Analysis of Modules from Accident WPR19MA177

S.R. Cain

Prepared for the National Transportation Safety Board

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IEEC
Integrated Electronics Engineering Center
S3IP
Binghamton University

Overview of the Analyses

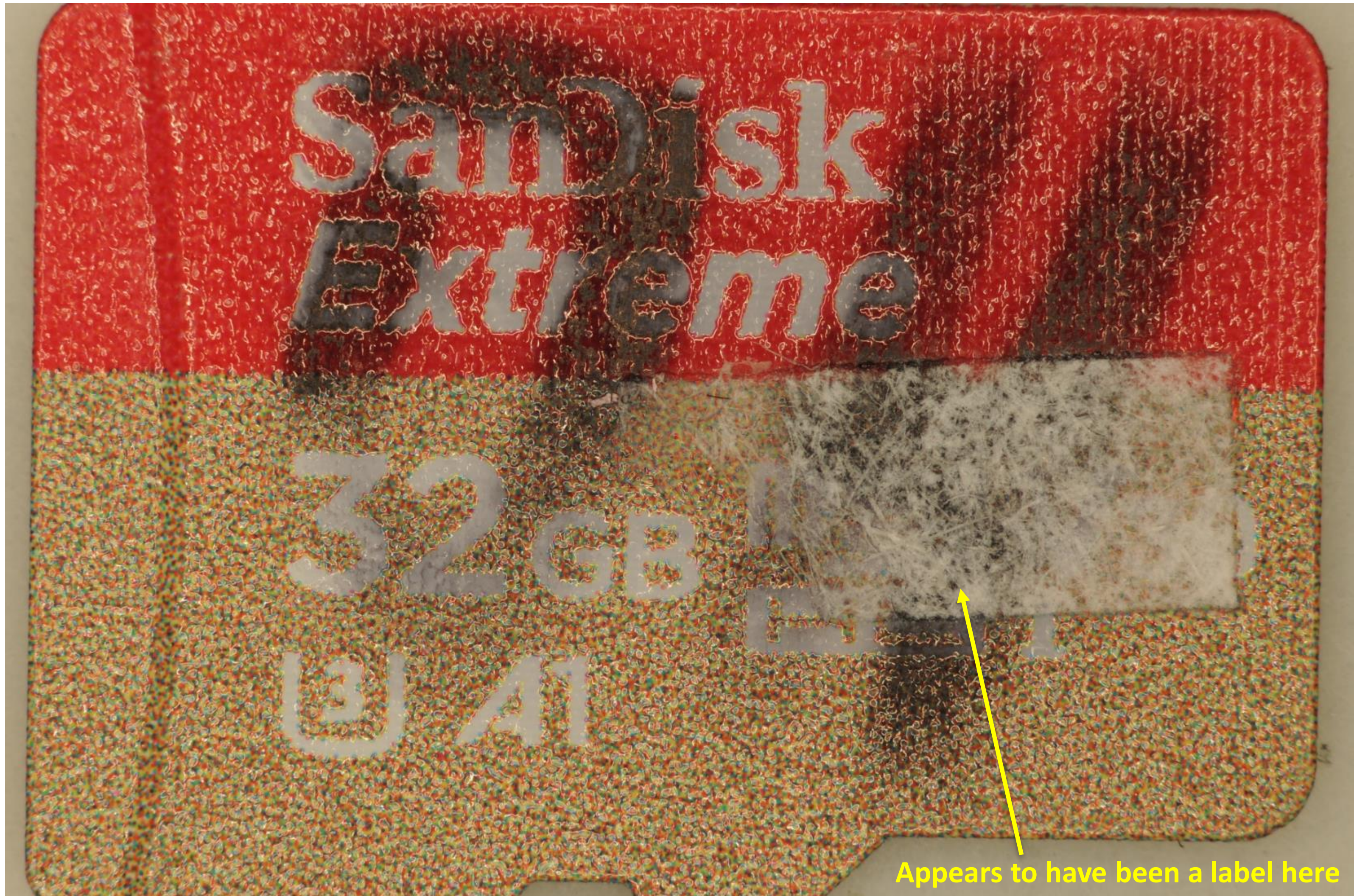
- **Background of the samples**
  - NTBS designation: WPR19MA177
  - Two samples received for non-destructive analysis
    - "Early recovery"
    - "Later recovery"
- **Optical microscopy**
  - Leica Wild M420 zoom stereoscope
  - Bright field and dark field mode
- **X-ray**
  - GE Nanomex
  - 60-75 KV acceleration voltage (60 KV used for direct imaging, 75 KV used for tilted view)
  - 20 uA current
  - Direct and 70° tilted view
  - X-rays hardened with 4 sheets of aluminum foil as a filter
- **Acoustic microscopy**
  - Sonix HS550
  - 50 MHz transducer focused to 16 usec time of flight
  - Pulse echo mode
  - 4 active gates

- **Results for "early recovery" module**
  - SanDisk Extreme 32 GB
    - 3 chips in the module
    - 2 of the chips were stacked
    - Wire bond connections
  - No evidence of thermal damage
  - No evidence of mechanical damage, other than exposure of the package circuit plane from mechanical sanding
  - Wire bonds were intact
  - No evidence of chip cracking or delamination
  - **Evidence would suggest that this is a good candidate for data recovery**
- **Results for "later recovery" module**
  - SanDisk Ultra 32 GB
    - 2 chips in the module
    - Wire bond connections
  - No evidence of thermal damage
  - Two cracks were observed
  - Wire bonds to one of the chips were broken; the crack "missed" this chip
  - Wire bonds to the other chip were intact, but the crack was in the area of the chip
  - **Effective data recovery is doubtful**

Section 1

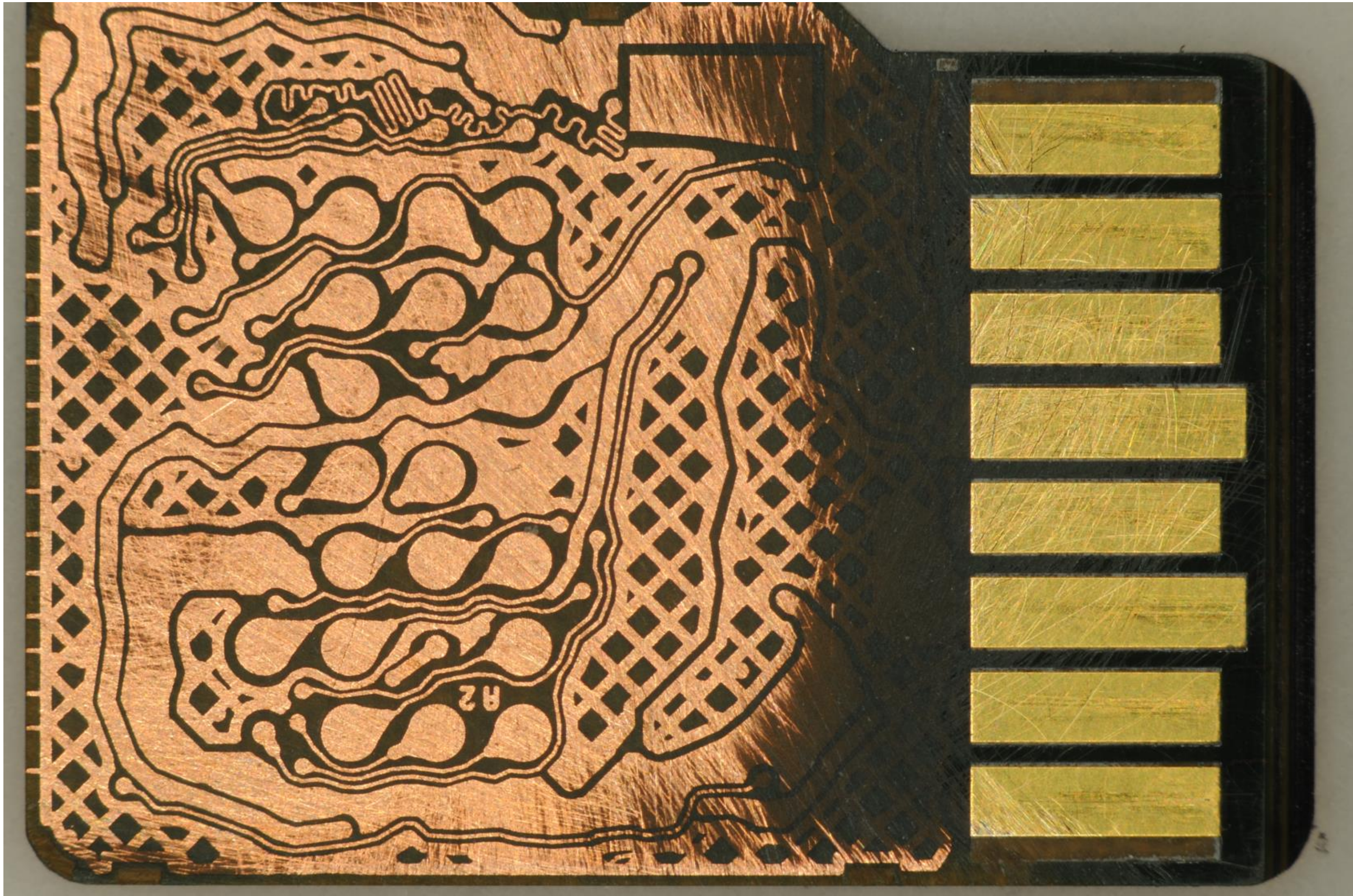
EARLY RECOVERY MODULE

Optical Image of the Top Side (Dark Field)



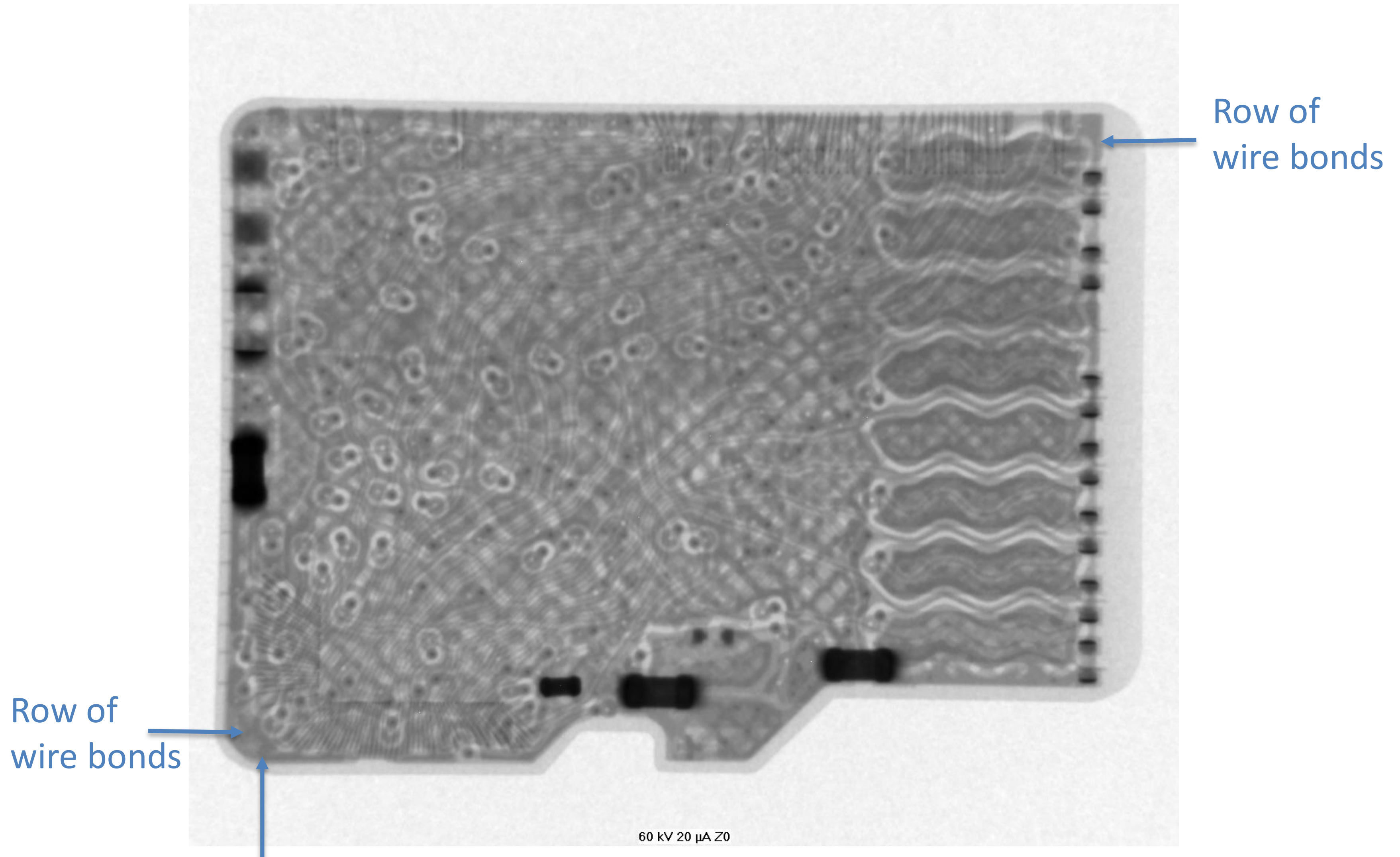
No evidence of thermal or mechanical damage

