Physical Analysis Report on CEN15FA290

Prepared by Binghamton University for the National Transportation Safety Board, September 15, 2015

Section 1

OVERVIEW

Summary of the Analyses

- Personnel Assignments for this Project
  - Dr. Stephen R. Cain – project manager and DECU analyses (optical, x-ray, and acoustic microscopy)
  - Dr. Lawrence Lehman – APPAREO optical microscopy
  - Dr. Anju Sharma – APPAREO x-ray and acoustic microscopy
- Summary of Findings
  - Configuration of the DECU modules
    - All parts were single chip modules with wire bond interconnections
    - Chip mounted on a lead frame with fan out from the wire bond pads to the external leads
  - Configuration of APPAREO modules
    - One module was a single chip module
    - Two modules had 4 large chips stacked on a lead frame (two on the top of the lead frame, two on the bottom of the lead frame
    - Wire bonds connected chips to external leads

Summary of the Analyses, cont'd.

Box & Part	Type	Optical	X-ray	C-SAM
Box 1, MN75*	DECU	Cracks, bulging	Wire bonds pulled from chip	No image
Box 1, MN76*	DECU	Cracks, bulging	Wires appear in tact	No image
Box 2, MN75	DECU	Cracks, bulging	Wire bonds pulled from chip	No image
Box 3, MN30	DECU	Cracks, blisters	Broken wires	No image
Box 4, MN30	DECU	Cracks, blisters	Wires appear in tact	No image
Box 5, SD	APPAREO	Part in two pieces with chip exposed	Inconclusive	No image
Box 6, Part 1	APPAREO	Cracks, blisters	Broken wires	Inconclusive
Box 6, Part 2	APPAREO	Cracks, blisters	Wires appear in tact	Inconclusive

*MN75 and MN76 could not be distinguished in box 1 – these labels could be switched

Likelihood of Data Recovery

- MN30 in box 4 (DECU) and Part 2 in box 6 (APPAREO): low to moderate
- MN75(76) box 1: low
- Remaining parts: poor

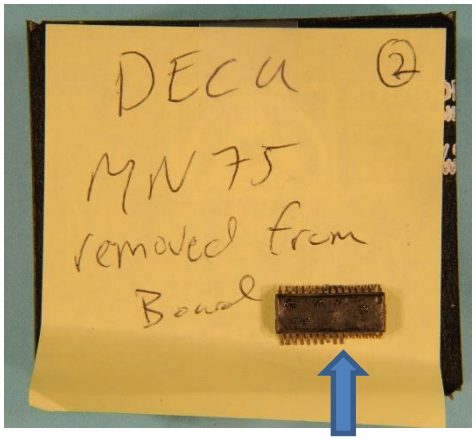
Section 2

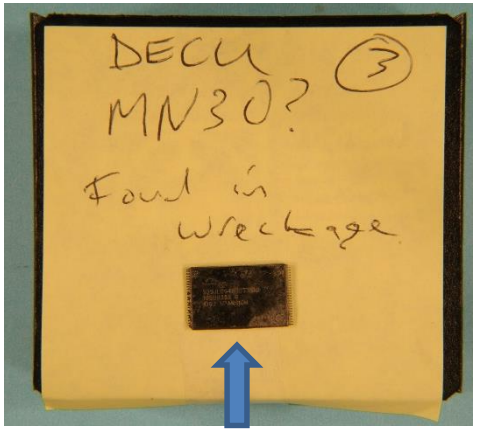
ANALYSES OF THE DECU MODULES

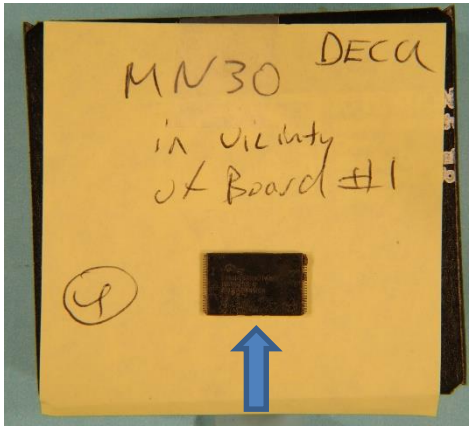
Instrumentation

- Wild 420 Zoom Stereoscope
- Fein Focus Series FSX 100.23 X-ray Imaging System
  - Voltage run between 60 and 80 KV
  - Imaging with 255 integrations
- Sonix HS500 Acoustic Microscope
  - 15 MHz transducer (low frequency for deep imaging)
  - Pulse echo mode
  - No sonograms could be obtained due to the heat damage of the overmold (fissures scatter the sonic pulse)

Catalog of DECU Parts

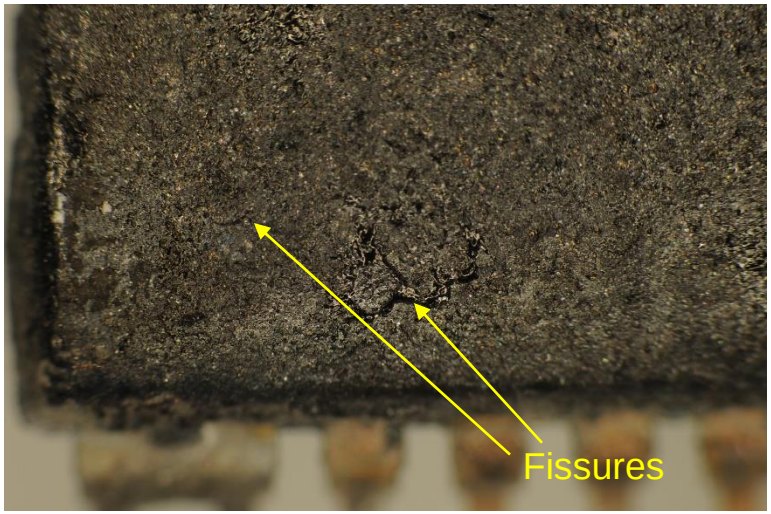


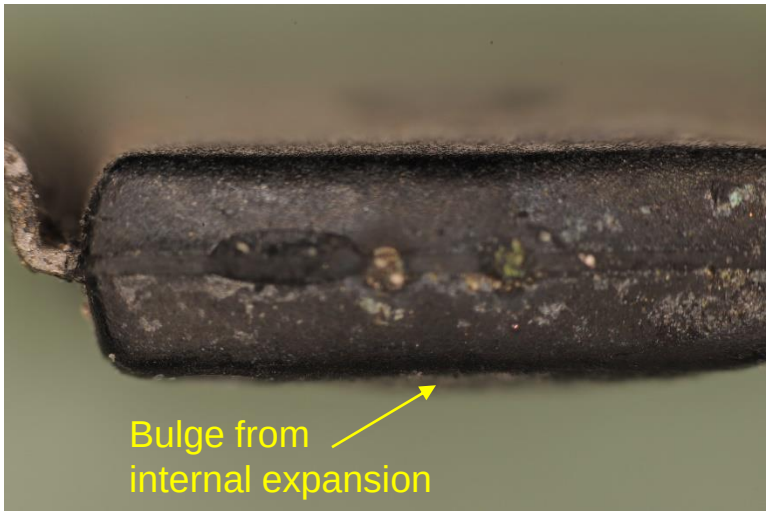


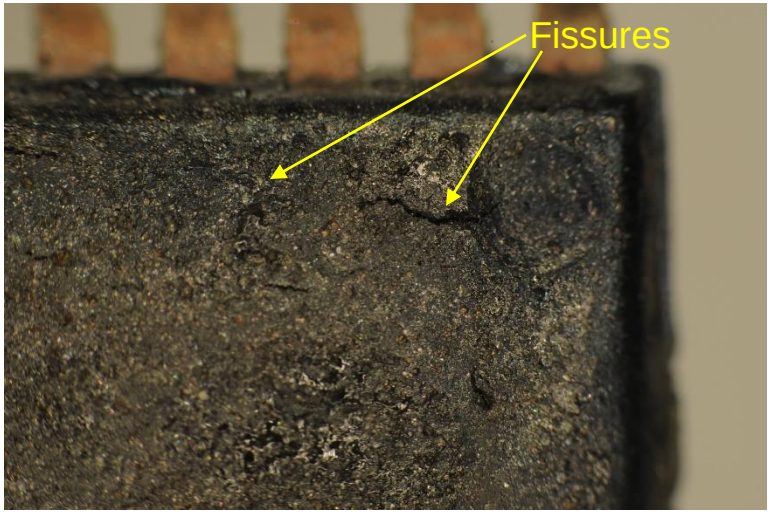


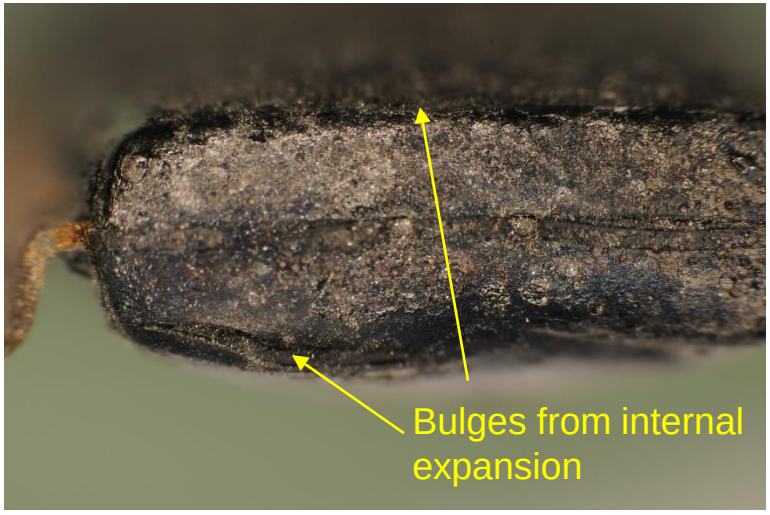
- Box 1
  - MN75 and MN76
  - Could not distinguish between the two
  - "Found in wreckage"
- Box 2
  - MN75
  - "Removed from board"
- Box 3
  - MN30 (?)
  - "Found in wreckage"
- Box 4
  - MN30
  - "In vicinity of board #1"

