Topics Addressed:

- **Getting A New Production Line Up Fast (Time to Market)**
- **Preventing Defects By Increasing Yield To Save Money Not Just Finding Defects Which Costs Money**

Presented By: Beltronics
Dr. Robert Bishop, Founder

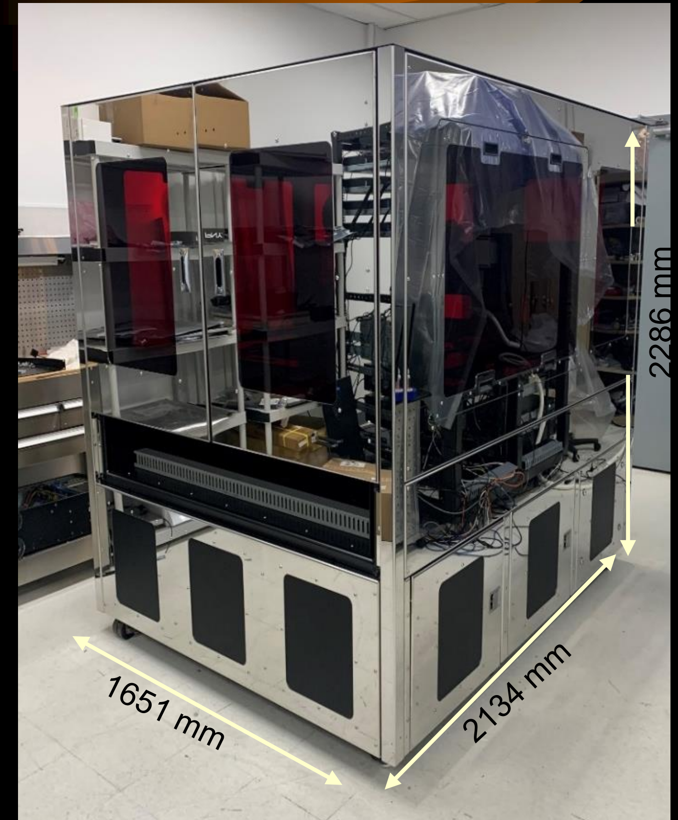
Beltronics Mscan

Preventing Defects By Increasing Yield To Save Money
Not Just Finding Defects Which Costs Money

- Increasing yield requires high levels of process control to ensure that every feature on the panel meets design specifications and detecting process drift before it causes defects

- The Beltronics Mscan is the first system in the world to combine: 100% metrology measurement, and defect inspection, into one system optimized for high volume inline factory production.

- The Mscan performs up to 10 billion metrology measurements while simultaneously inspecting the panel for defects.



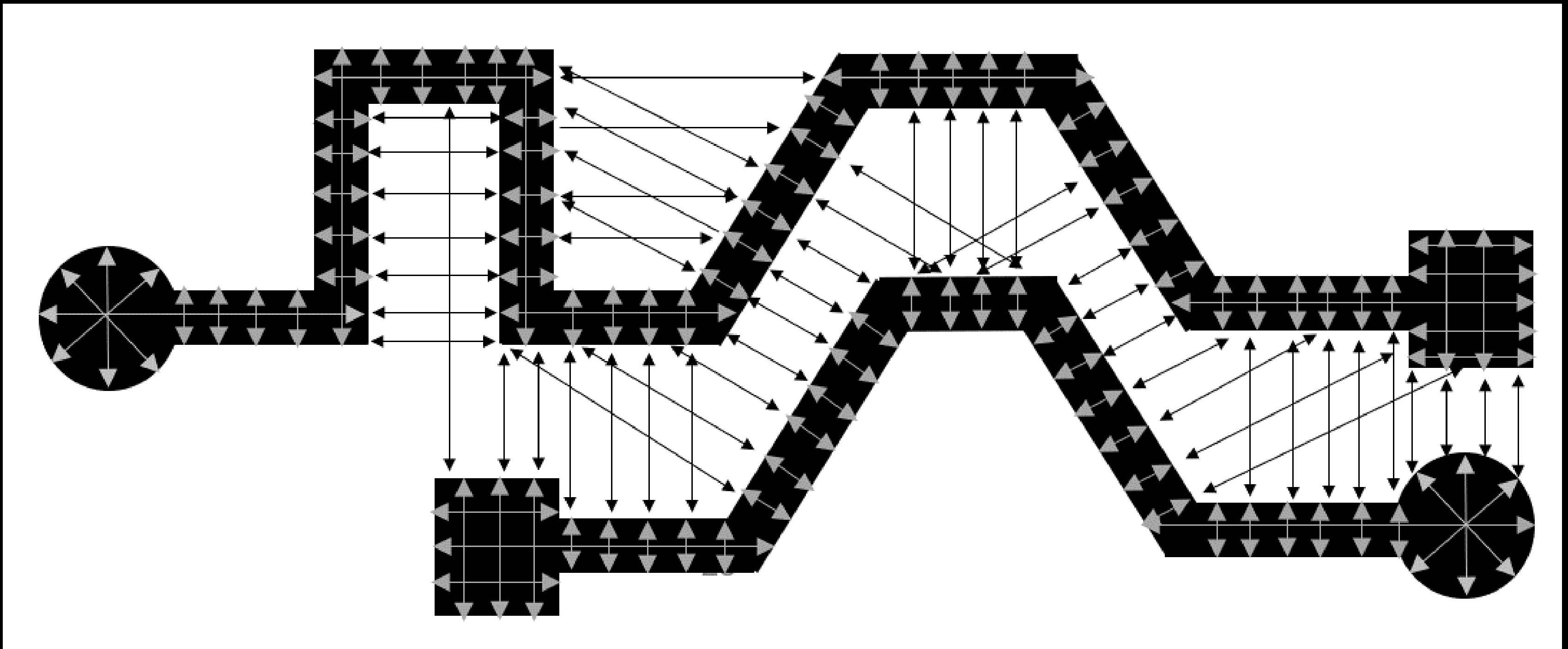
Beltronics High Volume Metrology- Inspection System

Measurements are Performed for Every Feature, at Every Location on the Panel, to Check for Correct Linewidth and Spacing, and To Detect Defects

minimum line/space, via 2 µm
measurement spacing: 1 pixel

smallest detectable line/space, via defect: 0.25 µm
measurement accuracy: 0.15 µm

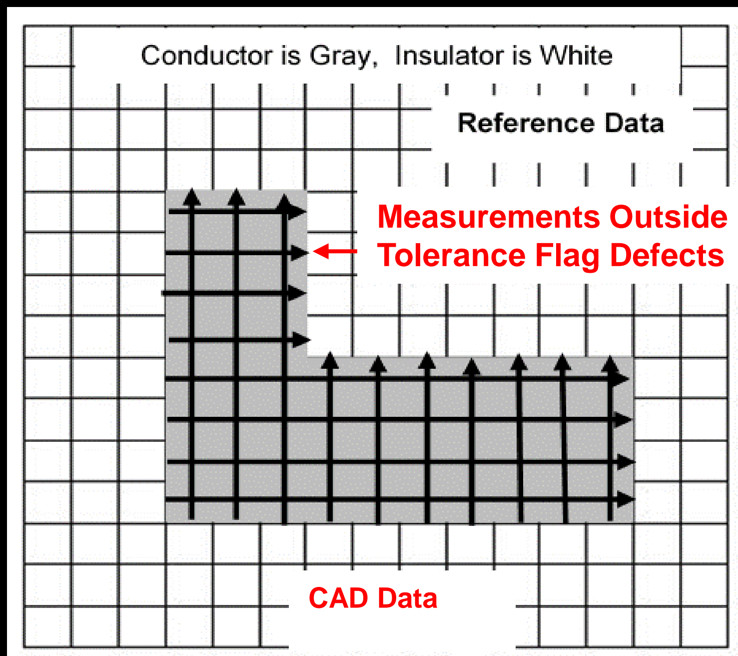
number of measurements: up to 10^{10}

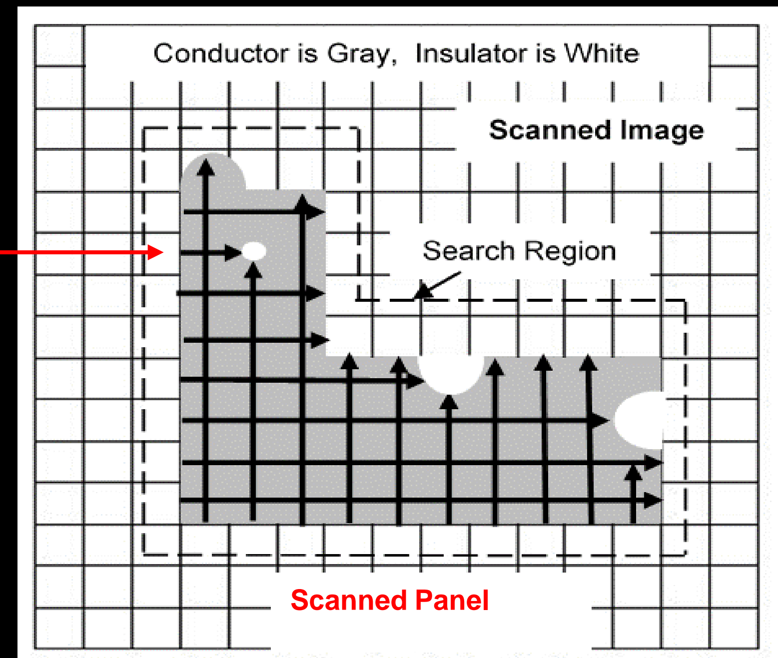


The Beltronics System Compares Measurements From The Part To Measurements From CAD Data

The Mscan:

- Searches For and Locates Each Feature In The Scanned Image.
- Measures Each Feature Along Its Perimeter at 1 Pixel Spacing.
- Compares Each Individual Measurement to a Corresponding Measurement Extracted from the CAD Data.
- Measurements Outside a Programmed Tolerance Are Classified As Defects
- Measurements Within Tolerance Are Used To Provide Linewidth and Space Statistics For Process Control