Optical Image of the Bottom Side (Dark Field)

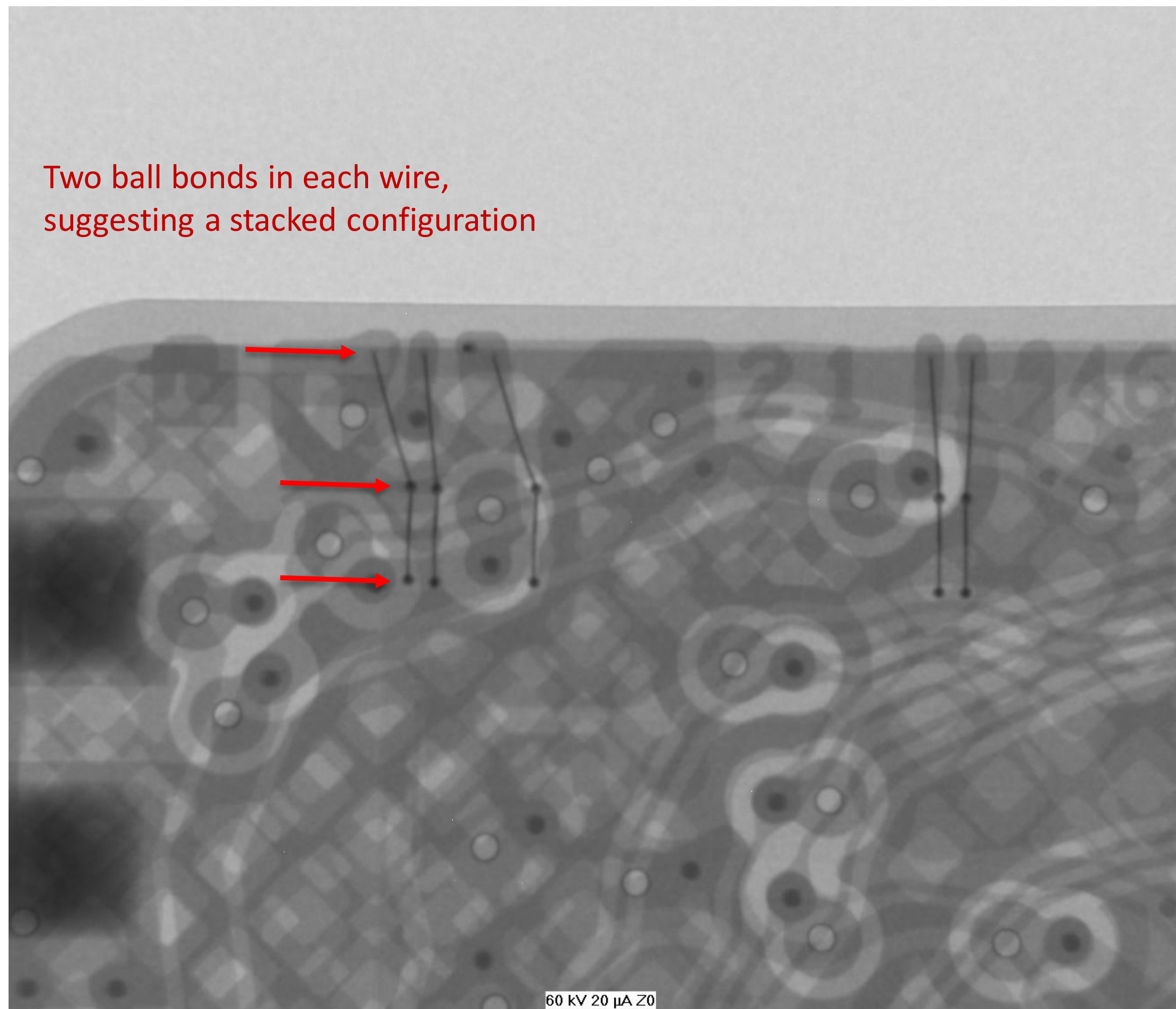


- No evidence of thermal or mechanical damage (other than the mechanical removal of the bottom dielectric)
- Grinding did not go through multiple planes

X-ray: Global View the Module

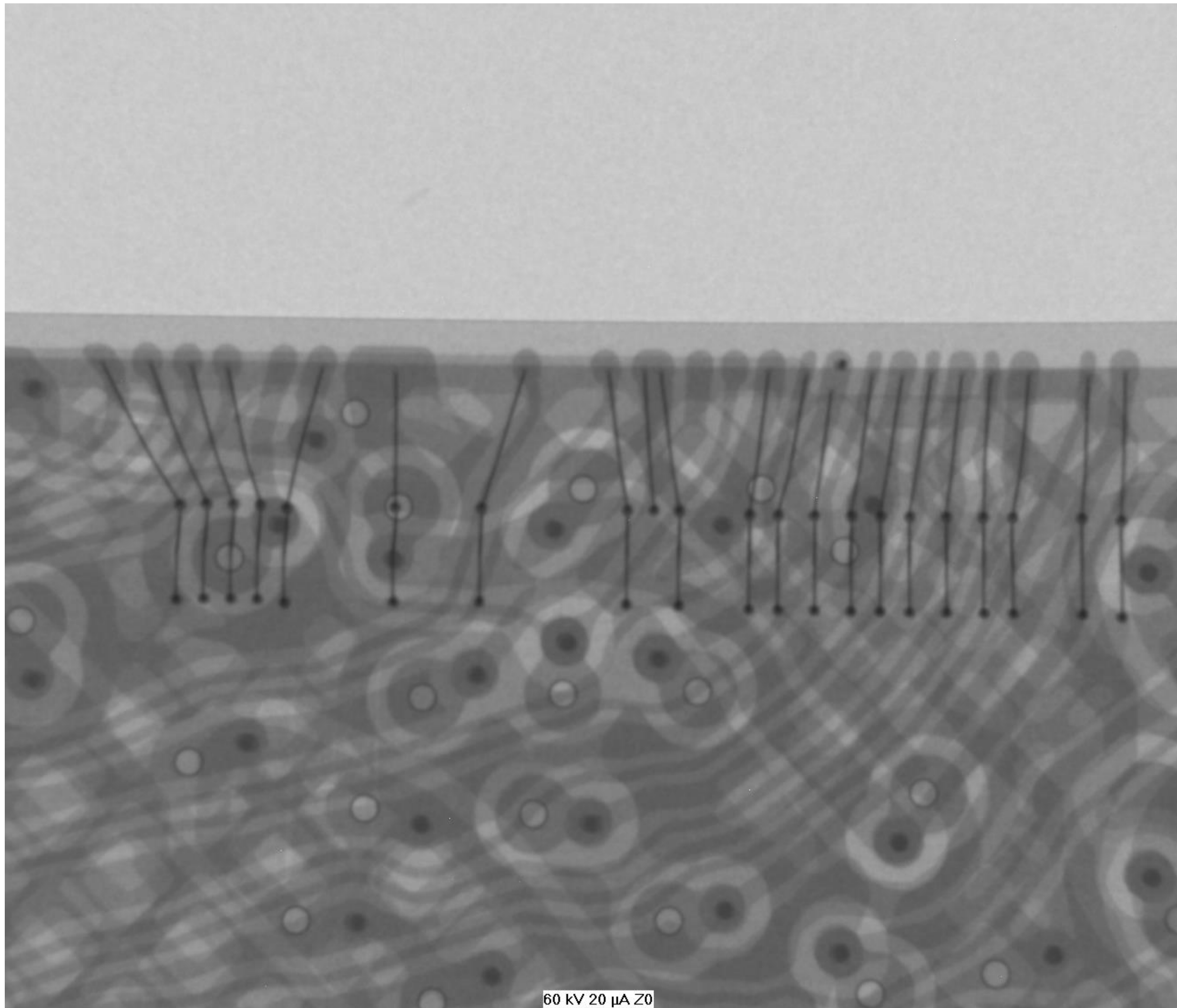


Top Row of Wire Bonds at Higher Magnification (1)



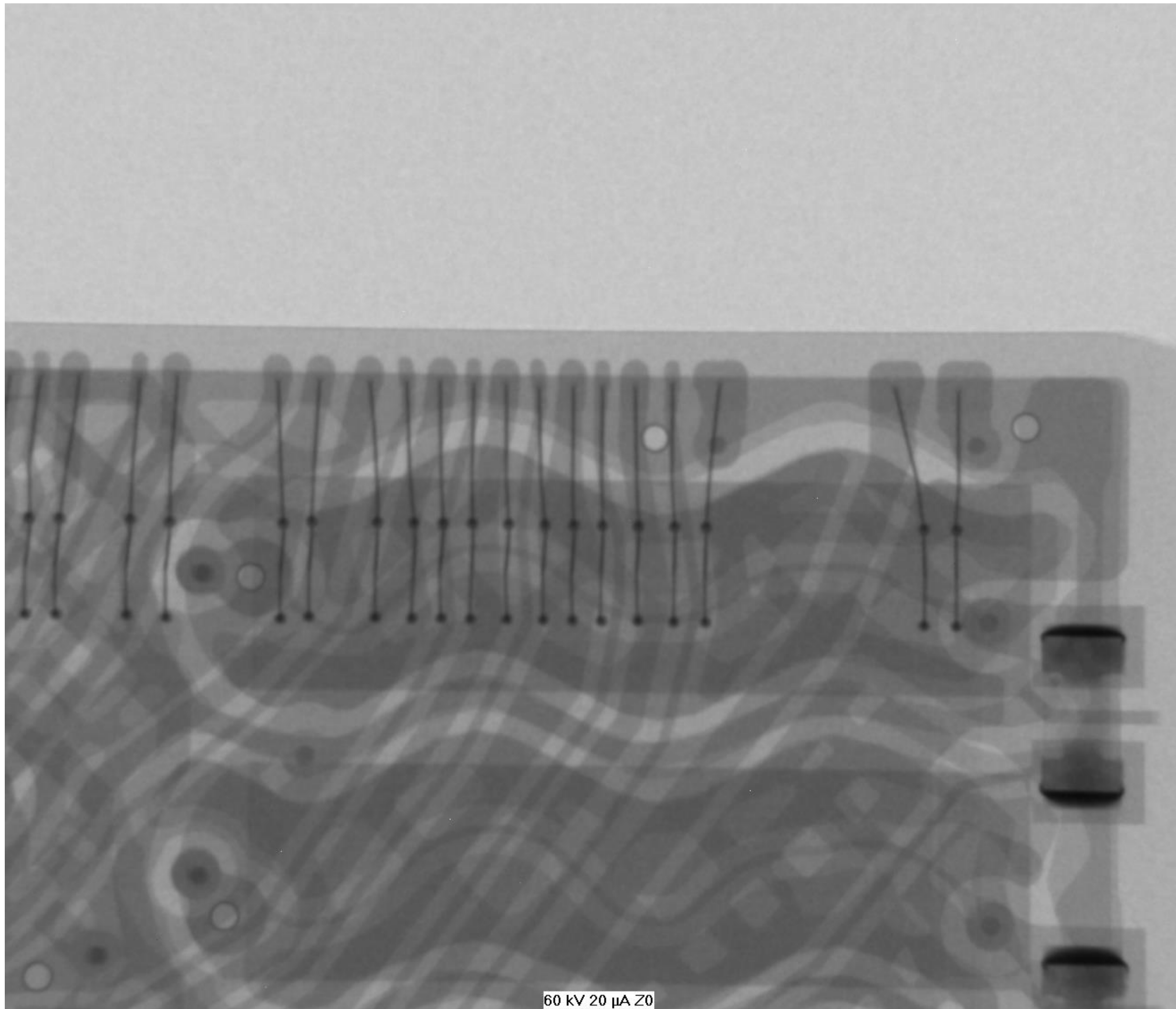
- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

Top Row of Wire Bonds at Higher Magnification (2)