Sample Optical Micrographs of DECU Parts, Box 1

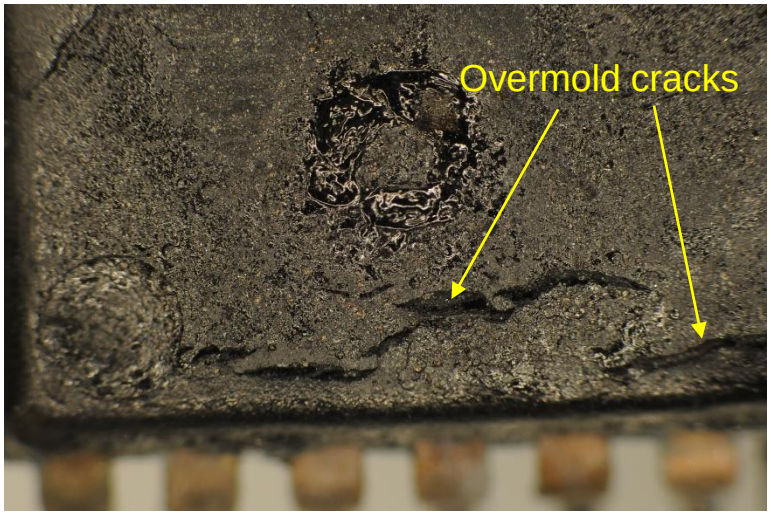


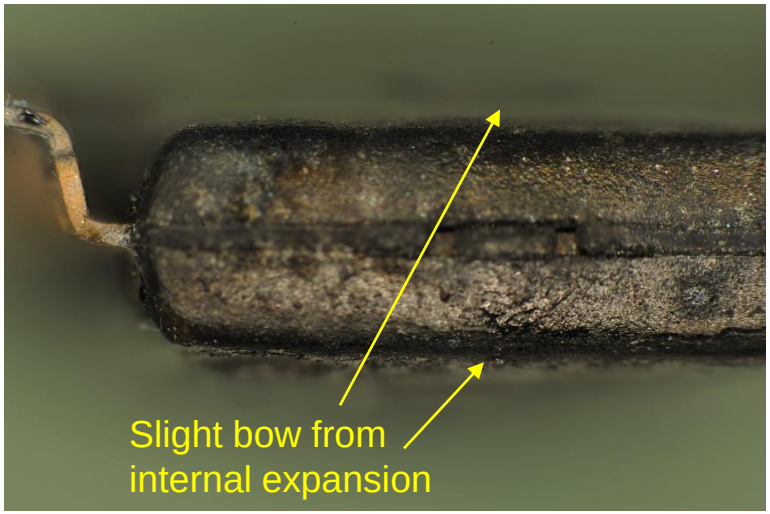


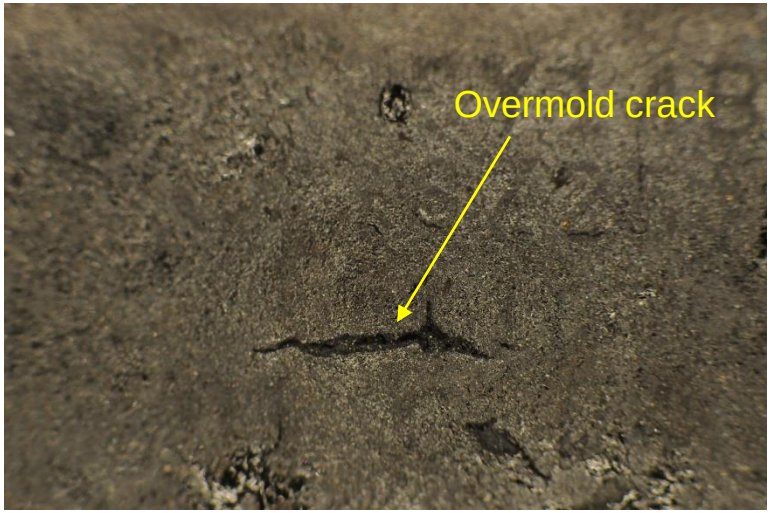


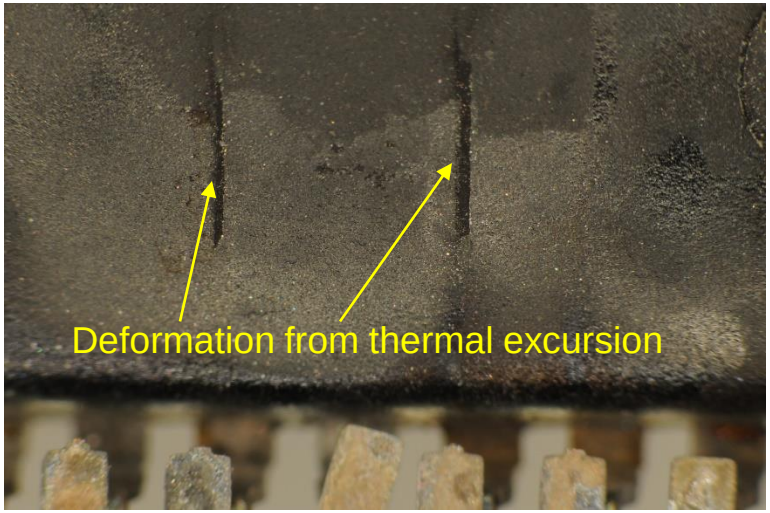


Sample Optical Micrographs of DECU Parts, Box 2

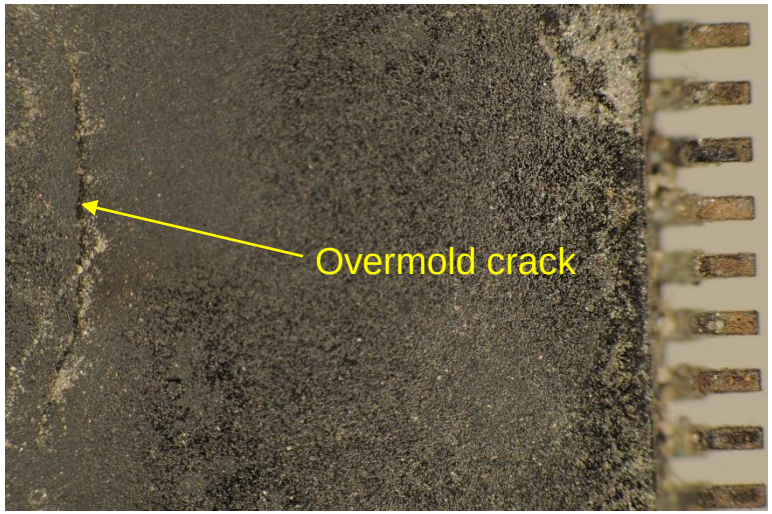


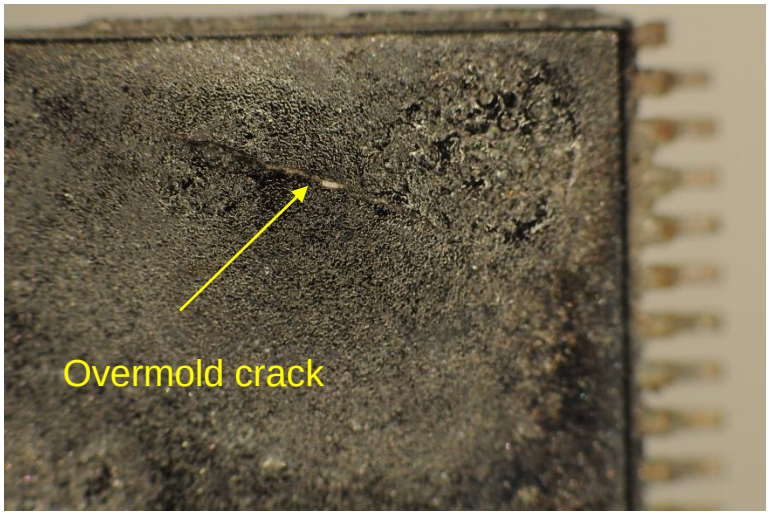


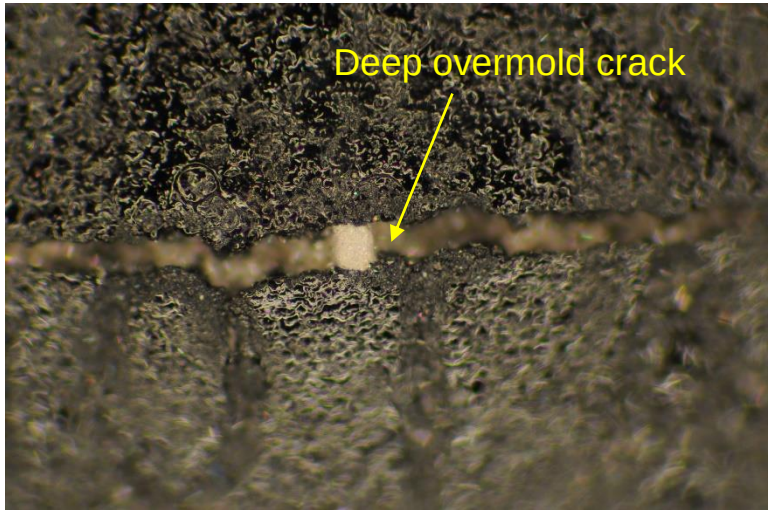




Sample Optical Micrographs of DECU Parts, Box 3

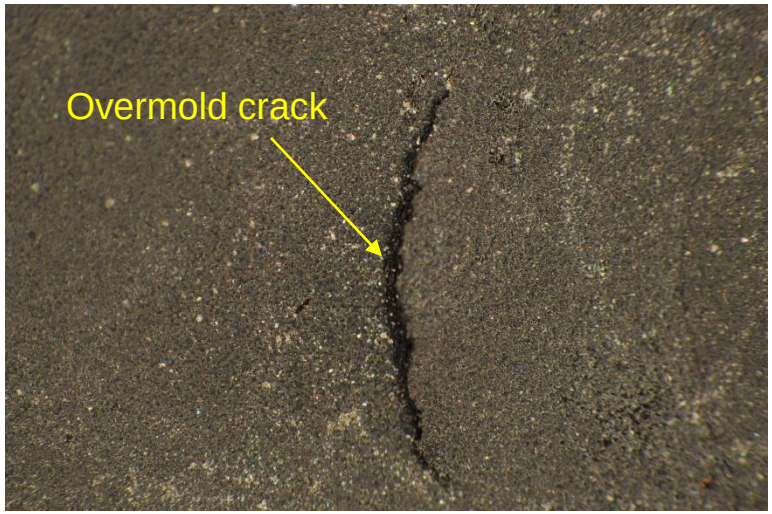


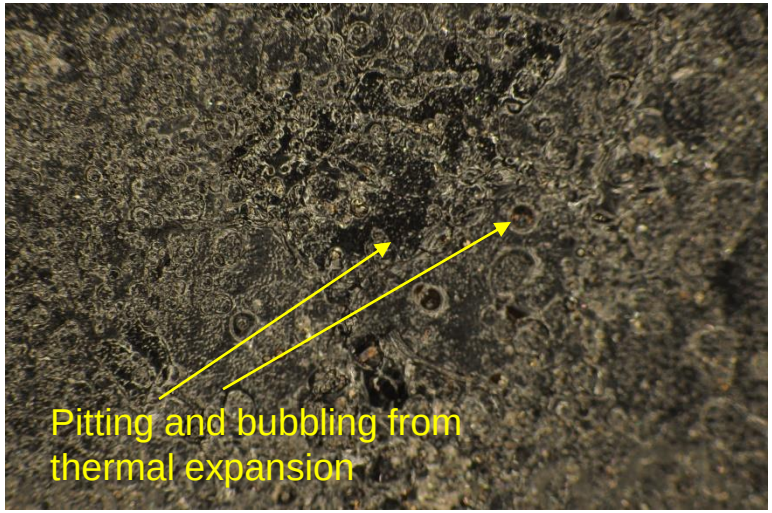




No evidence of bulging from internal expansion

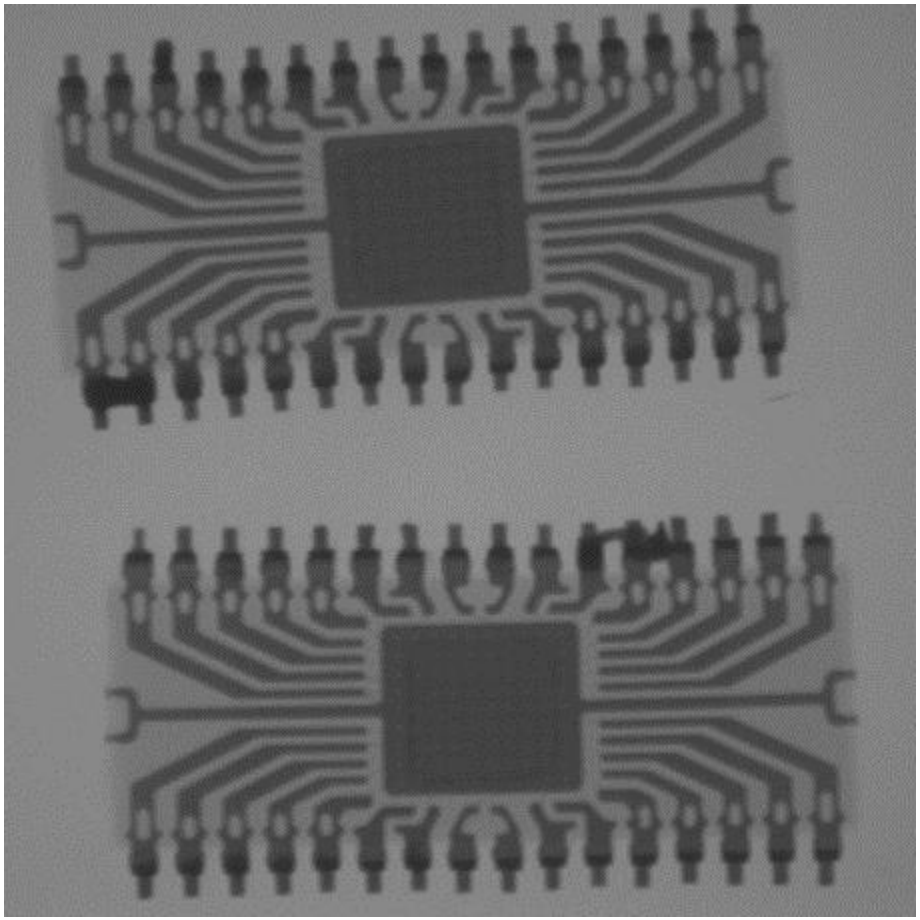
Sample Optical Micrographs of DECU Parts, Box 4





No evidence of bulging from internal expansion

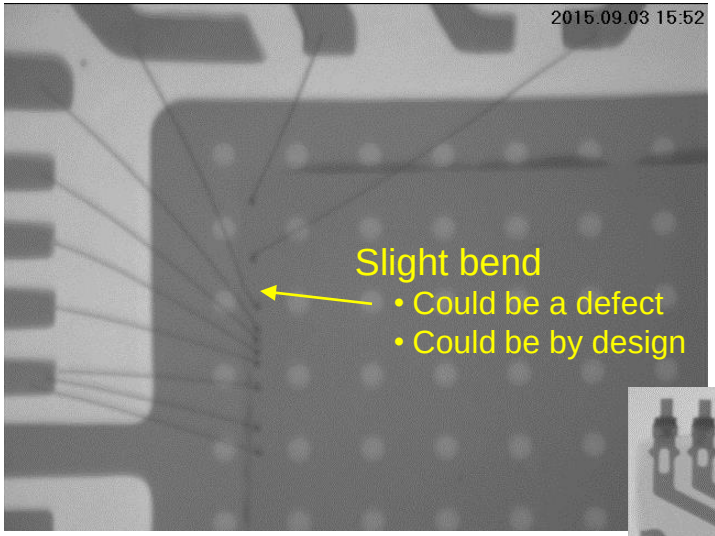
X-rays of DECU Parts, Box 1



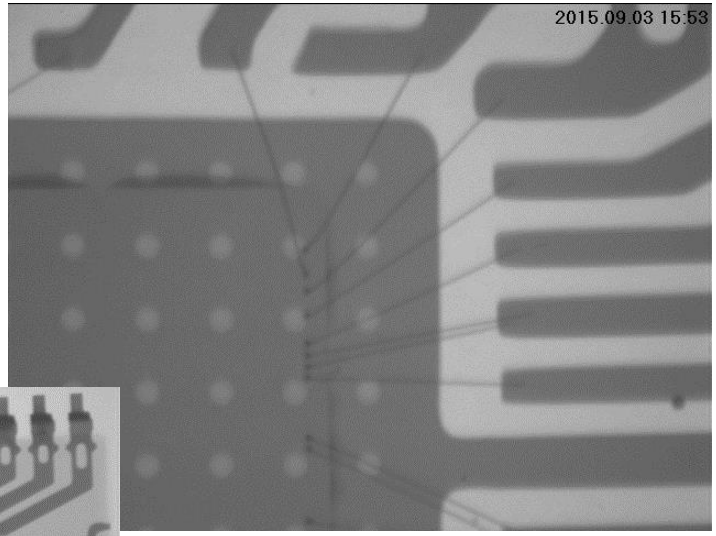
Both parts exhibit a simple fan out from the chip to the leads

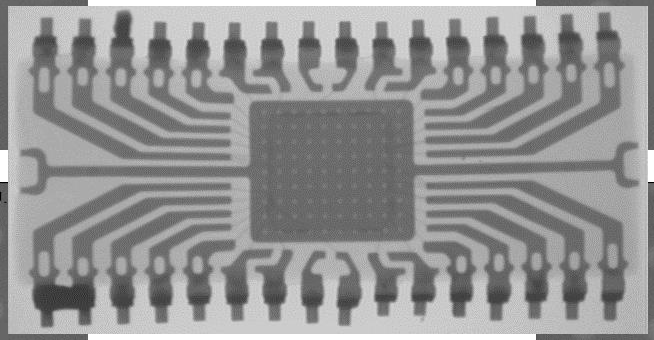
Fan out circuitry appears to be in tact

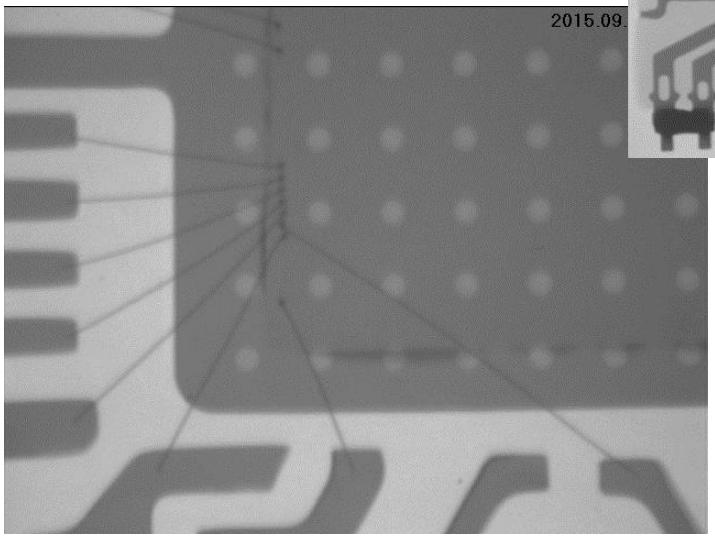
X-rays of DECU Parts, Box 1, cont'd.

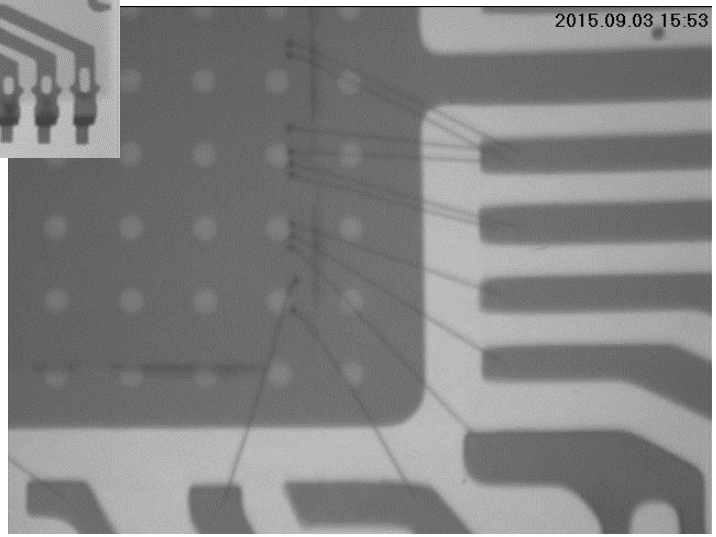


- Single chip, wire bond interconnection
- All wire bonds appear to be in tact
- Side view needed to see if balls are pulled from the chip

