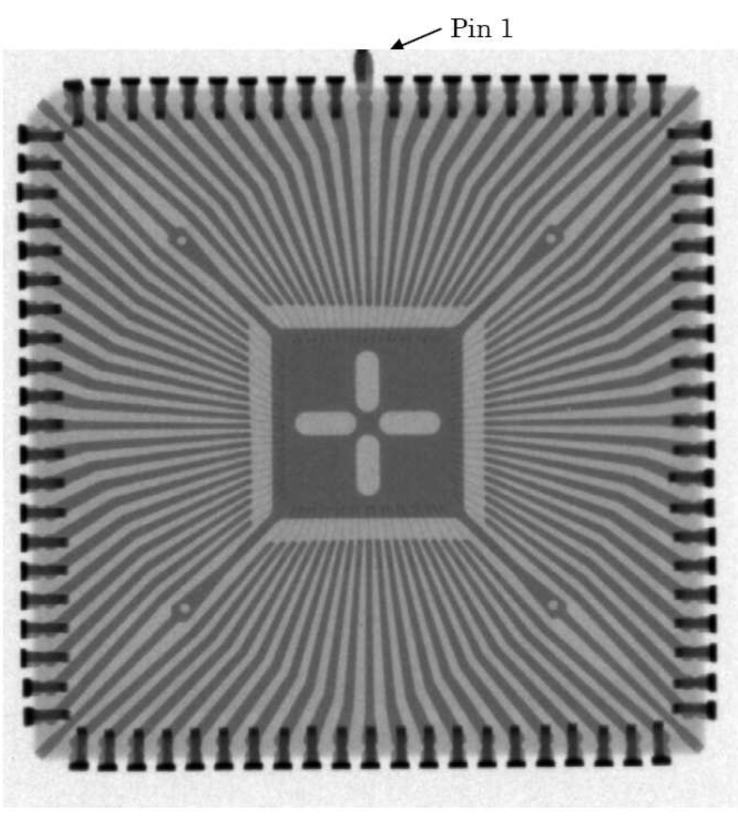
5V apply at line





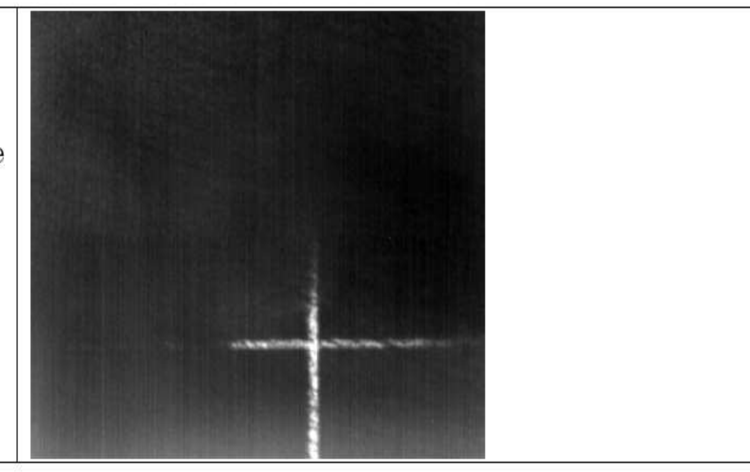
X ray and Thermal imaging approach

1.1.2 X ray image (Front side E=80keV)

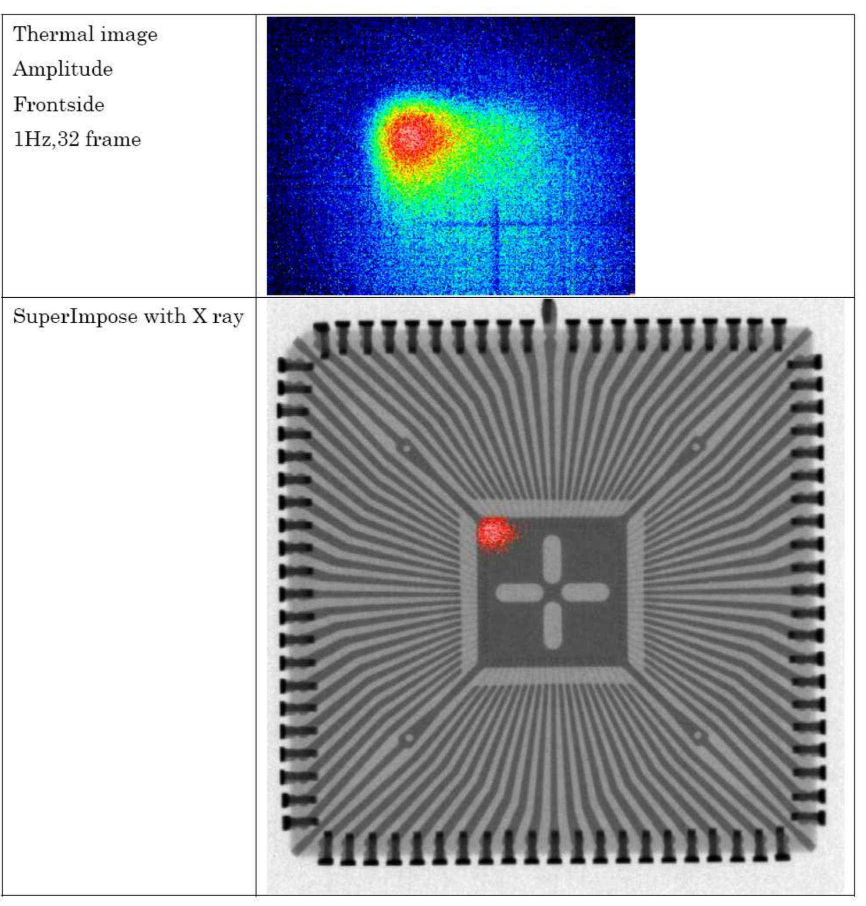


1.2 Evaluation with Themos

There is a cross hair marked on sample surface. Based on the cross hair point, we overlay the Themos pattern image + thermal image + X-ray image. How to align X-ray image and Themos pattern image shall be determined separately.

Themos Pattern image 0.8x Cross hair is shown the center of chip	

X ray and Thermal imaging approach



In the X-ray image, we can not see Si, but can see bonding wires. Thermal signal is observed around bonding wire area, which leads the guess that there may be something wrong under Si. Thermal signal is not round but looks like having a tail toward right direction

Open the package from backside for further investigation.