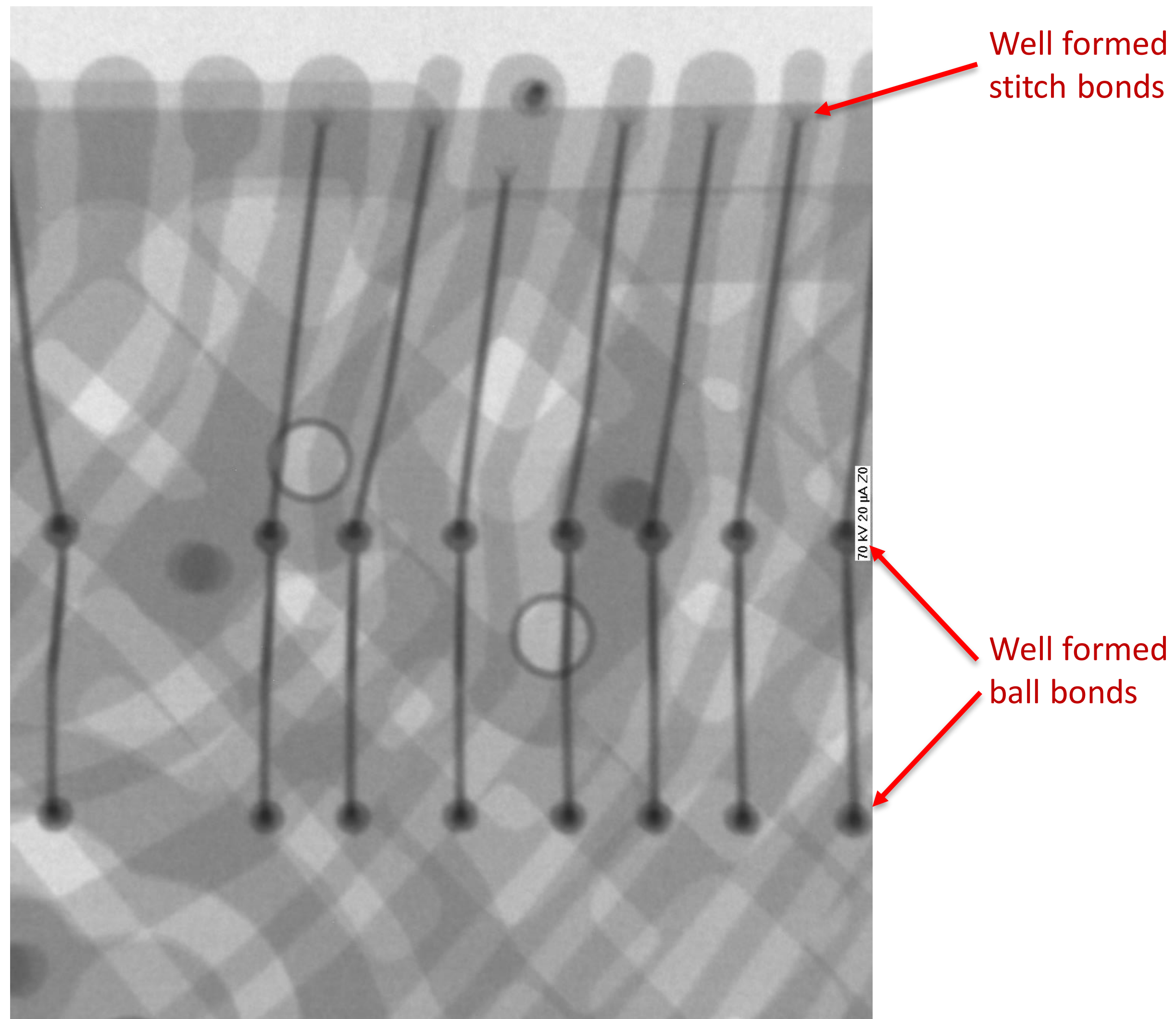
- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

Top Row of Wire Bonds at Higher Magnification (3)



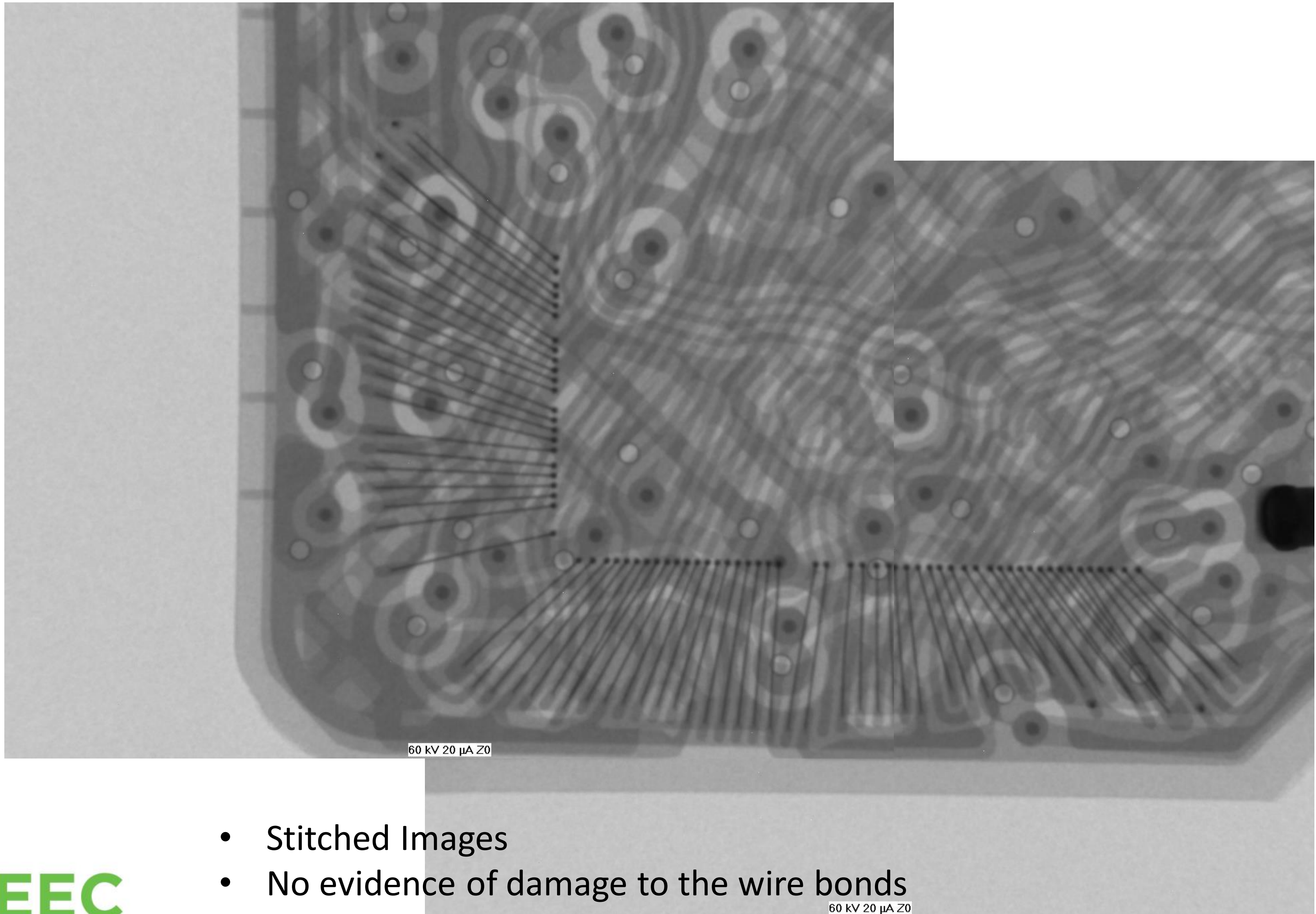
- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

Top Row of Wire Bonds at High Magnification



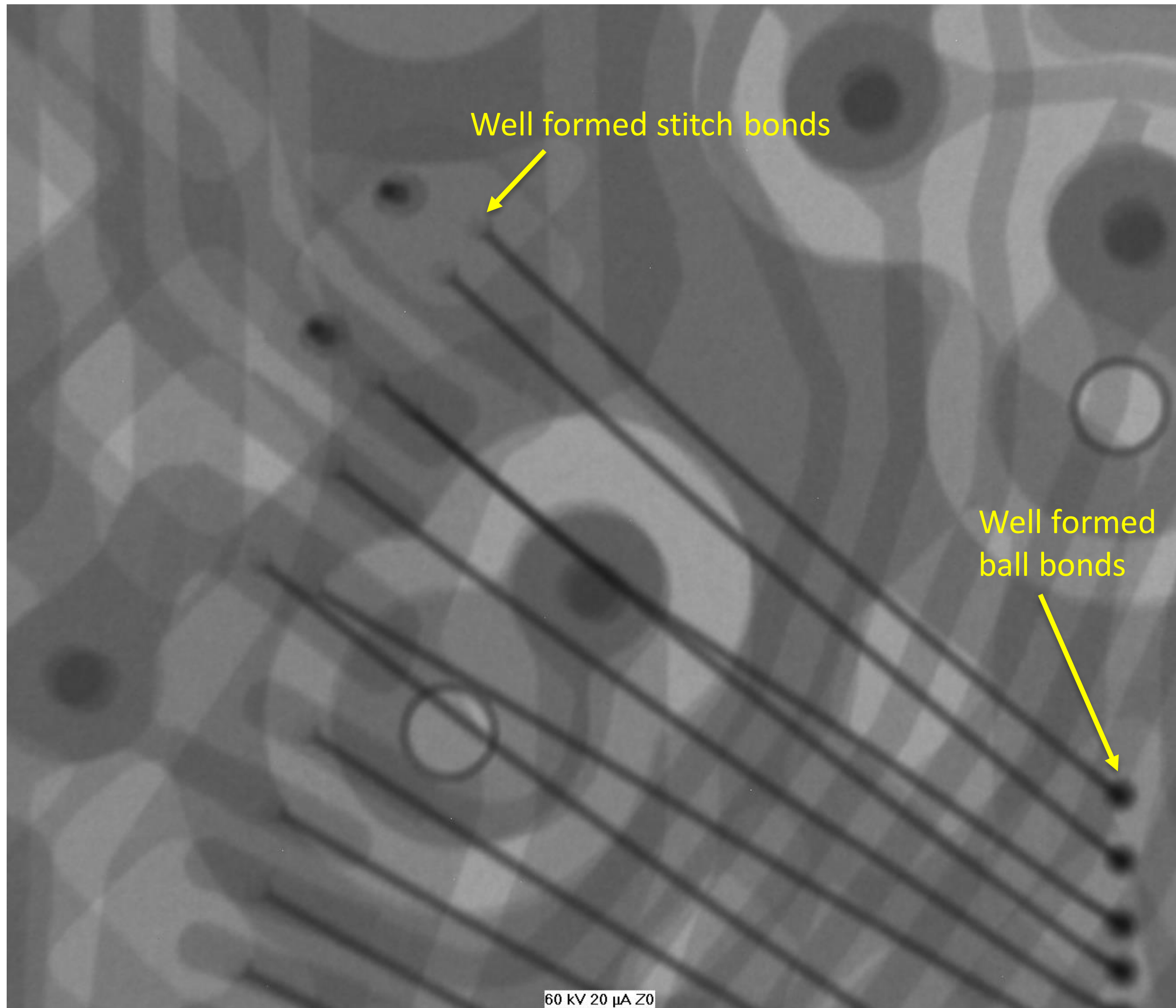
- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

Bottom Row and Left Column of Wire Bonds



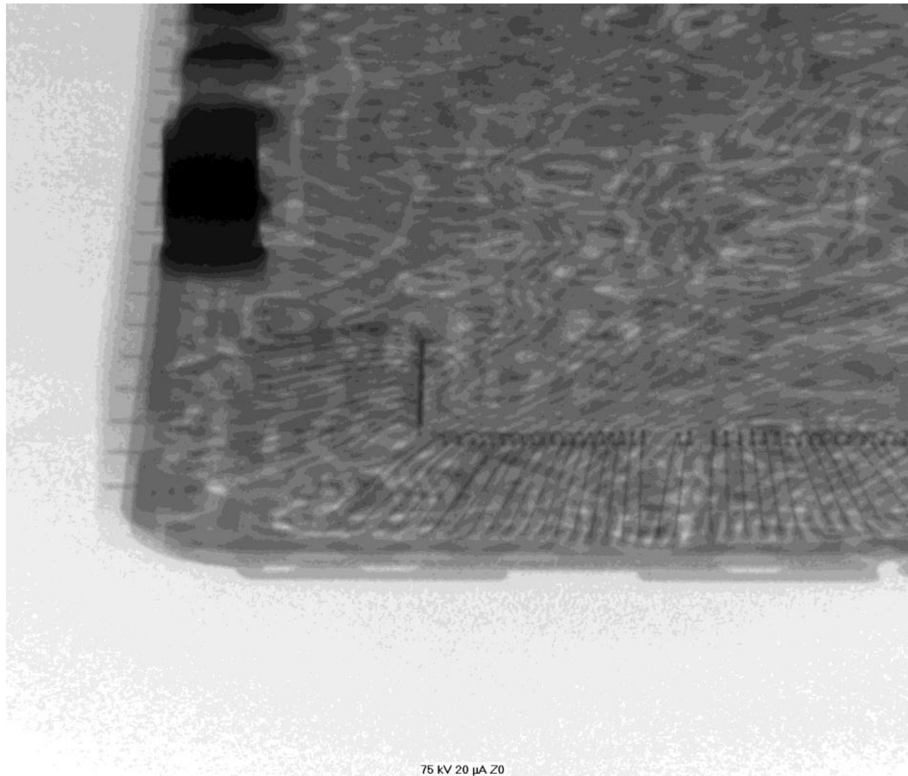
- Stitched Images
- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