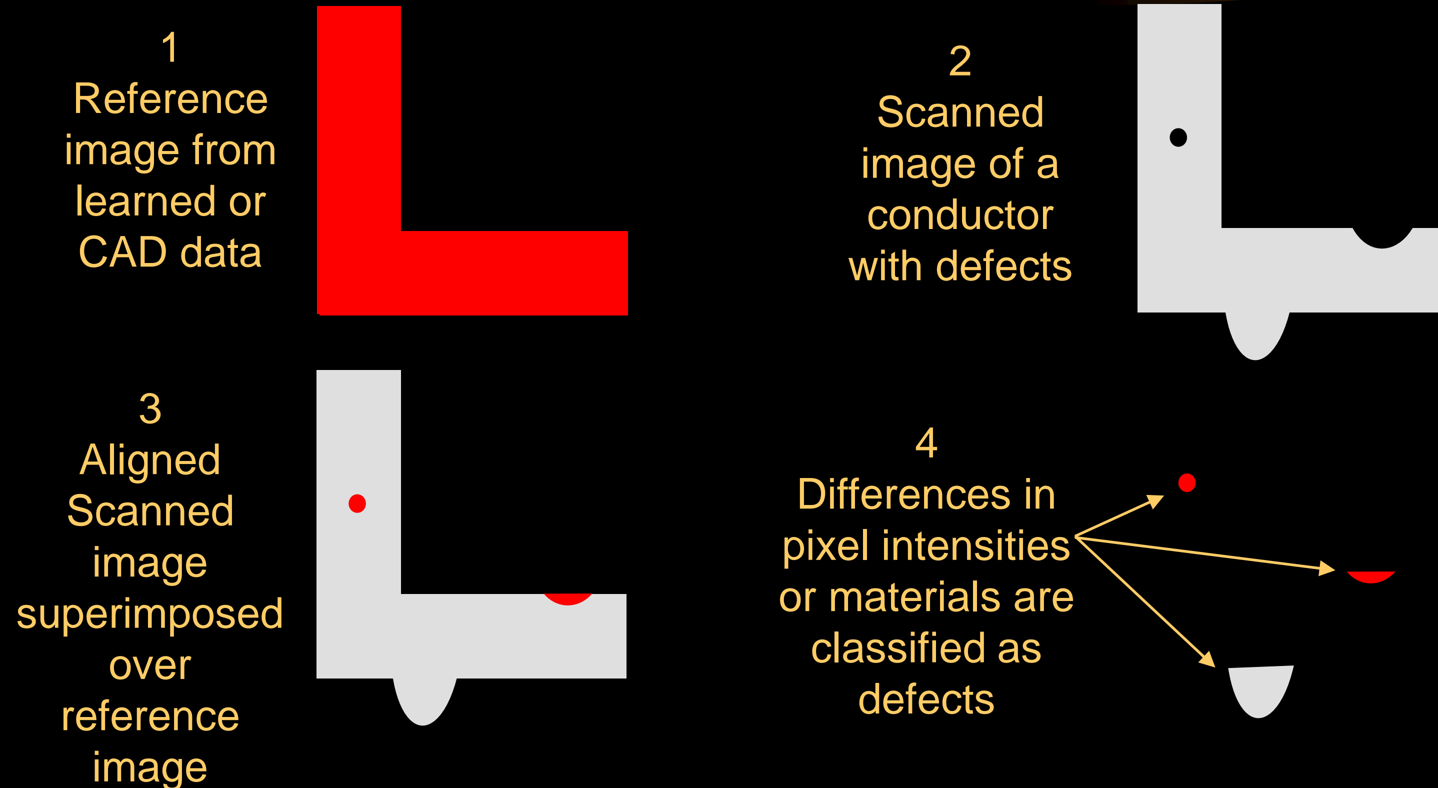




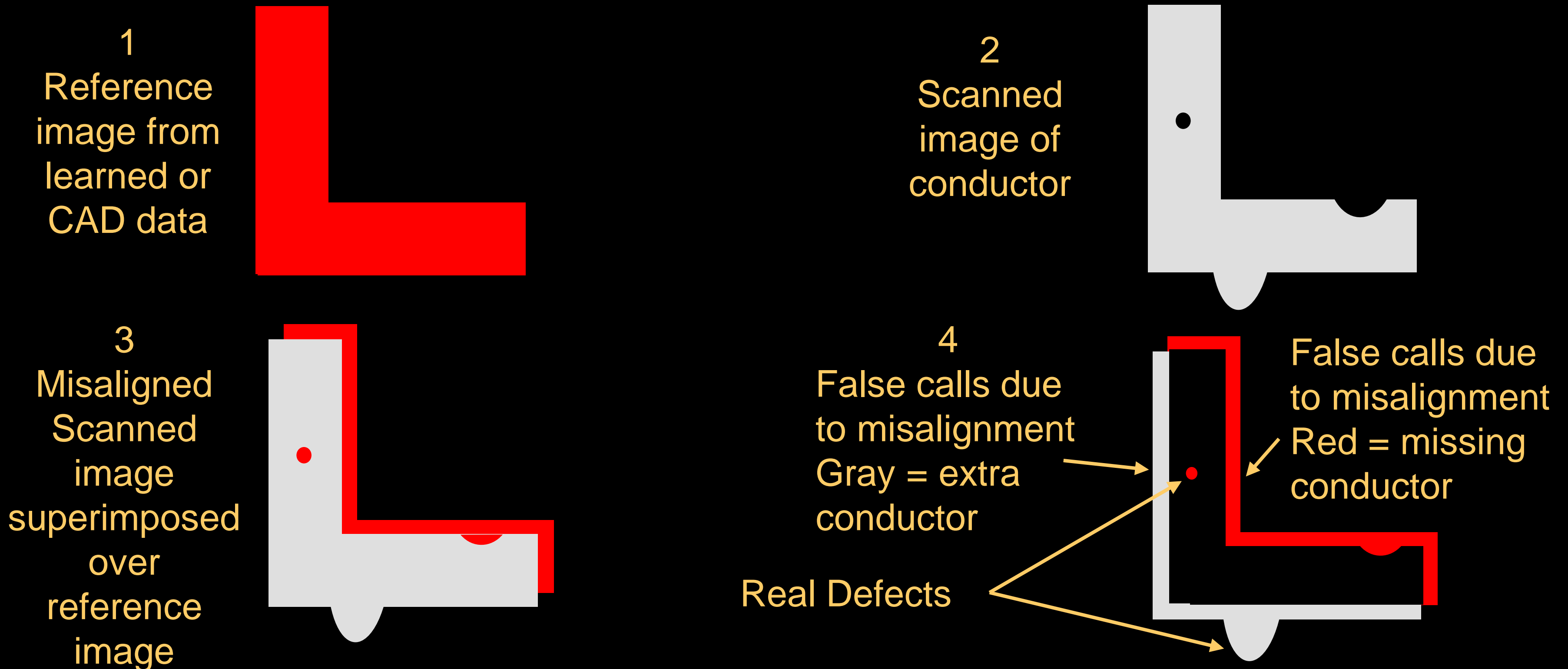
Search Region Is Proportional To Line Spacing

In Comparison:
Other Systems In The Industry Superimpose Scanned Images of A Part With Known Good Reference Images

Differences Are Classified As Defects

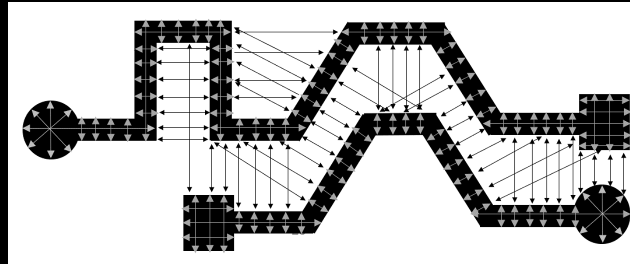


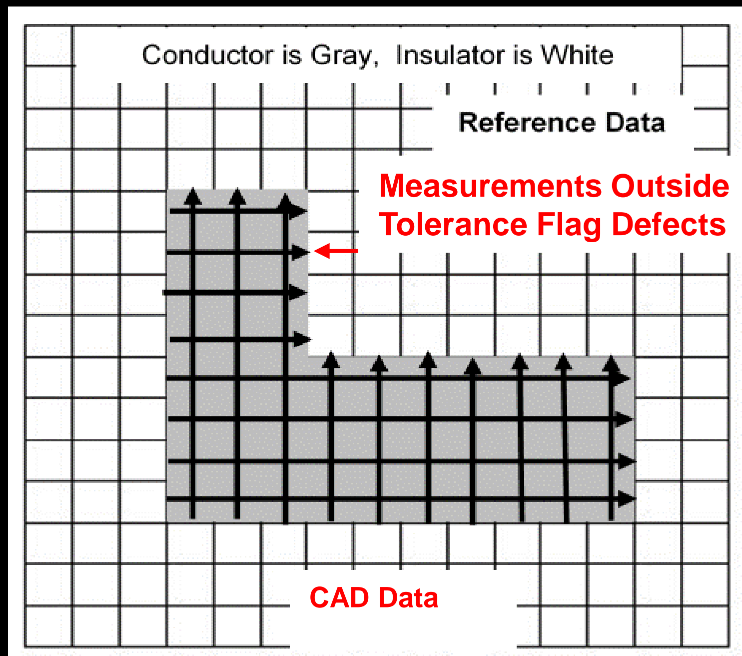
In Other Systems - Any Misalignment of Reference and Scanned Images, Due To Mechanical Limitations Of the Stage, Result In False Calls

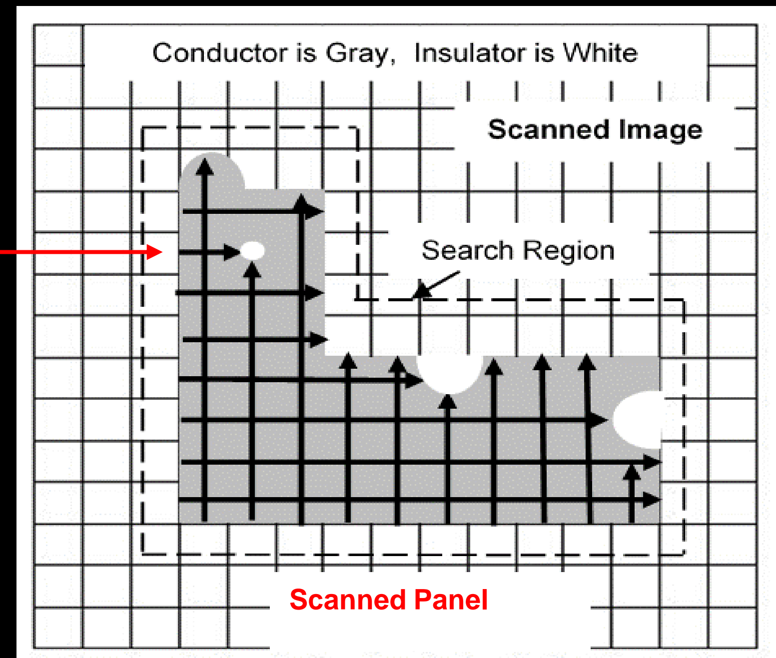


To Limit False Call Reporting The Errors Must Be Greater Than A Minimum Size

The Beltronics System Does Not Have This Limitation Because It Does Not Require Fine Alignment of The Scanned And Reference Image





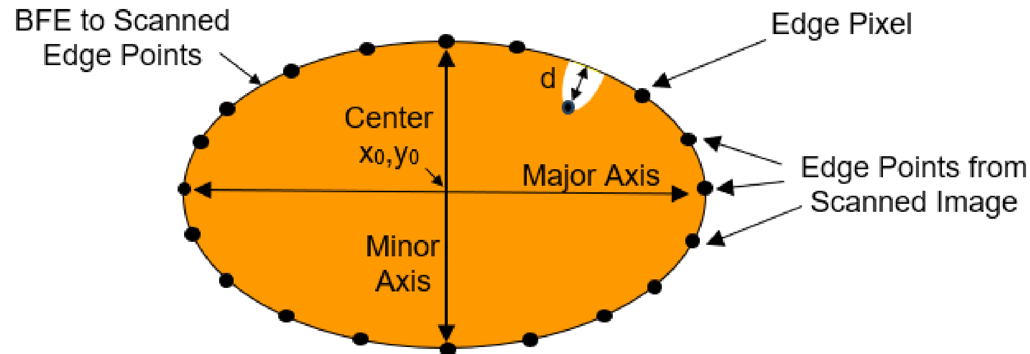


Search Region Is Proportional To Line Spacing

Every Via On The Panel Is Also Measured Relative To CAD Data

All Via's Are Measured To Sub Micron Accuracy

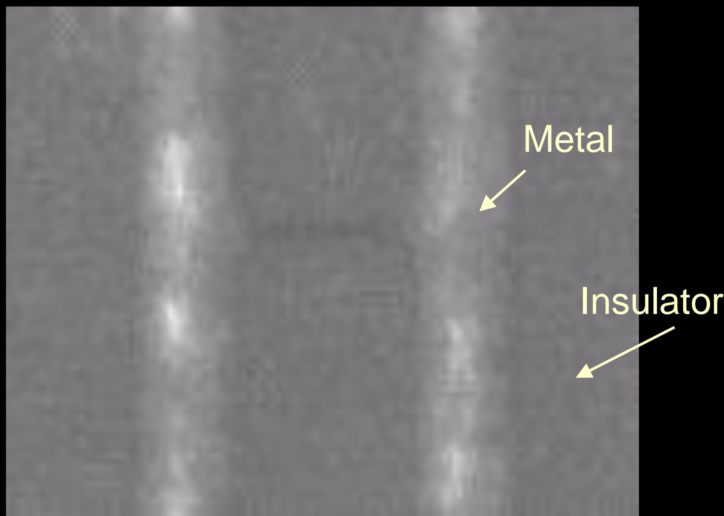
1. Locate all pixels along perimeter of every via on the panel.
2. Find Best Fit Ellipse (BFE) to Scanned Image Edge Points



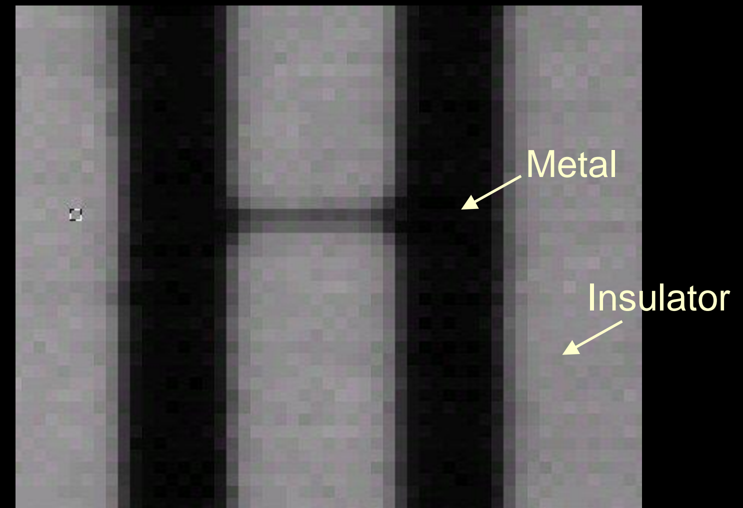
3. Compute Statistics
   a. Major Axis
   b. Minor Axis
   c. Area
   d. Centroid (Center)
   e. STD between Data Points and BFE
   f. How much each data point varies from BFE and if difference (d) exceeds programmed threshold then report as an error.