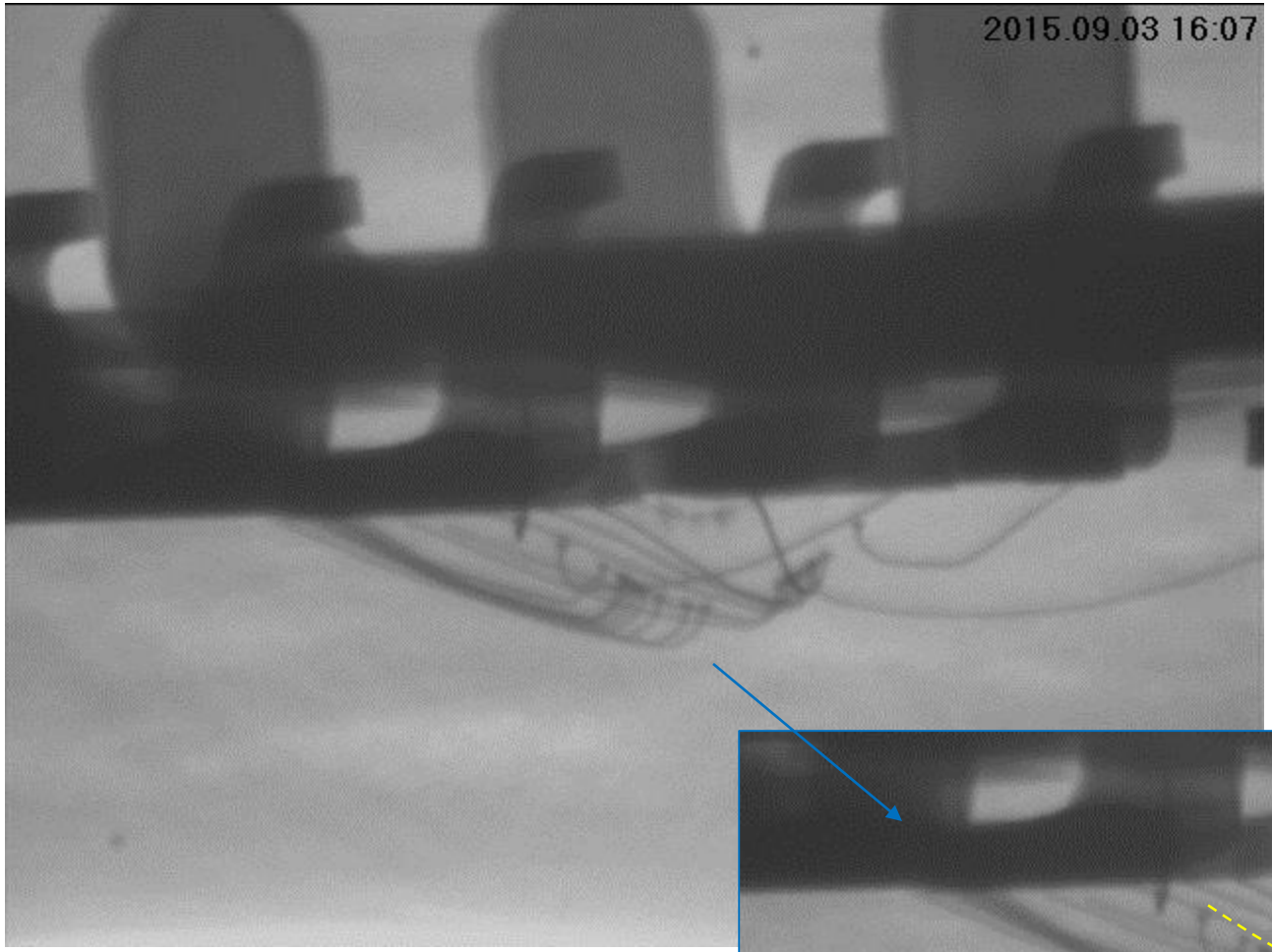




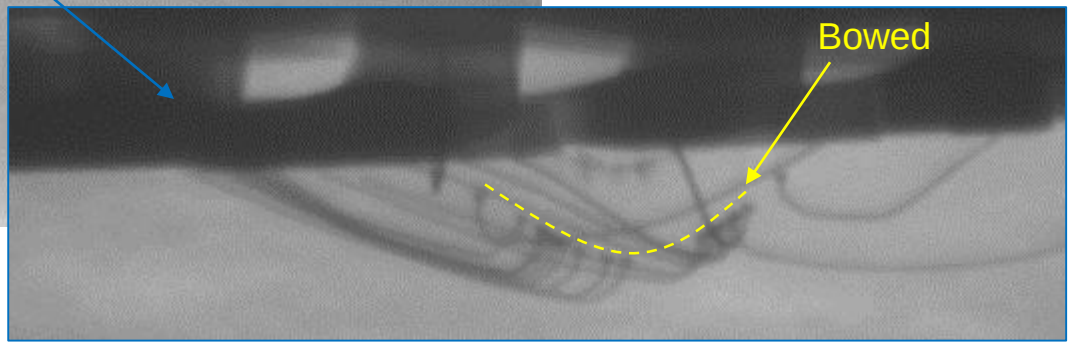




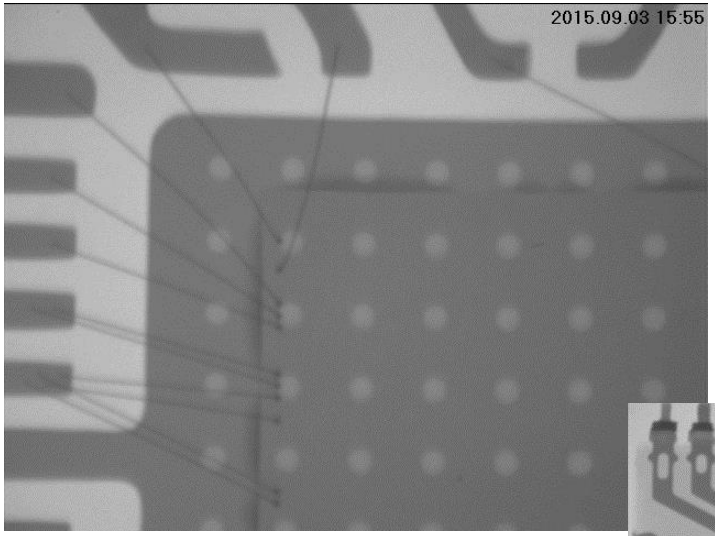
Side X-rays of DECU Parts, Box 1



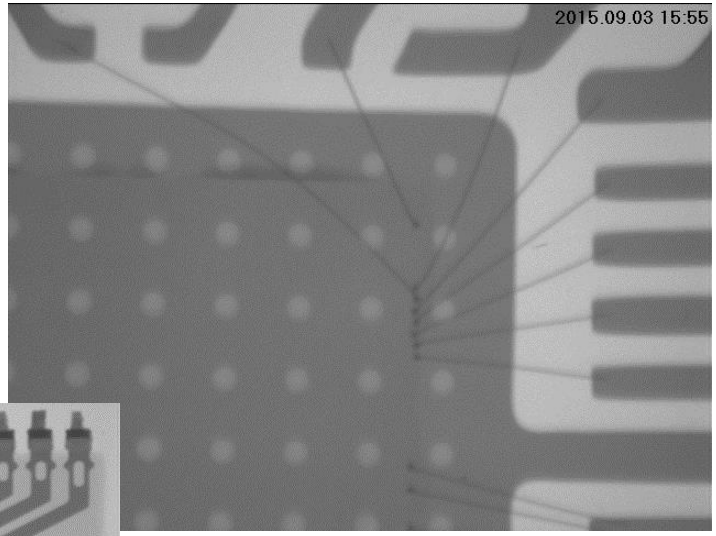
Z direction bowed pattern of the wire bond balls suggests they were pulled from the chip (presumably by the deformation during the thermal excursion)

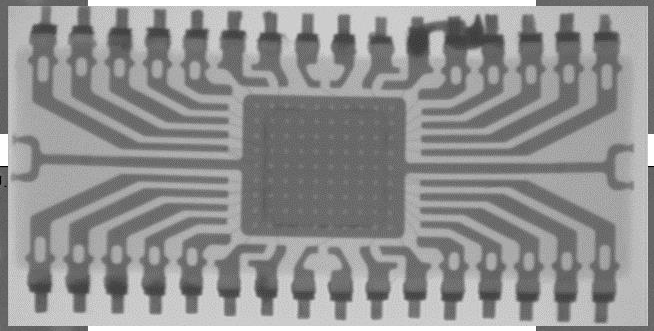


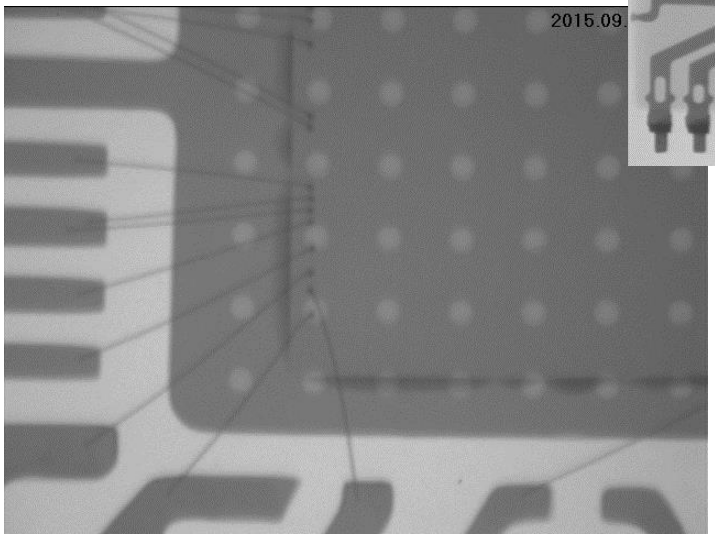
X-rays of DECU Parts, Box 1, cont'd.

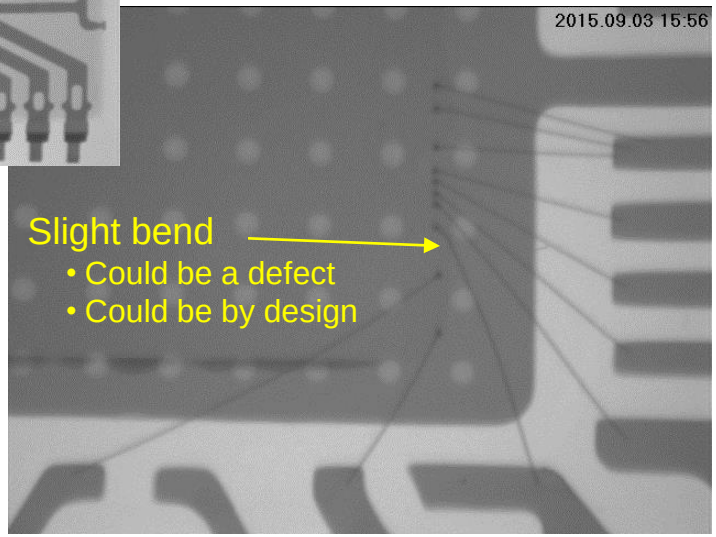


- Single chip, wire bond interconnection
- All wire bonds appear to be in tact
- Side view needed to see if balls are pulled from the chip

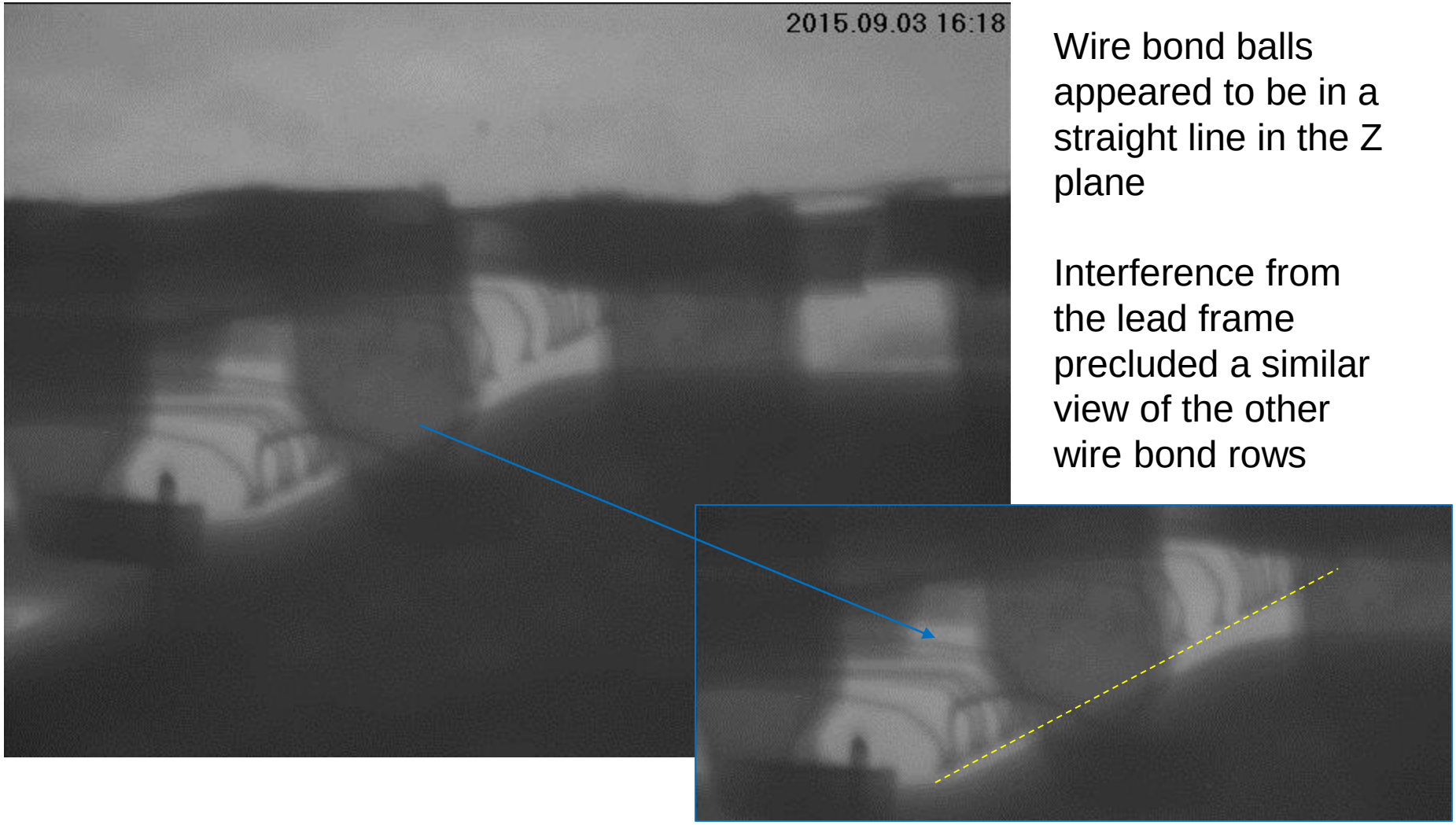








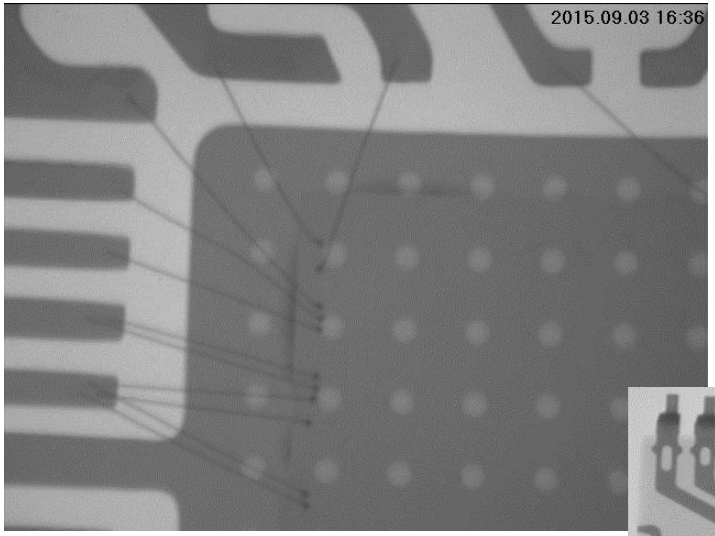
Side X-rays of DECU Parts, Box 1



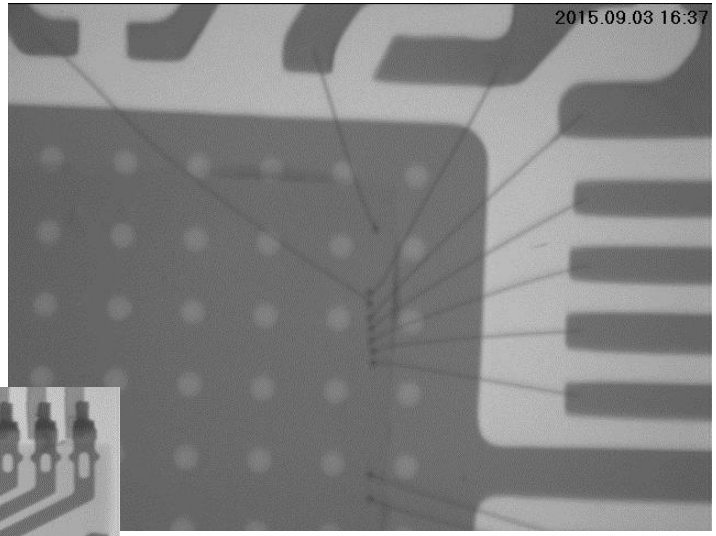
Wire bond balls appeared to be in a straight line in the Z plane