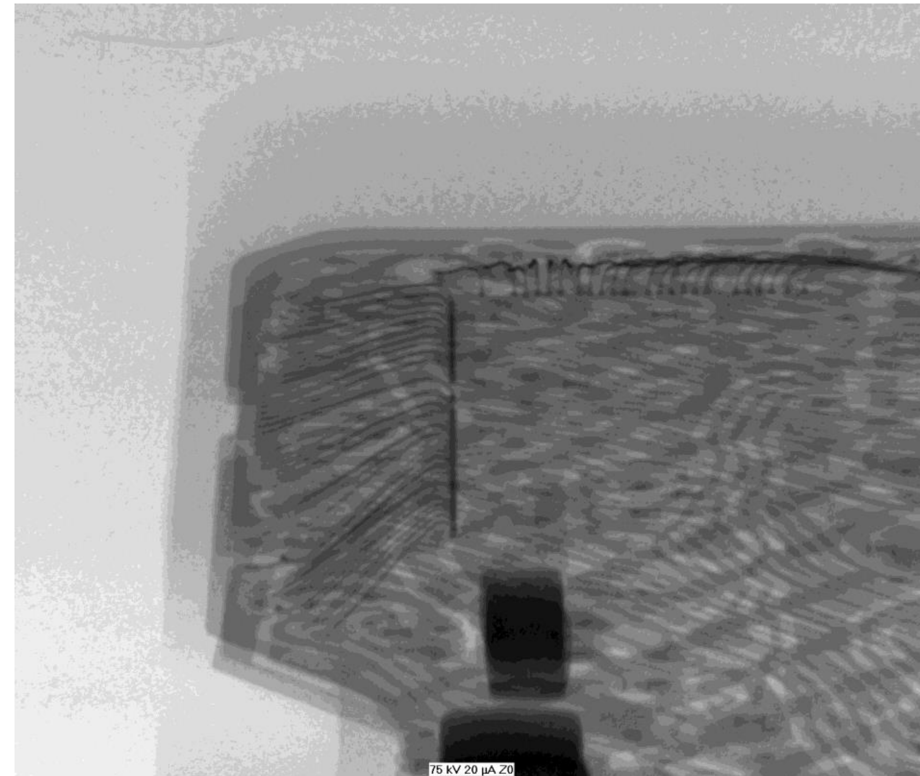
Left Side Wire Bonds at High Magnification



- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

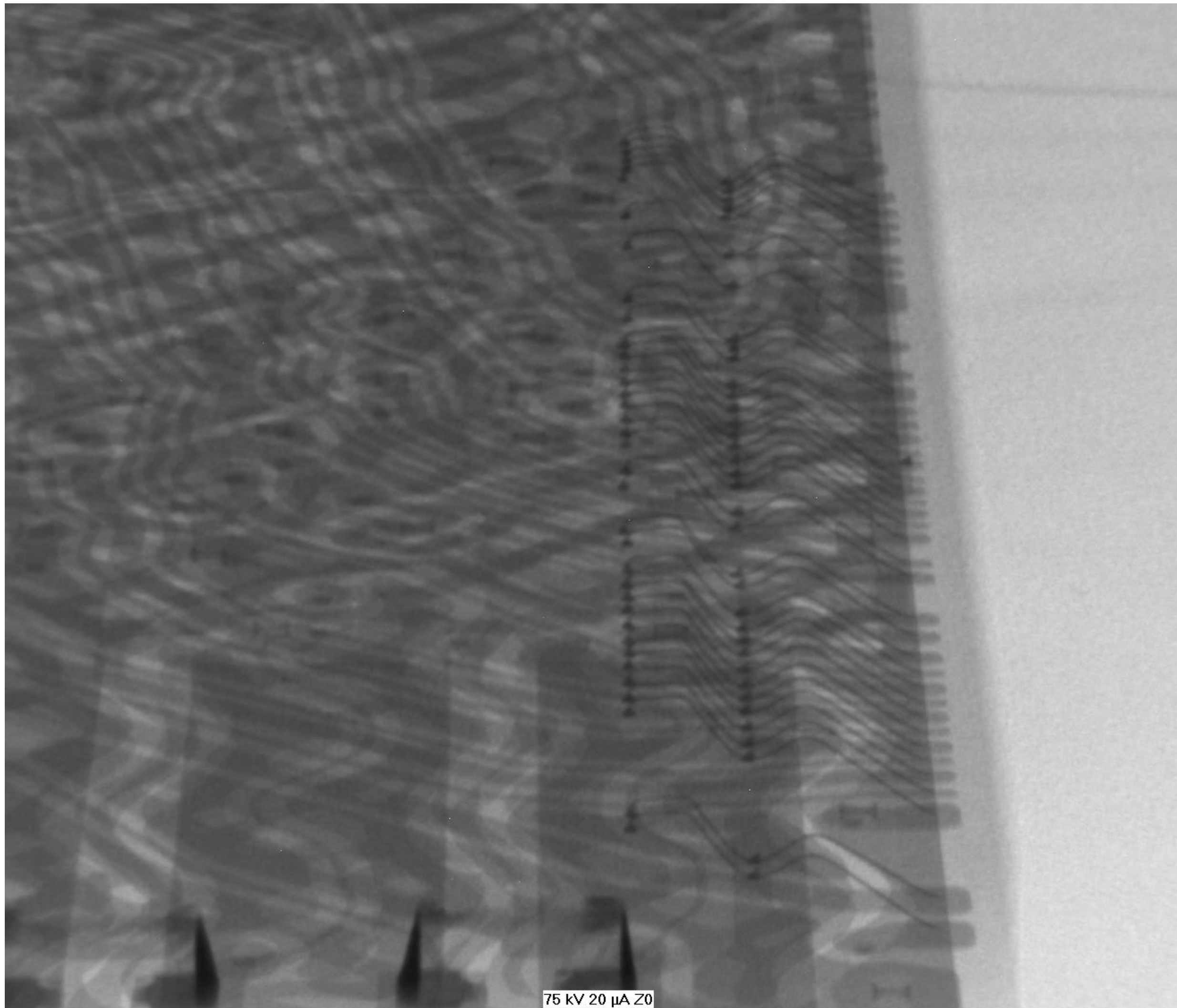
Tilted View of the Corner Bonds (70° Tilt)





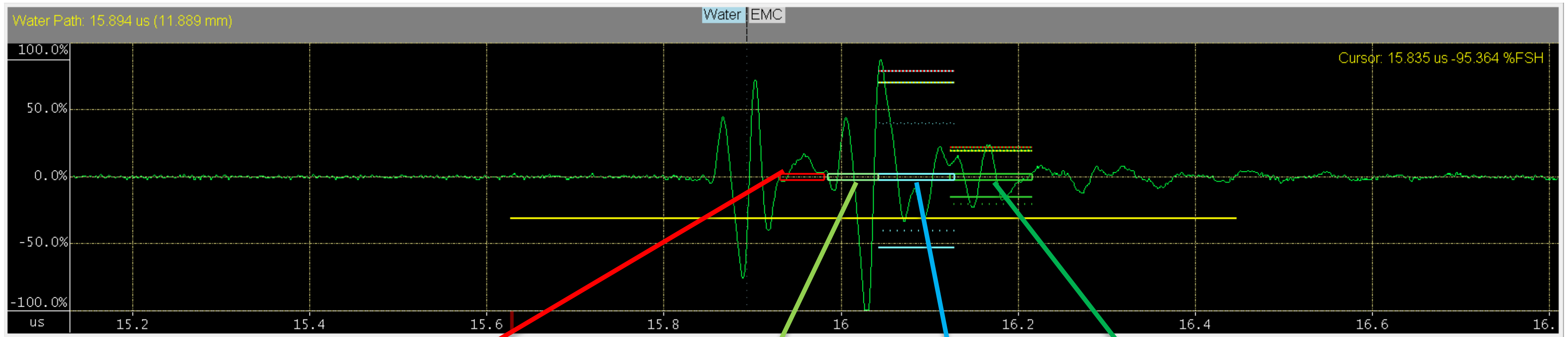
No evidence of out of plane string of bonds (lack of planar string can indicate that the wire bonds were pulled away from the chip)

Tilted View of the Top Row of Wire Bonds

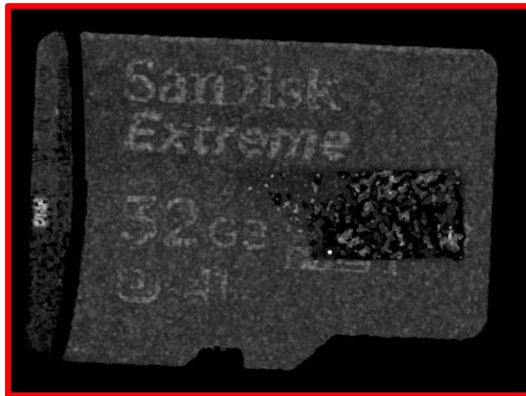


- No evidence of damage to the wire bonds
- Different row height confirms stacked configuration of the chips in this area

Setup for the Sonic Imaging

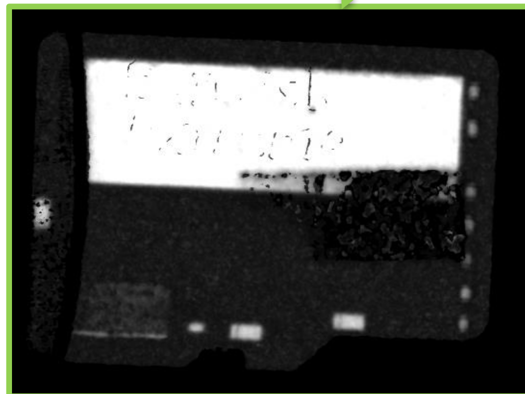


Overmold



Laminate

Top chip and SMT components



Bottom chip(s)

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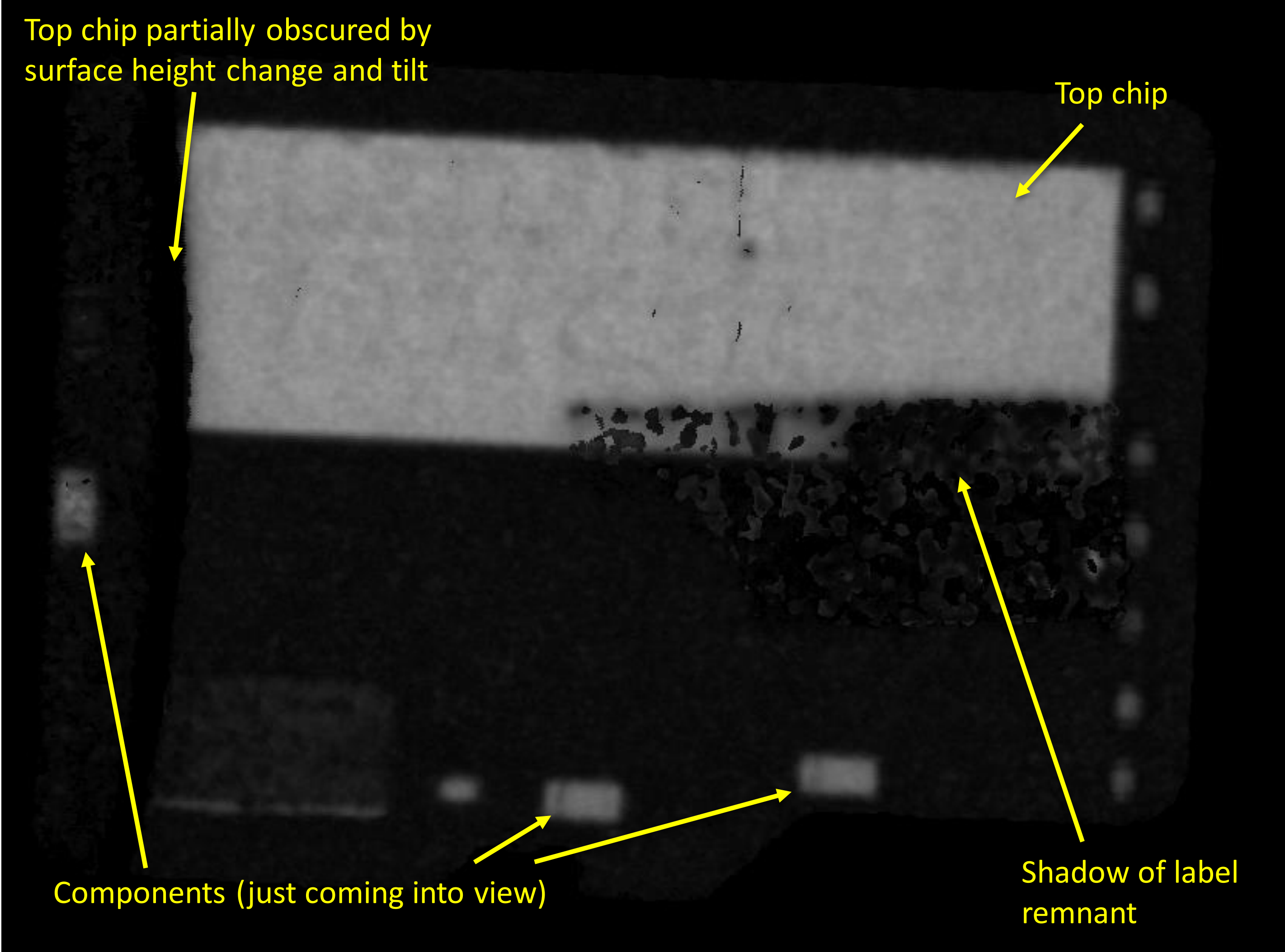
Image of the Top Chip