Comparing The Part To CAD Data

- CAD data provides the location of materials (metal and insulator) – it does not describe texture, color, or brightness
- To compare the scanned image to CAD data the image must be converted into materials (metal and insulator)
- The Mscan incorporates both white light and fluorescent illumination to identify material. Fluorescence is extremely useful to inspect organic substrates because it detects the <u>molecular signature of the material</u>. In fluorescence metal is black and the substrate is bright.



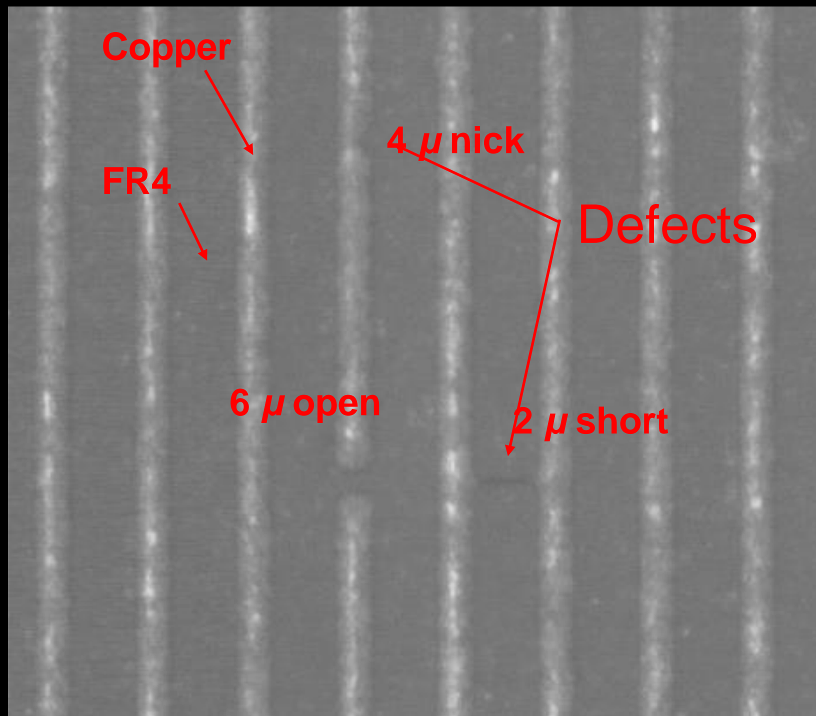
White Light Image of 2 μm short

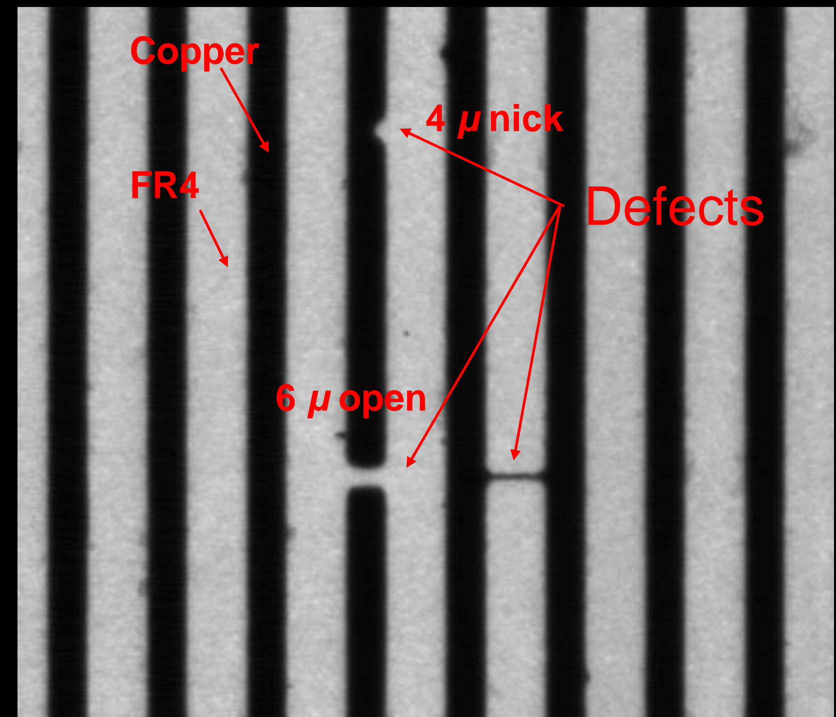


Fluorescent Image of 2 μm short

Fluorescence Detects The Molecular Signature Of The Material

In Fluorescence metal is black and the organic substate is bright



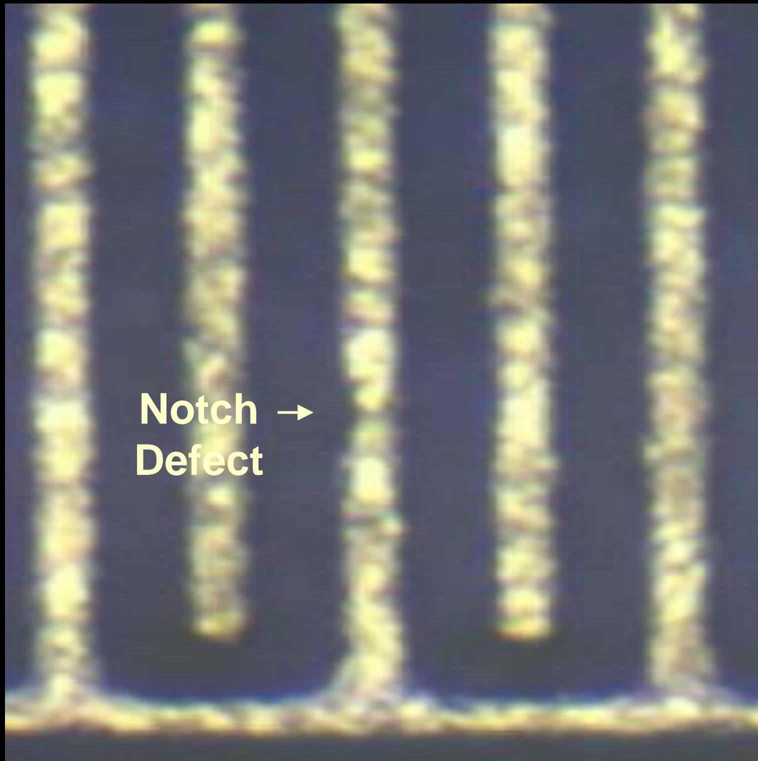


White Light Image — **0.7 Micron Pixel** — **Fluorescent Image**

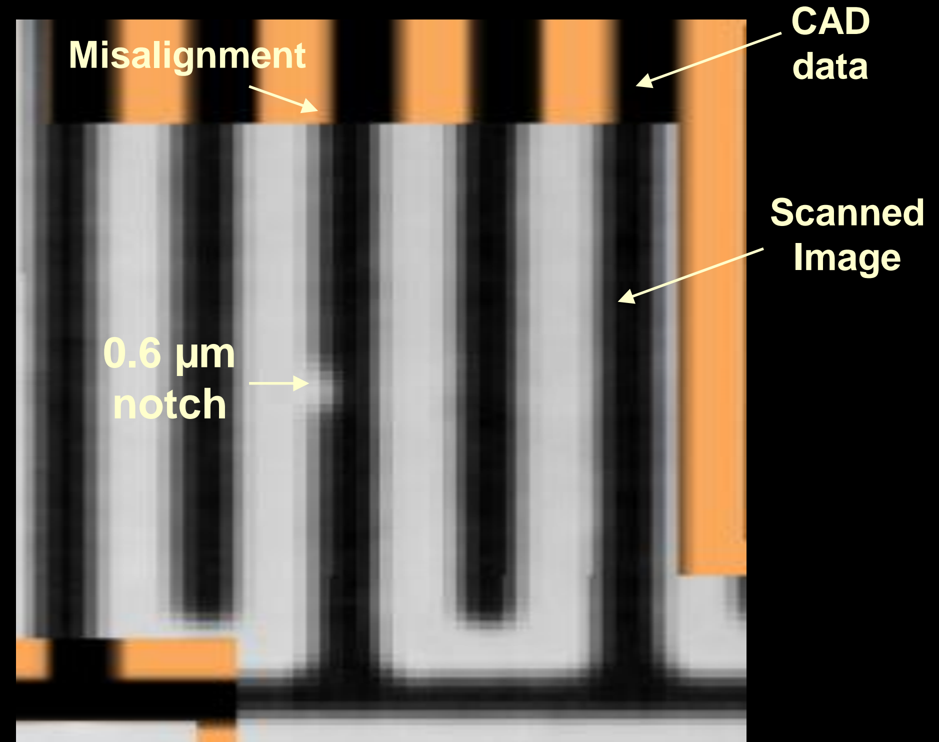
Copper on FR4 — **15 Micron Lines** — **Copper on FR4**

By Using Fluorescence To Identify the Material and Measurements To Find The Defects

Misalignment, In Addition To Grain And Texture, *Does Not Produce False Calls* or Limit Detection of Small Defects

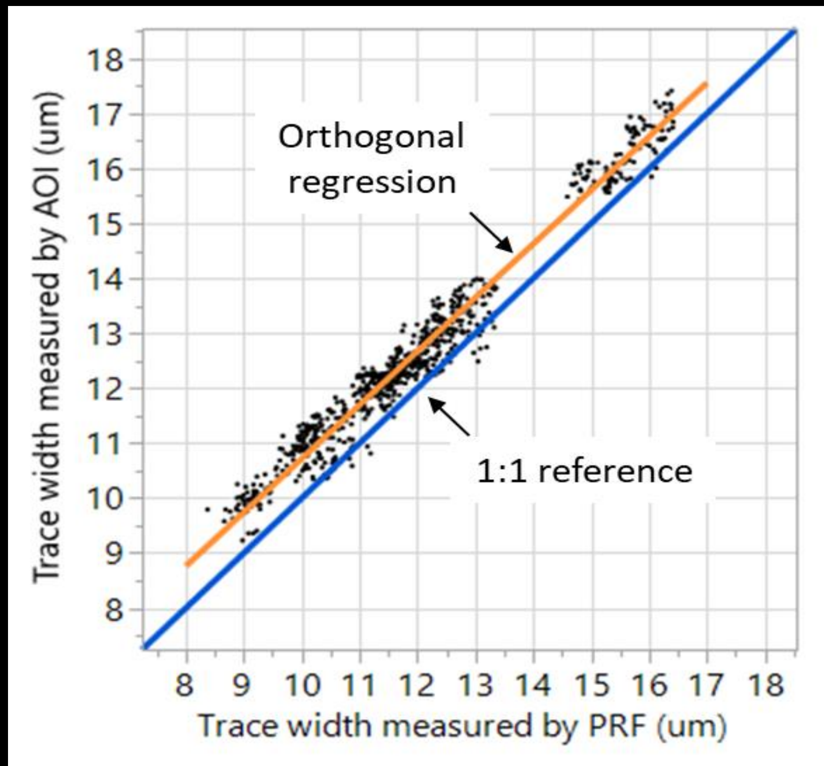


White light image of
3 μm traces with notch defect



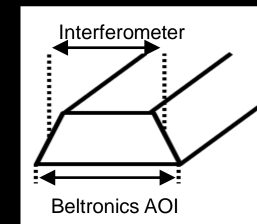
Scanned fluorescent image
superimposed over CAD data
metal is dark
substrate is bright