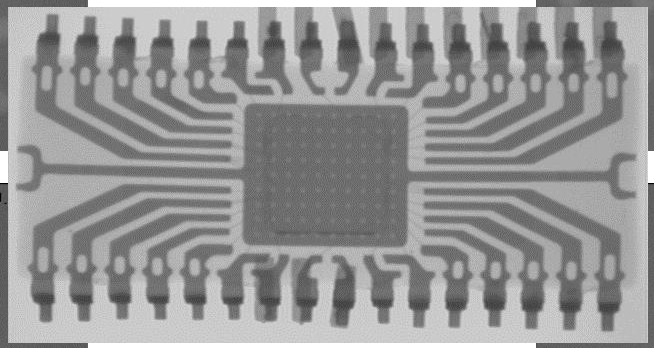
Interference from the lead frame precluded a similar view of the other wire bond rows

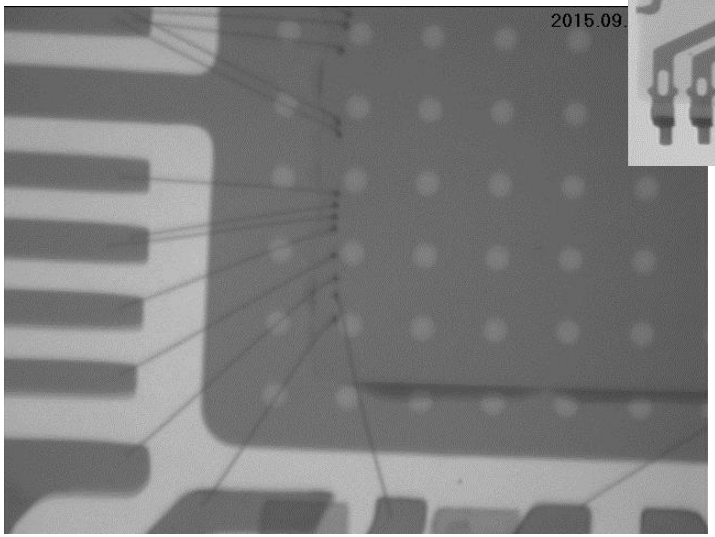
X-rays of DECU Parts, Box 2

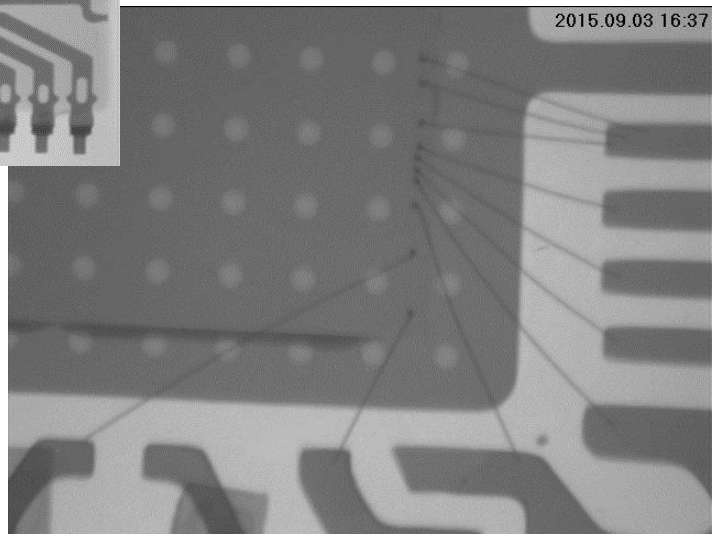


- Single chip, wire bond interconnection
- All wire bonds appear to be in tact
- Side view needed to see if balls are pulled from the chip

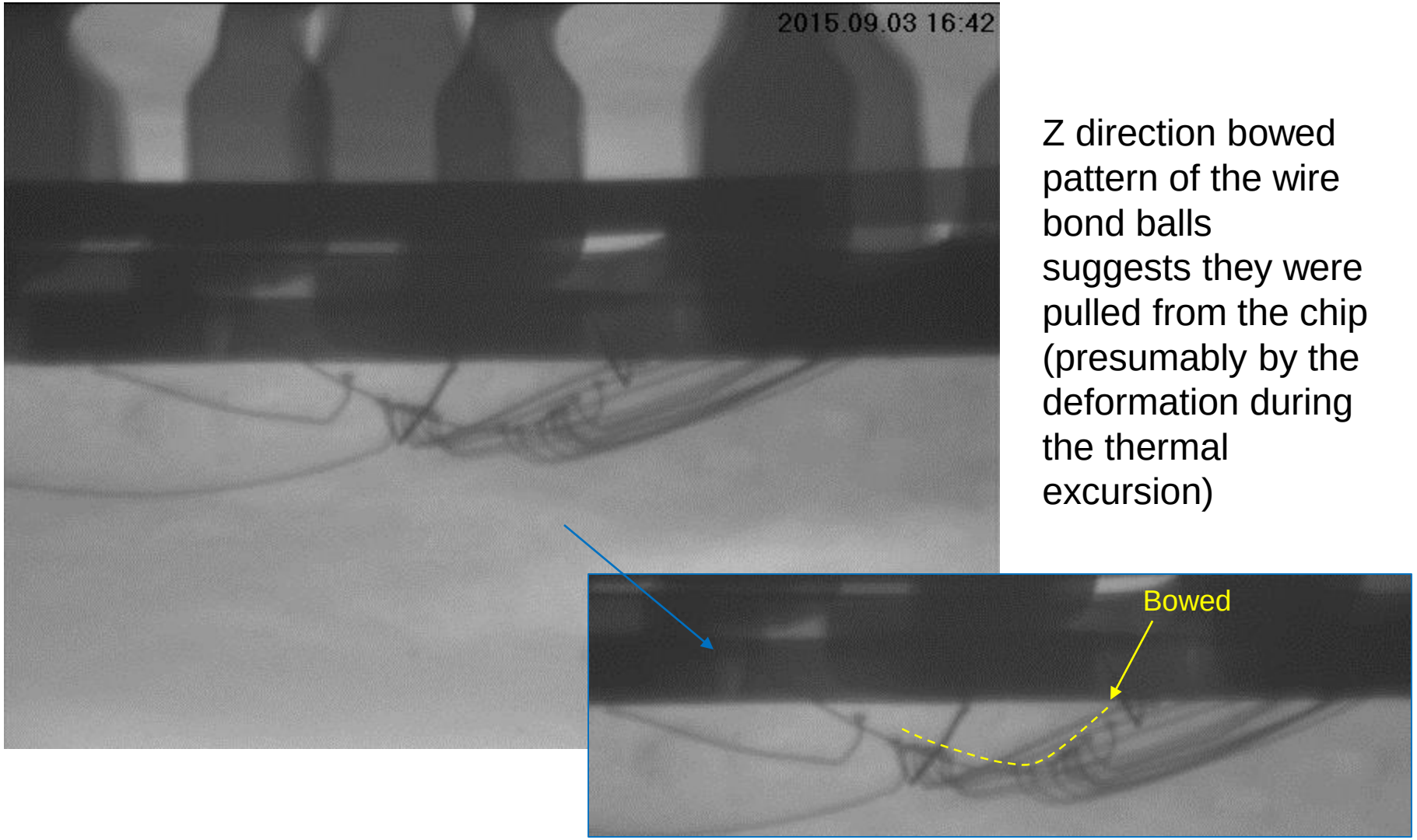






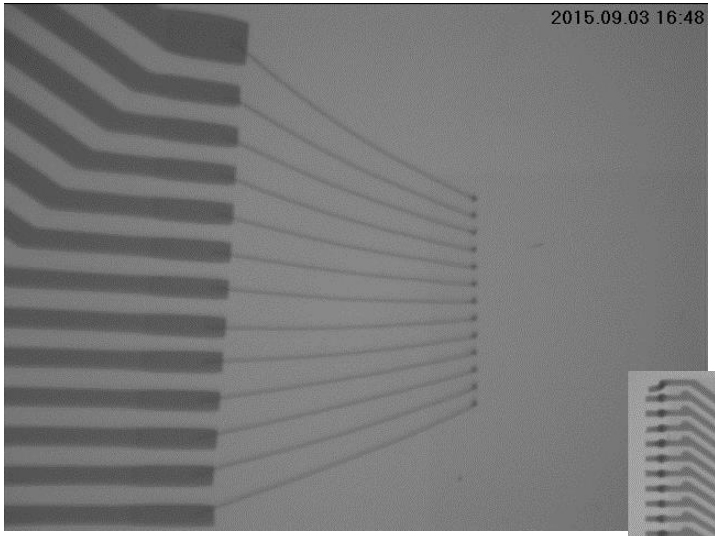


Side X-rays of DECU Parts, Box 2

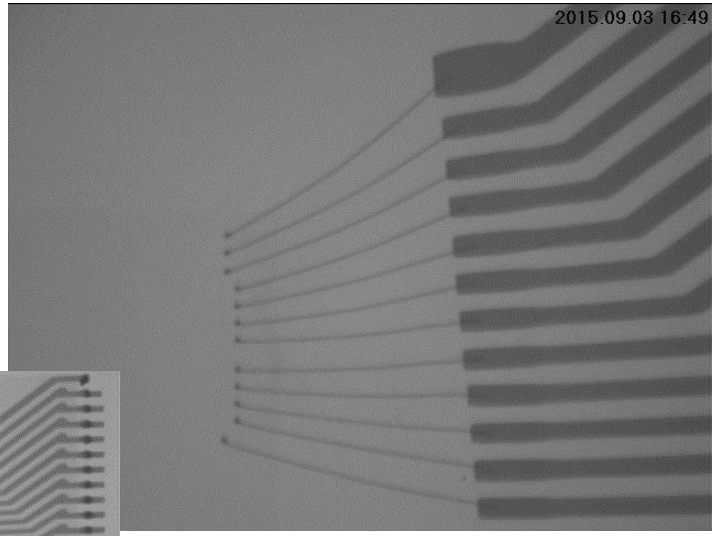


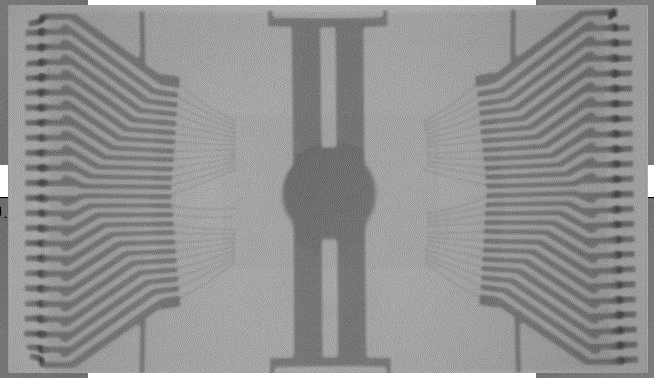
Z direction bowed pattern of the wire bond balls suggests they were pulled from the chip (presumably by the deformation during the thermal excursion)

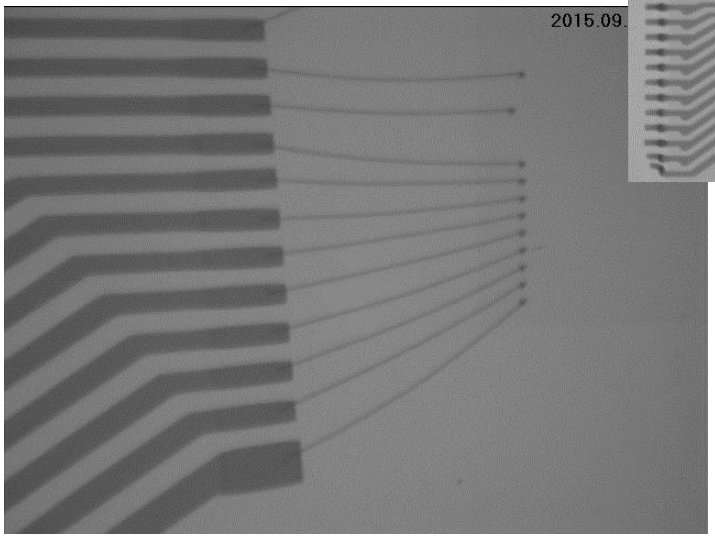
X-rays of DECU Parts, Box 3

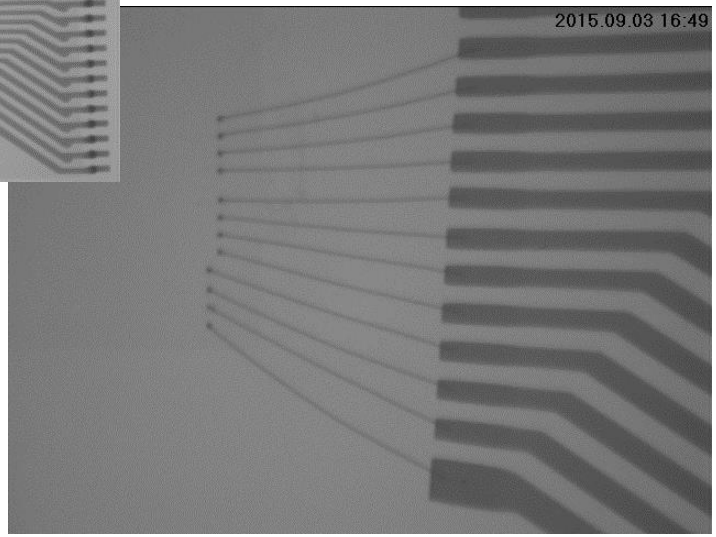


- Single chip, wire bond interconnection
- All wire bonds appear to be in tact
- Side view needed to see if balls are pulled from the chip