No evidence of damage to the chip

Image of the Bottom Chip(s)

No evidence of damage to the either chip

Image of the Top Layer of Circuitry in the Laminate

No evidence of suspicious delaminations in the package;

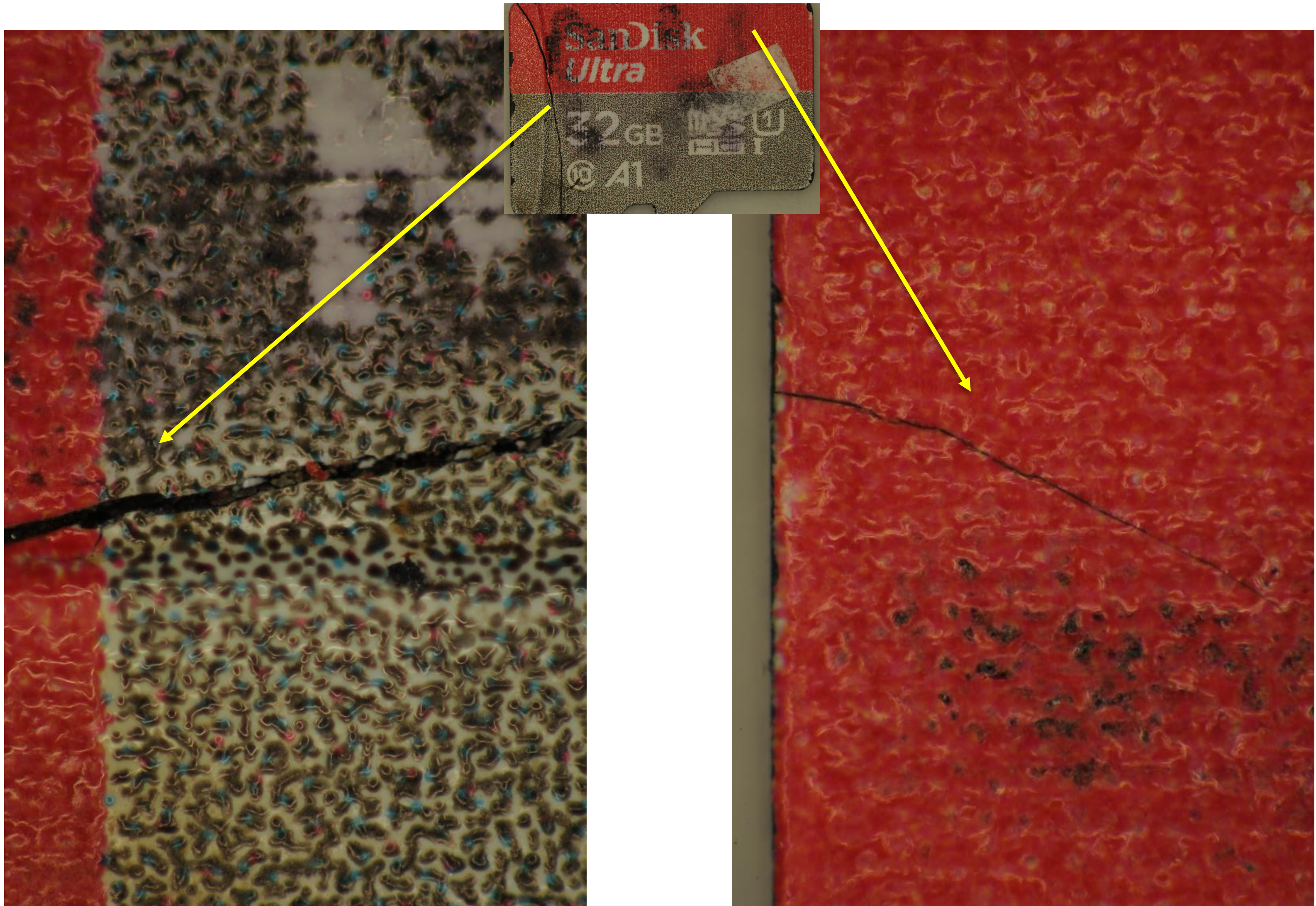
Section 2

LATER RECOVERY MODULE

Optical Image of the Top Side (Dark Field)

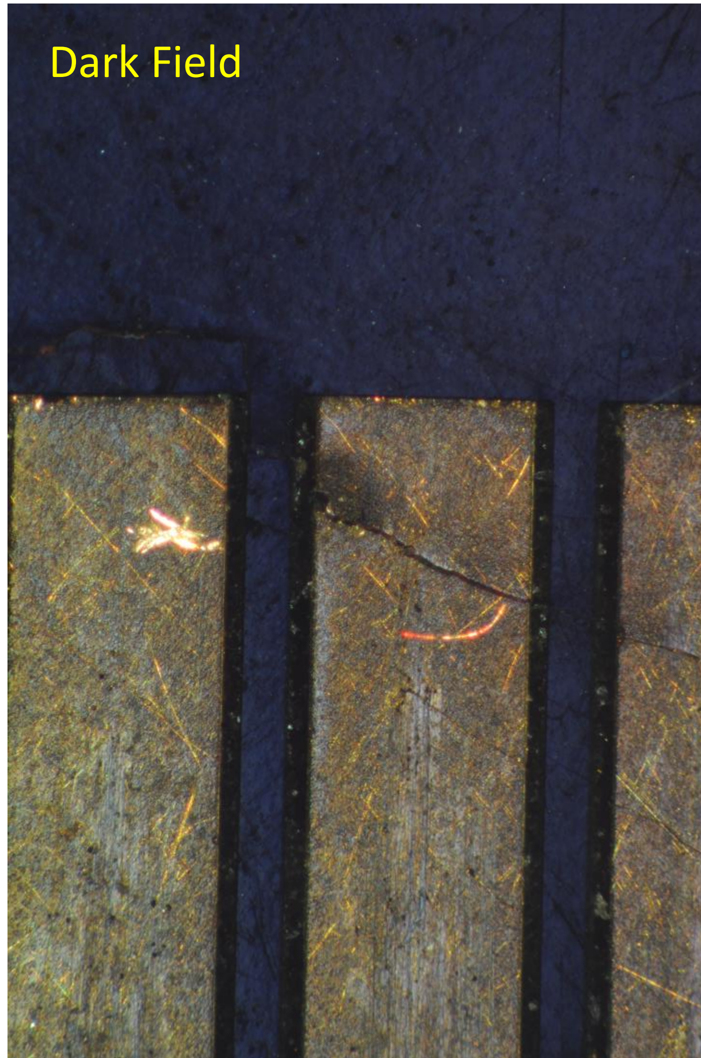
- No evidence of thermal
- Two cracks are visible from the surface

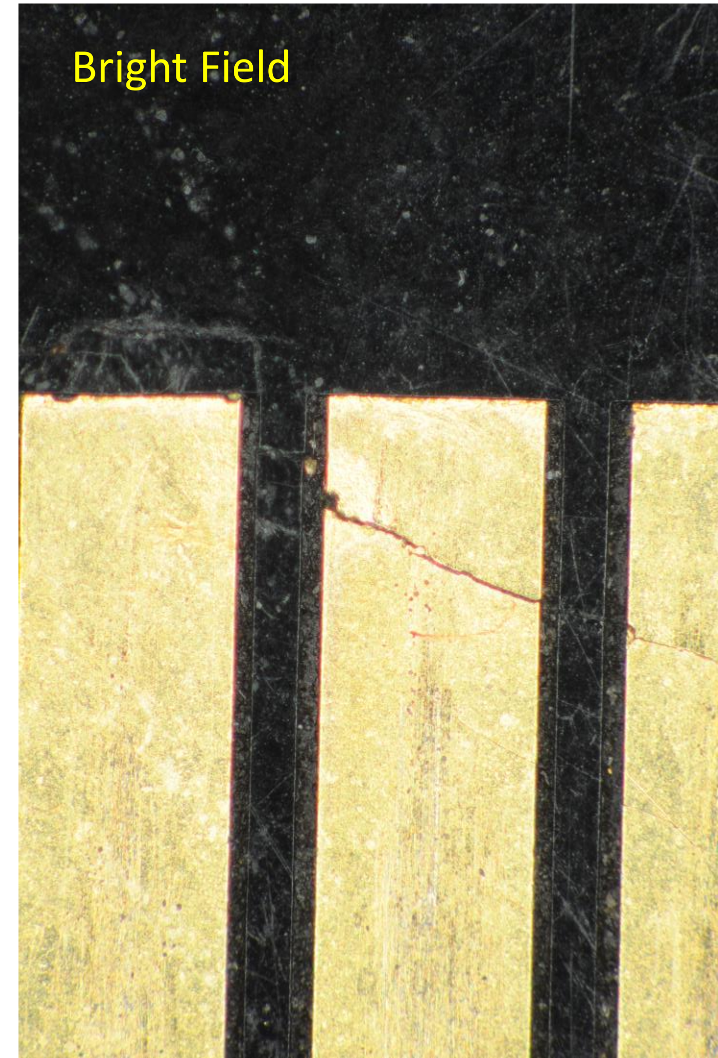
Zoomed View of the Cracks from the Top Side



