Non-destructive testing of a Garmin memory module, case CEN21FA150

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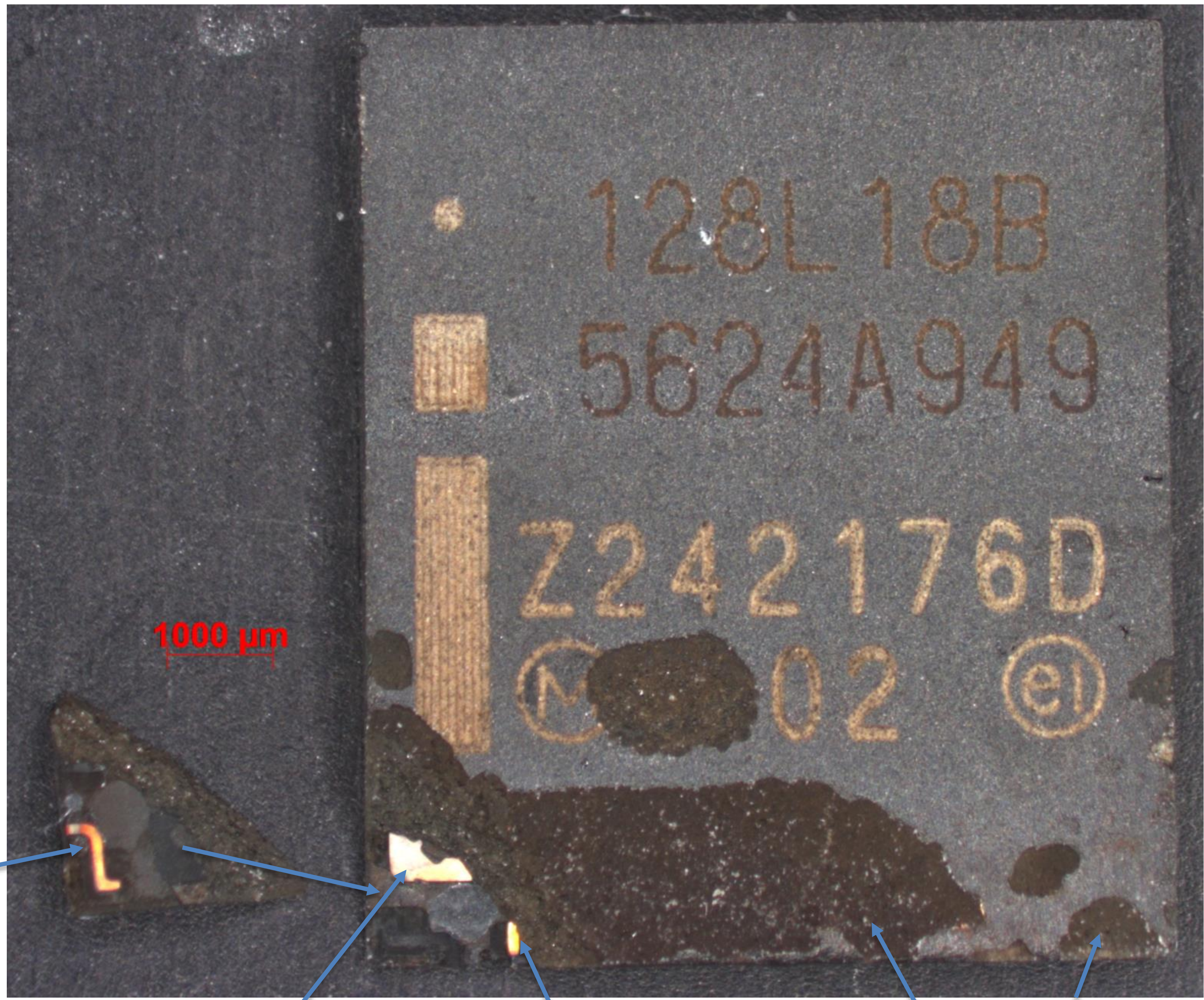
Summary and Conclusions

- One Garmin memory module, CEN21FA150, was received for non-destructive testing to evaluate any external and internal damage.
- The module was examined with the optical, x-ray and acoustic microscopy.
- Optical inspection results:
  - Physical damage and signs of thermal damage are seen in bottom 1/3 area of the module. There is damage to the mold compound as well as discoloration of the substrate material in this area. The module is slightly bent. Mold material is broken-off in the bottom right corner of the package exposing internal features such as Cu planes, gold wire with its wedge bond and a bent Cu line.
- X-ray imaging results
  - X-ray imaging was done with medium size x-ray spot (mode 1), minimal exposure time and Cu filter to prevent any data corruption from x-ray exposure.
  - Memory module contains a single die with wire-bonds on two sides of the die. All wire bonds were examined at high magnification and from various oblique angles. No wire and/or wire bond damage was seen except for the one in the chipped corner of the module.
  - Side view of the module reveals separation between the mold compound and the die in the damaged area. This separation extends all the way to wire-bonds likely resulting in their lift-off and electrical discontinuities, Mold compound shows internal damage. Substrate is bent in this area.
- Acoustic Microscopy (C-SAM) results
  - Acoustic imaging was performed in the pulse-echo mode using 100 MHz transducer.
  - C-SAM results show severe degradation and damage to the mold compound and substrate material in the bottom 1/3 area of the package. C-SAM imaging confirms separation at the mold/die interface and reveals delamination of the mold/substrate.
- Conclusions:
  - This module is damaged at multiple fronts, namely (i) possible wire-bond separation from the die, (ii) damage to Cu planes and material of the substrate (iii) mold compound damage. It will not be possible to repair this module.

OPTICAL MICROSCOPY RESULTS

Front side

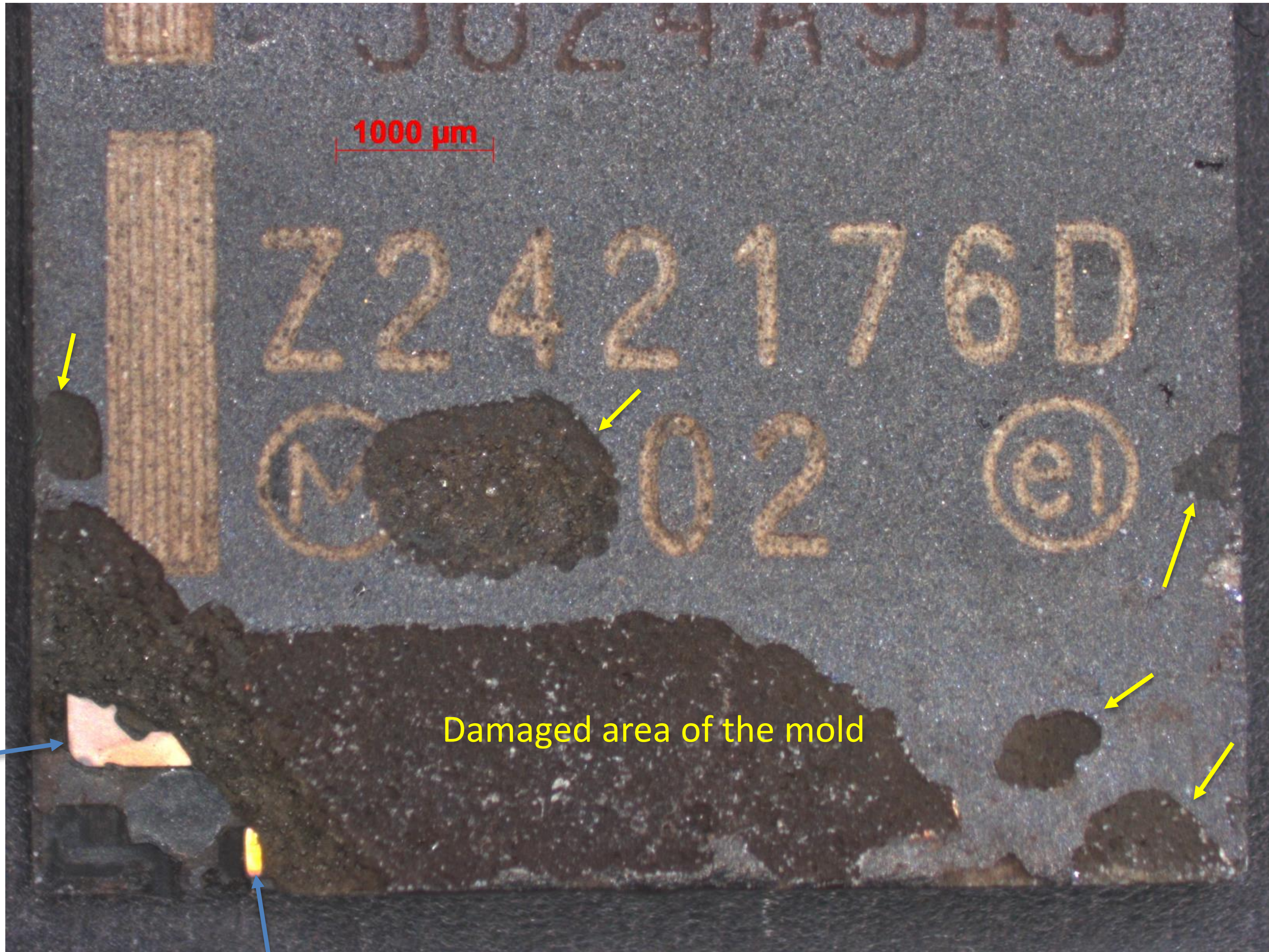


Separated piece from the damaged corner with a broken Cu line

Interior parts of the package are exposed

Mold is damaged

Front side



Exposed Cu plane of the substrate

Exposed wire bond

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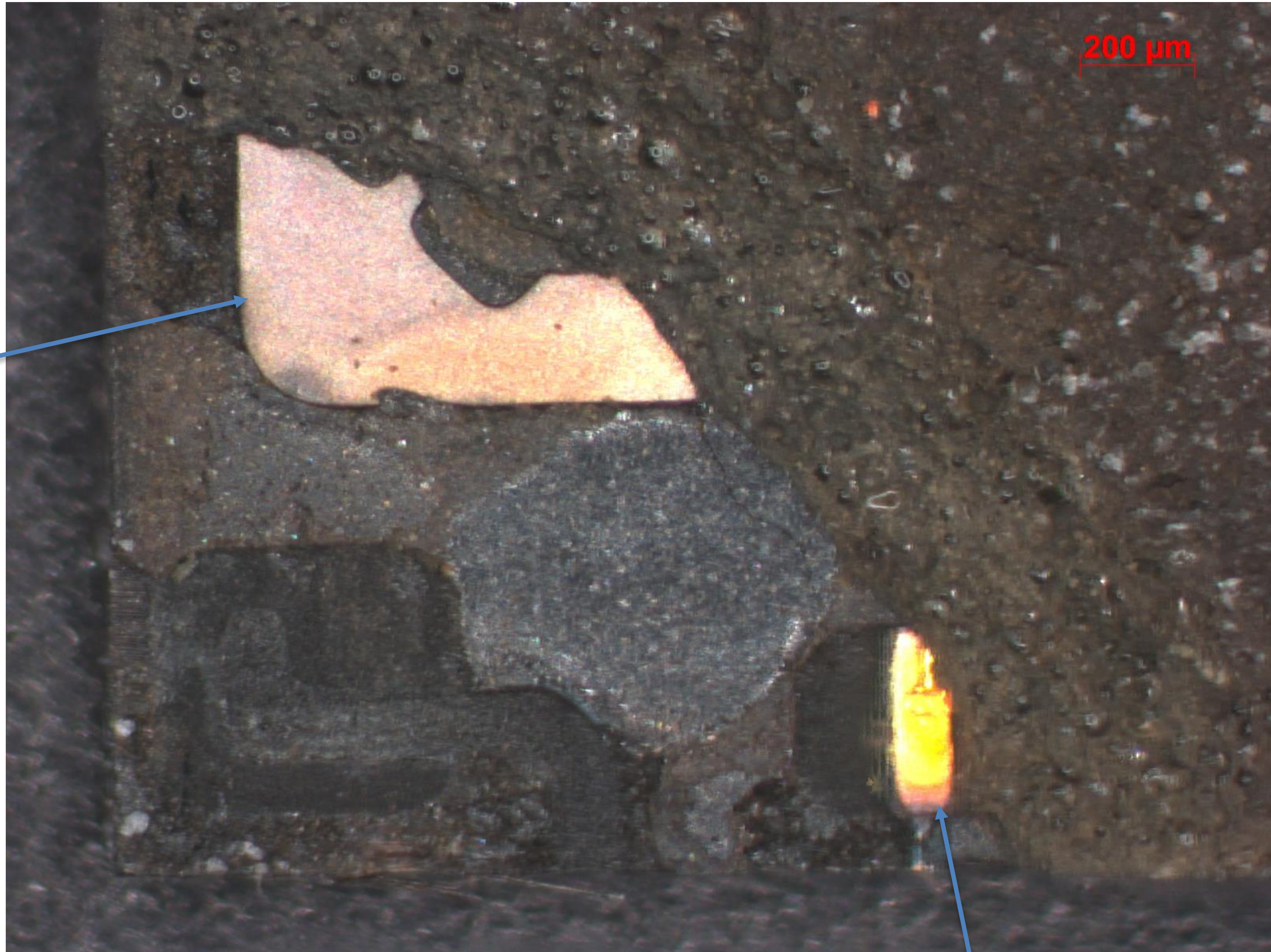
Damaged corner