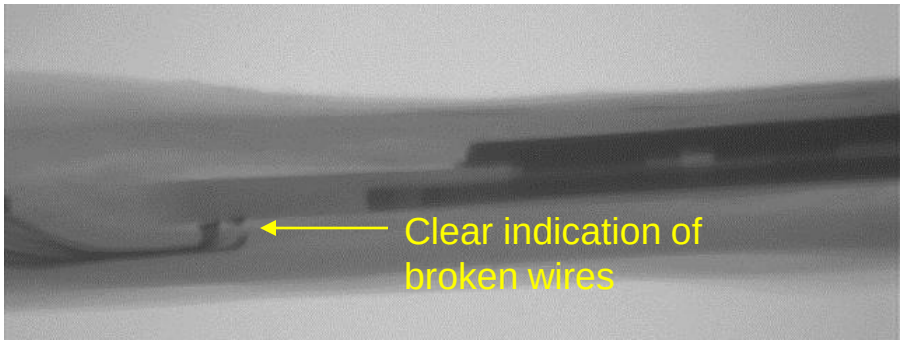


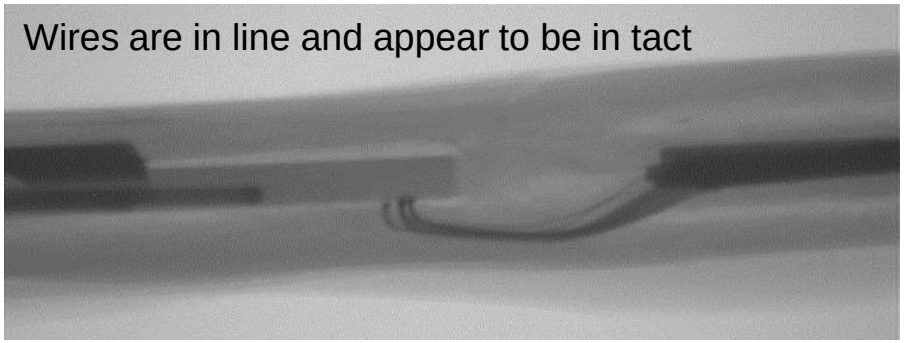


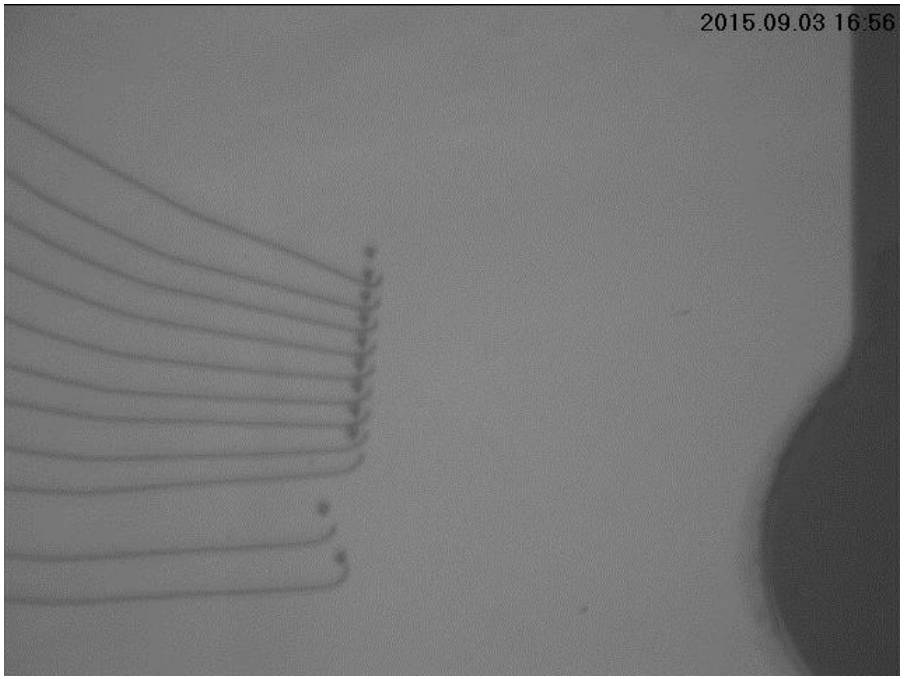




Side and Tipped View X-rays of DECU Parts, Box 3

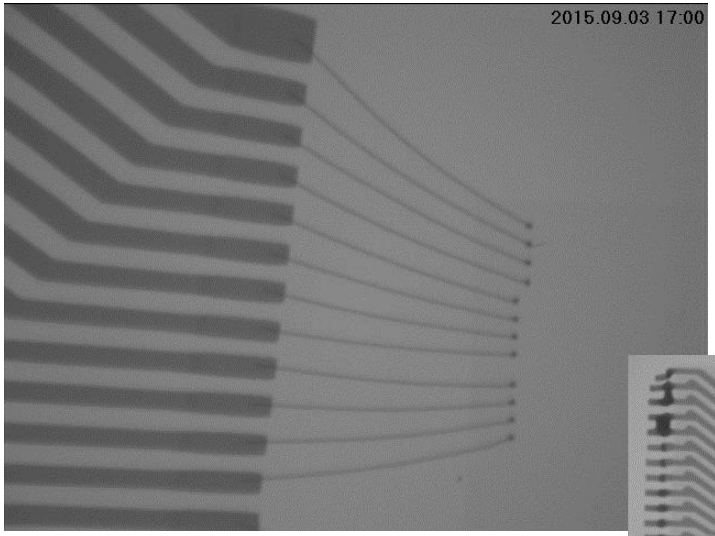




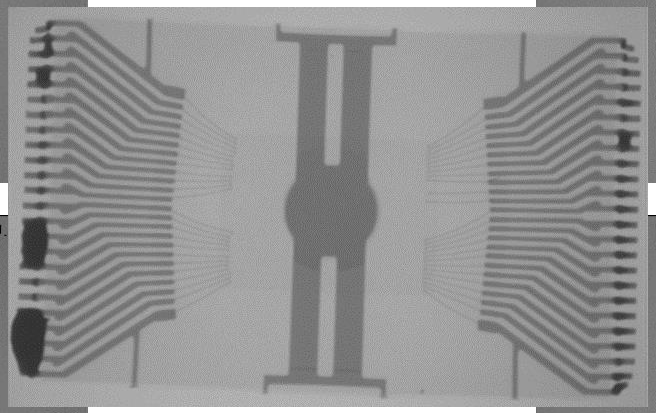


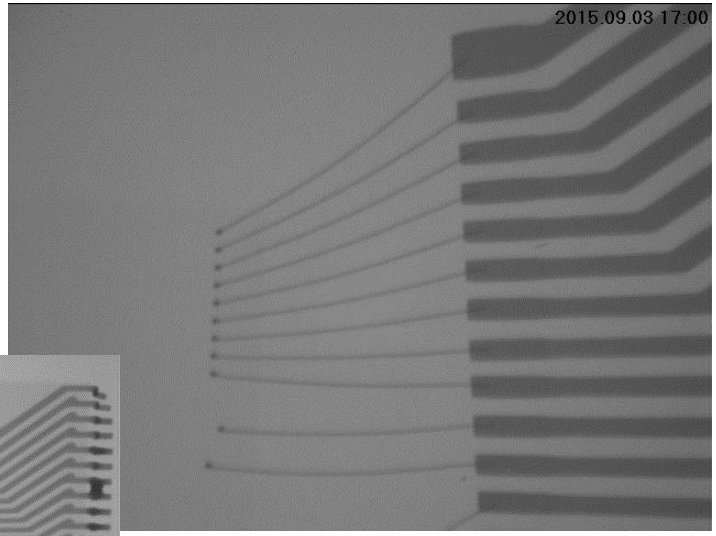
Tipped view also shows broken wires

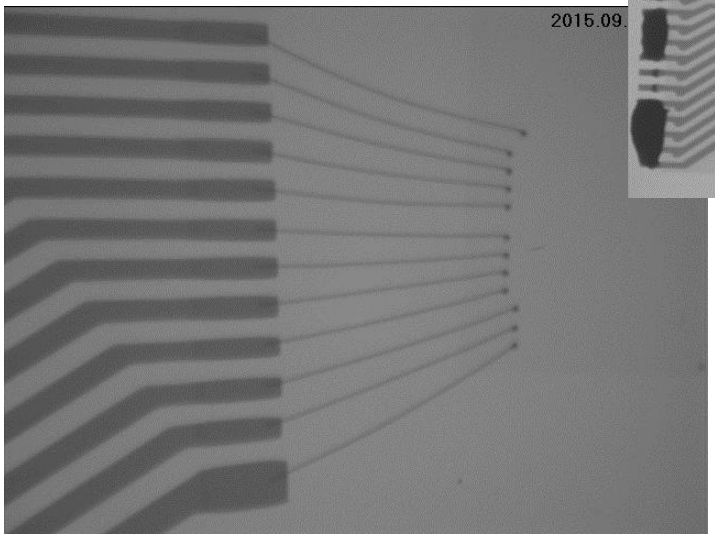
X-rays of DECU Parts, Box 4

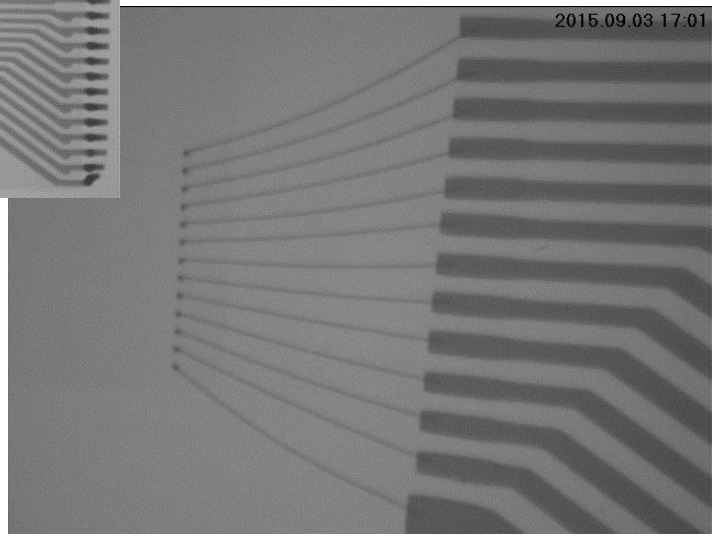


- Single chip, wire bond interconnection
- All wire bonds appear to be in tact
- Side view needed to see if balls are pulled from the chip

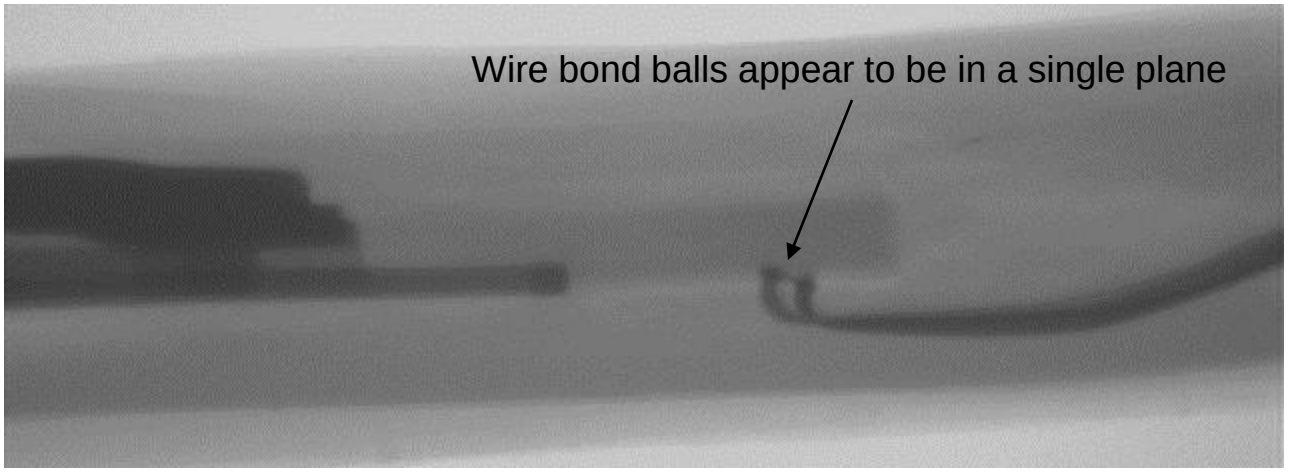


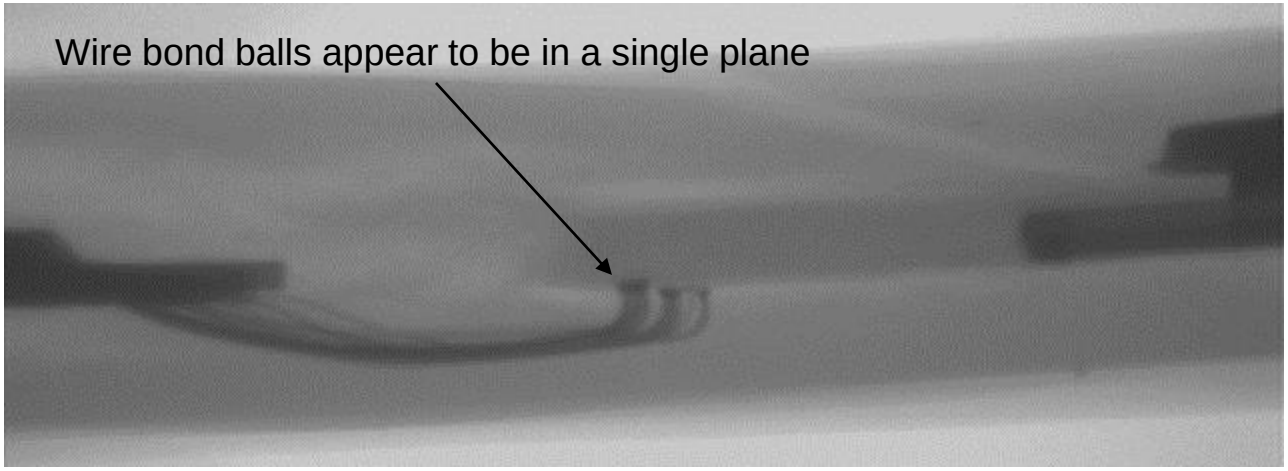






Side and Tipped View X-rays of DECU Parts, Box 4





Summary for the DECU Parts

- All parts were badly burned, and showed fissures and blisters
- Box 1
  - One part showed clear evidence of wire bond balls being pulled from the chip
  - The other part did not show evidence of wire bond damage, but because of the thermally induced bulging, it remains suspicious
- Box 2 – the part showed clear evidence of the wire bond balls being pulled from the chip
- Box 3 – wire bonds were broken near the ball
- Box 4 – the wire bonds and lead frame appeared in tact, but the condition of the chip could not be ascertained via acoustic microscopy
- Disposition: the part in box 4 is the only reasonable candidate for data recovery

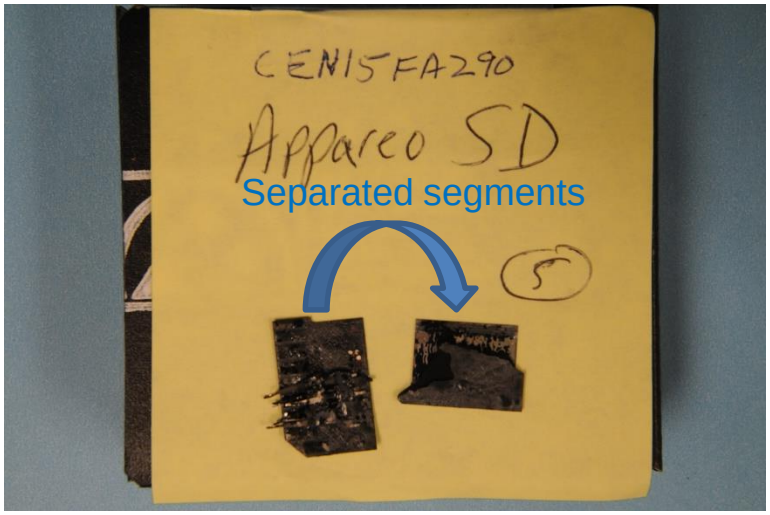
Section 3

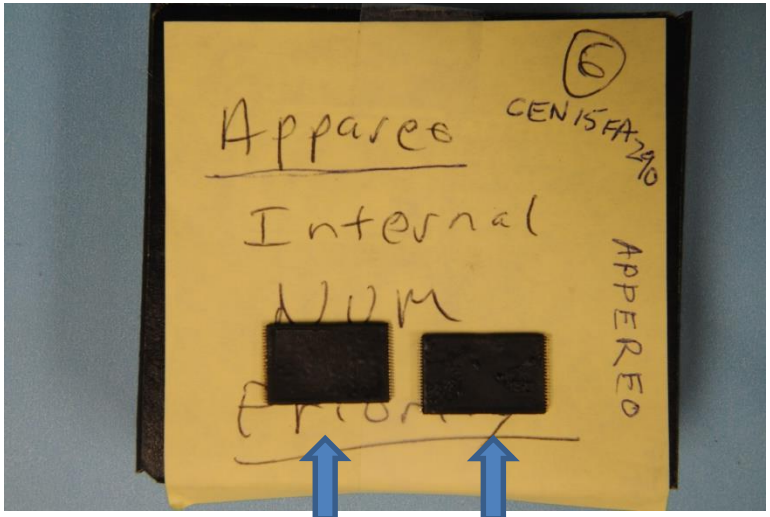
ANALYSES OF THE APPAREO MODULES

Instrumentation

- Zeiss V12 Stereoscope
- Phoenix X-ray Imaging System
  - Voltage run at 90 KV, tube current 50 uA (or less)
  - Imaging with 512 integrations, 100ms/frame
- Evolution II Acoustic Microscope
  - 50 and 100 MHz transducers
  - Pulse echo mode
  - Satisfactory sonograms could not be obtained due to the heat damage of the overmold (fissures scatter the sonic pulse)

