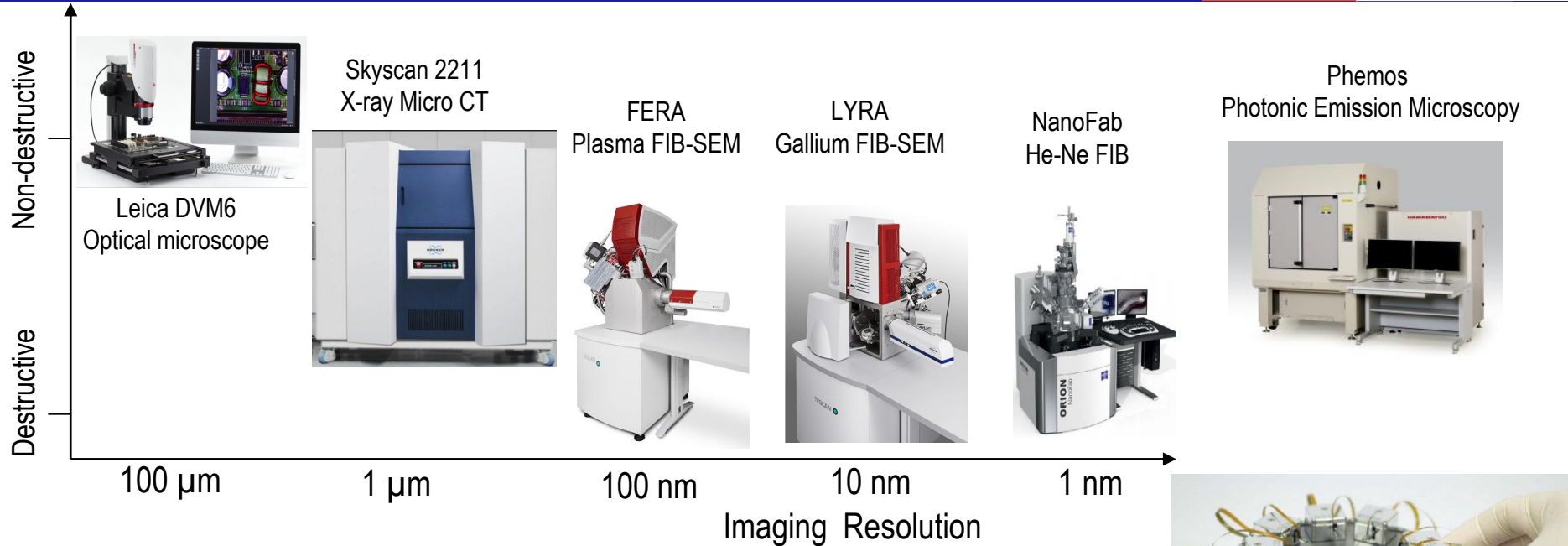


Counterfeit Electronics Optical Microscopy

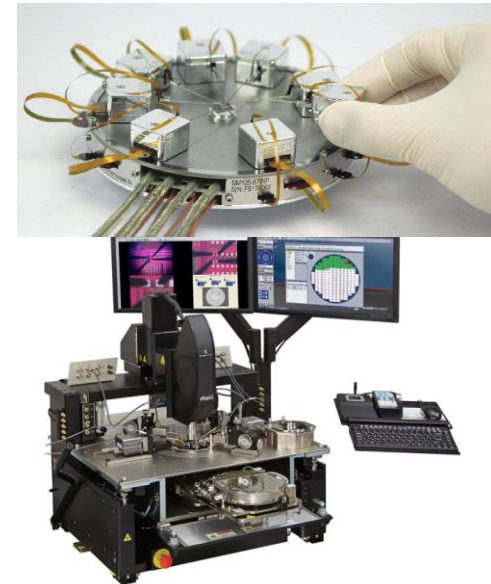
Navid Asadi

Physical Inspection and Attacks on ElectronicS (PHIKS)