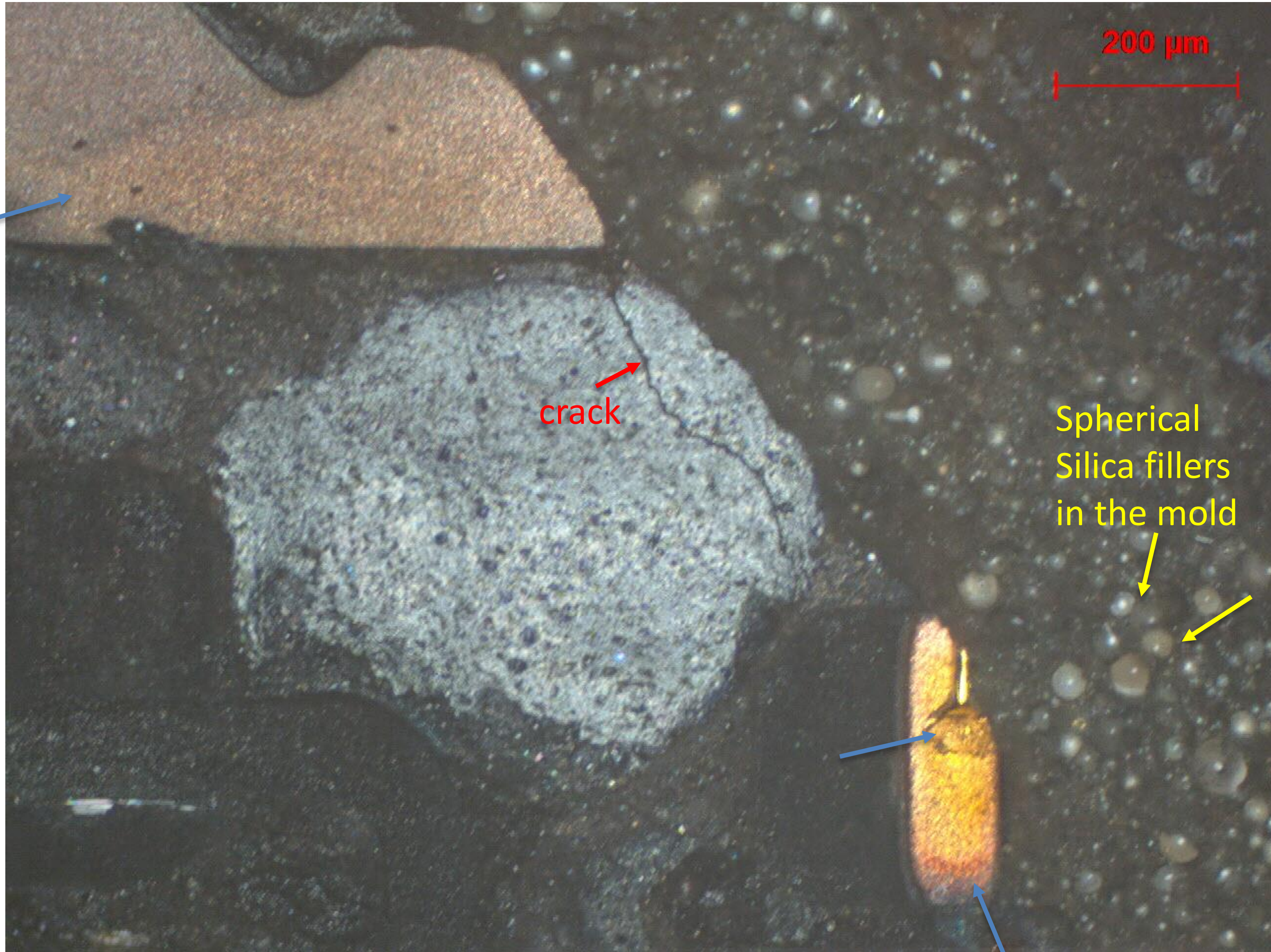
Exposed Cu plane of the substrate



Exposed wire bond

Damaged corner

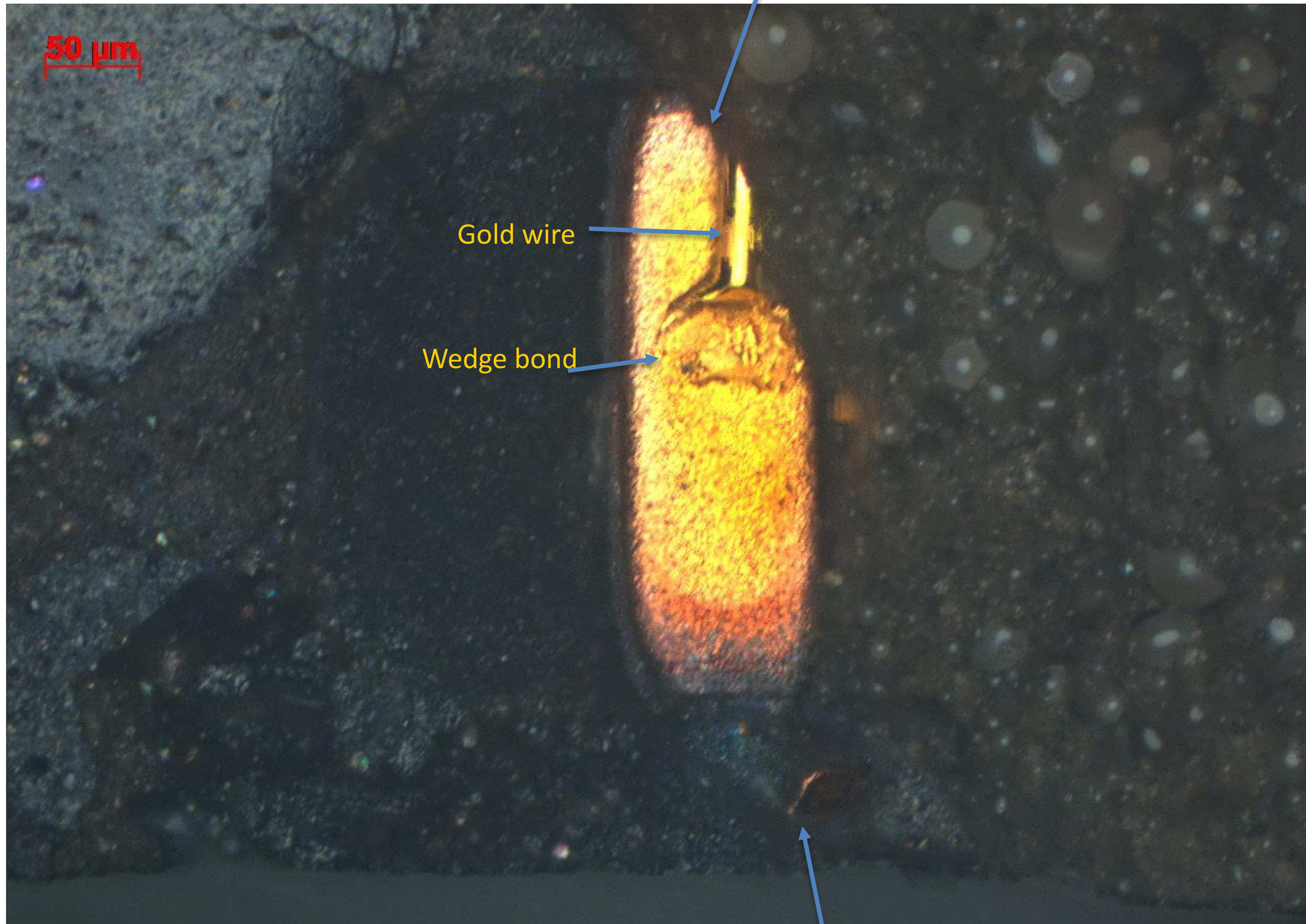
Exposed Cu plane of the substrate



Exposed wire bond on the substrate

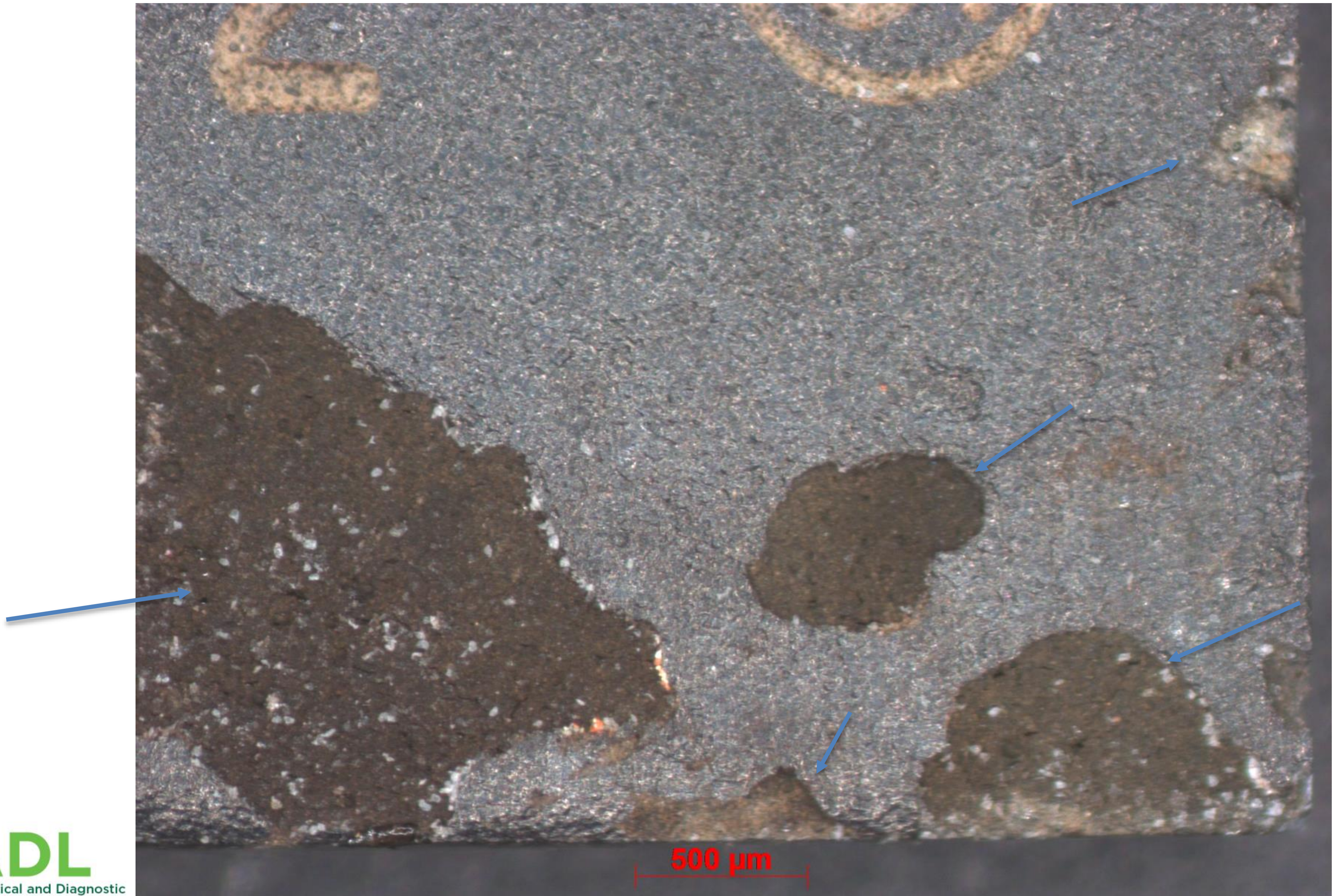
Exposed wirebond

Exposed gold wire with wedge bond on the substrate



Damaged Cu line

Damage to the mold



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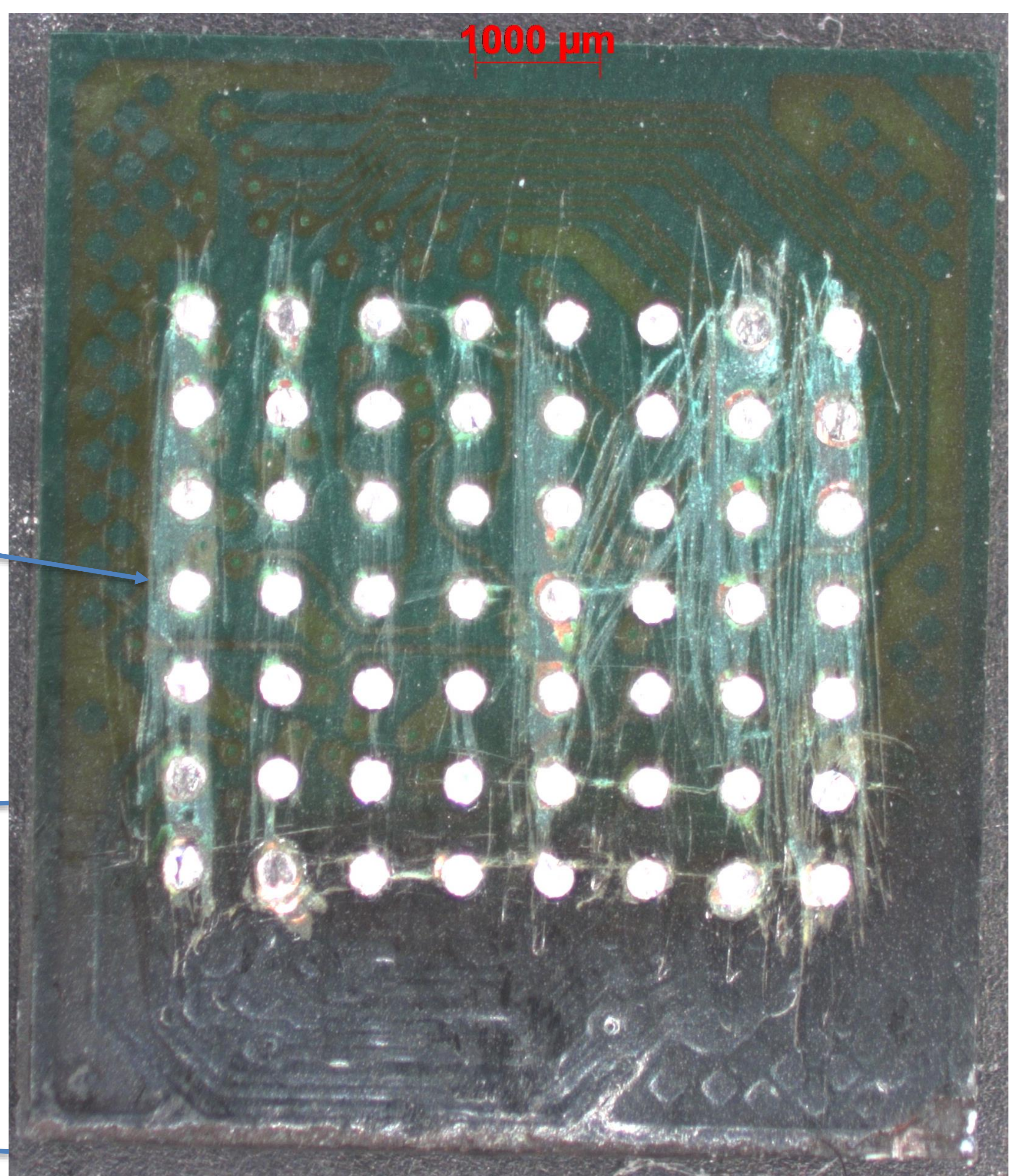
Back side