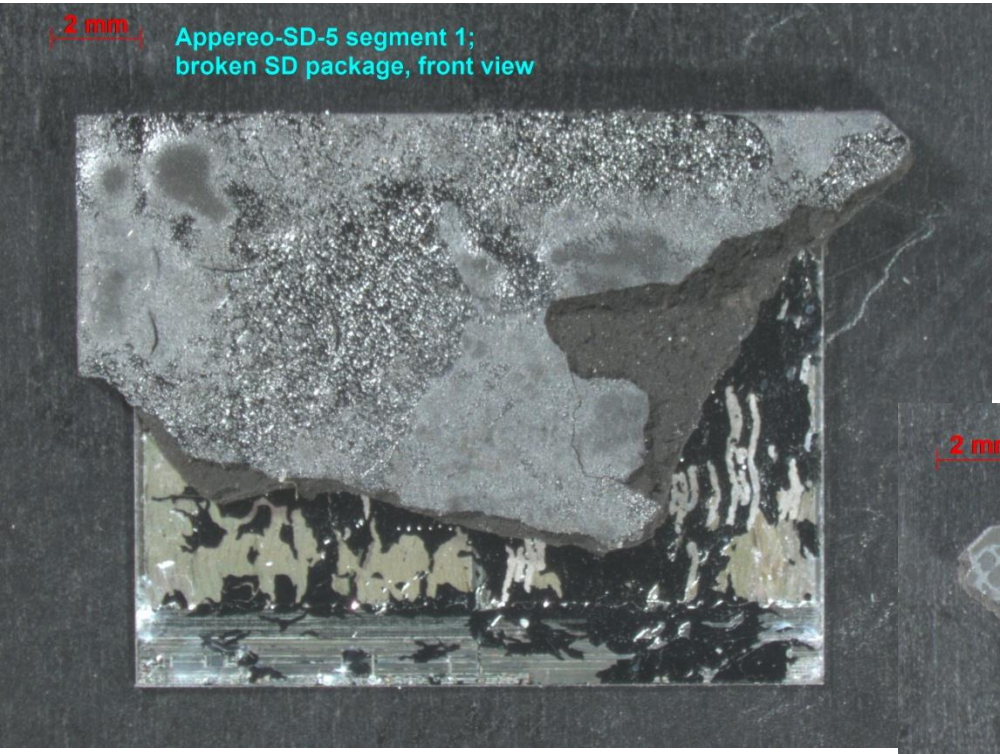
Catalog of APPAREO Parts

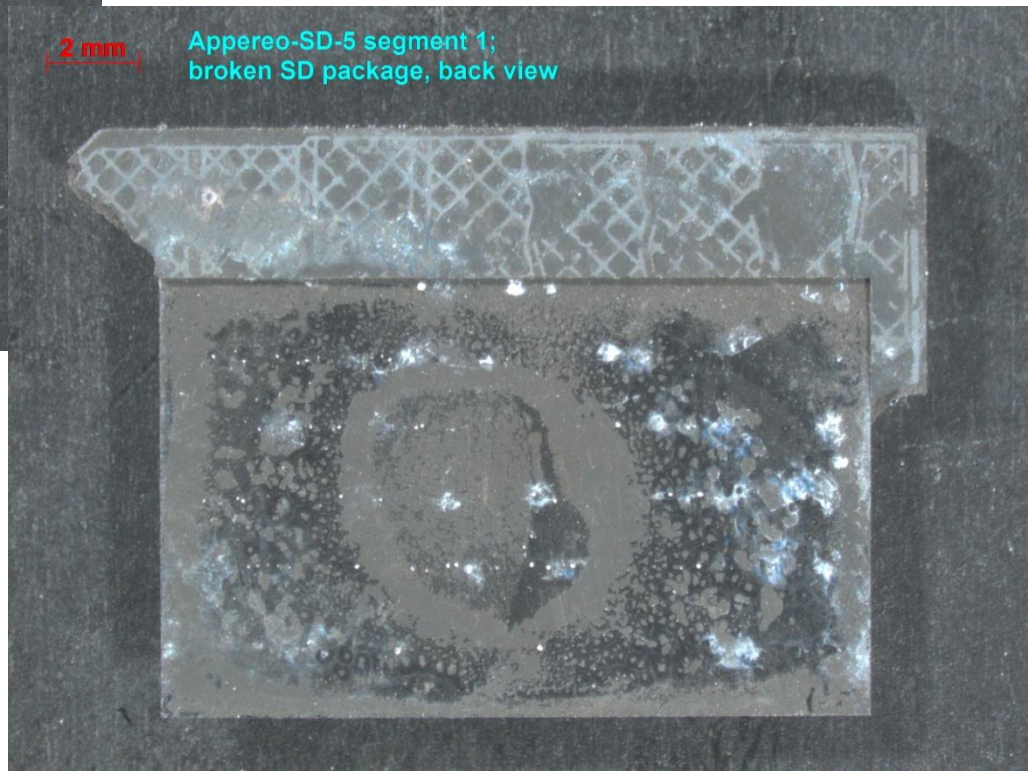




- Box 5
  - APPAREO SD
  - Two sections of the same device
  - Likely decomposed and separated from fire
- Box 6
  - APPAREO Internal Num
  - “Priority”
  - Two parts in bags, labeled “1” and “2”

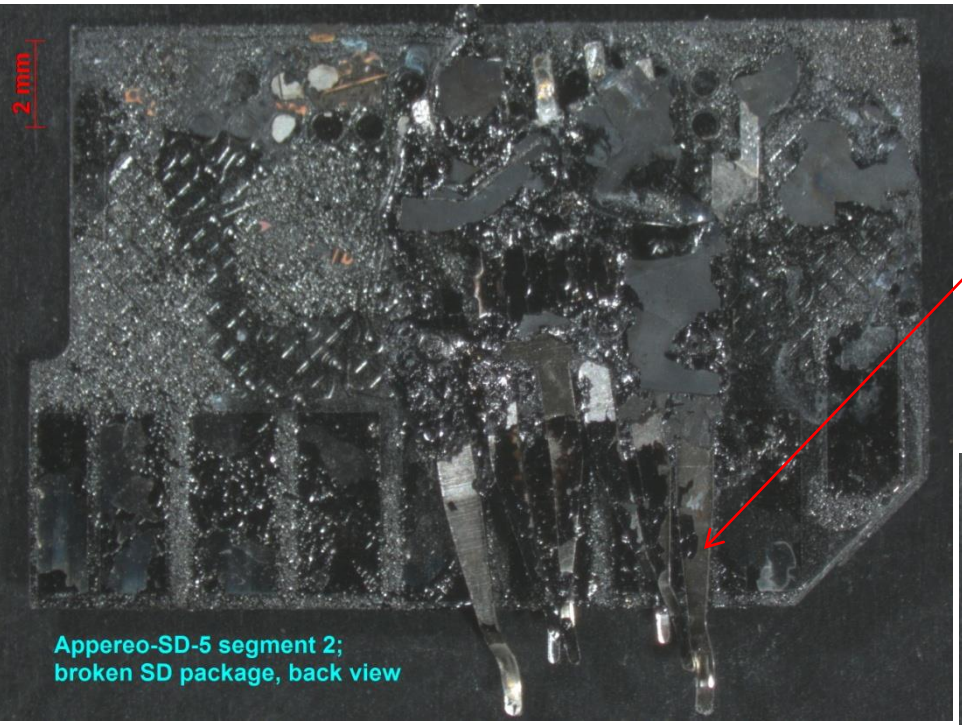
Appareo SD-5: optical images



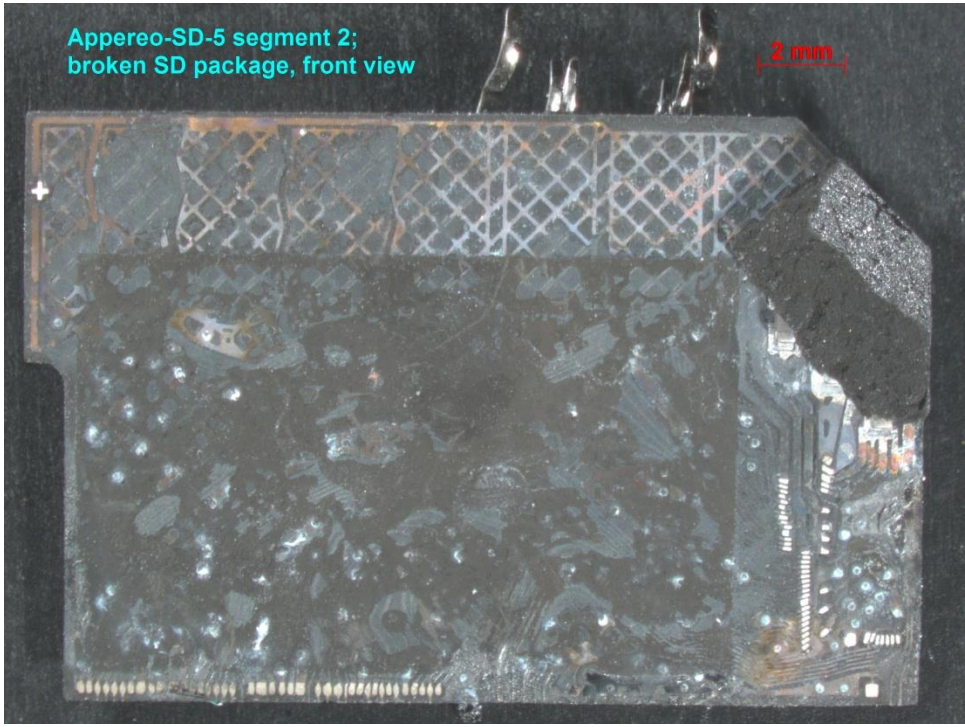


Front and back images of SD-5 package, segment 1 with die

Appareo SD-5: optical images

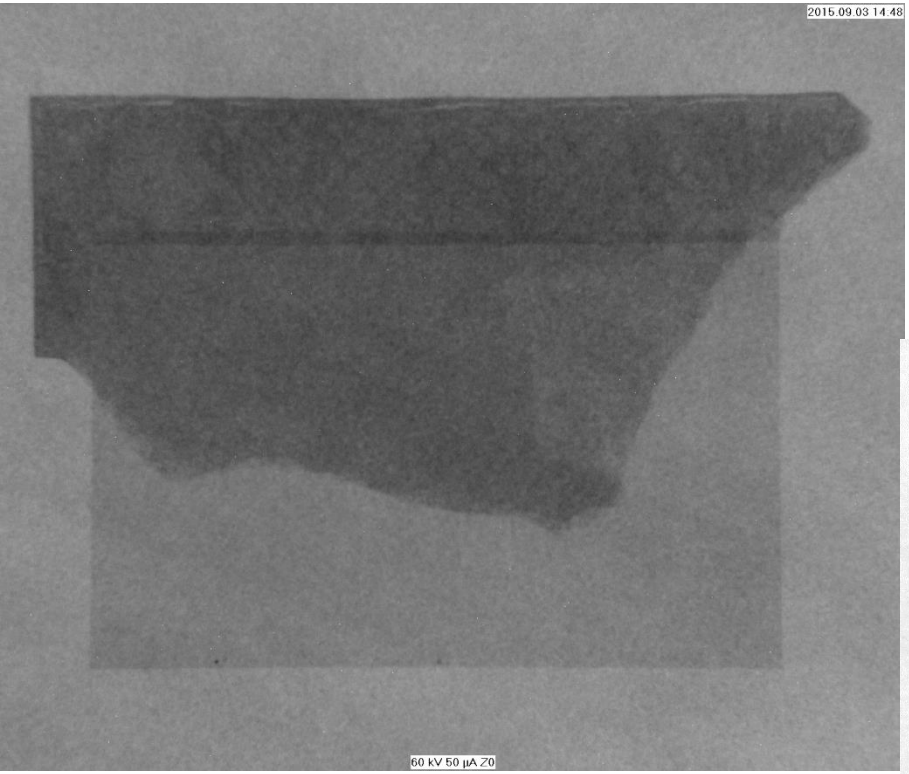


These pins are external and do not belong to the SD card



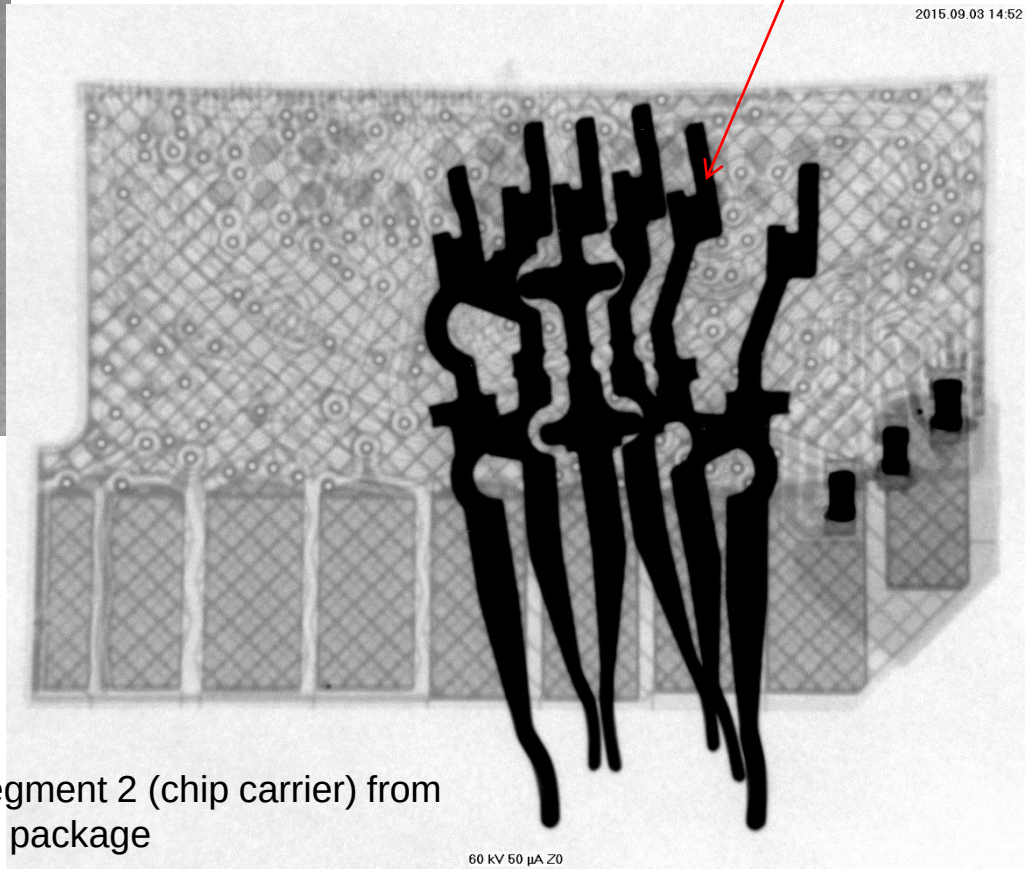
Front and back images of SD-5, segment 2 with chip carrier

Appareo SD-5: X-ray images



X-ray image of segment 1 (die) from broken SD package

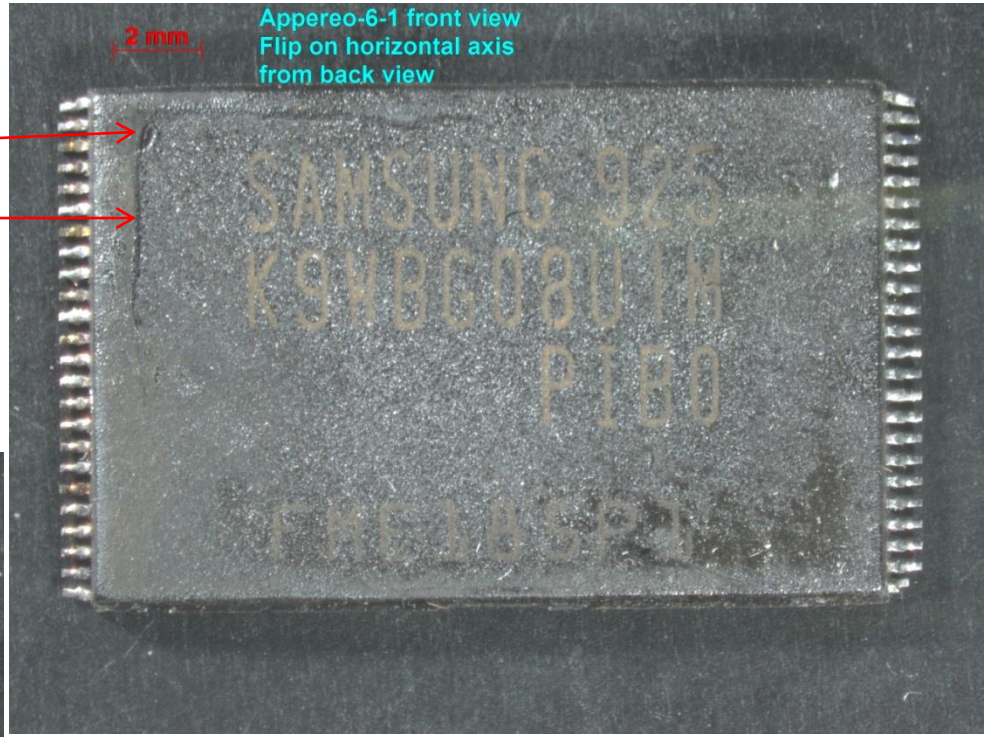
These pins are external and do not belong to the SD card