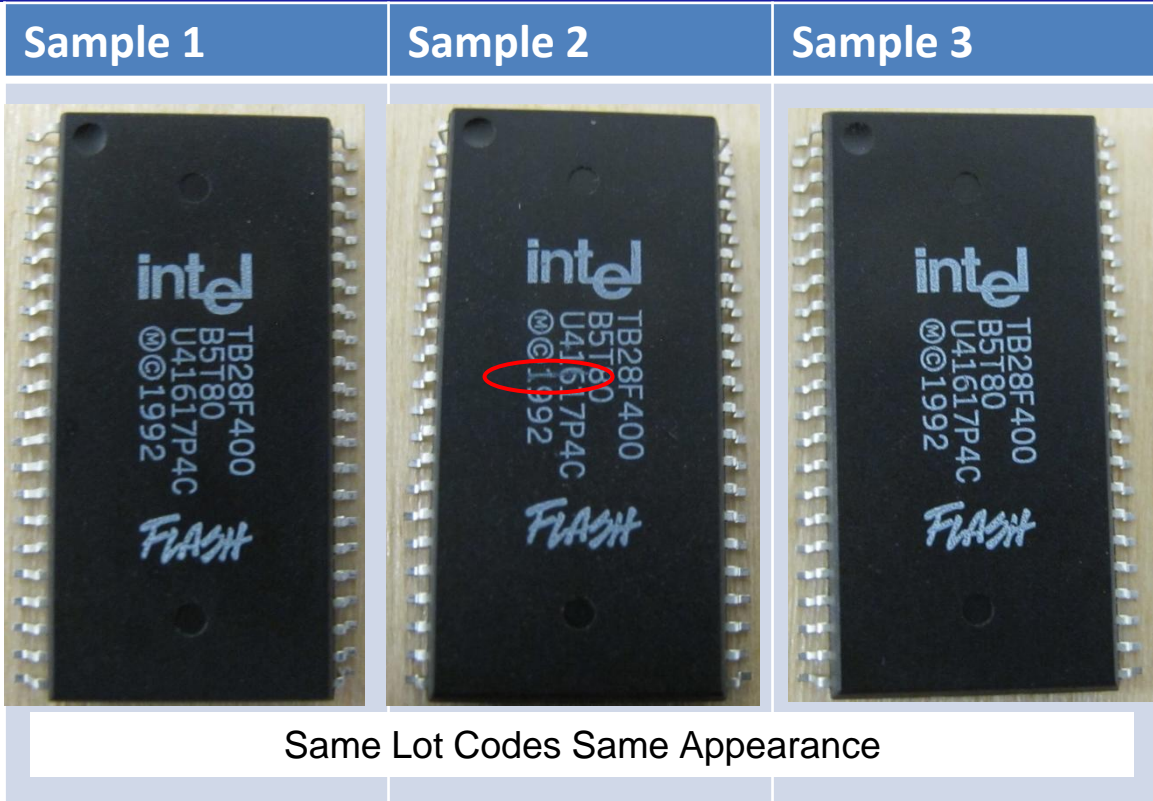
Microscopy and FA Tools



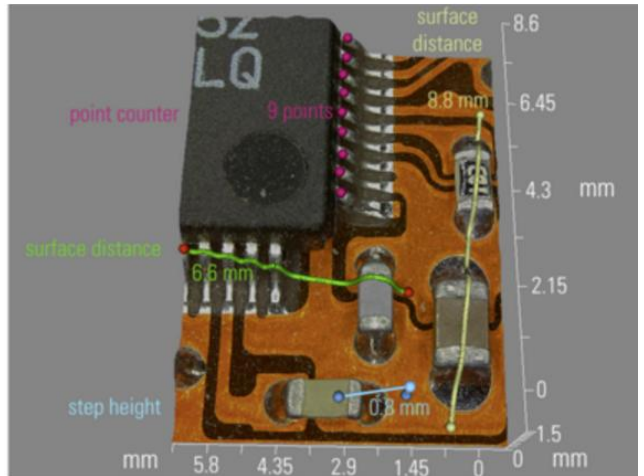
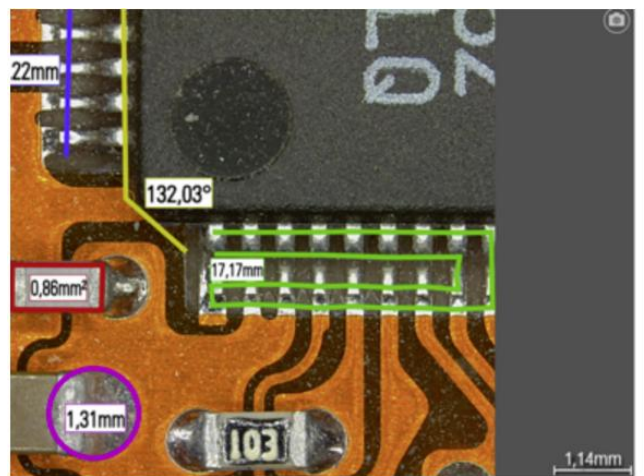
- Imaging and debugging tools are developed for fault analysis.
- Fast advancement in FIB/SEM imaging
- Advancement in photonic emission microscopy, LVS, IR analysis
- Development in micro and nano probing, EBIC, EBAC



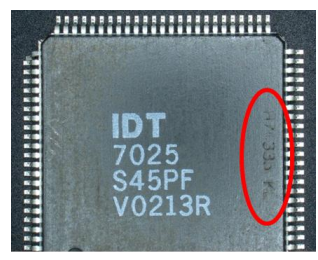
Optical Inspection



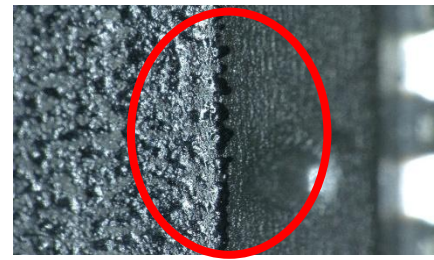
Components **detection** and **localization** on PCBs