Customer Verifies 98% Measurement Accuracy on Production Panel



Correlation coefficient between Beltronics AOI and manually acquired 740 Interferometer measurements shown in graph is 0.98

- Customer uses interferometer to manually measure linewidth at 740 locations across organic panel
- Beltronics AOI scans entire panel (up to 10 billion measurements acquired)
- Measurements at identical 740 locations extracted from Beltronics data
- Correlation coefficient between Beltronics AOI and Interferometer measurements shown in graph is 0.98
- Beltronics AOI measures width at the bottom of the trace and Interferometer measures the midpoint, therefore there is a fixed 0.5 micron offset between these two measurements. See drawing below

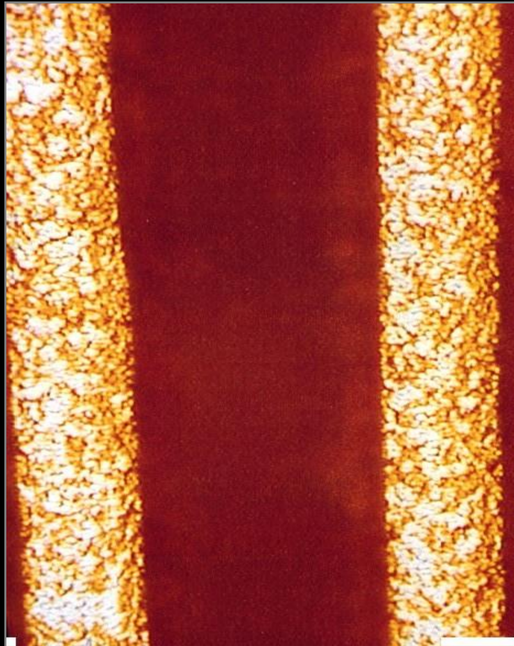


Beltronics Confidential and Proprietary

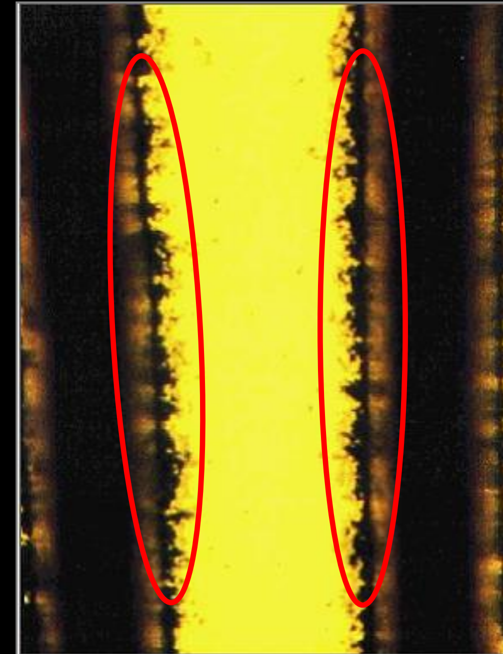
Beltronics Measurement Capability Enables Early Detection Of Process Drift

The Mscan can Detect the Etch Beginning to go Bad
Early Warning Enables Preventive Action to be Taken Before Defects are Produced

White Light Image



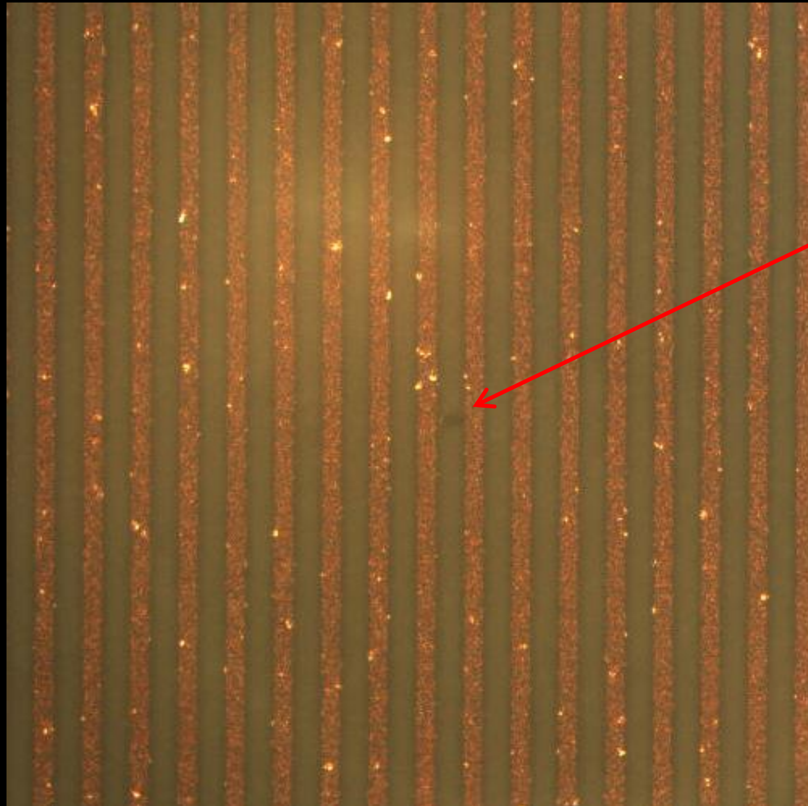
Fluorescent Image



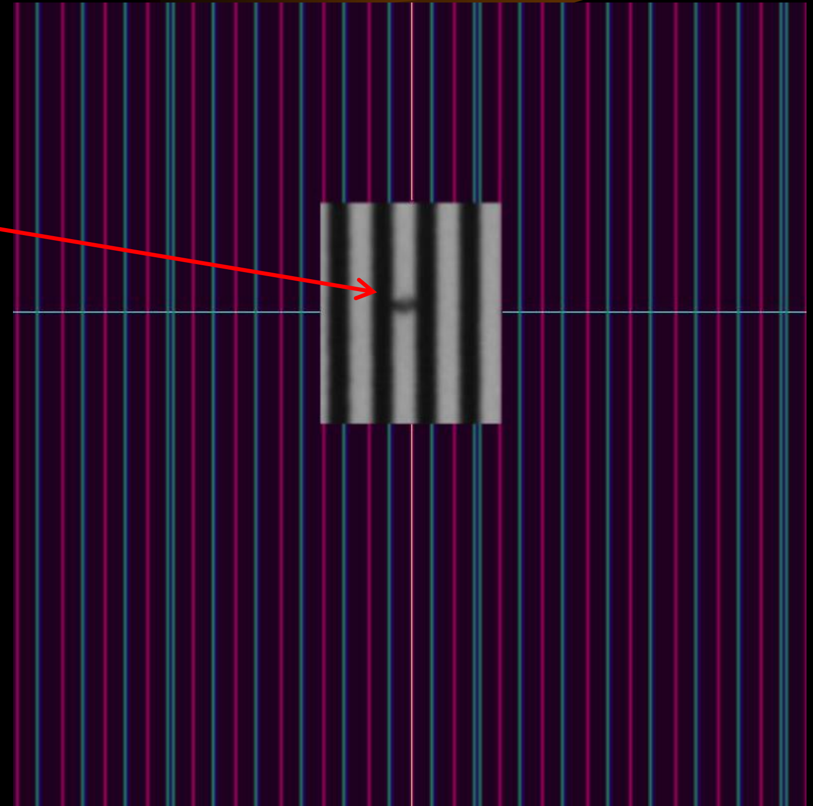
Its Not About Finding Defects – Which Costs Money
Its About Increasing Yield - Which Saves Money

Beltronics Mscan

E-less Copper Short
Missed By Competitors White Light Inspection System



E-less Copper Short

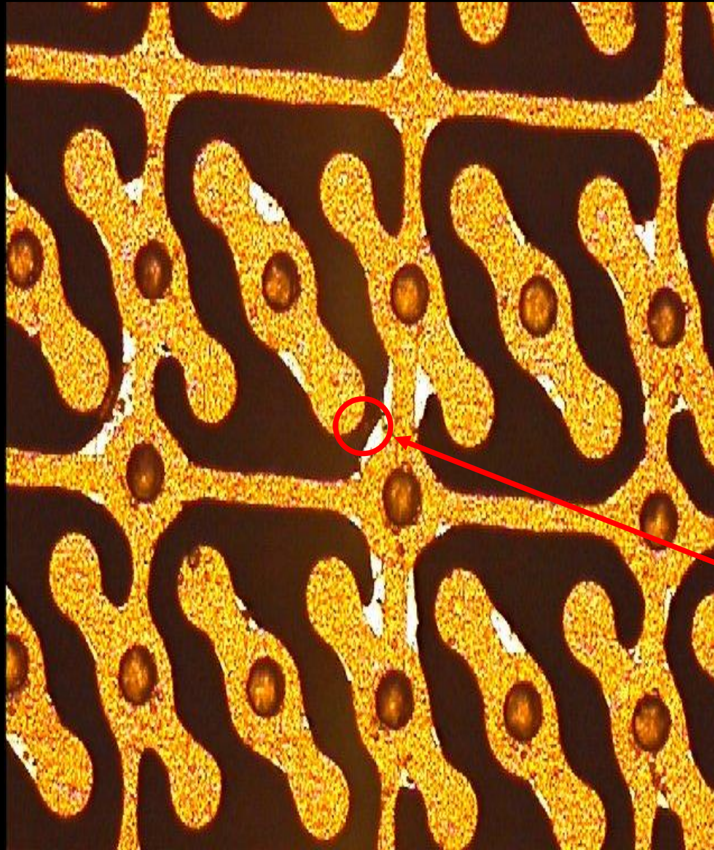


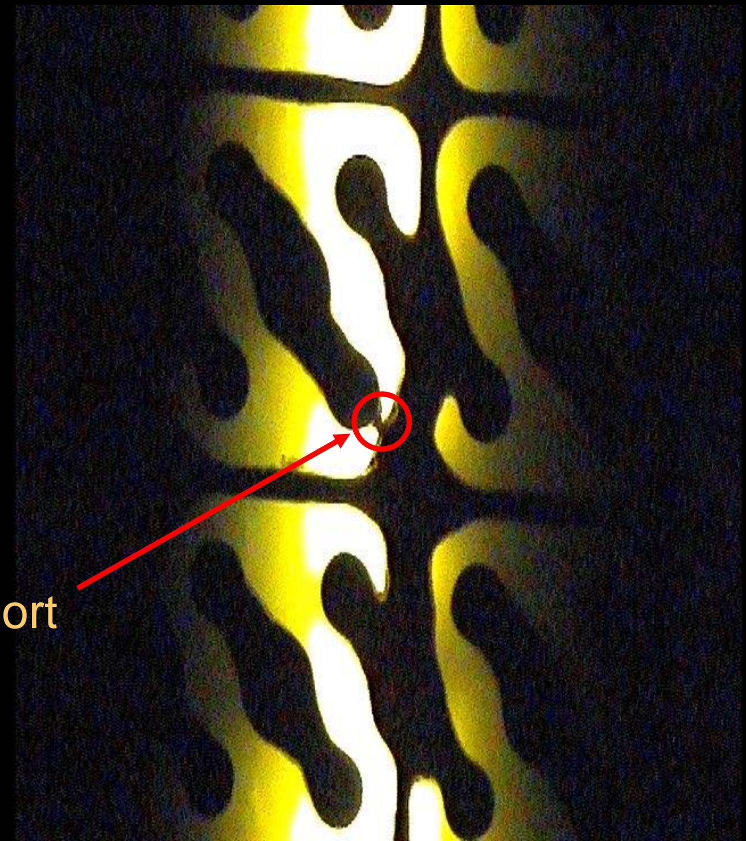
White Light Image of E-less Copper Short