X ray and Thermal imaging approach

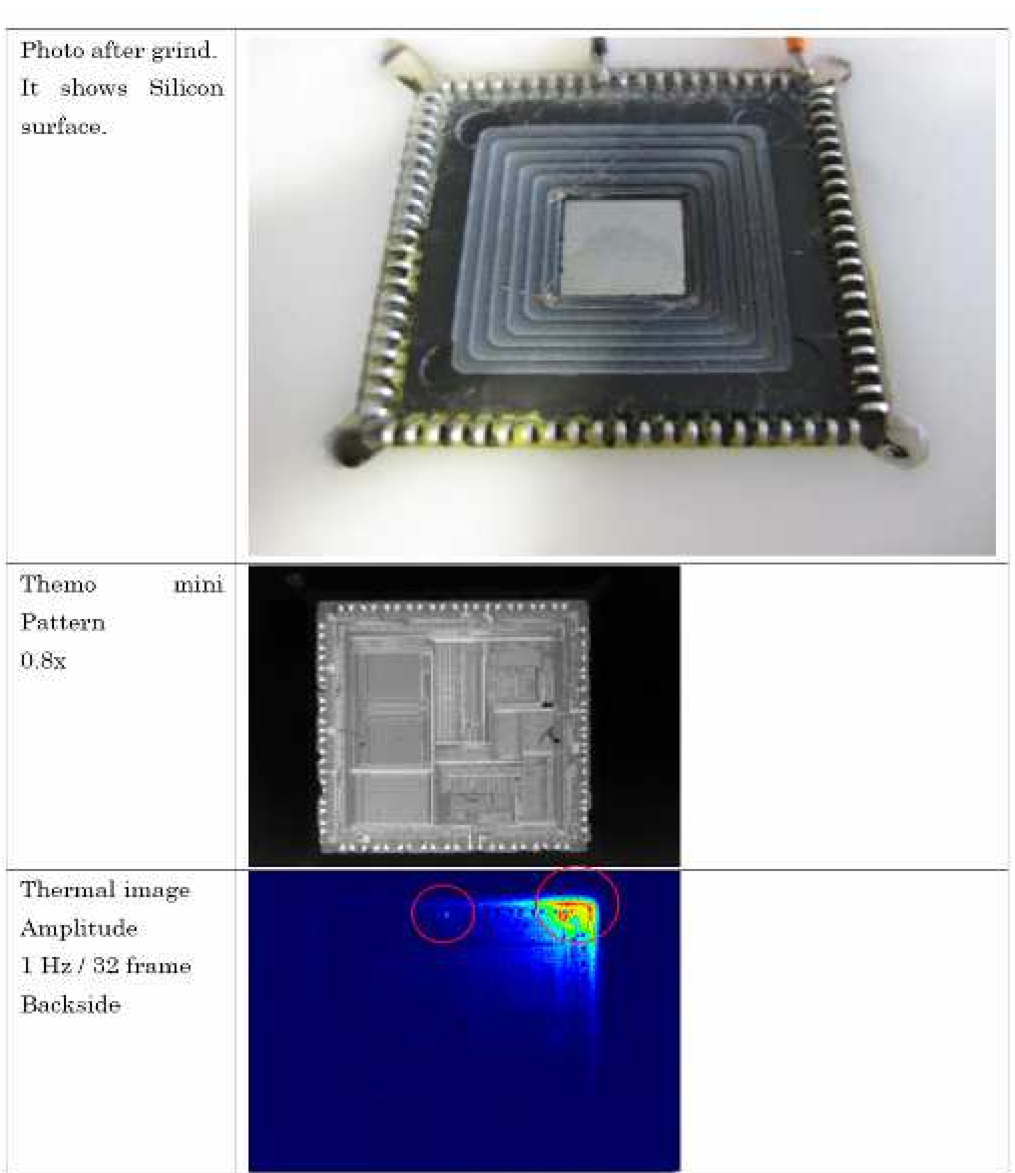