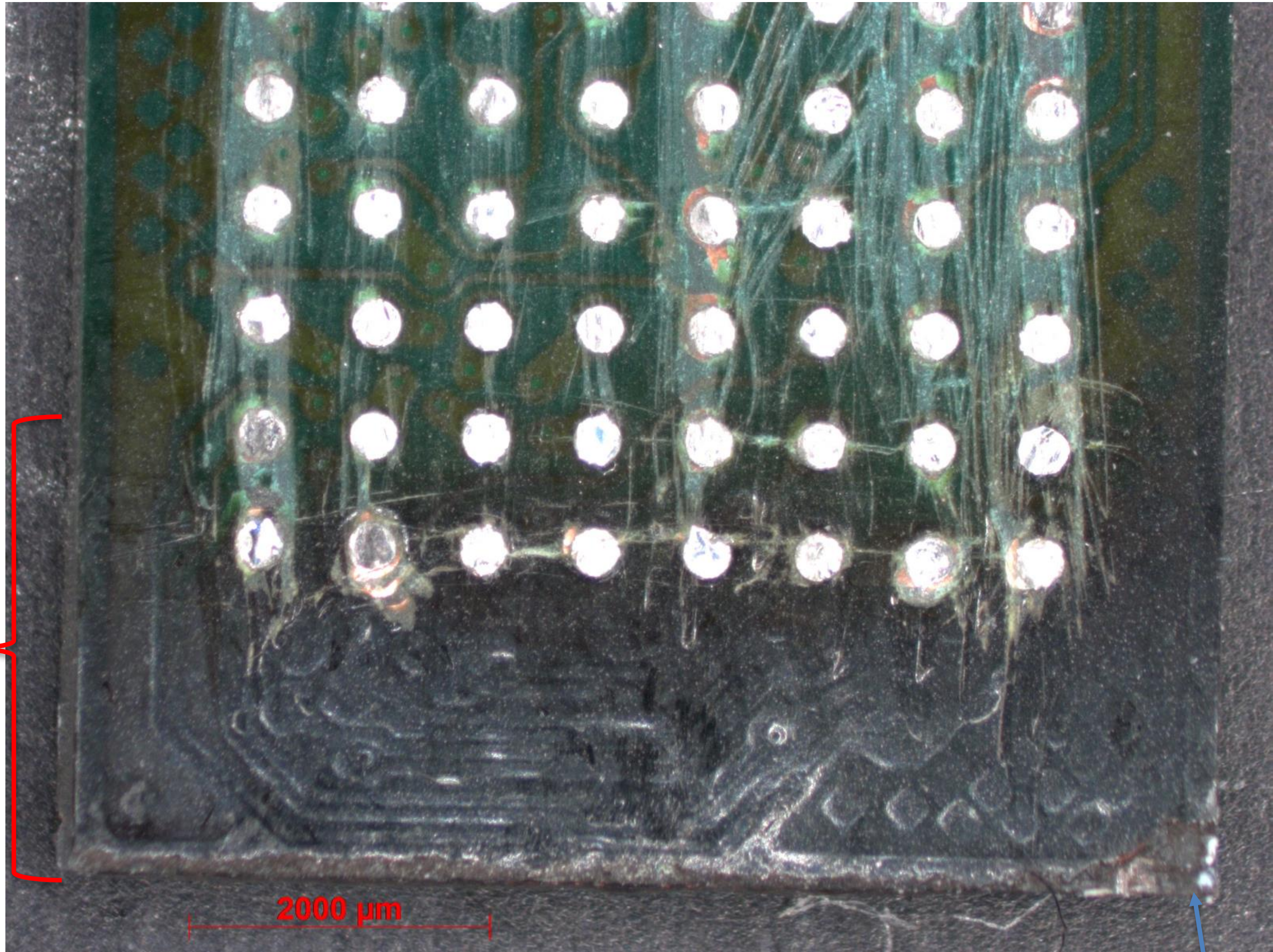
Solder ball grid array



Discoloration of the substrate material suggests possible thermal damage

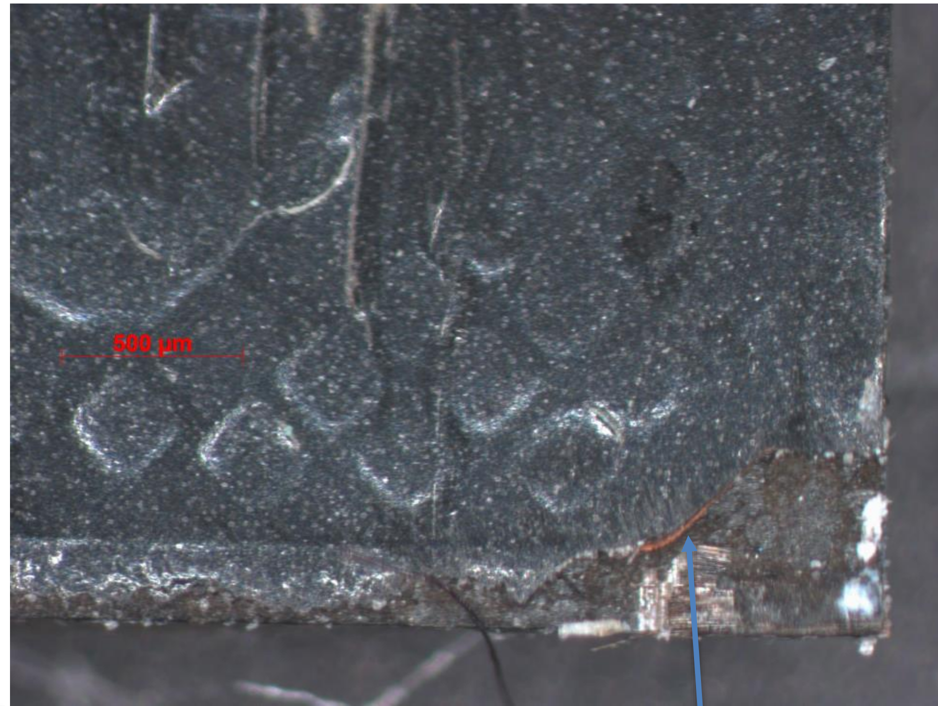
Backside: Damaged area

Discoloration of the substrate material.



Damaged corner

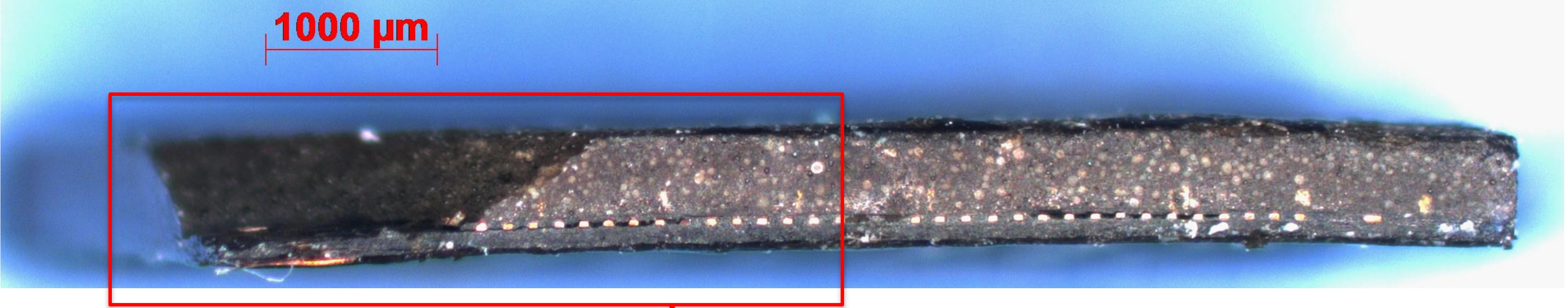
Backside: Damaged corner and edges of the package



Damaged edge of the package

Damaged corner with exposed Cu plane

Side view of the package: side 1



Package is bent.