NOTE: zoomed images are rotated 90°

Back Side View of the Area with the Fine Crack

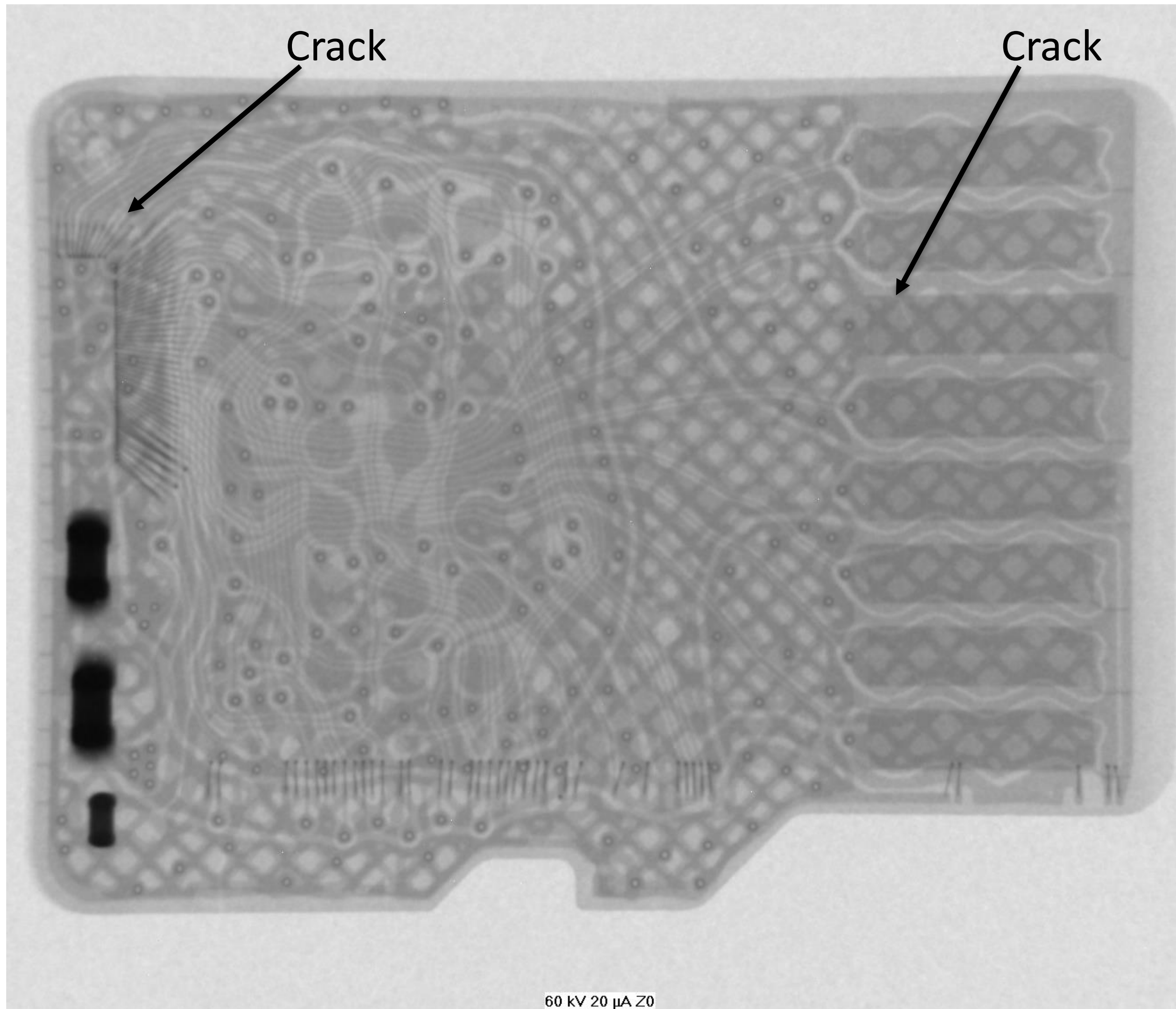




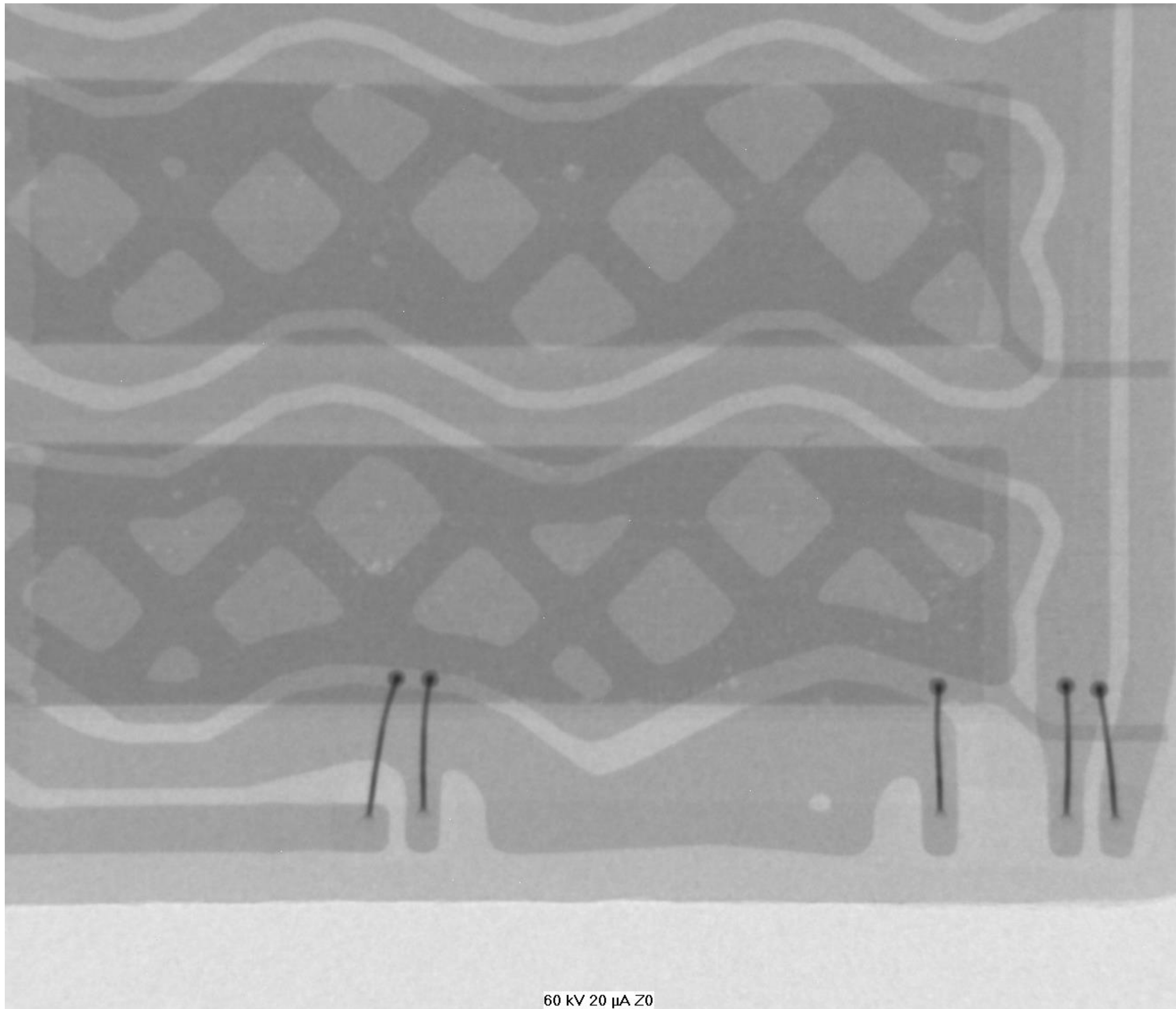
- Crack has propagated through the module to the back side circuitry

Permanent Deformation of the Package

X-ray Global View of the Package



Bottom Row of Wire Bonds at Higher Magnification (1)



- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

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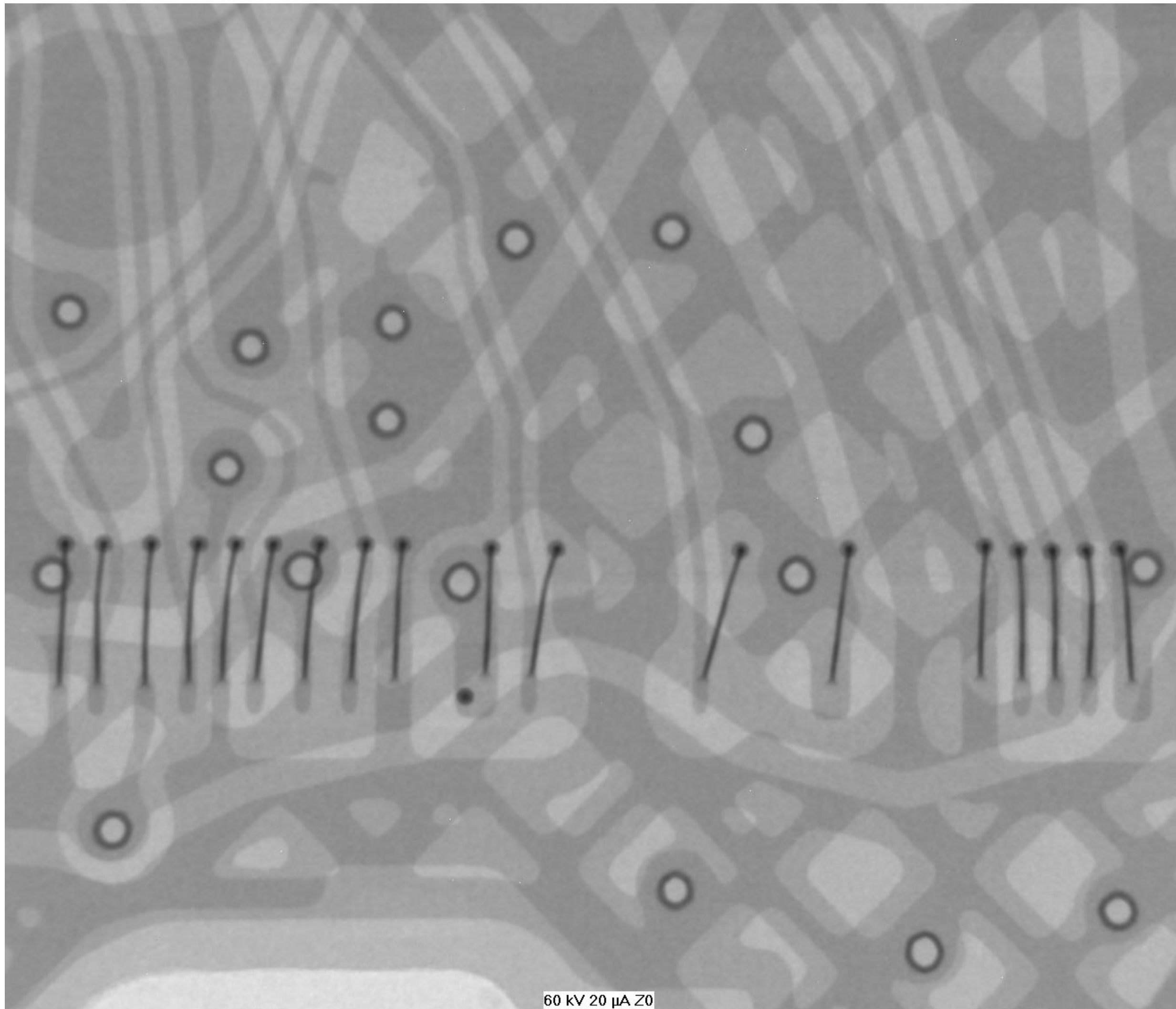
Bottom Row of Wire Bonds at Higher Magnification (2)



- No evidence of damage to the wire bonds
- Circuitry of the laminate appears to be intact