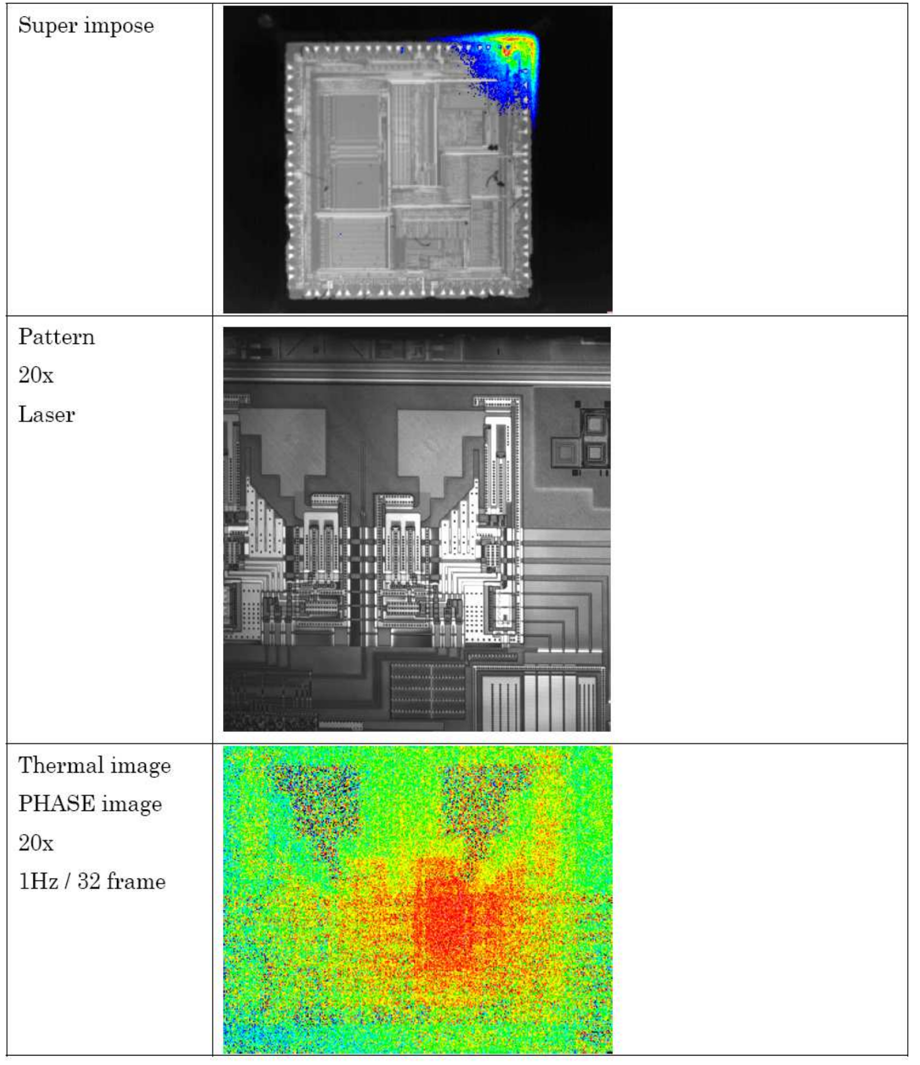