Image of Short Captured by Beltronics Mscan

Mscan Detects Seed Layer Short

Grain and Texture Do Not Cause False Calls

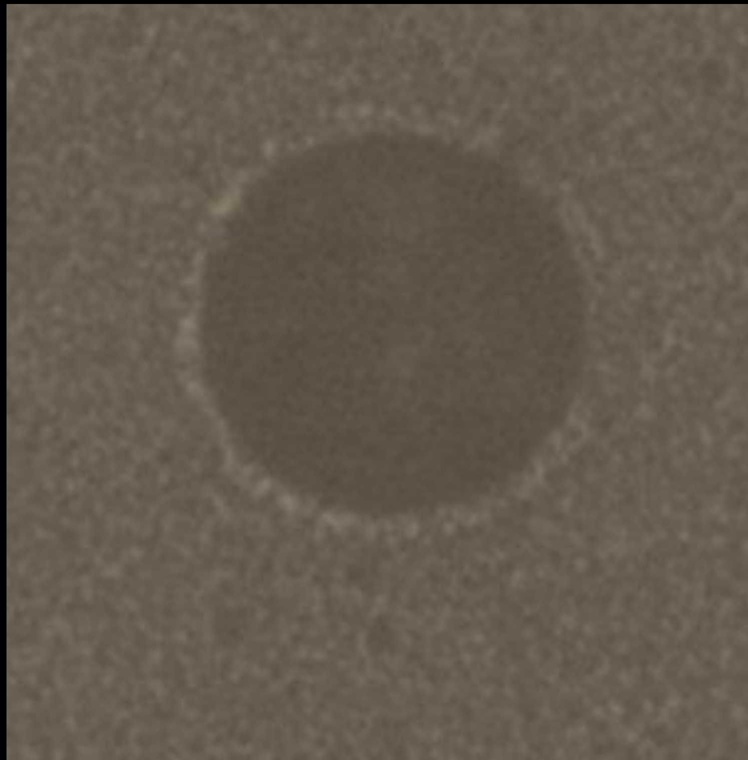




White Light Image With Grain and Texture
Defect difficult to detect
metal is bright, substrate is dark

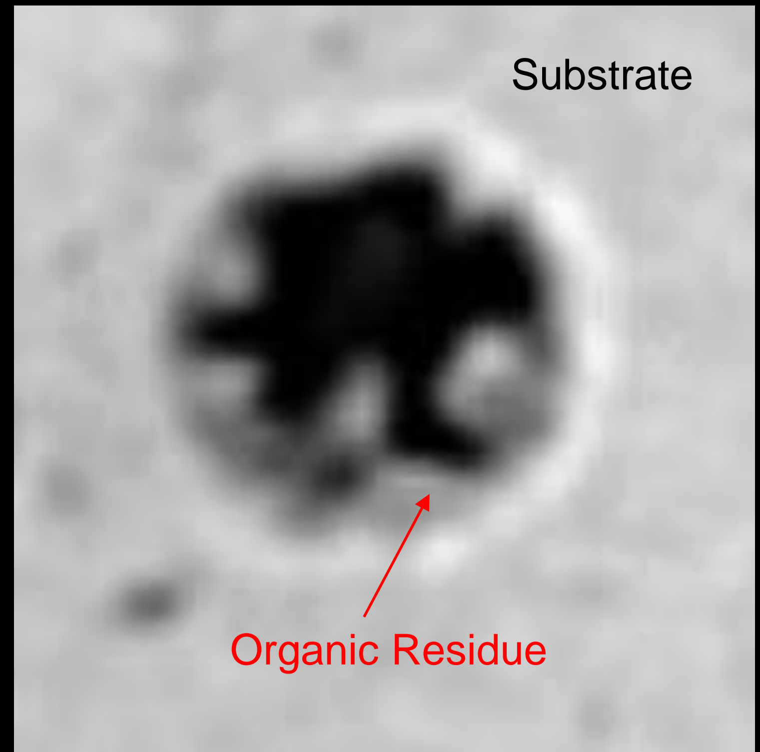
Fluorescent Image
Defect easy to detect
metal is dark, substrate is bright

The Mscan Can Find Defects at The Bottom of Vias



White Light Image

50-micron Via



Mscan Image Showing Organic Residue at Bottom of Via

Defect Review Screen Shows Position of Defect Relative To CAD Data

Import Defects

Help

Clear | View summary window

LotNr

Panel Sn

Front | Back

InspPass ID: 260

Display defect type: all

Ignore defect type: none

Display die Nr: all

Ignore dies in file: none

Exclude
- same type defects
- all defects

within .200 mm of

InspPassID or CompareFile

View unaligned dies

Get defects | Report

Selected defects: 4453 total

Total	Type
3782	Missing Metal PM
56	Missing Edge Insulator
202	Extra Metal PM
20	Thin Insulator
58	Missing Edge Conductor
17	Wide Conductor
310	Wide Insulator
8	Thin Conductor

Current defect

Grayscale

Reference

Field	Value
Type	Missing Metal PM
DieNr col-row	12 (5, 1)
Die posX mm	15.828
Die posY mm	-7.920
Pnl posX mm	213.578
Pnl posY mm	-129.920
Size	L=0.000, W=0.000, A=1
Clus-ter	
InspPass DefectId	1397726

View DefectNr: 1140 | View

ClusterNr | View

< View previous | View next >

View on Map

^

< | Out | In | >

Out 100% | v | ShowRef

Cursor information:

PnlX	PnlY	X	Y	hR	hG	hB	Avg	StatVal
213.370	-129.693	037	001	CC	00	66	102	-04.159

Review camera

View with camera | Exposure | 152060 us

Rotation: 7-Rotate270FlipX | Capture image | Other settings

Illumination

Laser	0	0-255
Upper	10	0-255
Lower	0	0-255

Upper filter: 0

Lower filter: 0

Objective Nr: 1

Beamsplitter: 0

Update

Show Statistics Panel | Defect Transparency: 50 | Metal RGB | Substrate RGB

Enable Defect Transparency

Organic Residue Via Defect Superimposed Over CAD Data

Beltronics Confidential and Proprietary

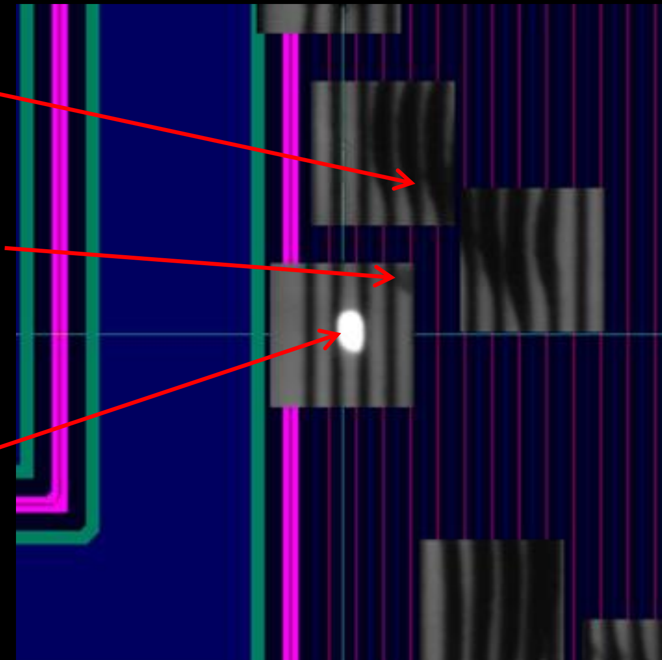
Detection of Resist Residue and E-less Copper

White Light Image 9 μm lines

Defective Traces

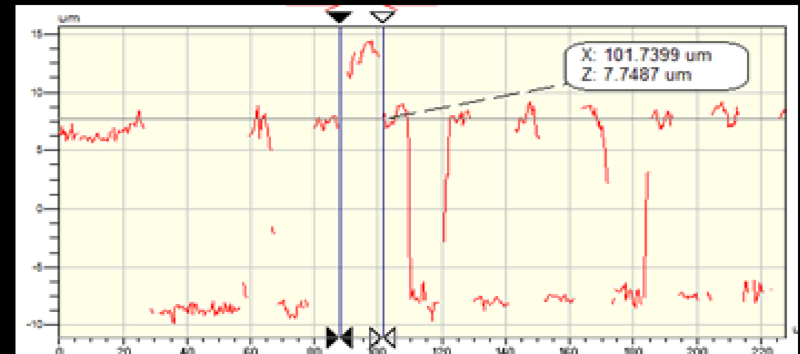
Dark E-less Copper

Resist Residue



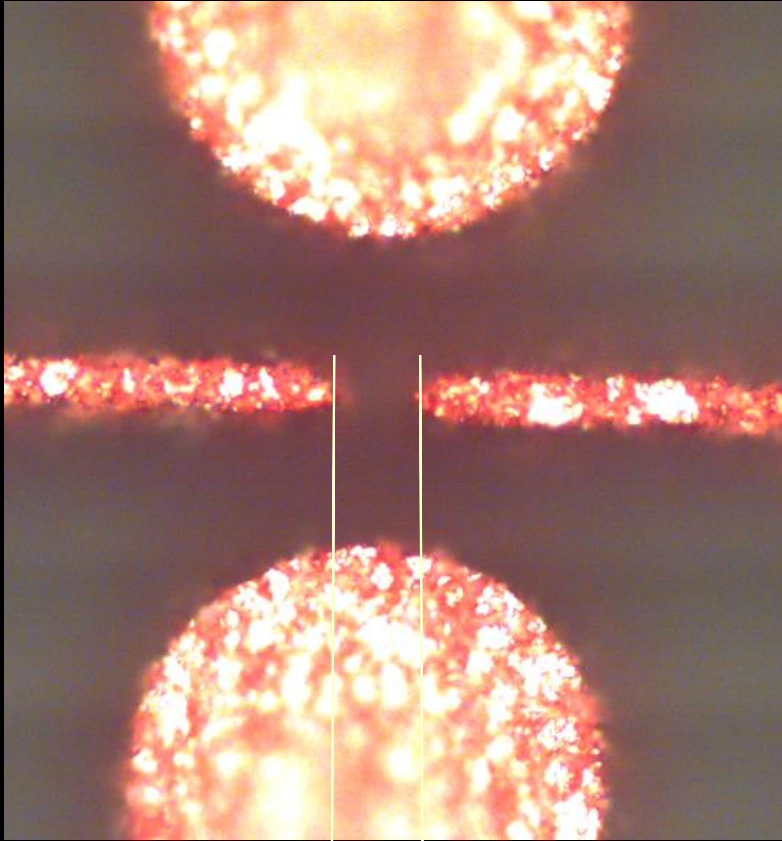
Fluorescent Image

Fluorescent imaging detects resist residue which is not visible in white light and E-less copper which can appear very dark in white light

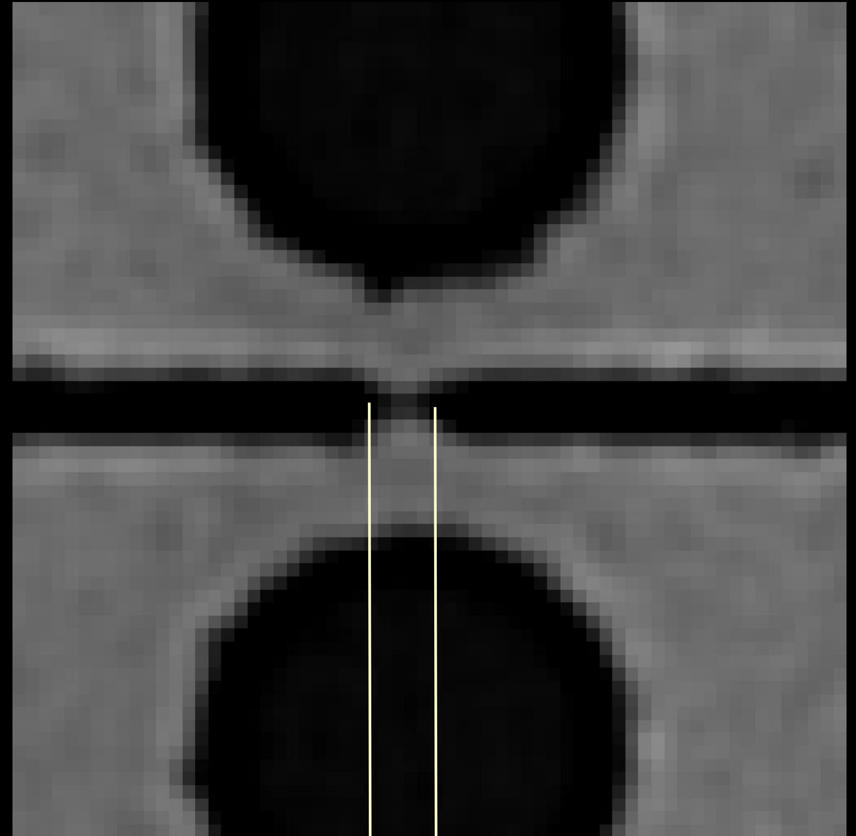


3D Independent Measurement By Customer Confirms Presence of Resist Residue

The Mscan System Looks through the Entire Depth of the Trace to Detect And Measure Defects Not Visible By Competitors