1000 µm

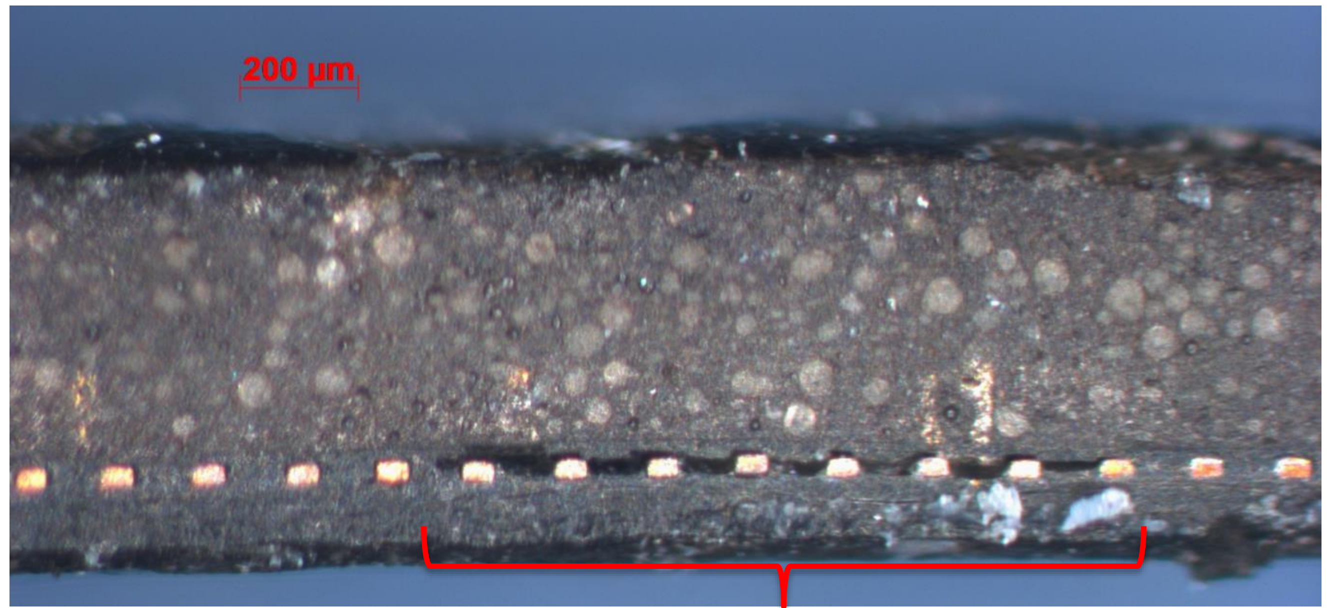
Damaged corner

Exposed Cu planes

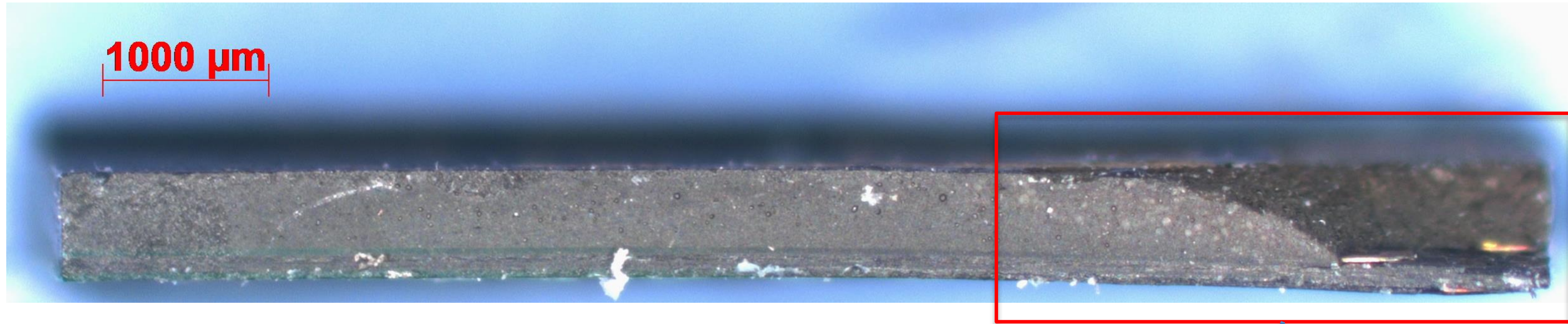
Cracks/separation of Cu lines in the substrate

Side view of the package: side 1

Cracks/separation of Cu lines in the substrate possibly due to bending of the package



Side view of the package: side 2

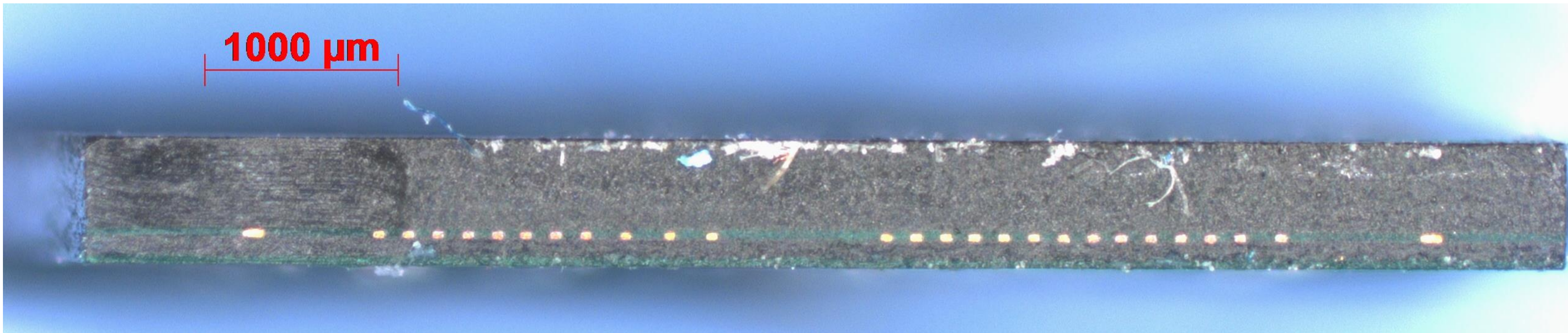


500 µm

Exposed Cu planes

Damaged corner

Side view of the package: side 3



200 µm

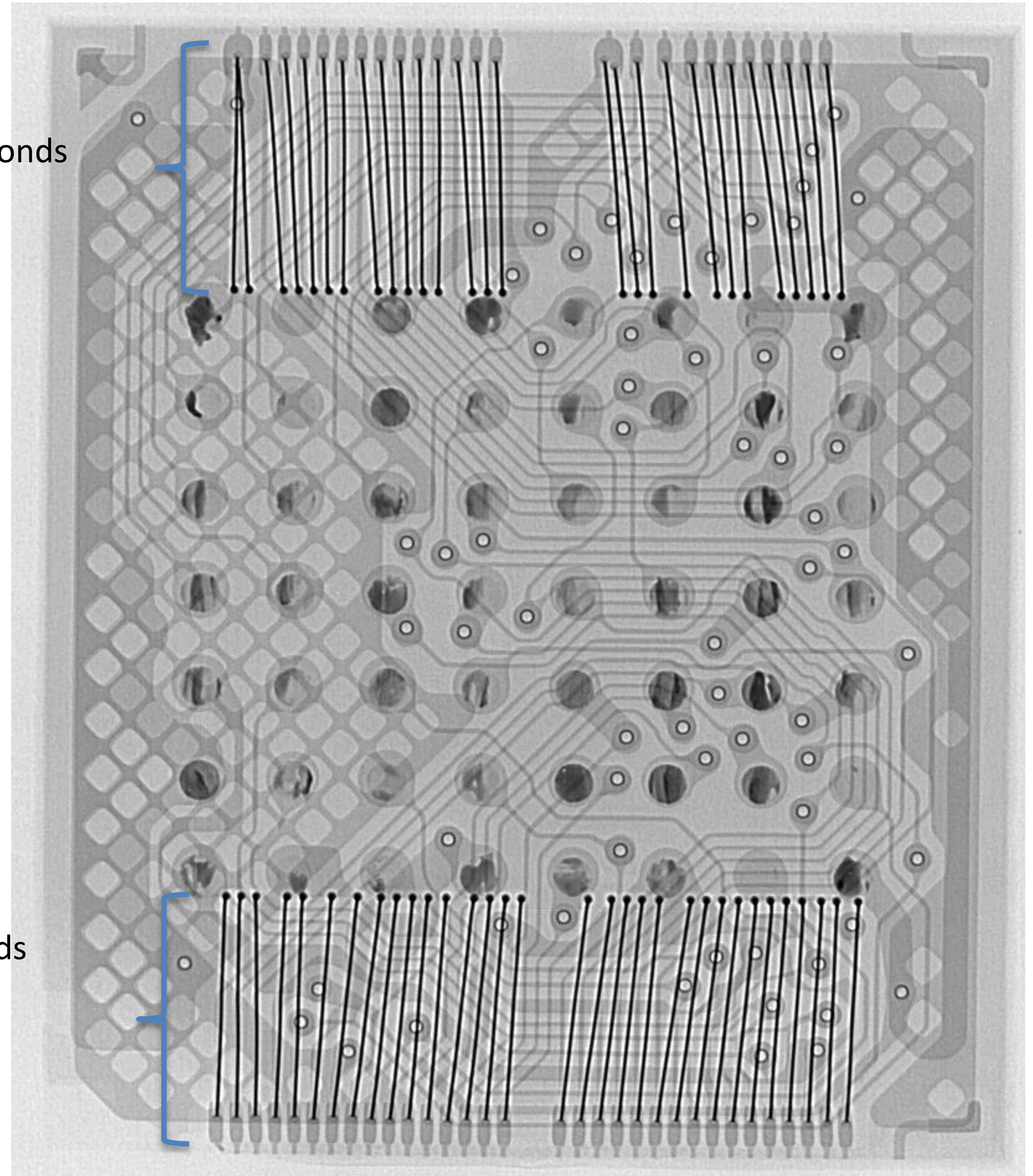
Undamaged side of the package

X-RAY MICROSCOPY RESULTS

X-ray image of the entire package

Row of wire-bonds

The memory module has a single die with wire-bonds on two sides



Row of wire-bonds

Damaged corner

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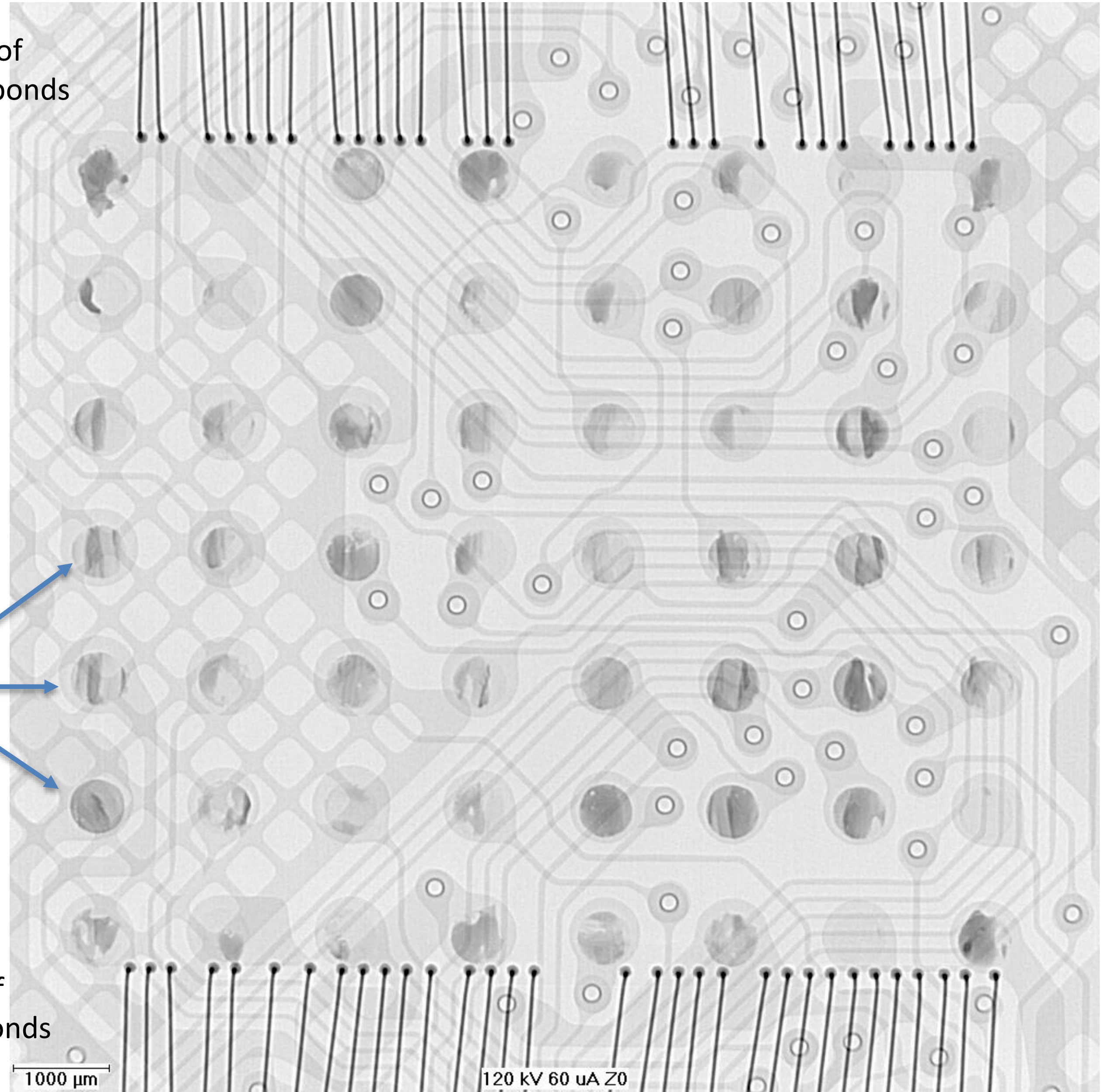
X-ray image of the die with wirebonds