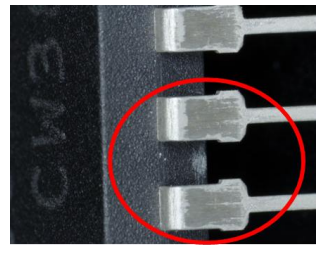
www.leica-microsystems.com



Ghost markings

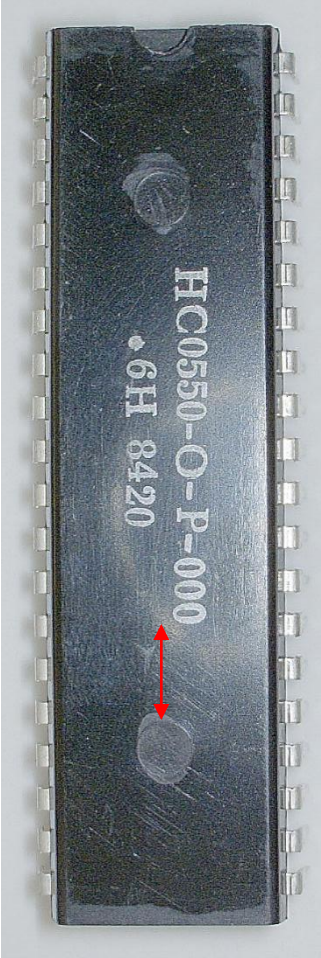


Black top



Retinning/color variations

Optical Inspection



26



27

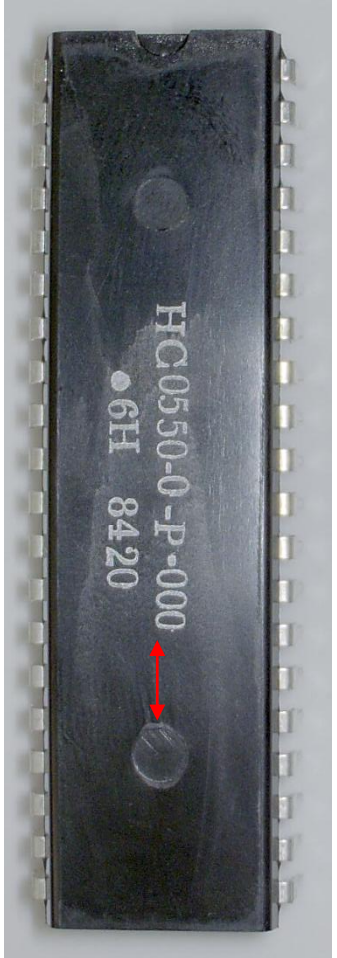