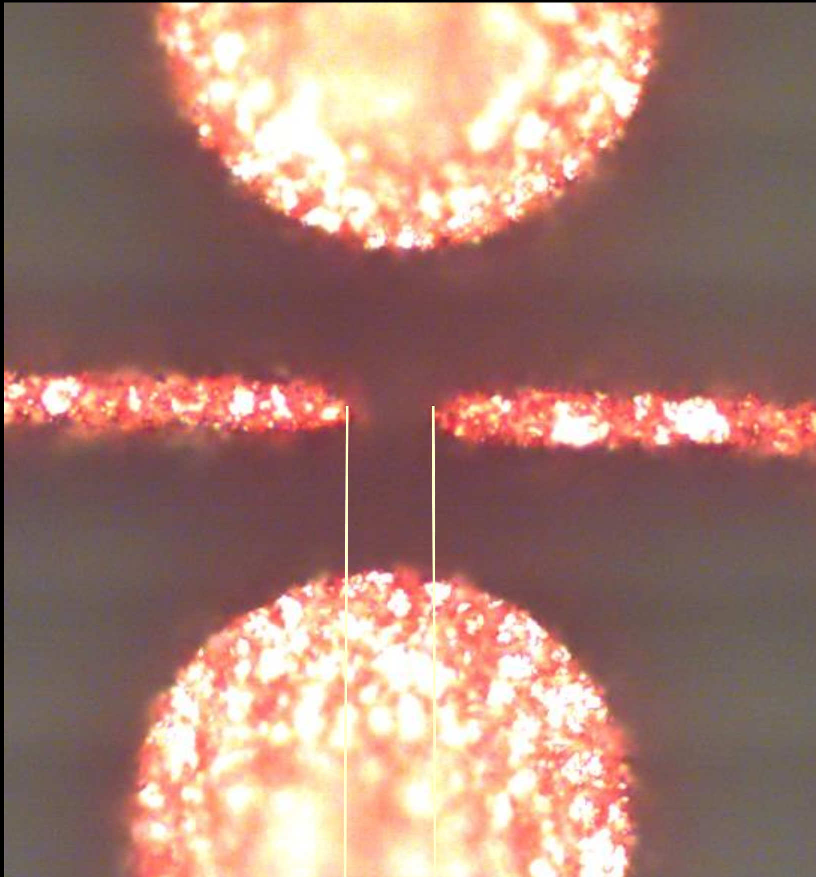


White Light Image
Focused on top of Metal Layer
Does Not Show Short

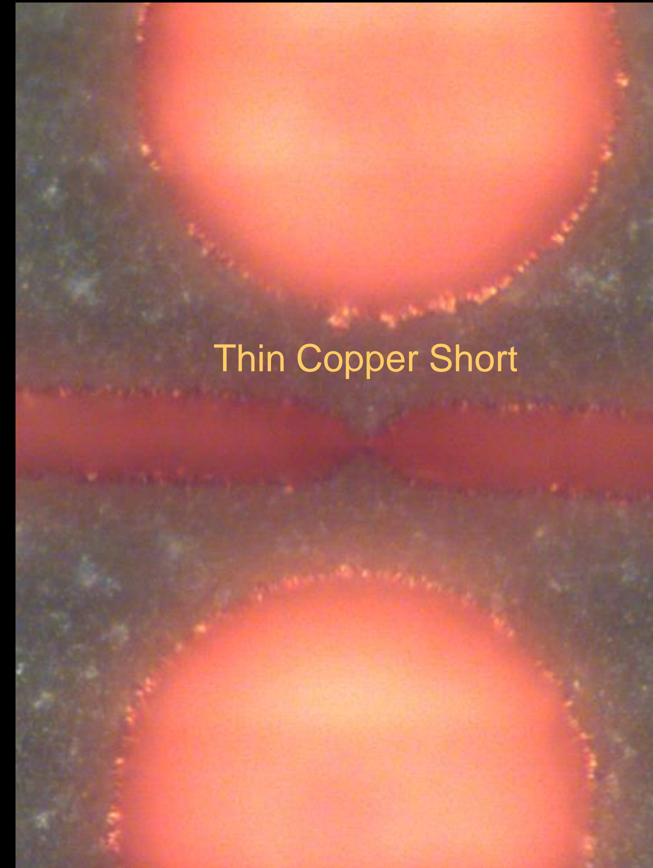


Mscan Looks Through Entire Trace
To Detect 2 Micron Short
Across 6 micron Gap

Thin 2 Micron Wide Short Detected By Mscan



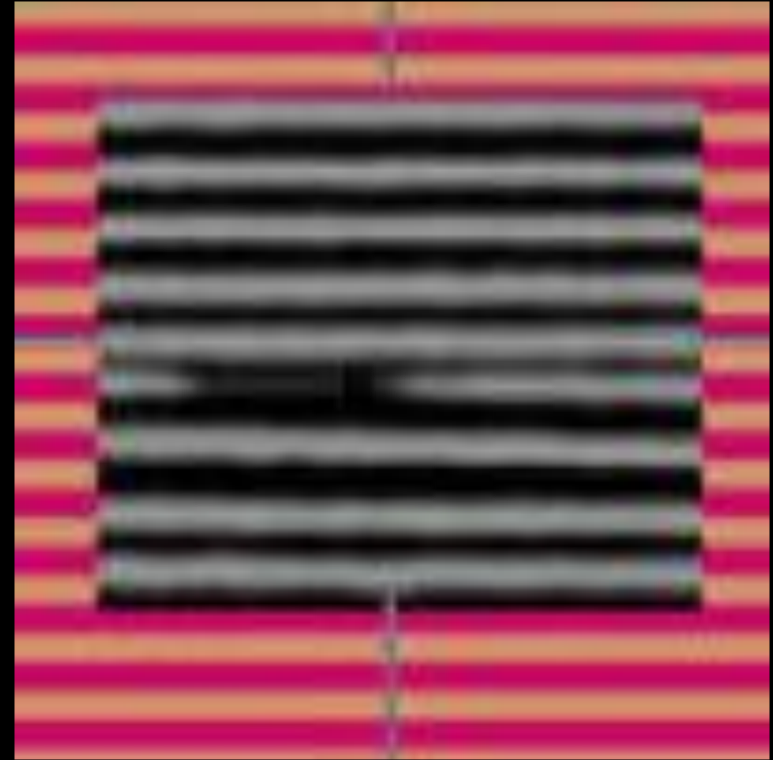
White Light Image
Focused on top of Metal Layer
Does Not Show Short



White Light Image
Focused on Substrate Shows
2 Micron Short Across 6 micron Gap

Customer Uses Metrology Based Technology To Expedite Bringing Up A New Production Line ….. Parts Can Only Be Compared To CAD Data

2 Micron Lines / Spaces
White Light Image

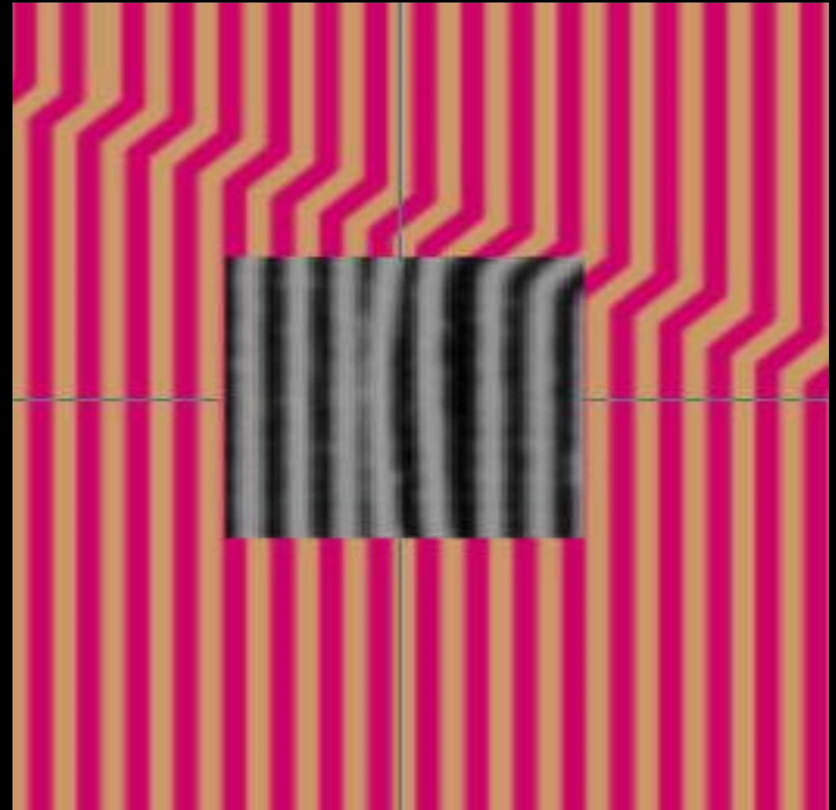


Scanned Image Superimposed
Over CAD Data

System Finds Thin Line, Wide Line and Short Defects While Allowing For Small Amounts Of Misalignment Which Is Not A Defect Because Layer Interconnect's Are Made Through Larger Diameter Vias

Thin and Wide Line Defects

2 Micron Lines / Spaces
White Light Image



Scanned Image Superimposed
Over CAD Data

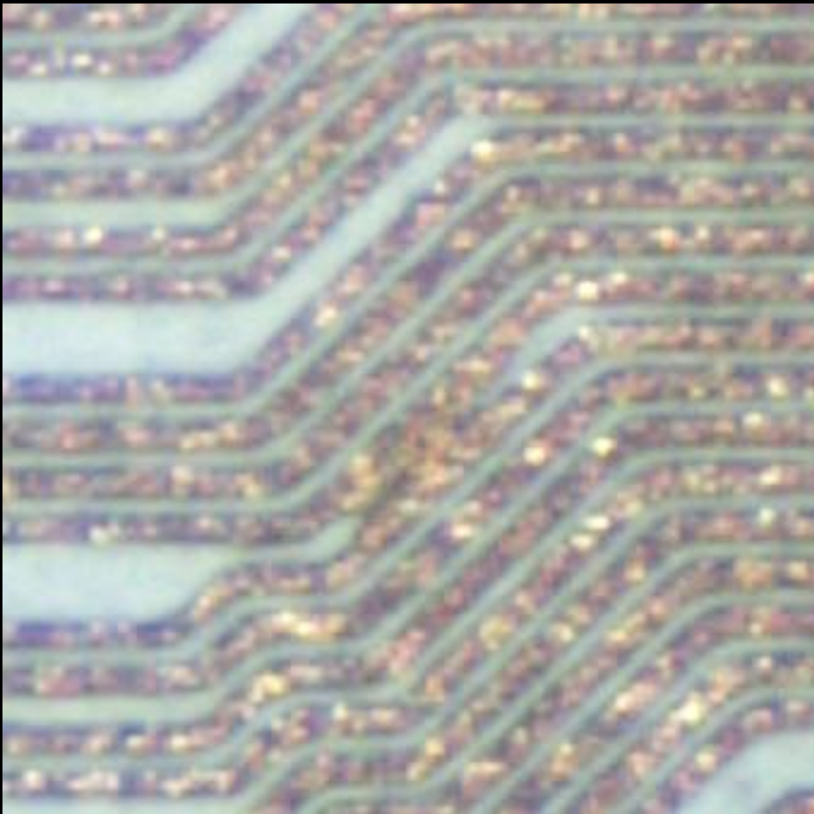
A 1 Micron Change In Linewidth Is A Defect While 1 Of Misalignment Is Not