The memory package has a single die with wirebonds on two sides

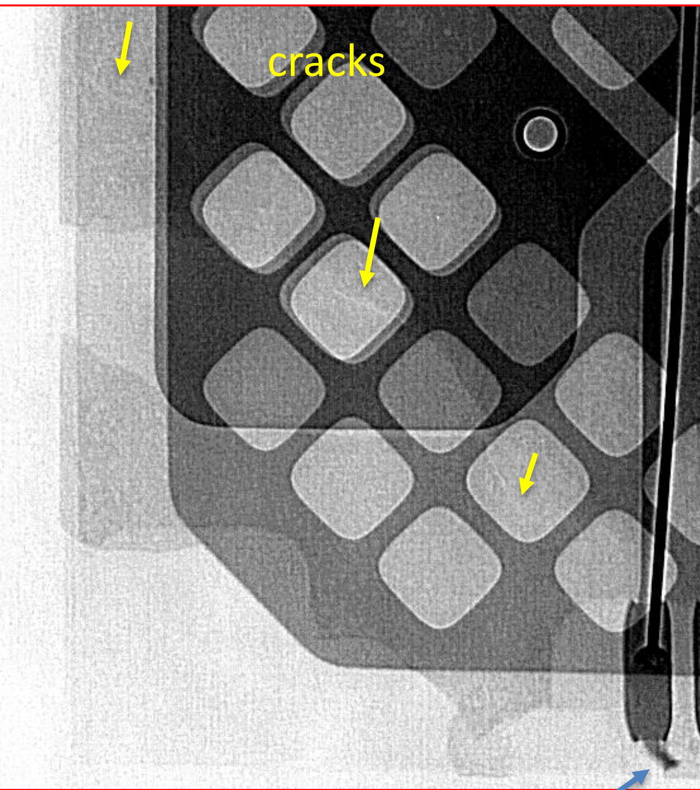
Solder ball grid array

Row of wirebonds



Row of wirebonds

X-ray image of the damaged corner



Exposed wirebond with damaged Cu line

X-ray image of the wire-bonds

Damaged wire-bond at the corner

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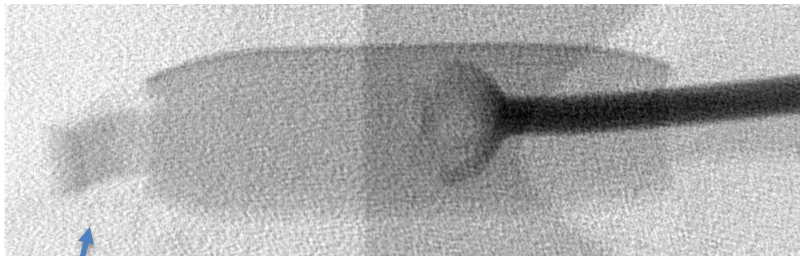
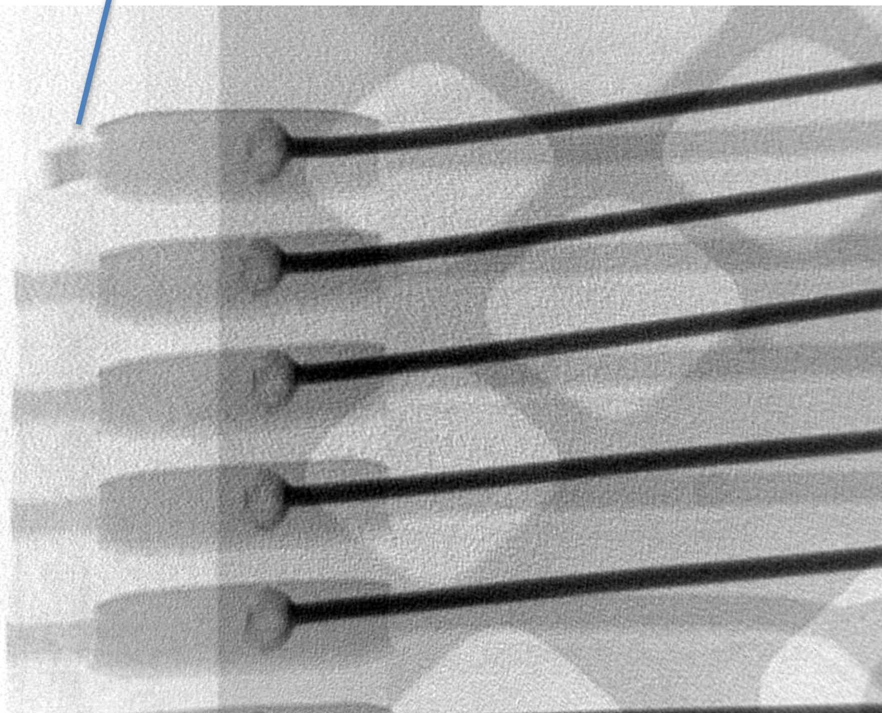
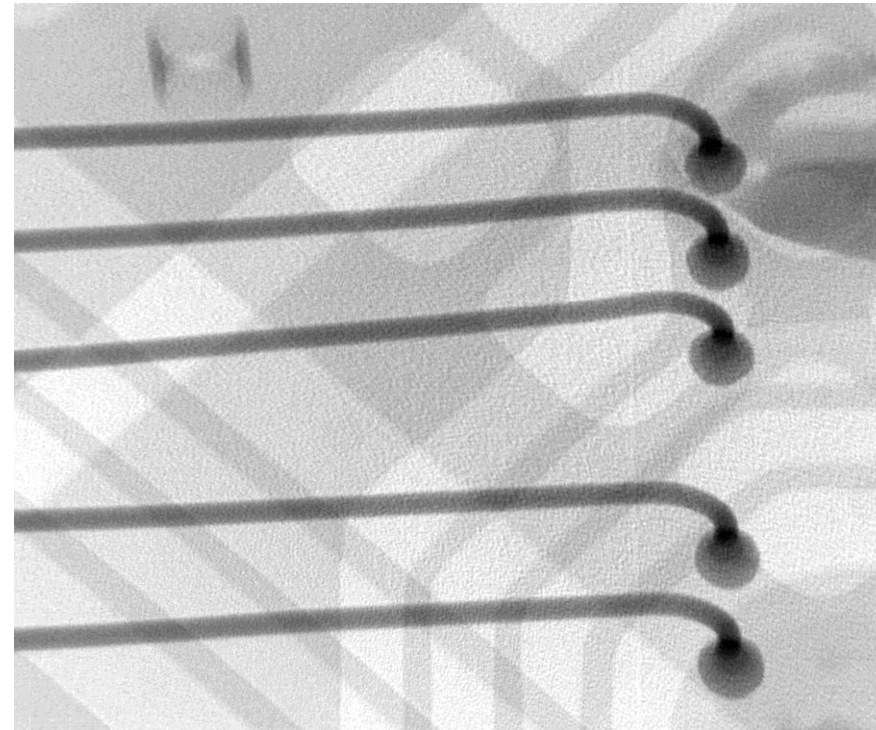
X-ray image of the wire-bonds: Oblique view



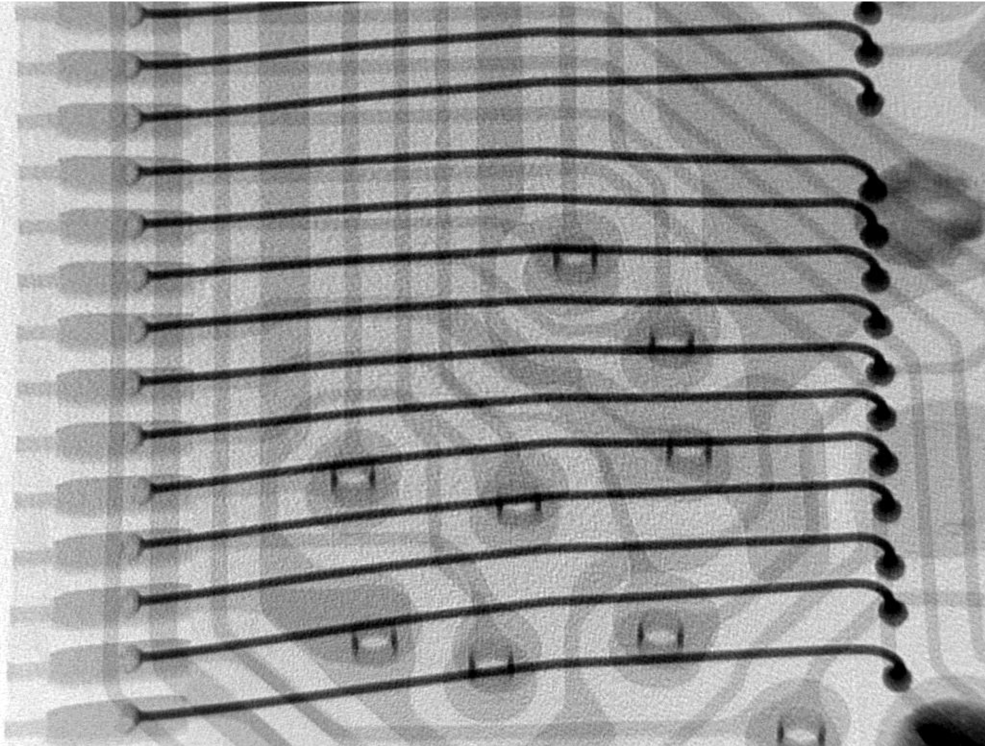




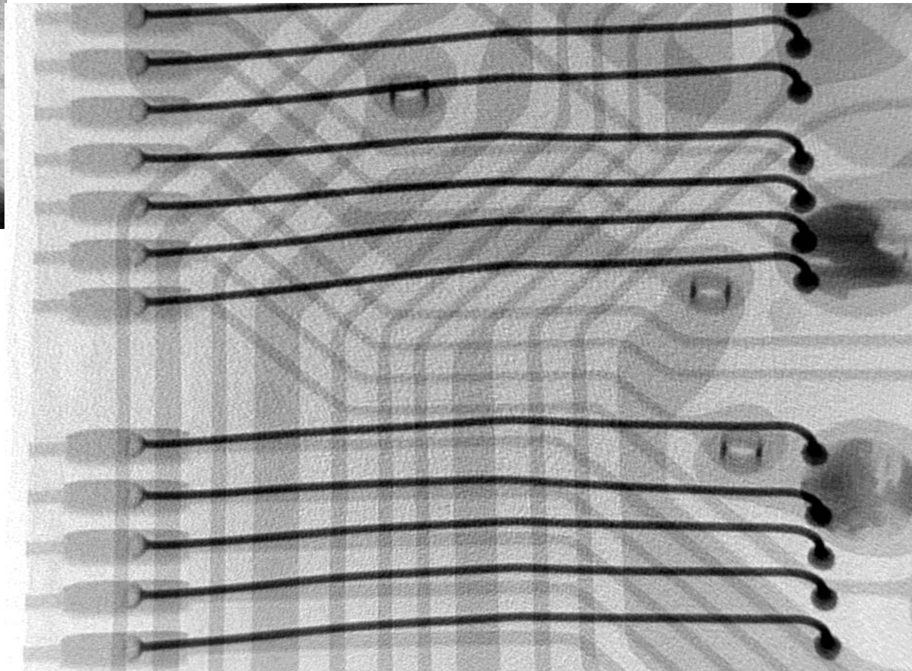
Die edge

No broken wires seen except for the damaged wedge bond at the corner.