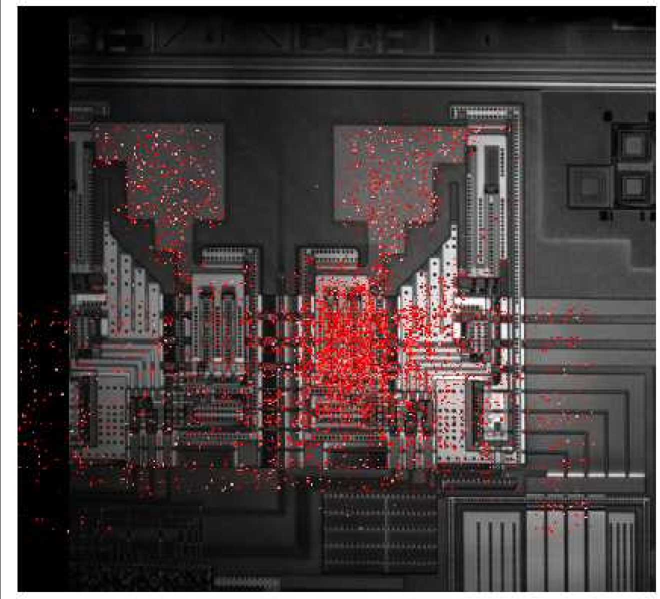
Photo after grind. It shows Silicon surface.	
Themo mini Pattern 0.8x	
Thermal image Amplitude 1 Hz / 32 frame Backside	

X ray and Thermal imaging approach



Super impose	
Pattern 20x Laser	
Thermal image PHASE image 20x 1Hz / 32 frame	

X ray and Thermal imaging approach

Super Impose	

Thermal signal is observed around bonding part on Si.
There is another thermal signal observed at left side of large one. We guess this small spot causes a tail in the signal we observed on the device surface.

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