28

Different marking location

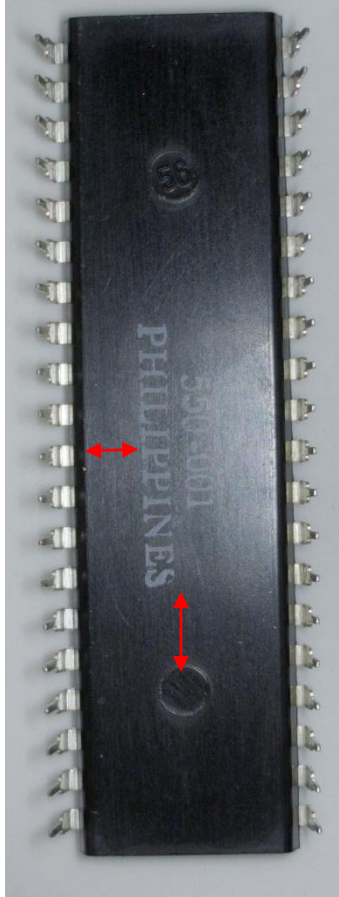


29

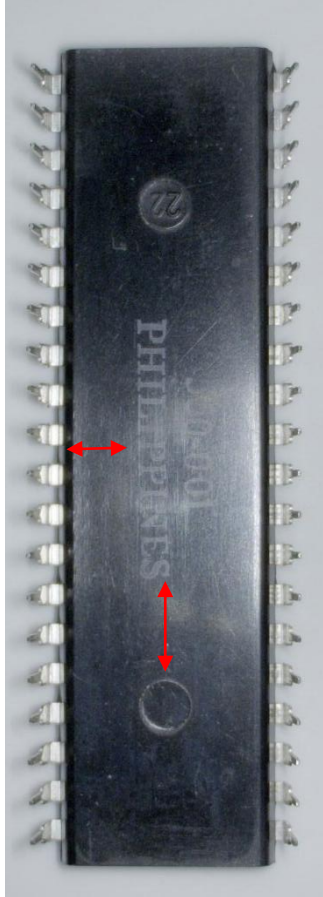


30

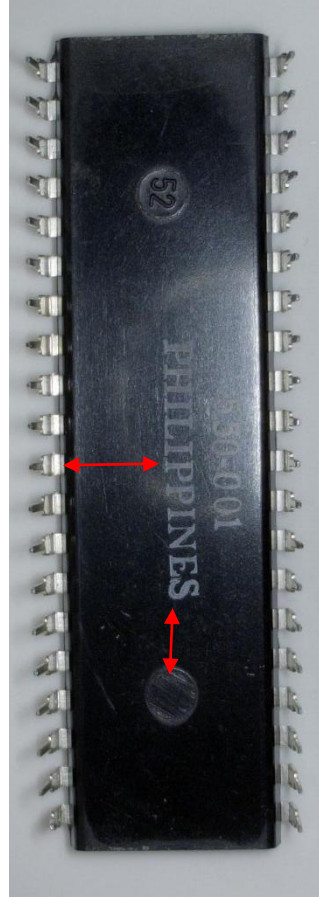
Back Surface



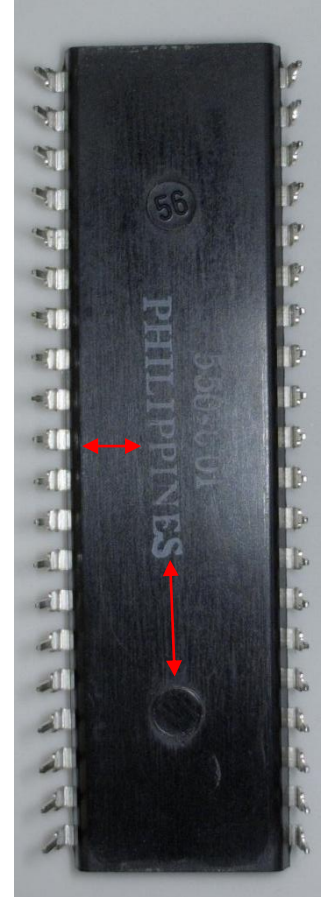