X-ray images of the wire-bonds: Oblique view

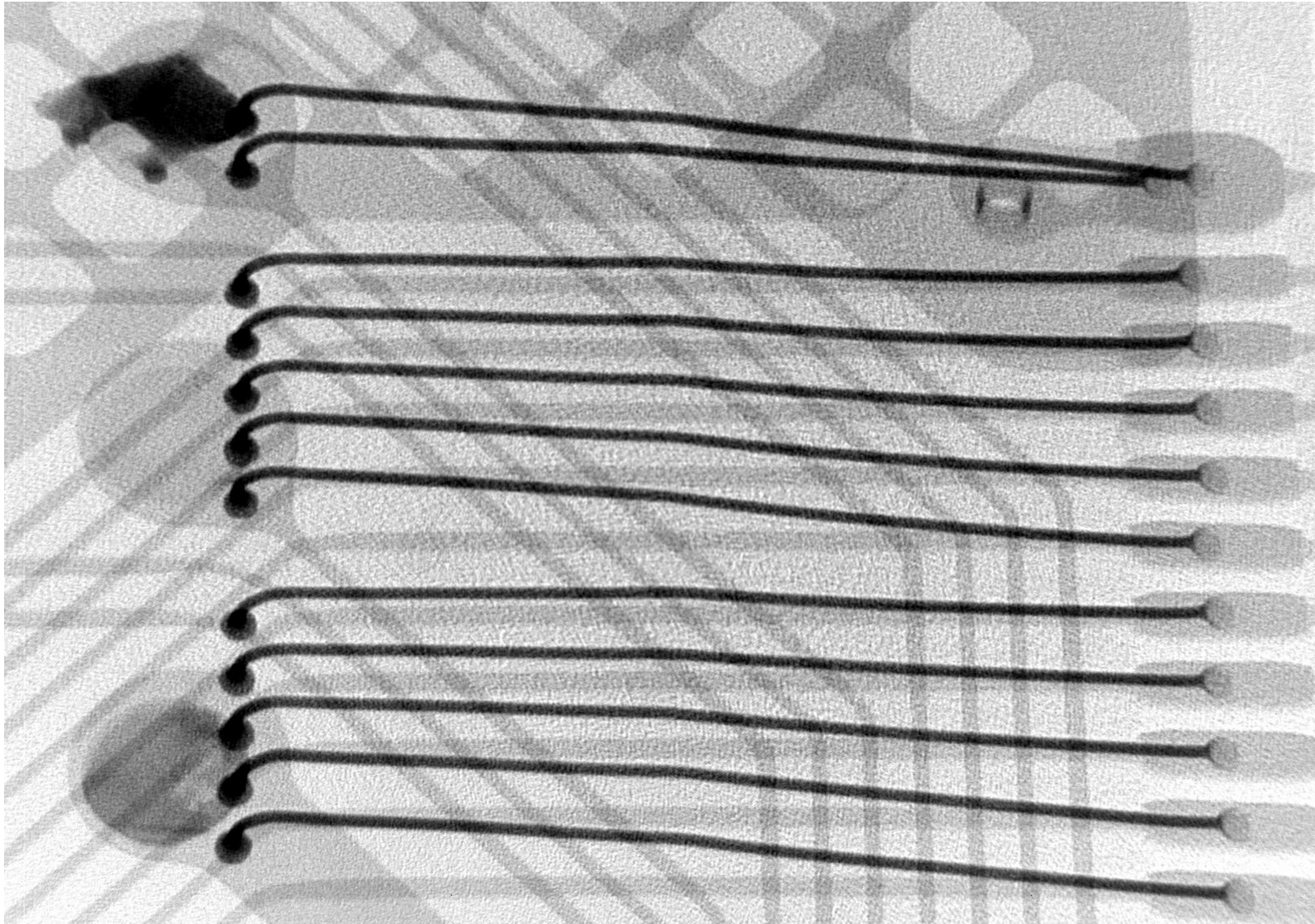


No broken wires seen



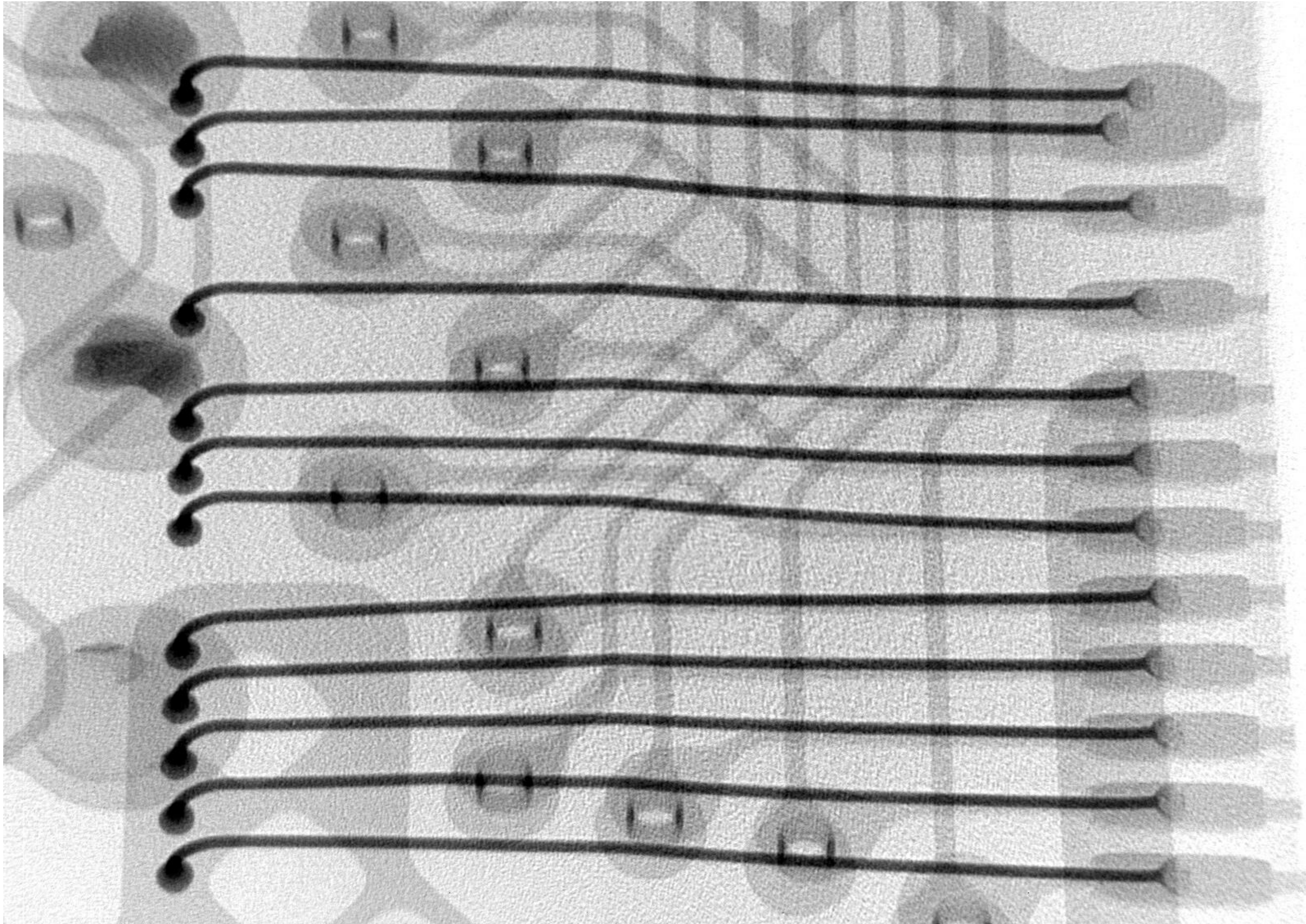
X-ray image of the wire-bonds: Oblique view

No broken wires seen



X-ray image of the wire-bonds: Oblique view

No broken wires seen



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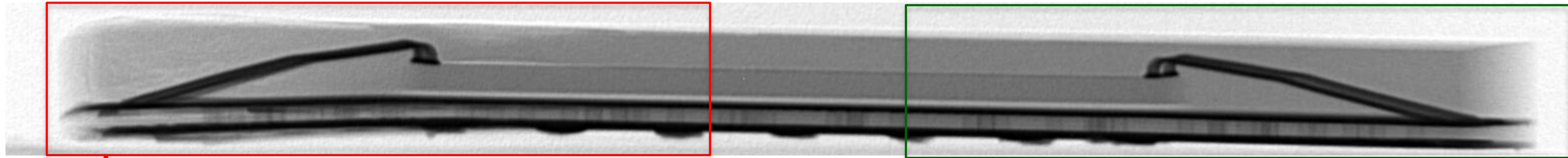
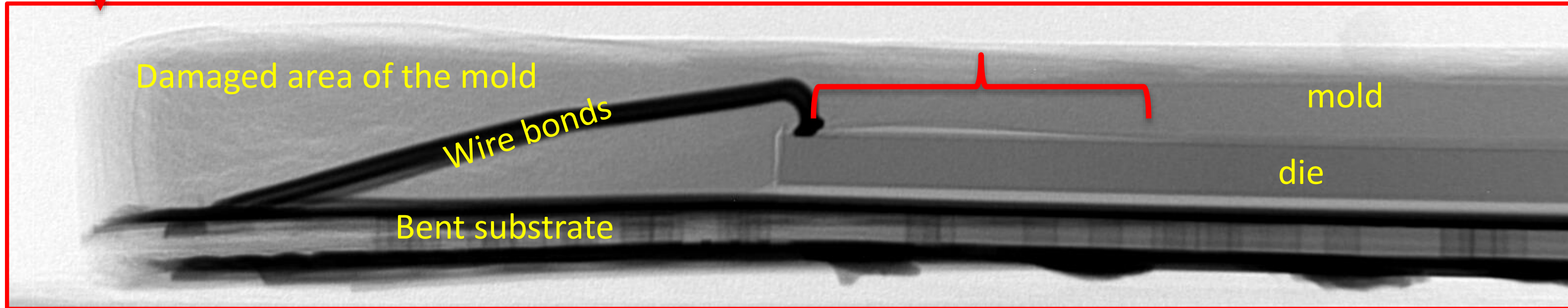
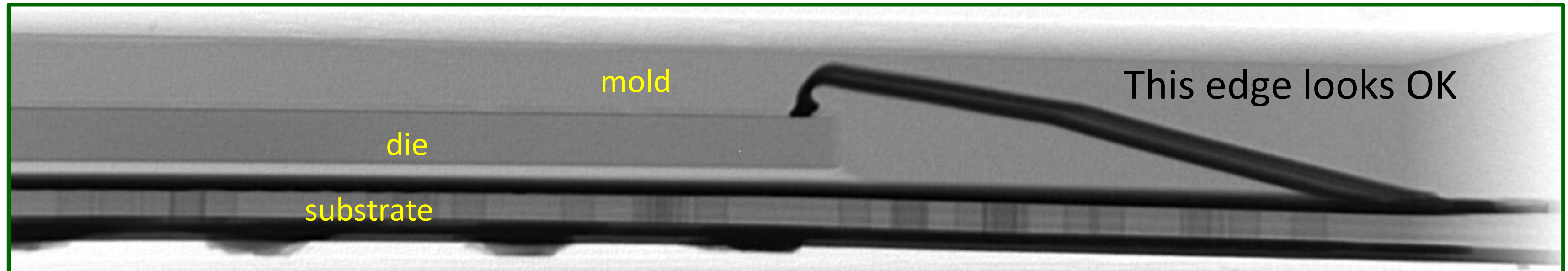
X-ray image of the side of the package





There is separation between the mold and the die which extends to the edge where wire-bonds are located. Wire-bonds are likely lifted off the bond pads.