As Reference A Human Blood Cell Is Only 6 to 8 Microns In Diameter

Alignment Can Very Rapidly Over Only a few Millimeters

In This Area Of The Same Die The Part Is Well Aligned To CAD Data

Wide Line Defects

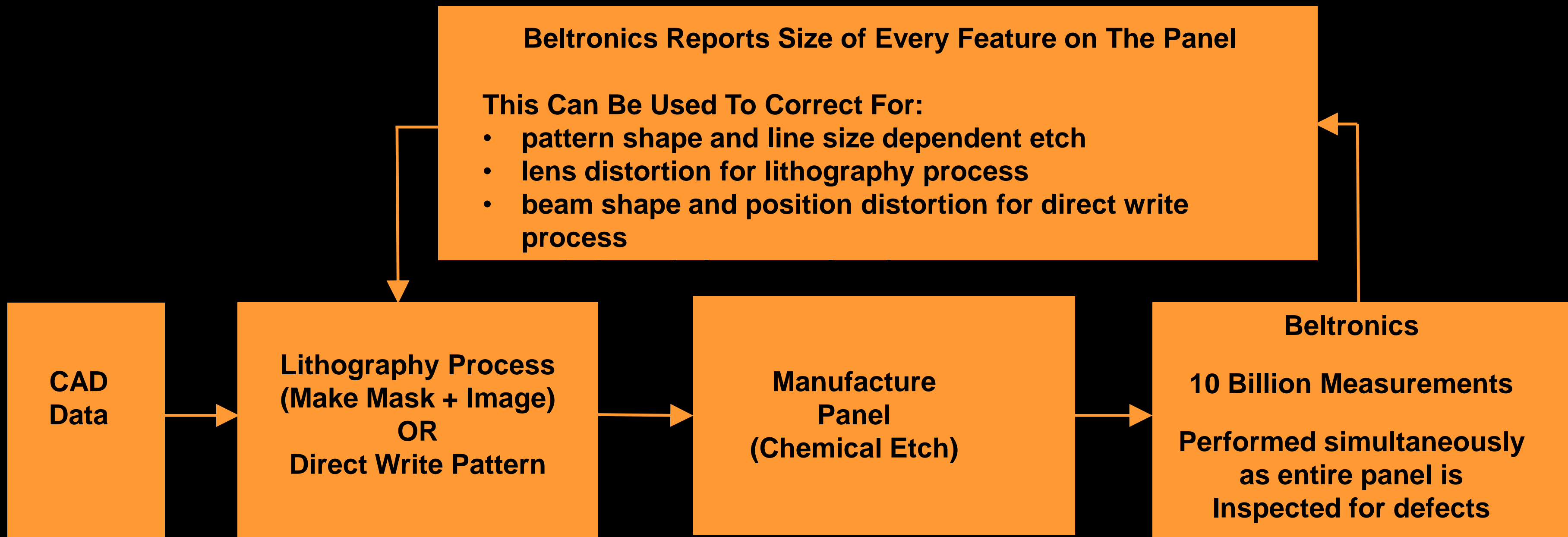


2 Micron Lines / Spaces
White Light Image

Scanned Image Superimposed
Over CAD Data

In Addition To Finding Defects The Beltronics System Can Be Used As A Process Monitor To:

- *Provide Feedback For The Lithography or Direct Write System*
- *Monitor Etch Quality and Degradation Over Time For Mature Processes*



Every Die on a Panel is Divided into Subsections Measurements are Used to Compute Statistics

Subsection 1

Width & Angle	Count	Value
M 2.500 µm +90°	1×10^6	+0.055
M 11.999 µm +90°	3×10^4	-1.244
M 2.500 µm +45°	3×10^4	+0.005

Subsection 2

Width & Angle	Count	Value
M 2.500 µm +90°	2×10^6	+0.066
M 11.999 µm +90°	4×10^4	-1.250
M 2.500 µm +45°	2×10^4	+0.005

Measurement Statics are Superimposed over CAD Image for Each Die Subsection

Width & Angle:
- Indicates width and angle of lines measured

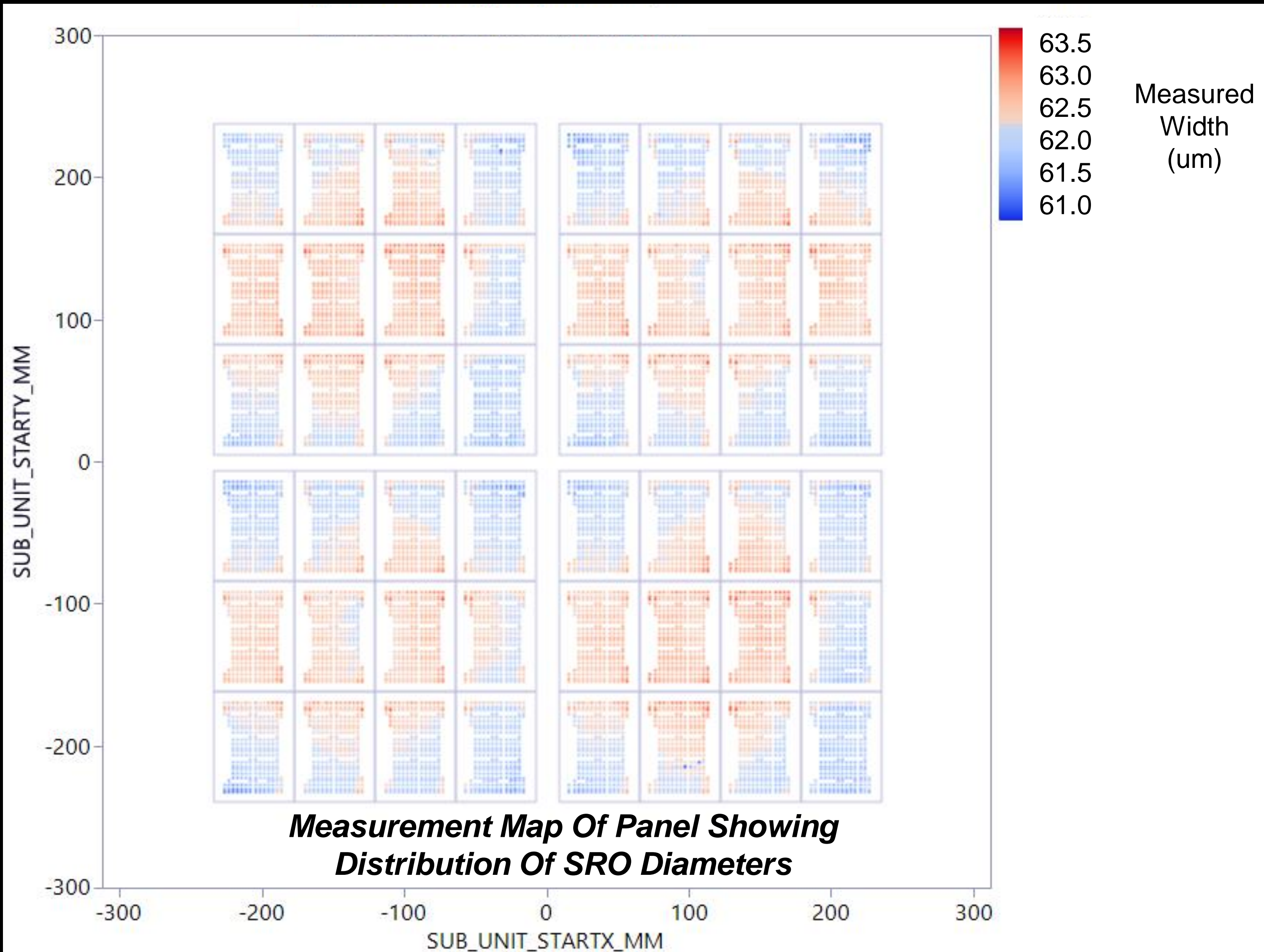
Count:
- Number of measurements

Value:
- Difference in microns between measured linewidth and CAD data

This Information Can Be Used to Correct For Lithography and Process Distortions

Beltronics Confidential and Proprietary

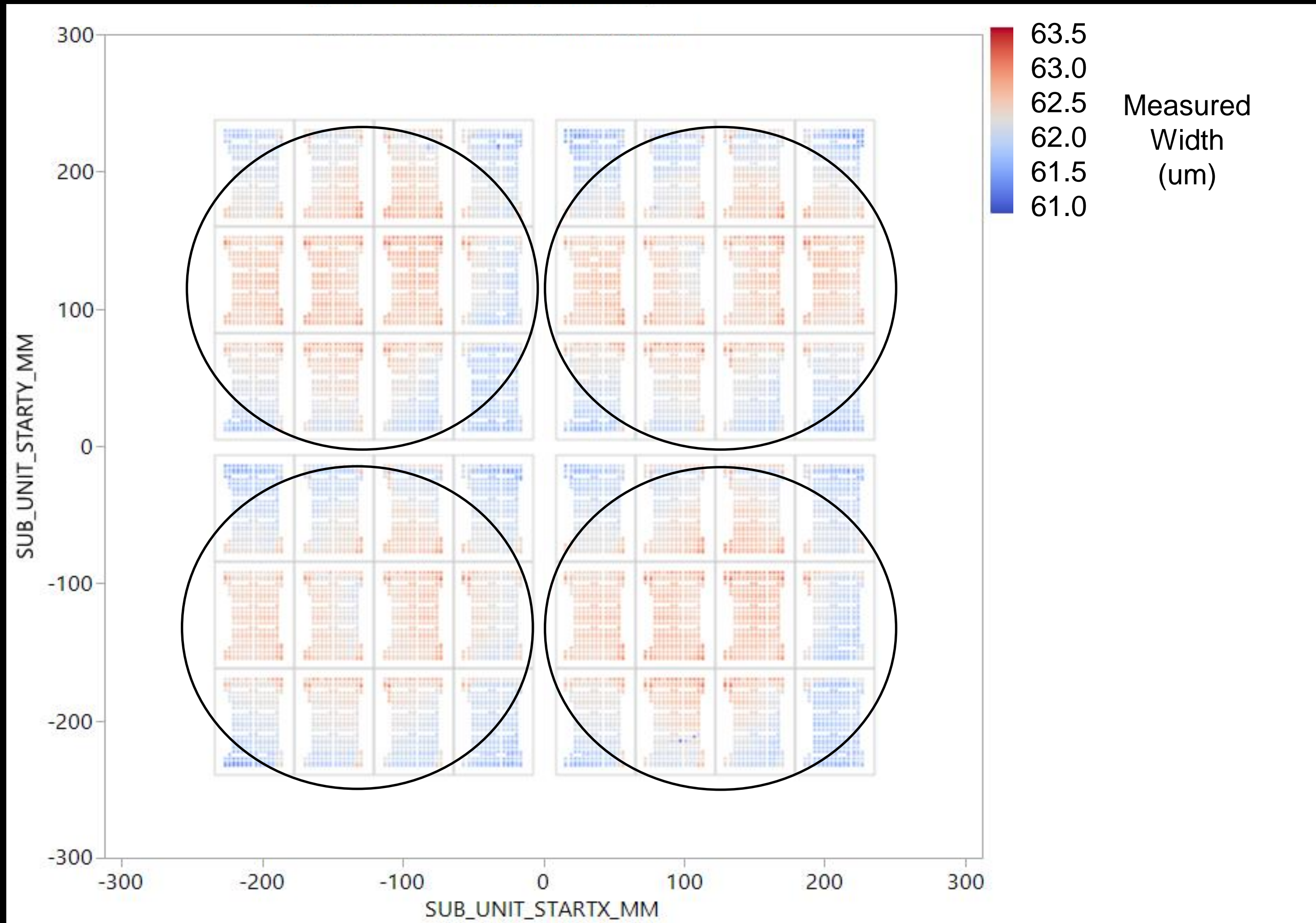
Example Of Mscan Monitoring Every Solder Resist Opening (SRO) On a 500mm x 500mm Panel



Measurement Map Of Panel Showing Distribution Of SRO Diameters

Analysis Shows Non-Linearities In Imaging Optics

This Is Used To Correct Errors In The Lithography Process
Essential To Bringing Up a New Production Line



System Throughput

System Throughput Should Be Calculated As The Sum Of inspection Time + Defect Verification Time.