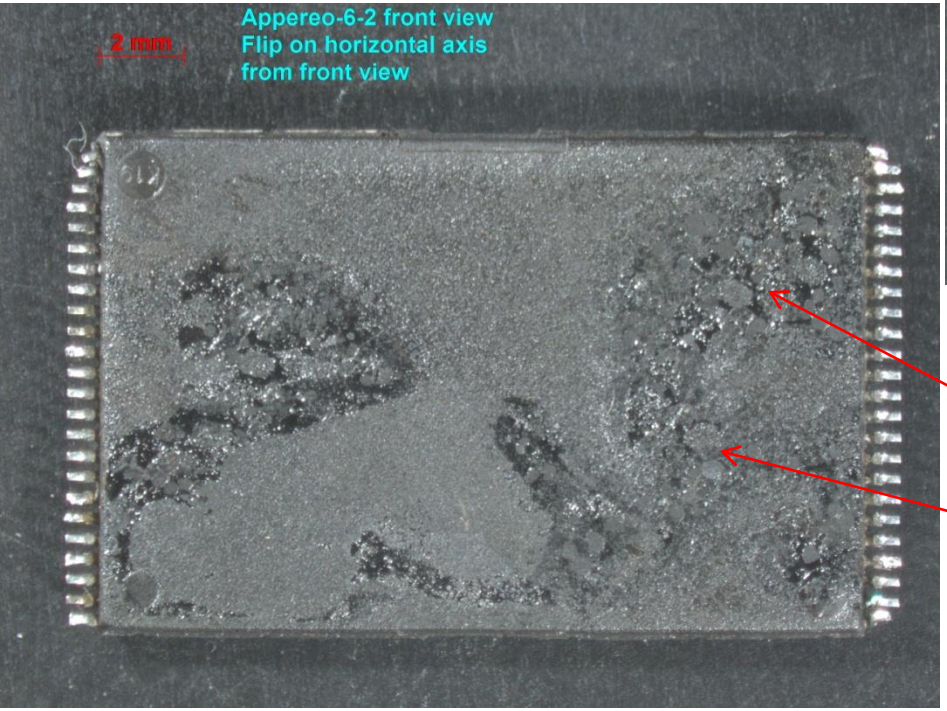


X-ray of segment 2 (chip carrier) from broken SD package

Appareo 6 -1: optical images

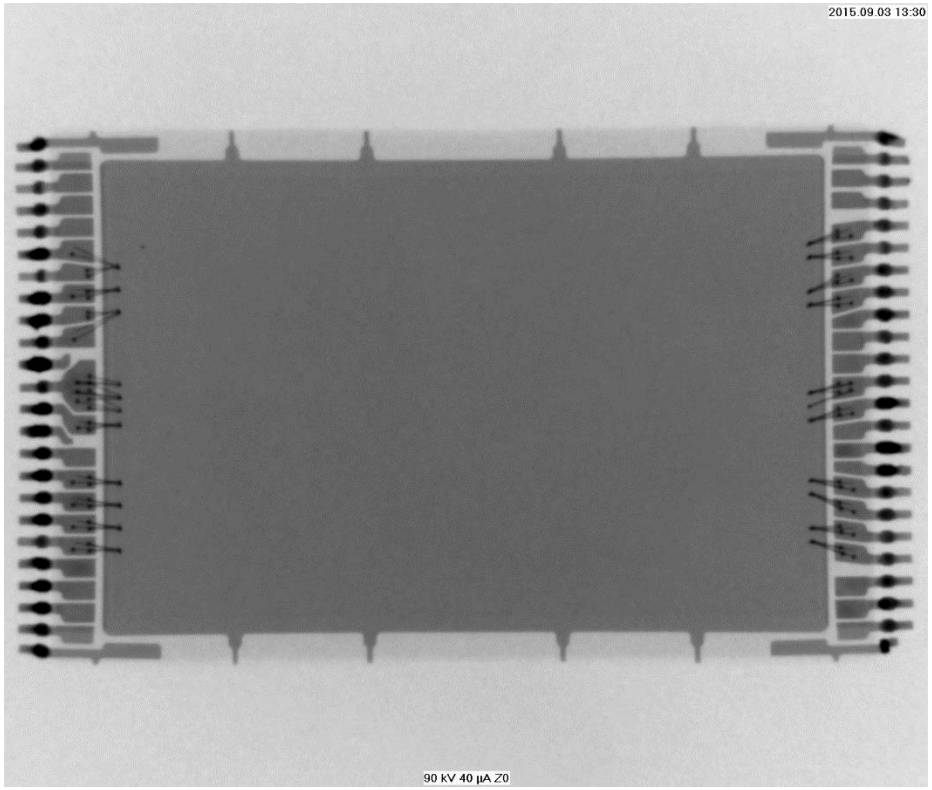
This end of the package is damaged:
it is slightly lifted and cracked.



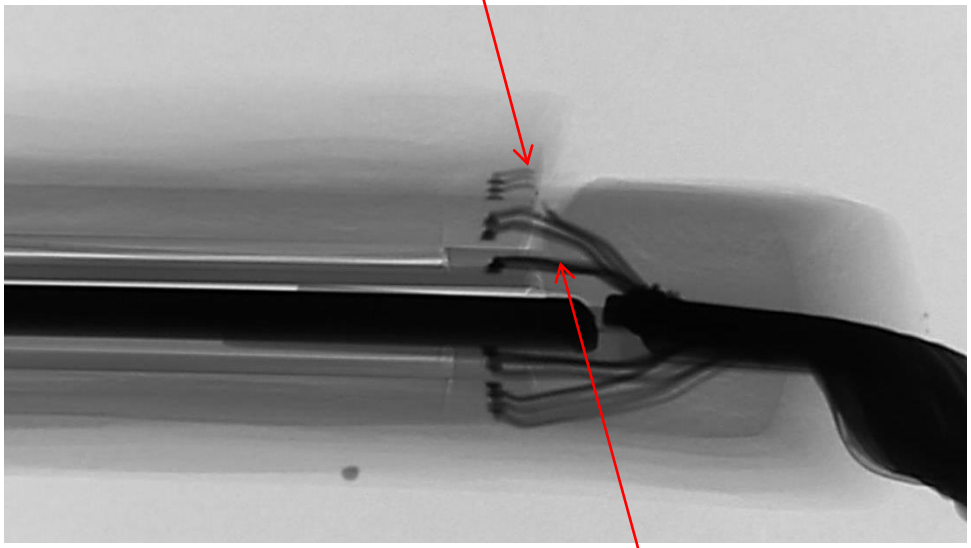


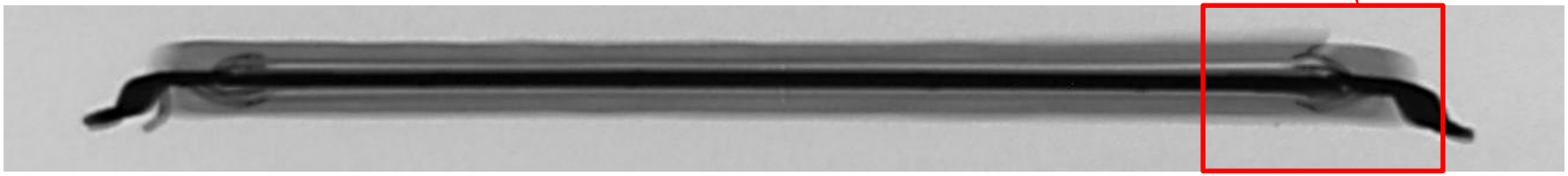
Severe damage to the molding compound

Appareo 6 -1: x-ray images



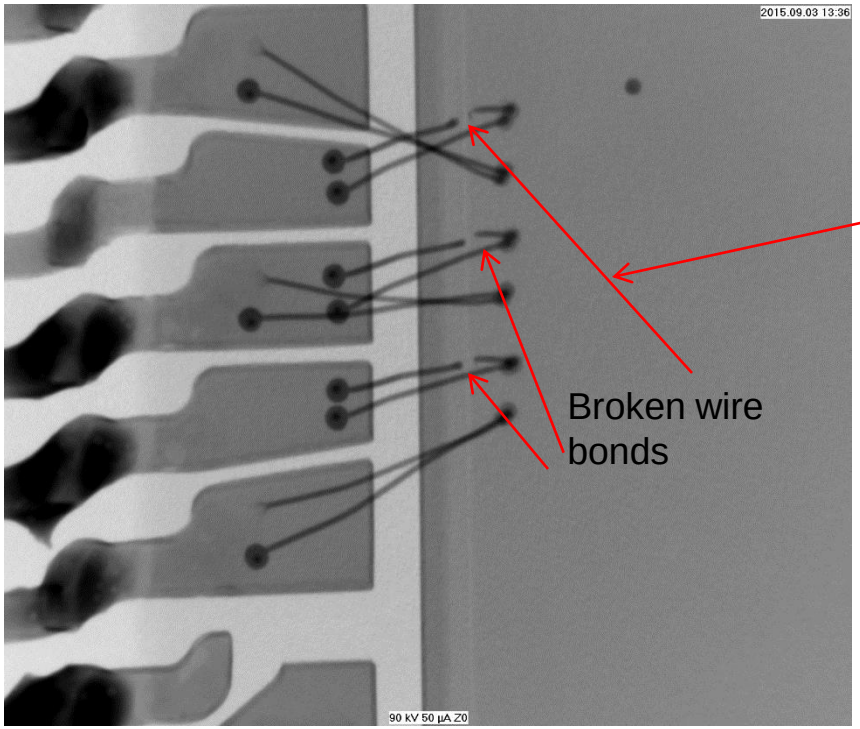
Damaged corner of the chip with broken wire bonds



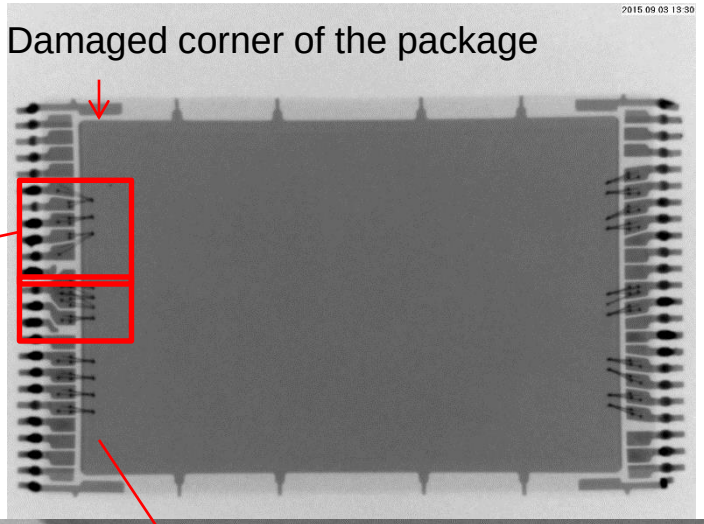


X-ray images showing the side view of the package, suggest that there are 4 stacked dies in the package two on each side of the chip carrier.

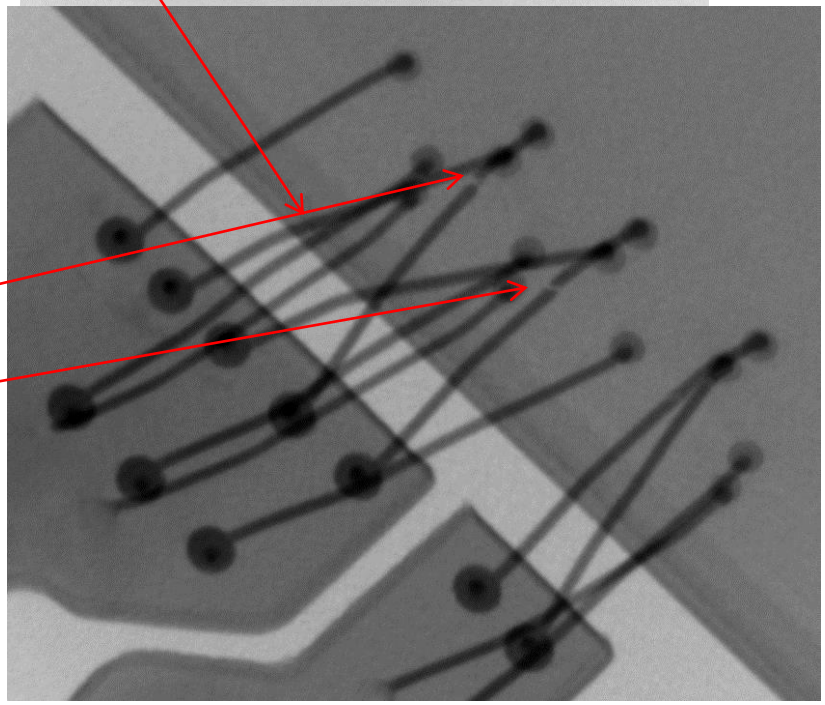
Appareo 6 -1: x-ray images



Broken wire bonds



Damaged corner of the package

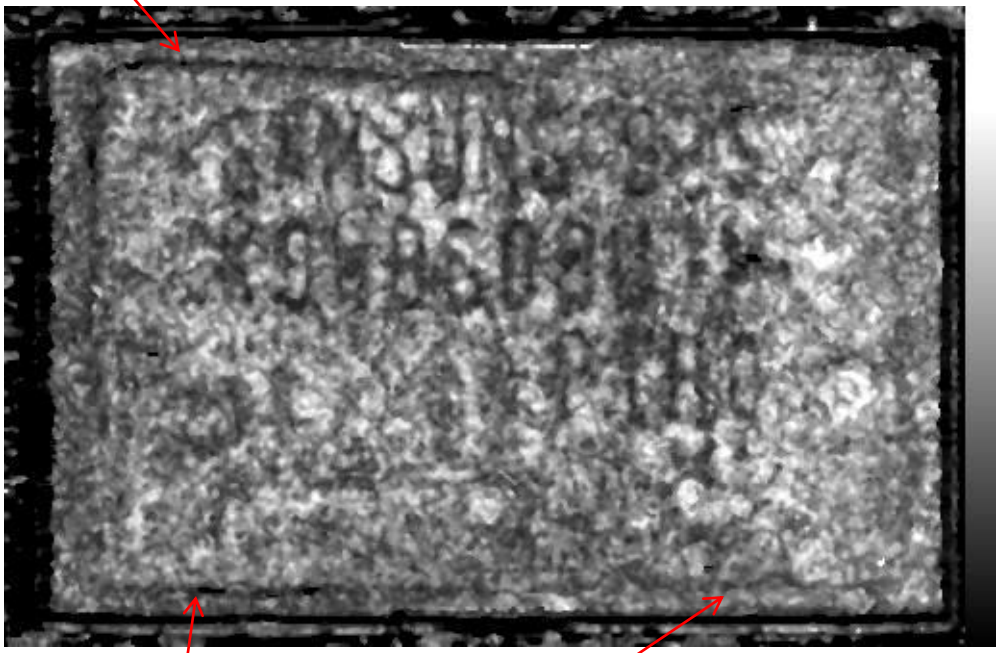


Broken wire bonds

Broken wire bonds were detected only in the damaged corner of the package.