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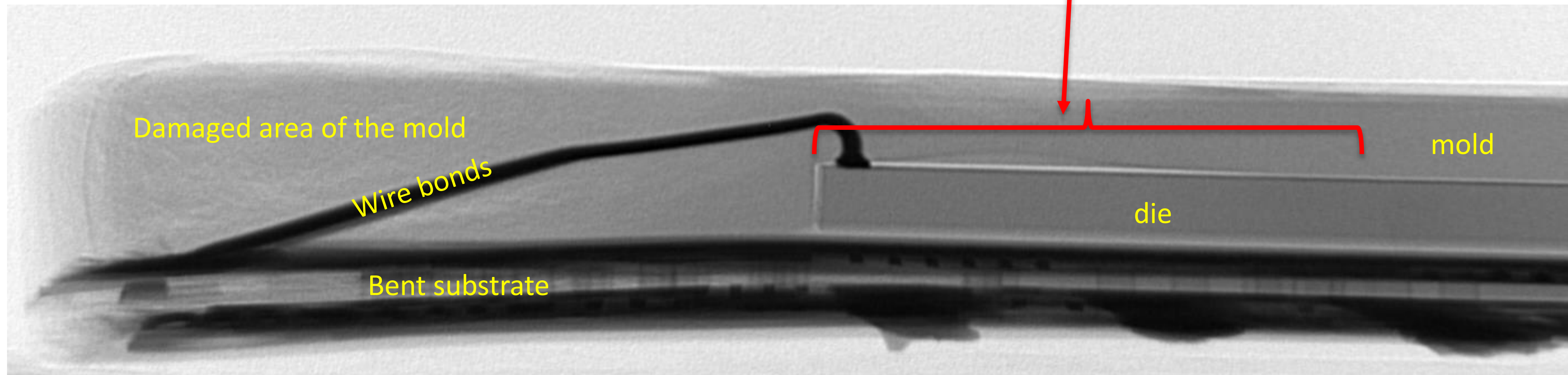
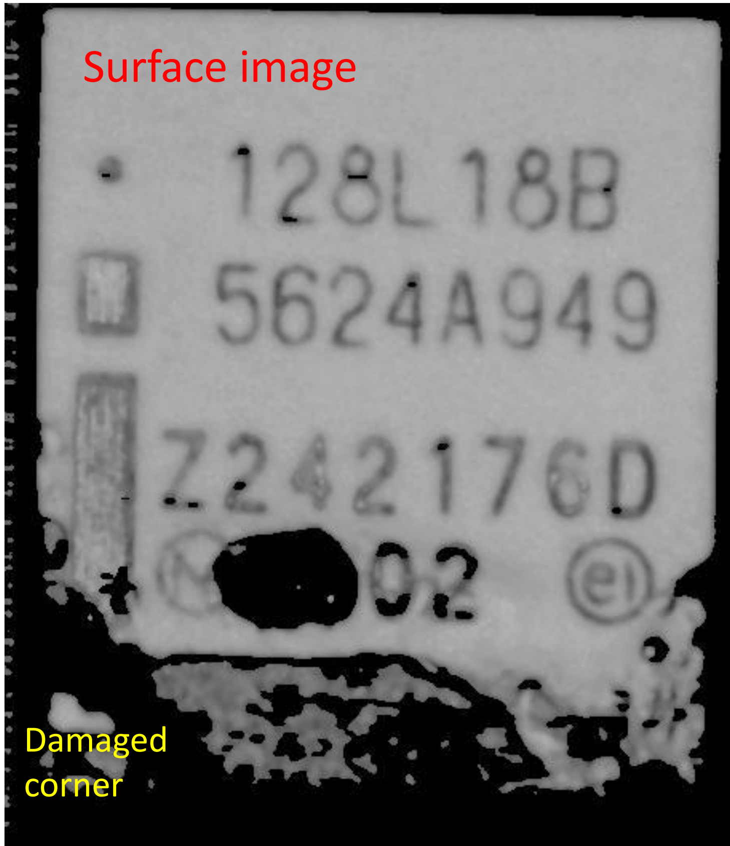
X-ray image of the damaged side of the package

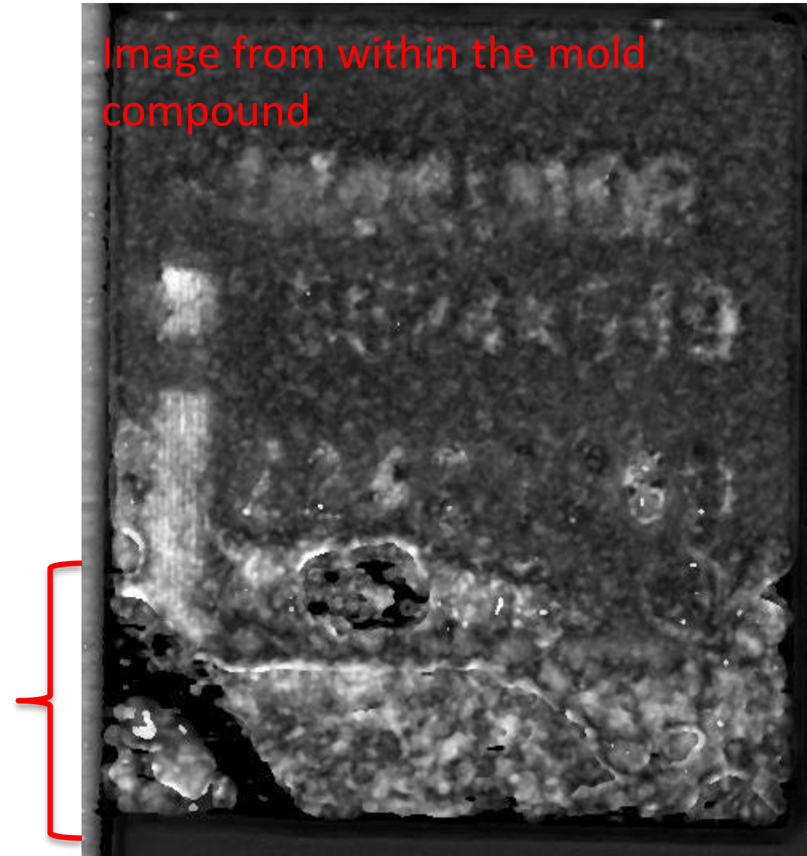
There is separation between the mold and the die which extends to the edge where wire-bonds are located. Wire-bonds are likely lifted-off the bond pads possibly resulting in discontinuities.

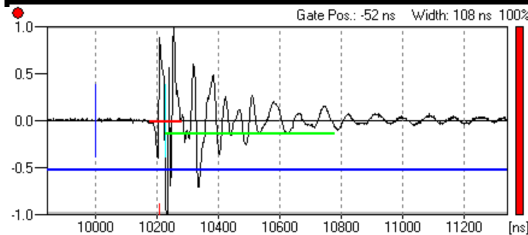


ACOUSTIC MICROSCOPY RESULTS

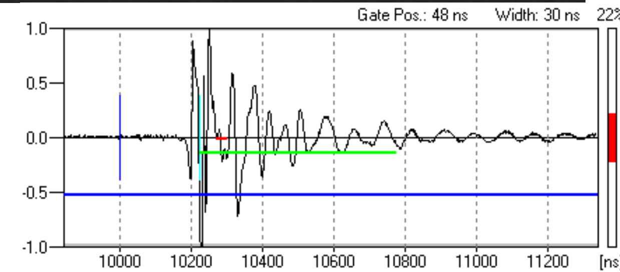
Acoustic images of the memory module: Front side



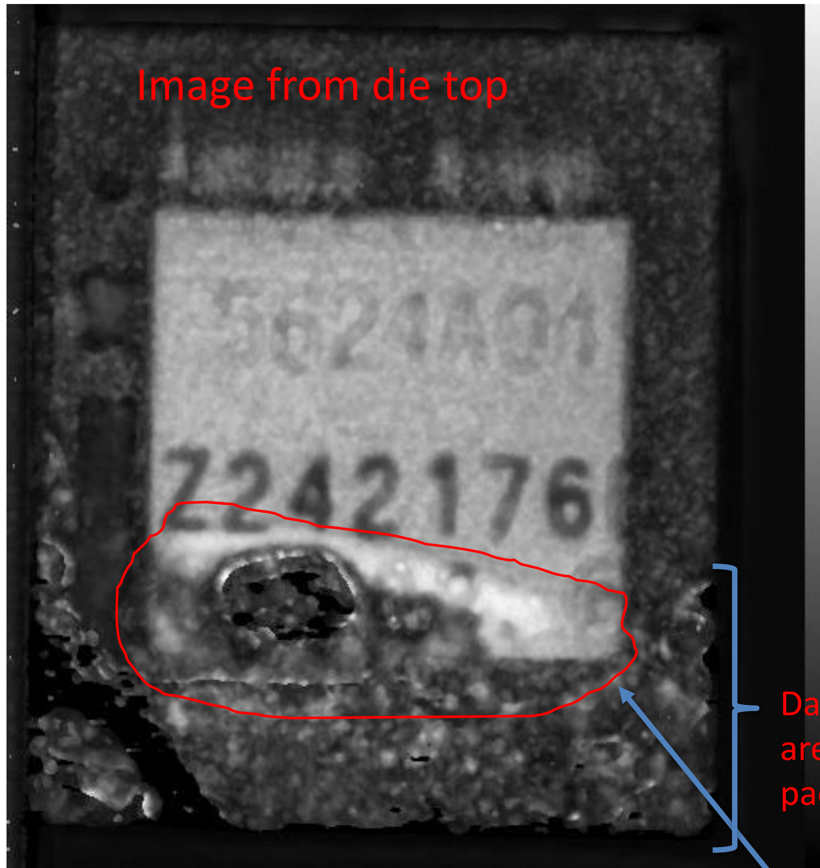




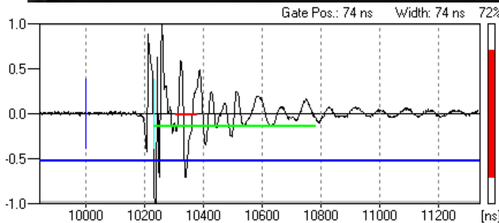
Acoustic imaging shows that there is lot of sound attenuation/ scattering/ reflection from the mold compound in bottom 1/3 area of the package. This area exhibited voiding/cracks/ degradation in the mold material.



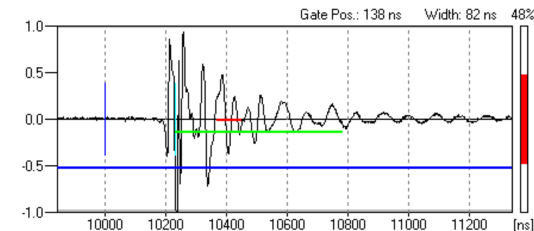
Acoustic images of the memory package



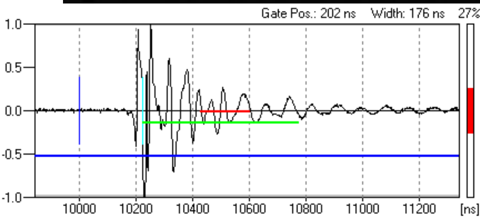
Damaged area of the package



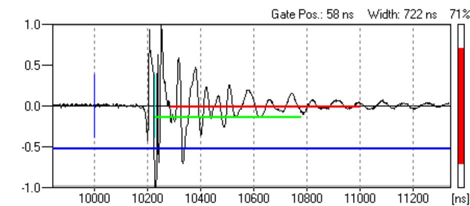
- Acoustic imaging confirms separation of the mold from the die (brightest areas due to high sound reflection)
- Because of the damaged mold in the bottom area of the package, sound is scattered/ reflected/attenuated and can not travel beyond the mold thickness.