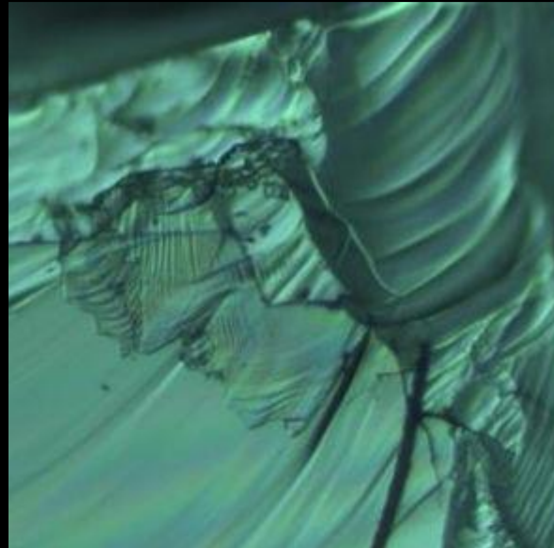
Elimination of False Calls Significantly Reduces Verification Time, Thereby Greatly Increasing Real Factory Throughput

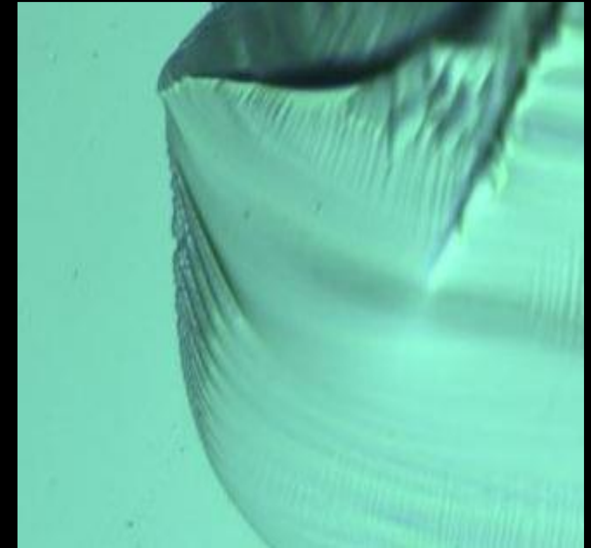
Time Required To Inspect Panel And Perform Up To 10 Billion Line/Space And Via Measurements As A Function Of Minimum Line Size, Pixel Size And Lens Numerical Aperture

Pixel Size µm	Numerical Aperture	Measurement Accuracy µm	Suggested Minimum Line width µm	Inspection Time for a 500mm x 510mm Inspection Area
1.75	0.1	+/- 0.26 µm	5.25 µm	2 min 53 sec
0.875	0.13	+/- 0.15 µm	4 µm	5 min 14 sec
0.875	0.2	+/- 0.15 µm	3 µm	5 min 14 sec
0.7	0.3	+/- 0.10 µm	2 µm	13 min 48 sec
0.35	0.3	+/- 0.05 µm	1.7 µm	20 min 22 sec

Beltronics Confidential and Proprietary

In Addition to Measurement Based Inspection The System Also Incorporates Intelligent Based Processing To Detect Chips On The Edge Regions Of Glass Panels



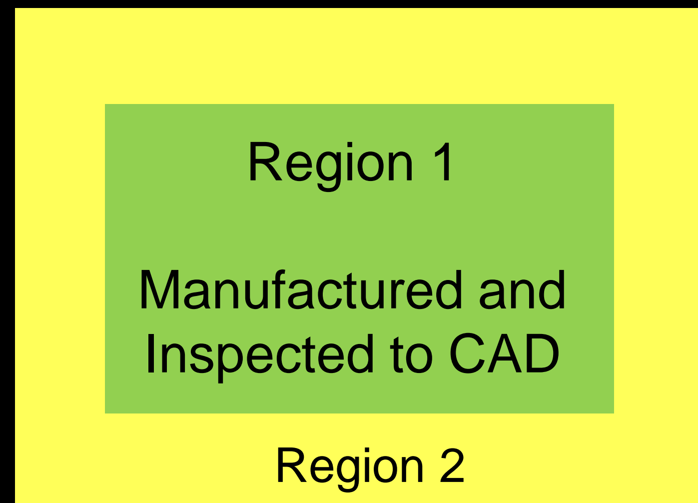


Examples of Glass Chips Detected Along The Edges Of A Glass

Regions Inspected On A Glass Panel

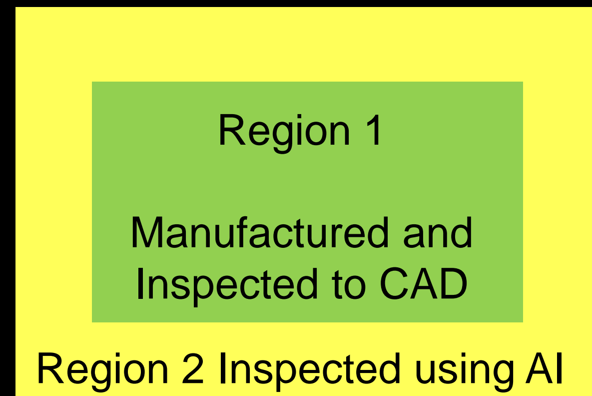
Panels contain 2 regions:

- **Region 1:** is manufactured and inspected using Measurement based CAD data.
- **Region 2:** is located outside the CAD region , contains no patterns, includes the edges of the panel and historically has not been inspected for defects



AI Based Edge Inspection Capability

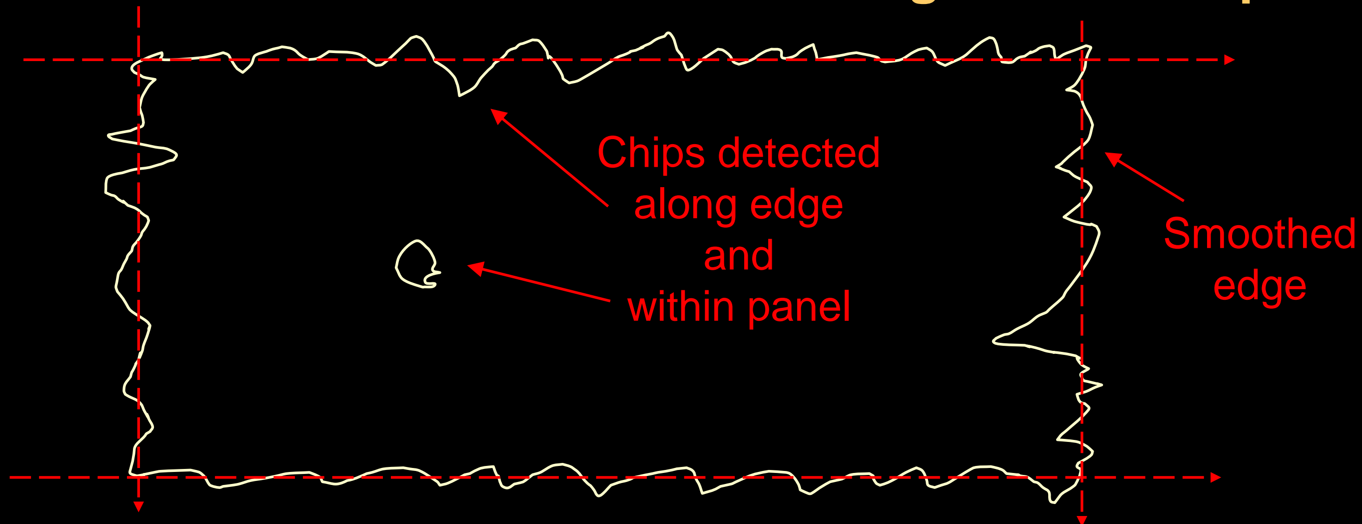
- There is no CAD data available for the edge region (Region 2)
- Therefore, the only option was to develop an algorithm that could intelligently scan and locate the entire perimeter of the panel and then inspect this region for defects, including glass chips



New Intelligent Based Glass Edge Processing

- **Over scans panel <u>searching for</u> edge of glass along entire perimeter.**
- **Locates and records edge coordinates with a programmable perimeter sampling density (typically 0.1 to 1mm spacing)**

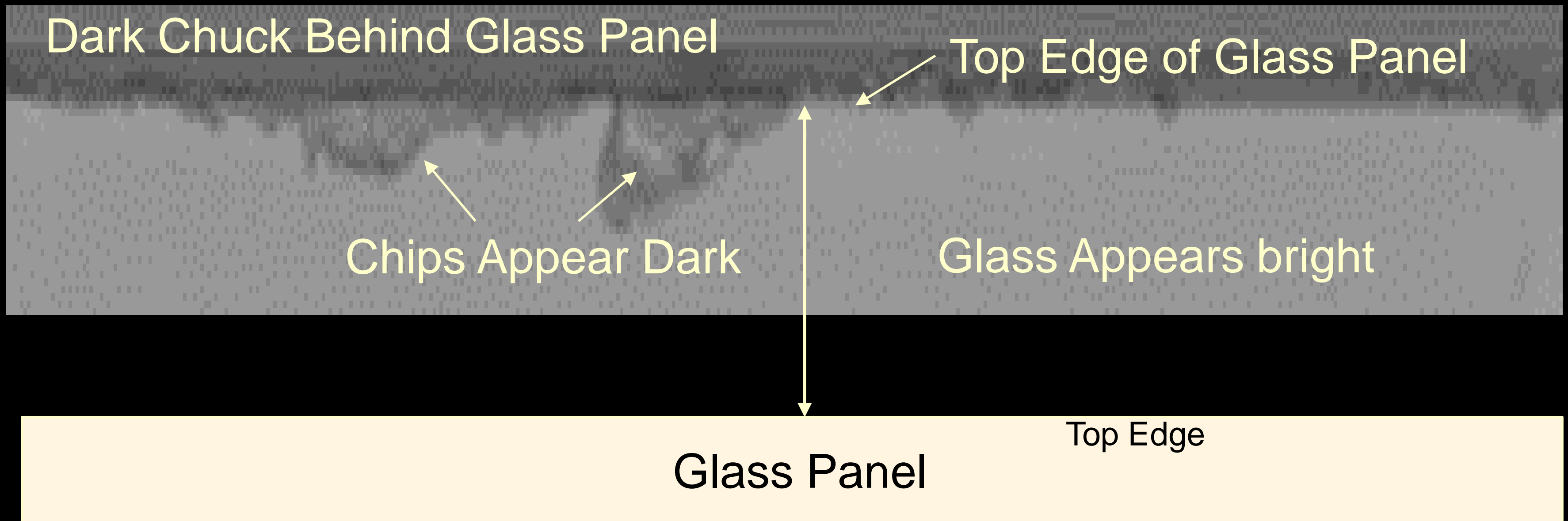
- **Filters out variations from a smooth edge to find chips**



- **Detects glass chips as small as 10 microns:**
  - **along perimeter edge**
  - **and within region defined by perimeter boundary**

Beltronics Confidential and Proprietary

Example of Glass Chips Along Edge of Panel Imaged Using Top Coaxial Illumination



Chips As Small As 10 Microns Were Imaged

Beltronics Technology Is Patented Internationally

We Believe Our Technology Will Replace Pattern Matching Technologies – The Old Way Of Finding Defects

(12) **United States Patent**
Bishop et al.

(10) **Patent No.: US 10,475,179 B1**
(45) **Date of Patent: Nov. 12, 2019**

(54) **COMPENSATING FOR REFERENCE MISALIGNMENT DURING INSPECTION OF PARTS**

(71) Applicant: **Velocity Image Processing LLC**, Needham, MA (US)

(72) Inventors: **Robert P. Bishop**, Newton, MA (US); **Timothy Pinkney**, Somerville, MA (US)

(73) Assignee: **Velocity Image Processing LLC**, Needham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/357,590**

(22) Filed: **Mar. 19, 2019**

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,427,024 B1 7/2002 Bishop
6,829,382 B2 * 12/2004 Lee G06T 7/0002 382/151
9,401,014 B2 * 7/2016 Zafar G03F 1/84
2002/0168099 A1 11/2002 Noy
2010/0215247 A1 * 8/2010 Kitamura G06T 7/001 382/149
2015/0228063 A1 * 8/2015 Minakawa H01J 37/244 382/151
2019/0147579 A1 * 5/2019 Fang G06T 7/0004

* cited by examiner

Primary Examiner — Yon J Couso
(74) *Attorney, Agent, or Firm* — David J. Thibodeau, Jr.; VLP Law Group LLP

(57) **ABSTRACT**

Methods and apparatus for inspection of electronic parts

For Additional Information About The Beltronics Mscan
Contract: Dr. Robert Bishop
Email: Rbishop@beltronicsinc.com
Phone: 1 617 519 8696