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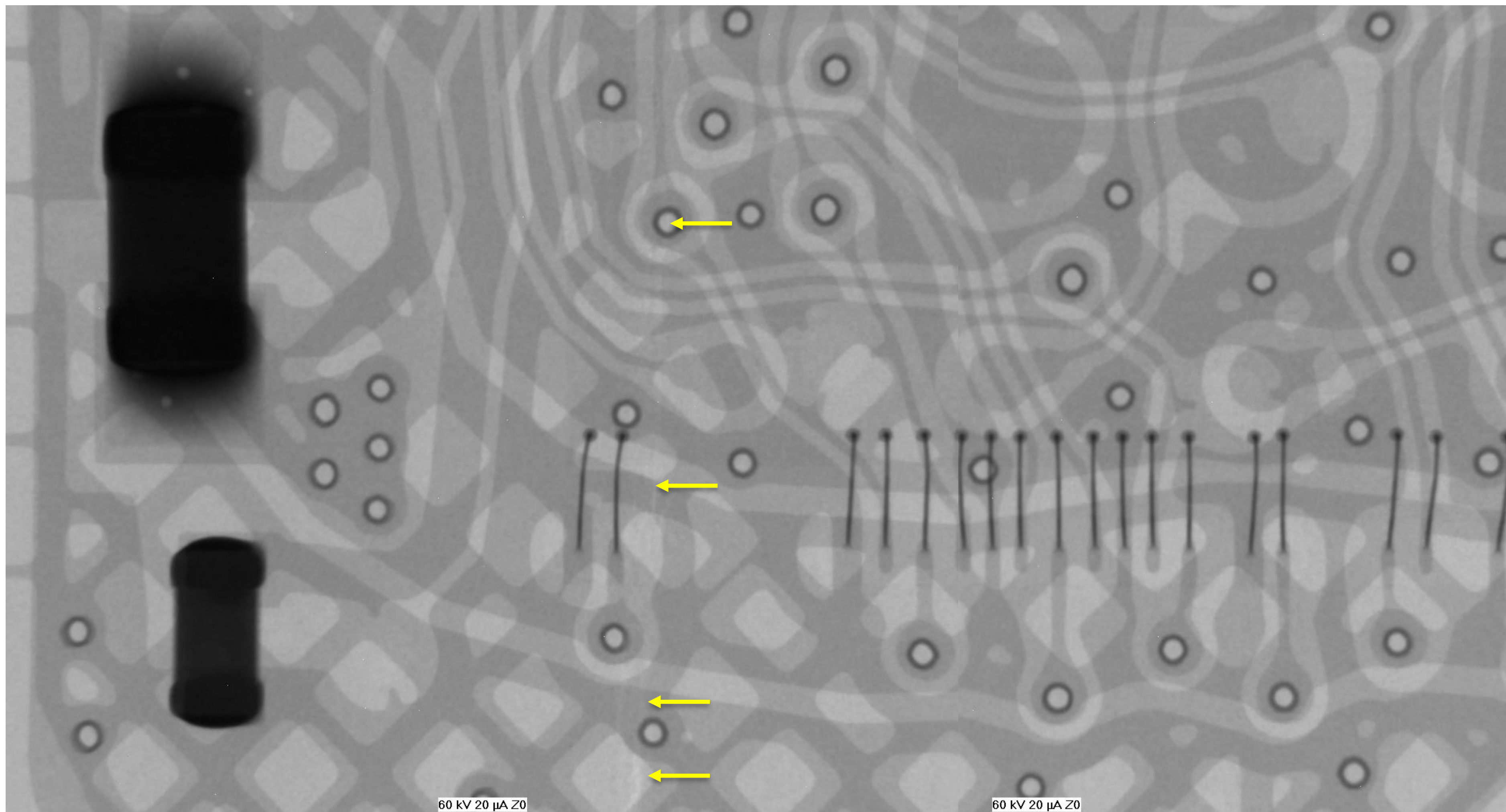
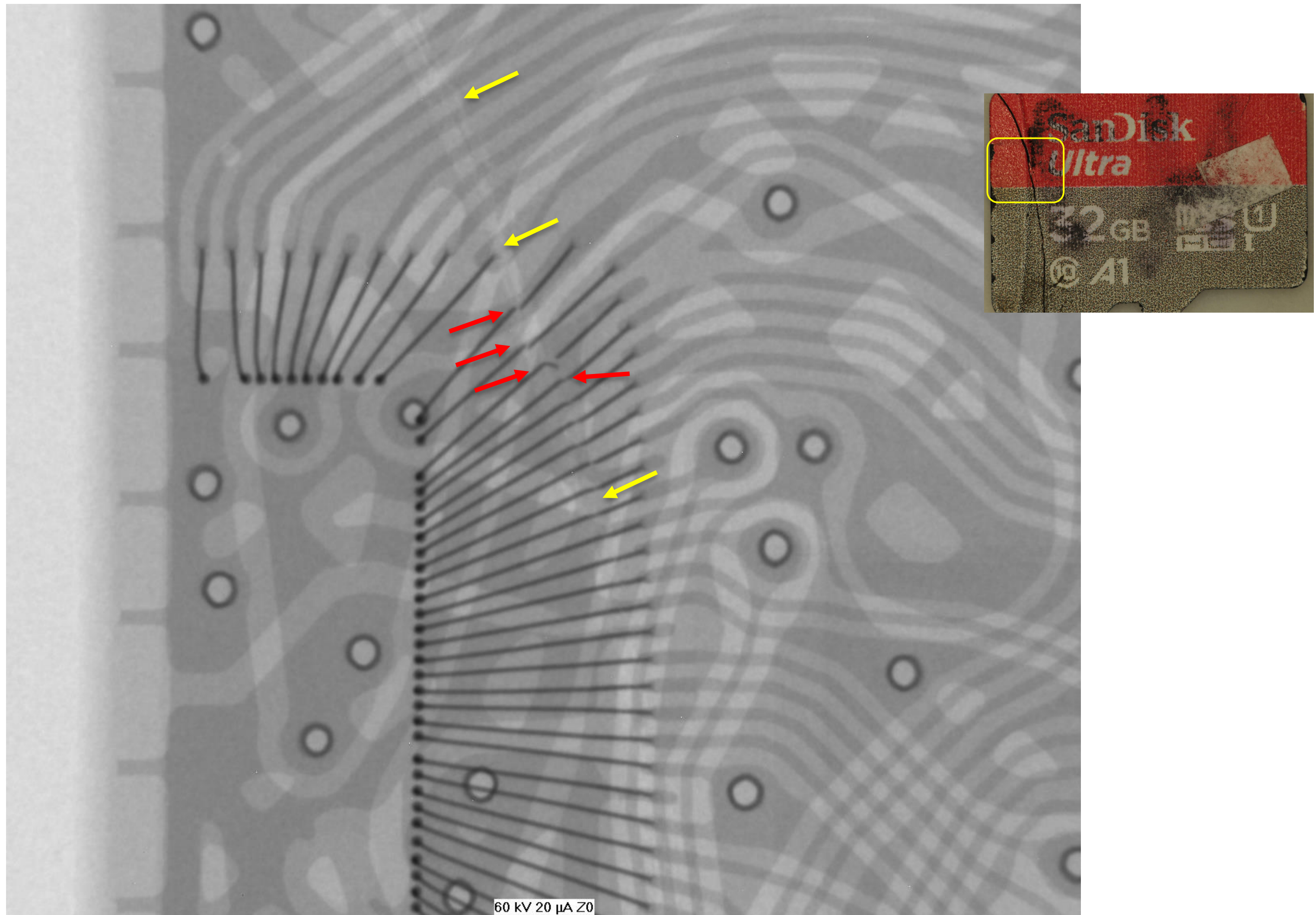
Bottom Row of Wire Bonds at Higher Magnification (3)



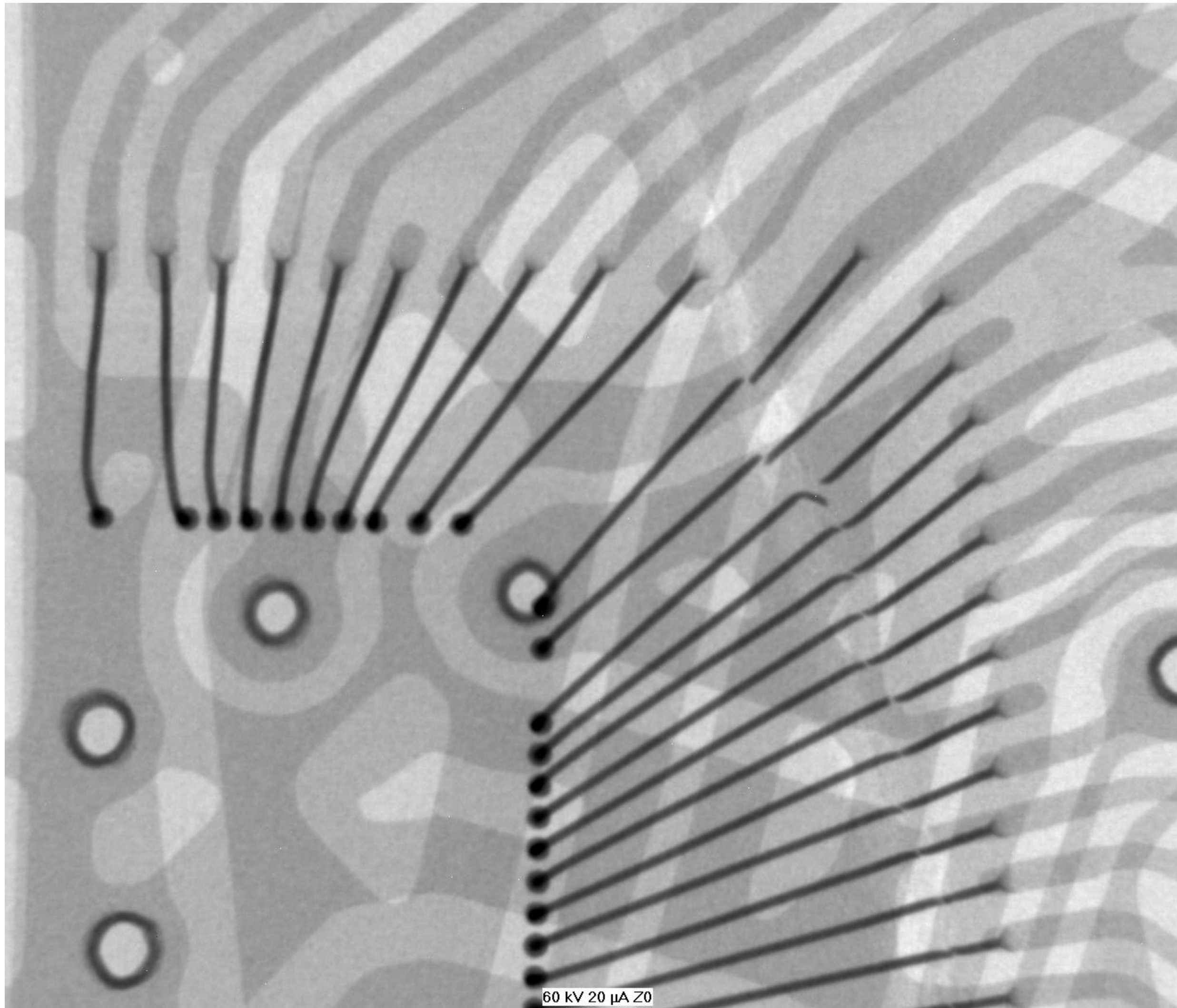
- Stitched image
- No evidence of damage to the wire bonds
- Circuitry of the laminate may be damaged in the area of the crack (arrows)

Crack in the Area of the 2nd Chip (Left side of the Package)

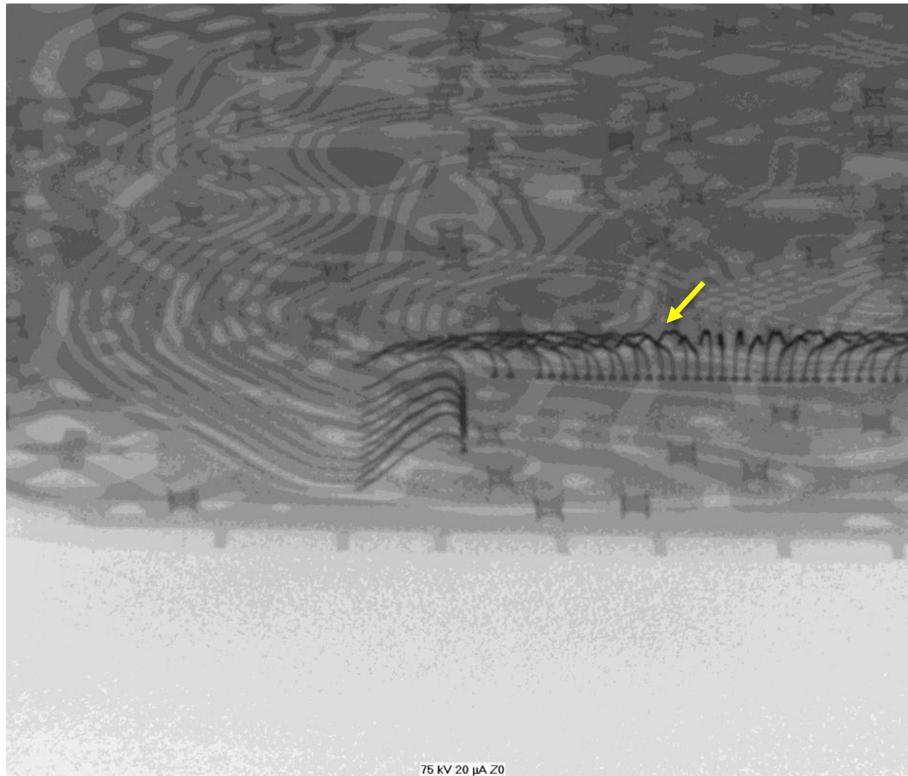


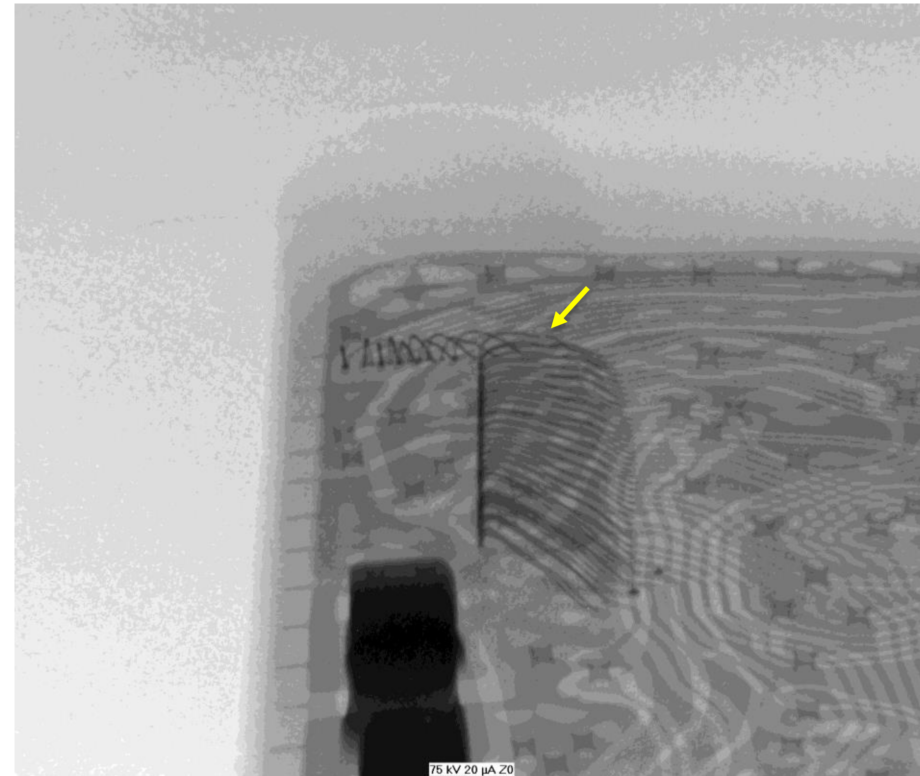
- Broken wire bonds (red arrows)
- Circuitry of the laminate may be damaged in the area of the crack (yellow arrows)
- Crack appears to miss the chip in this area (ball bonds are typically on the periphery of the chip)