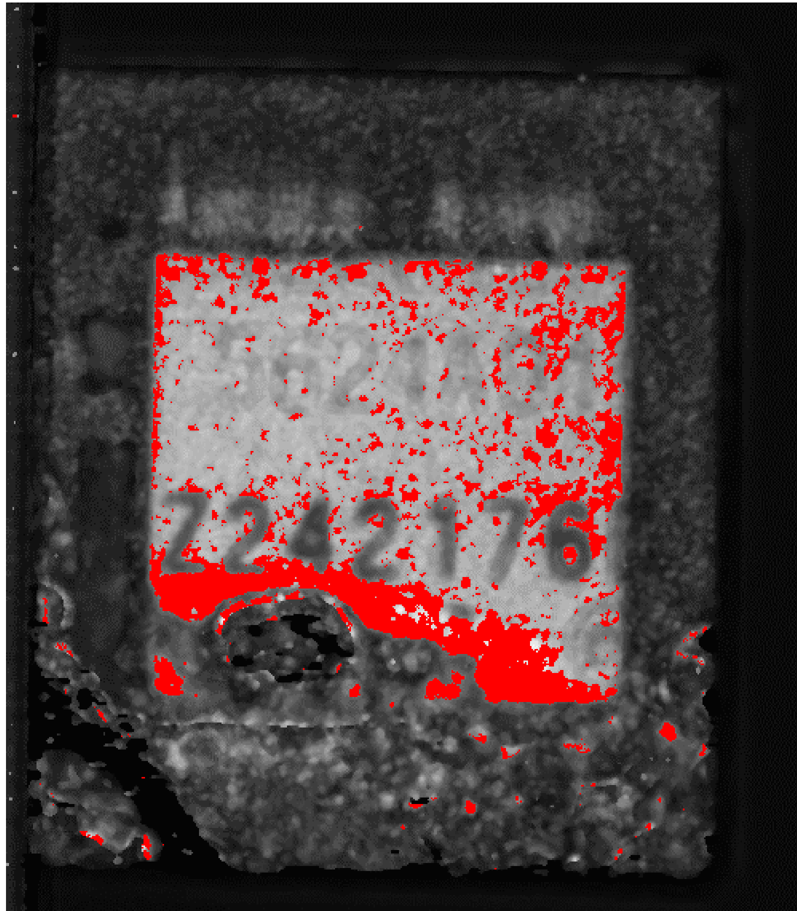
Acoustic images of the memory package



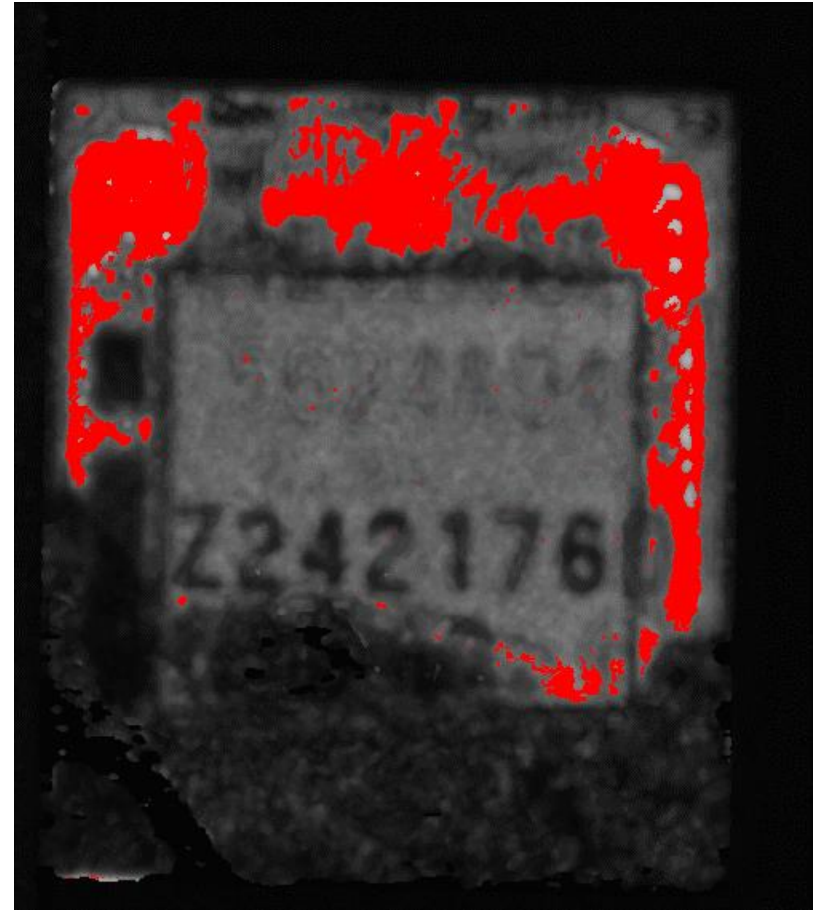
- Because of the damaged mold in the bottom area of the package, sound is severely attenuated and can not travel beyond the mold thickness.



Acoustic images of the memory package

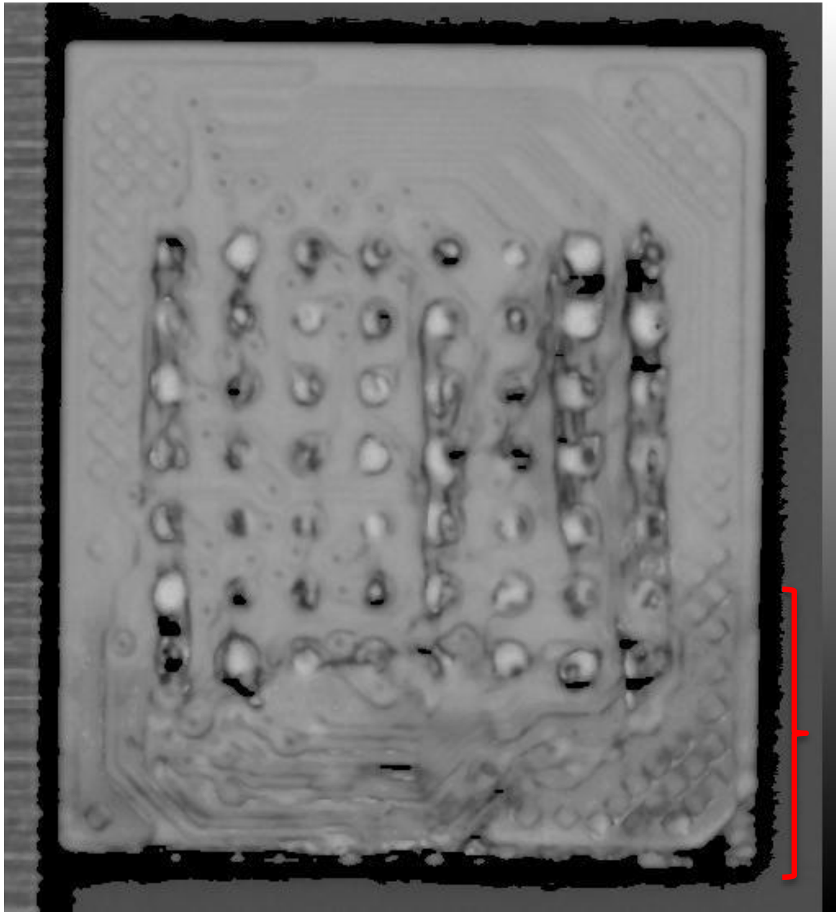


Red areas indicate possible delamination between the die and mold compound

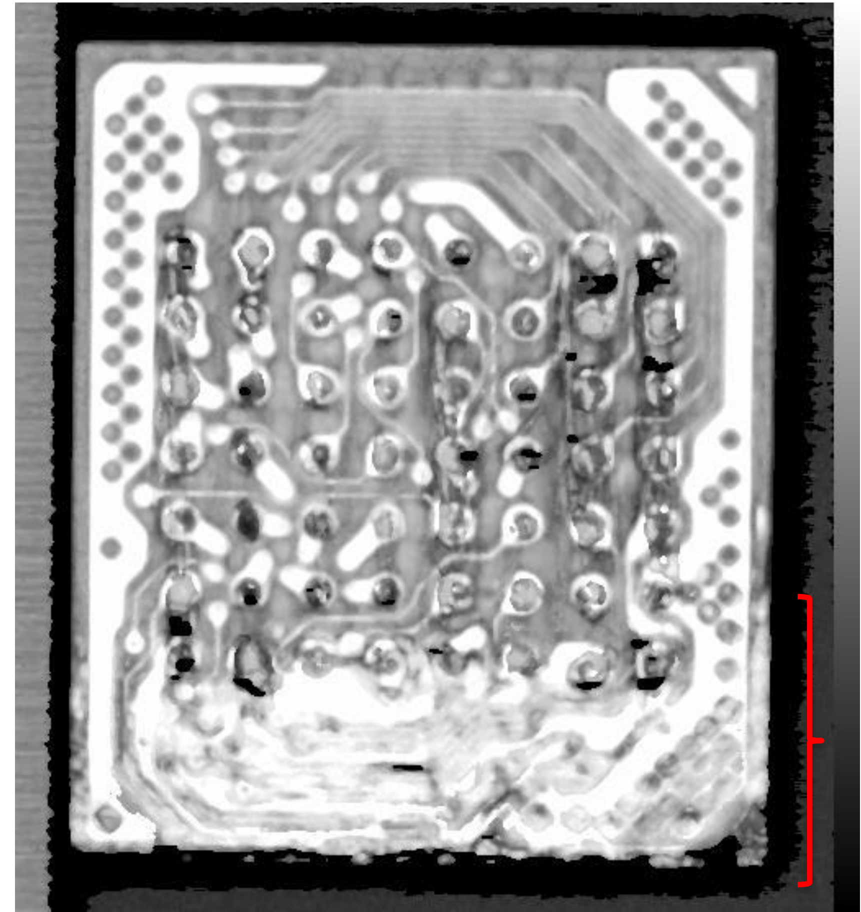


Red areas indicate possible delamination between the substrate and the mold compound

Acoustic images of the memory module from the backside



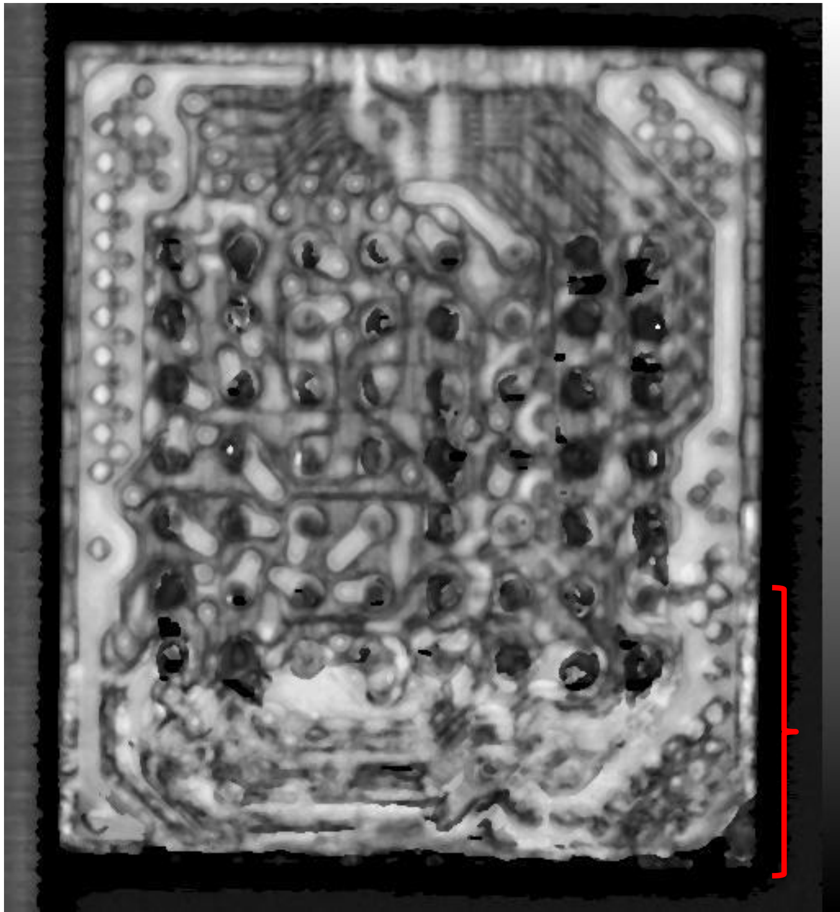
Substrate Surface



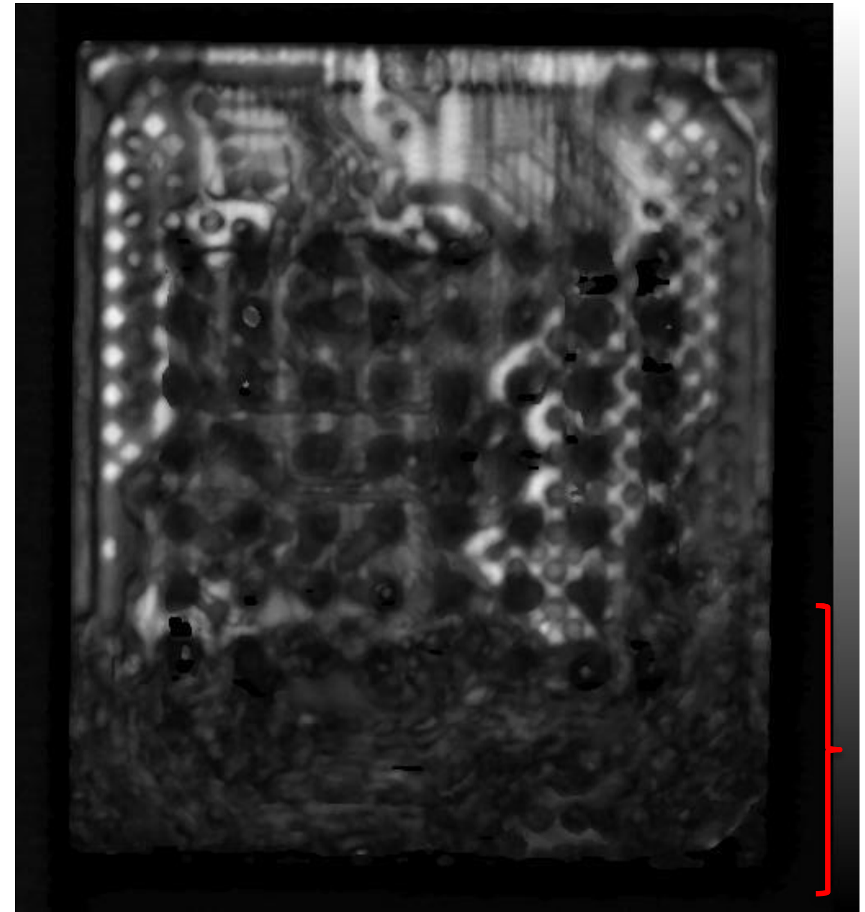
Within the substrate

Acoustic imaging from the backside of the module shows internal damage within the substrate in the bottom area of the package

Acoustic images of the memory module from the backside



Deeper layers



Deeper layers

Acoustic imaging from the backside of the module shows internal damage within the substrate.