26



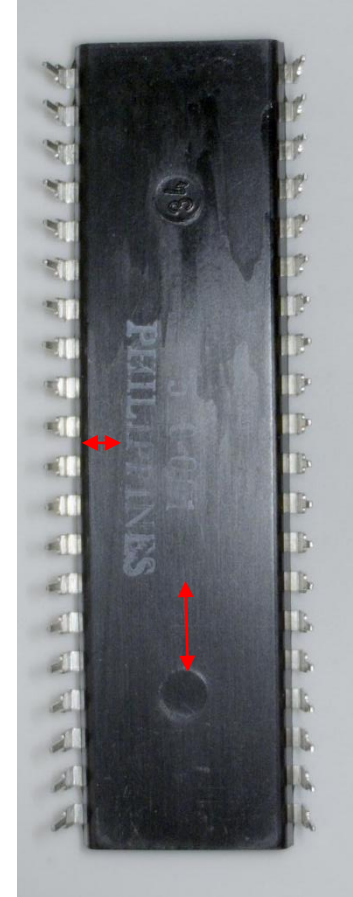
27



28



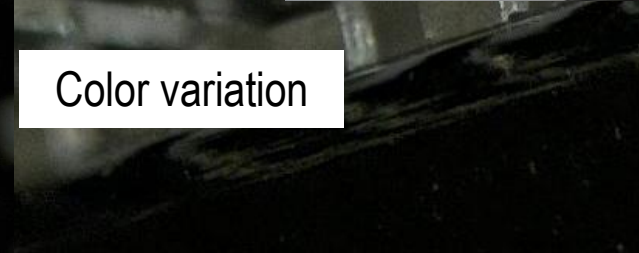
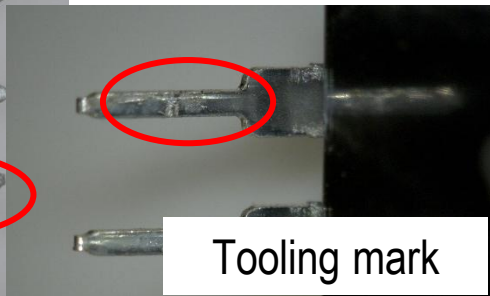
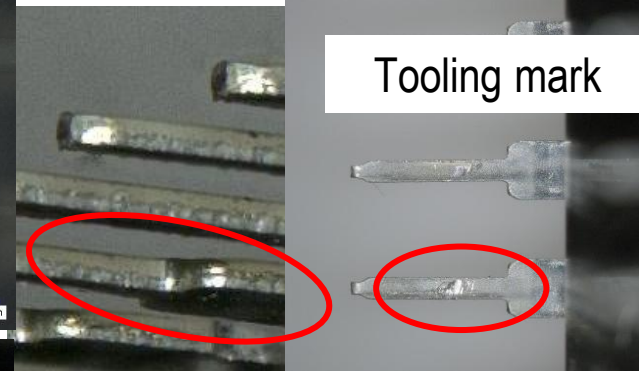
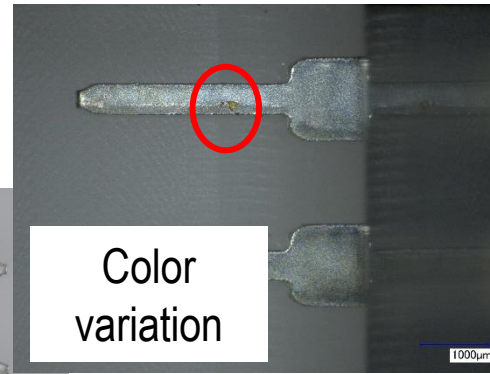