Cracked Area at High Magnification



Tilted View of the Cracked Area (70° Tilt)





- No evidence of out of plane string of bonds (lack of planar string can indicate that the wire bonds were pulled away from the chip)
- Broken and bent wire bonds, nonetheless, are evident (arrows)

Setup for the Sonic Imaging

Water Path: 15.800 us (11.818 mm)

Water | EMC

0.183 us (0.220 mm), Peak: 85.548 %FSH

Cursor: 15.756 us -105.960 %FSH

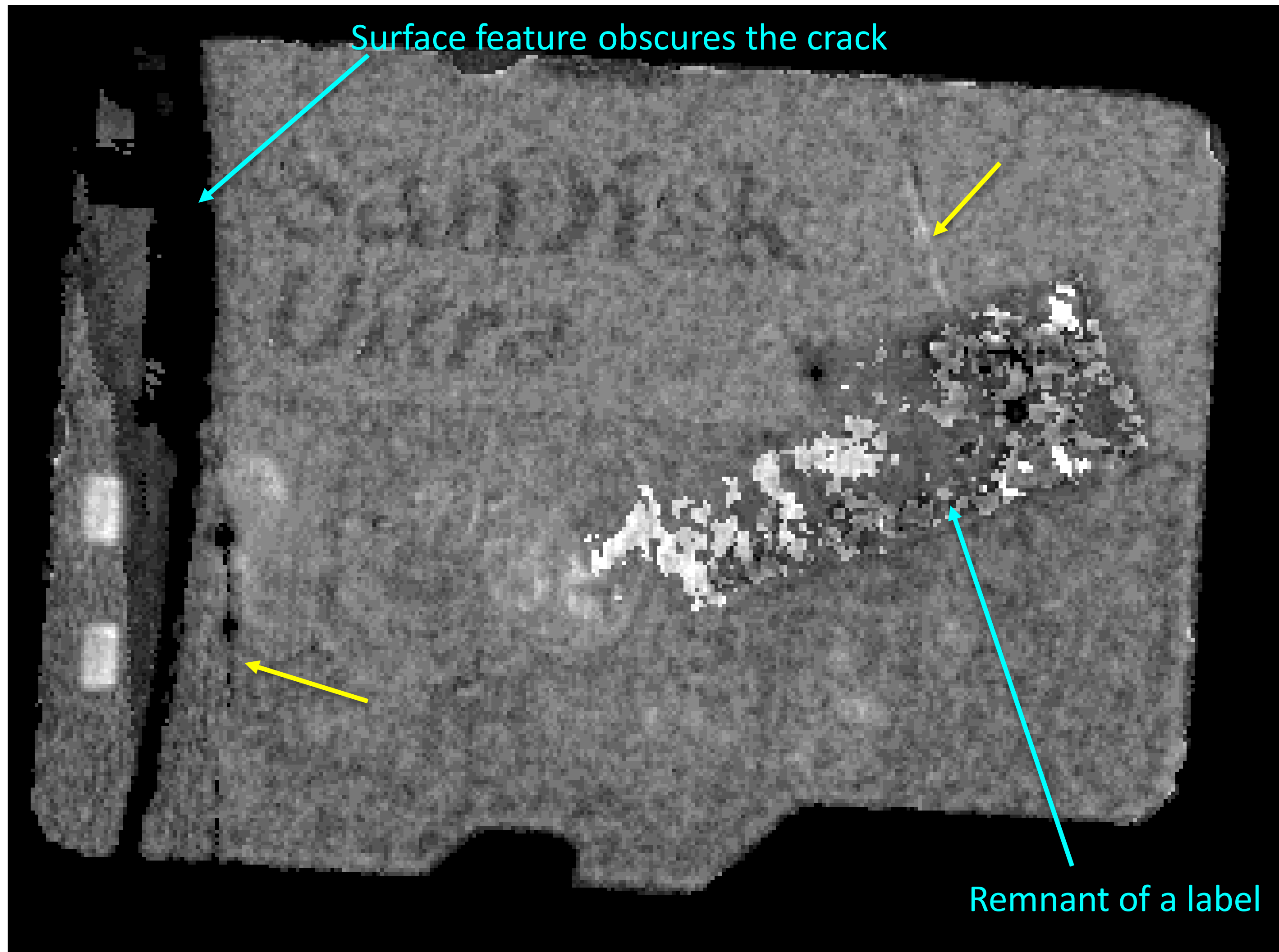
Surface

Laminate

Overmold

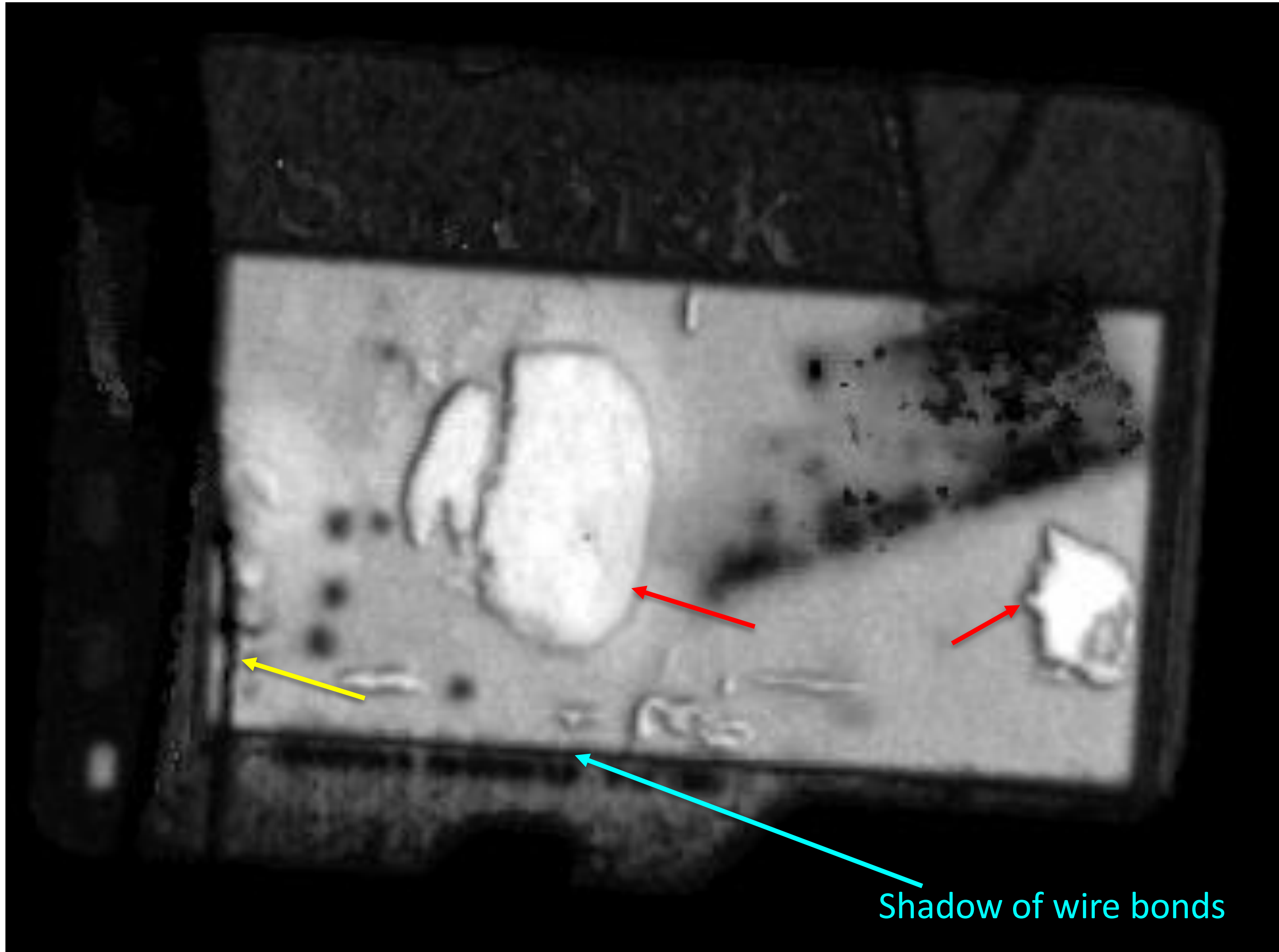
Chip

Cracks Through the Overmold



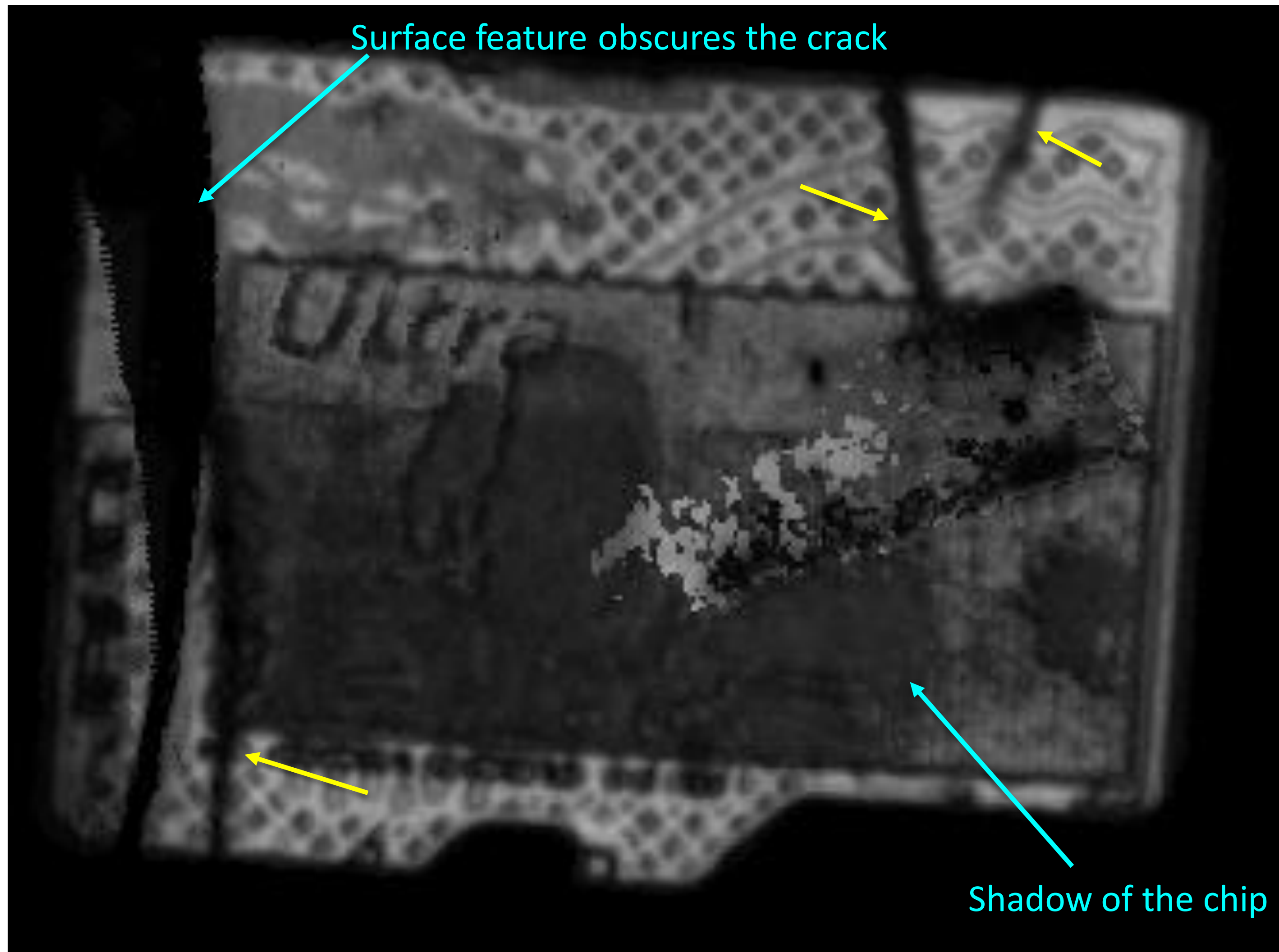
- Yellow arrows highlight the cracks in the overmold
- The larger crack (left) is partly obscured by the difference in surface height

Anomalies in the Chip



- Yellow arrow highlight the crack (or shadow of the crack) in the chip area
- Suspicious delaminations (bright spots in the chip area, red arrows)
- 2nd chip is not visible (obscured by the surface feature)

Cracks (or Shadows of Cracks) on the Laminate



- Yellow arrows highlight the cracks
- Based upon the optical images of the back side of the laminate, these cracks are not mere shadows, but indeed penetrate to the laminate