Appareo 6 -1: C-SAM images

Damaged corner of the package

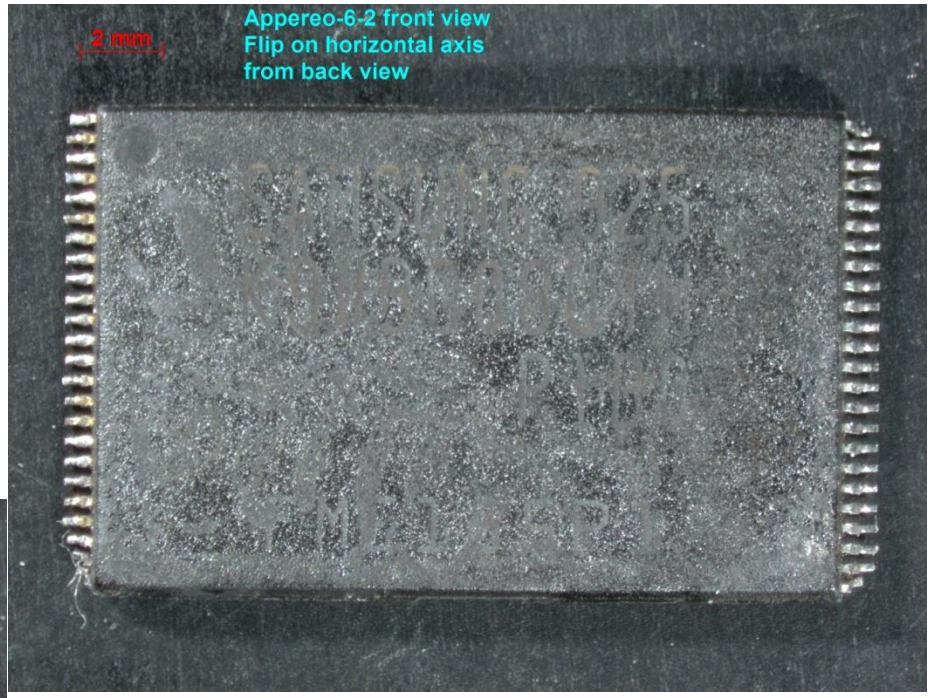


Both 100 MHz and 50 MHz transducers, were tried to acquire good images of the stacked dies within the package. But features resulting from the severe damage (disintegration) of the molding compound, prevented detection of any details on dies.

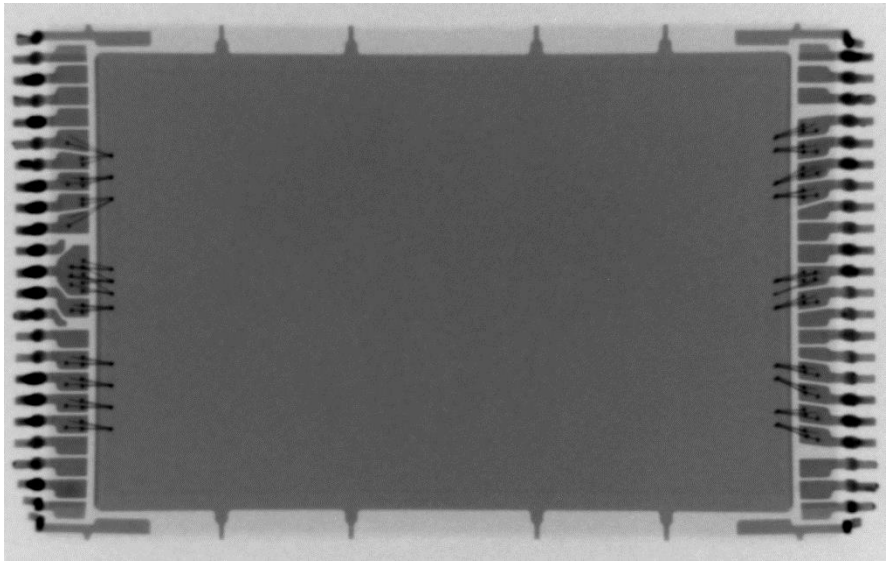
Top die outline

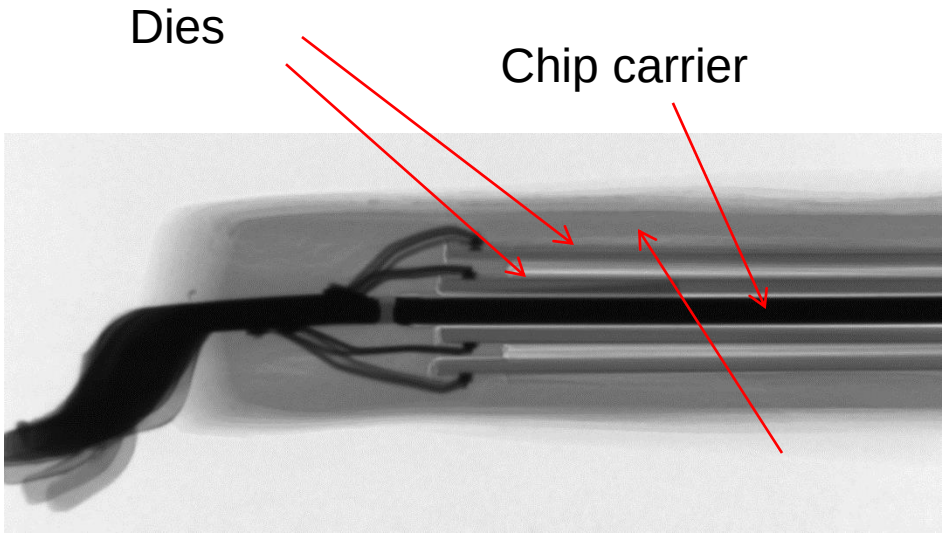
Appareo 6 -2: optical images

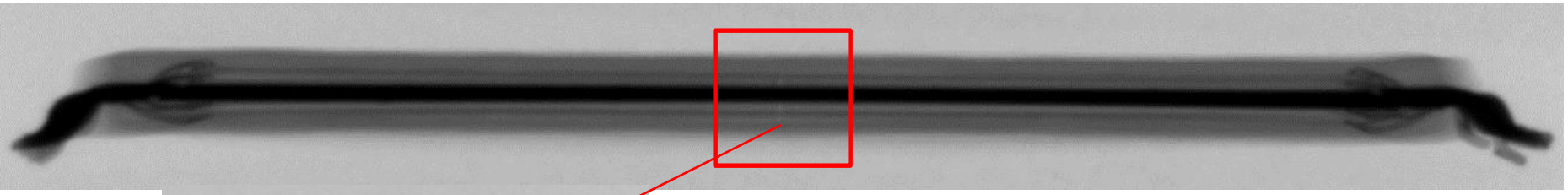
Optical images indicate severe damage to the molding compound of the package probably from high temp/fire

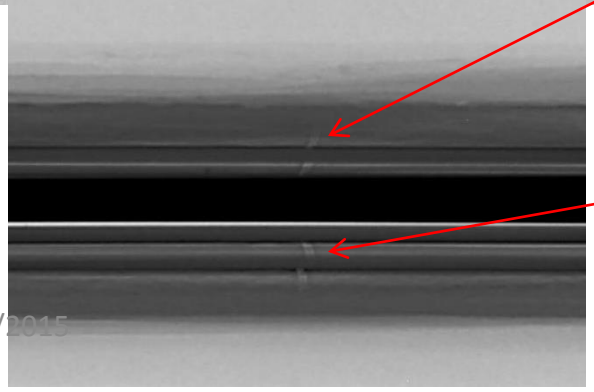


Appareo 6 -2: x-ray images





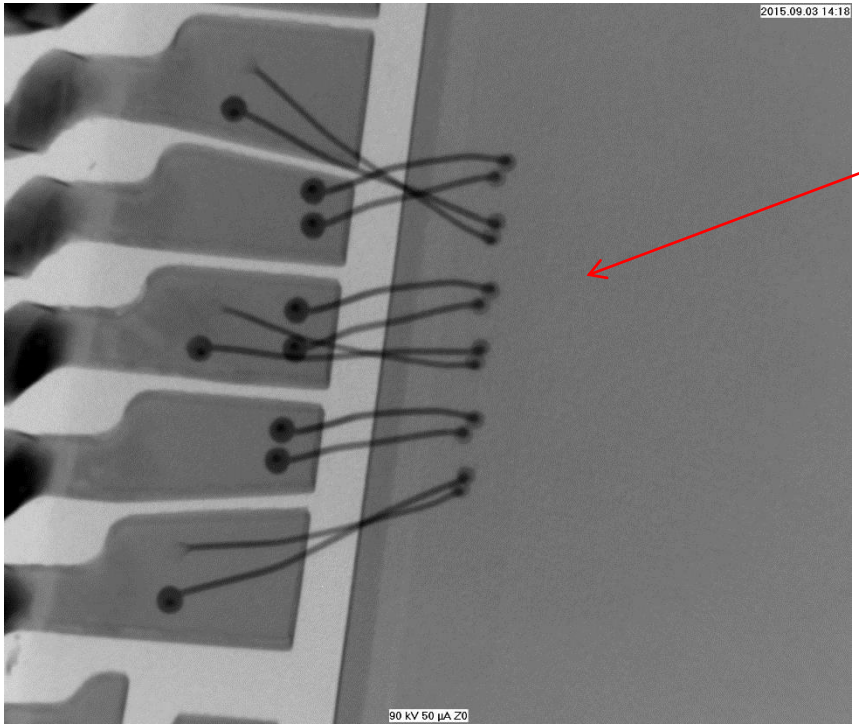


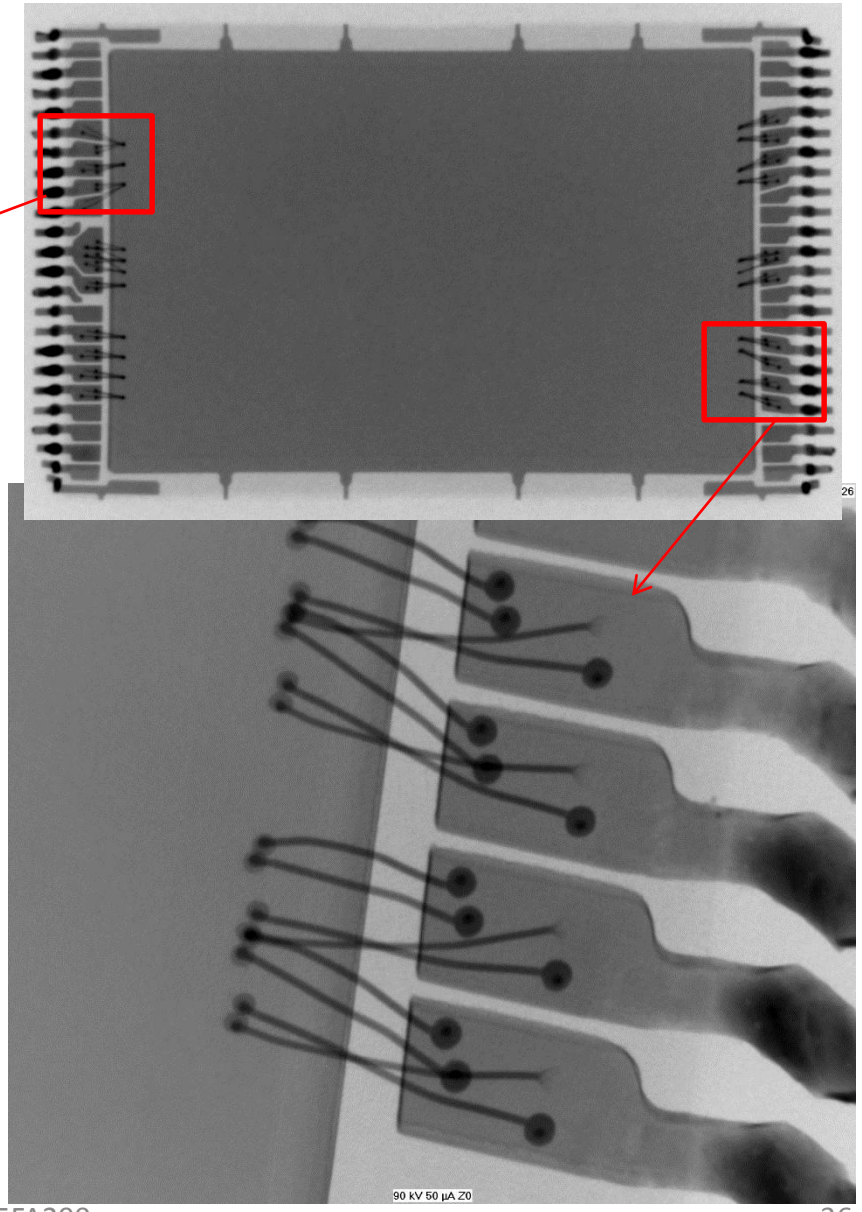


This feature found in both packages 6-1, 6-2

X-ray images of the side view of the package suggest that there are 4 stacked dies in the package two on each side of the chip carrier

Appareo 6 -2: x-ray images

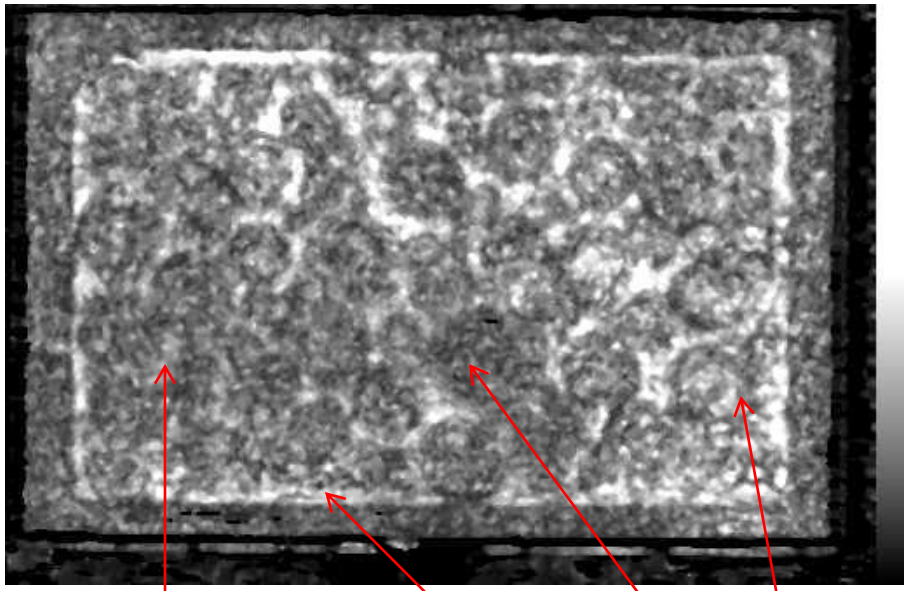




No analomies detected in any wire bonds in this package

Appareo 6 -2 : C-SAM images

Surface image



Top die image

Shadow of defects within mold compound (preventing detection of details on the dies)

Both 100 Mhz and 50 MHz transducers, were tried to acquire good images of the stacked dies within the package. However, features from the molding compound damage (disintegration) overshadowed any details on dies.

Summary for APPAREO PARTS

- Appareo SD card SD-5 is broken into two pieces, one with the die and the other with the chip carrier.
- X-ray images indicate that both Appareo packages 6-1, 602, are of the same kind with 4 stacked dies, two on each side of the chip carries.
- One corner of package 6-1 was found to be damaged with interior die lifting off the mold. X-ray images show that some wire bond close to this corner are discontinuous/broken
- No wire bond anomalies in package 6-2 were found using the x-ray evaluation.
- Molding compound of both 6-1, 6-2 packages was found to be severely damaged probably from high temp/fire. This prevented achieving any useful information about the dies integrity from acoustic imaging.
- Disposition: Part number 2 from box 6 may be worth an attempt at data recovery – other parts were too badly damaged