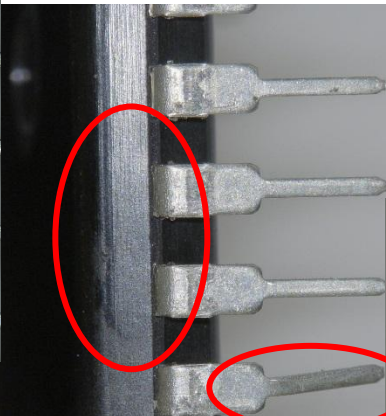
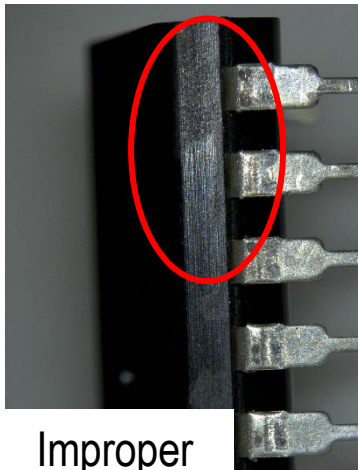
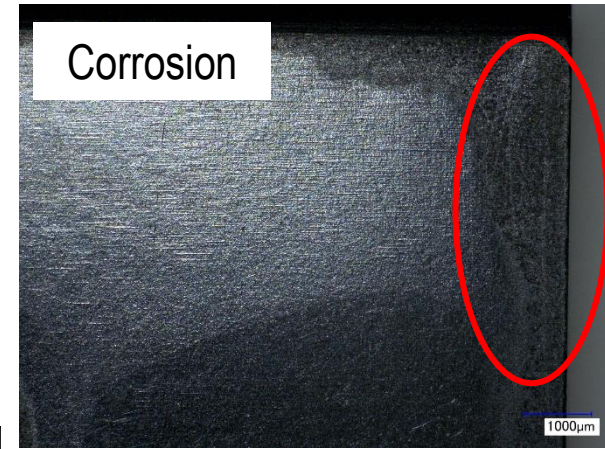
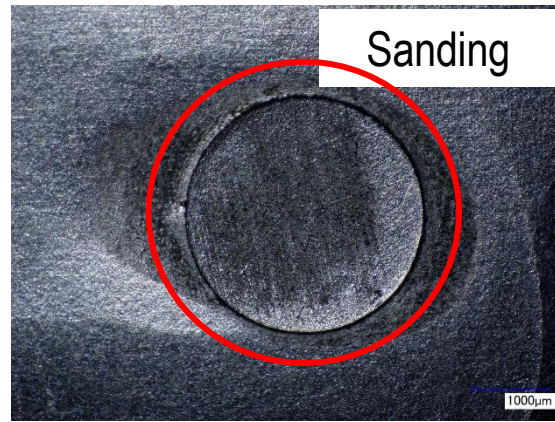
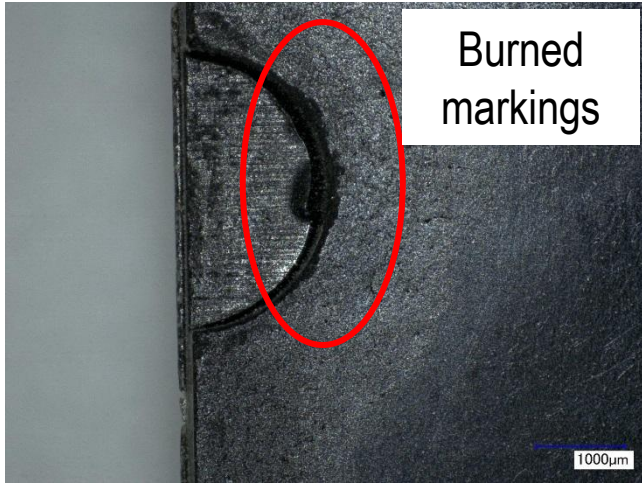
29



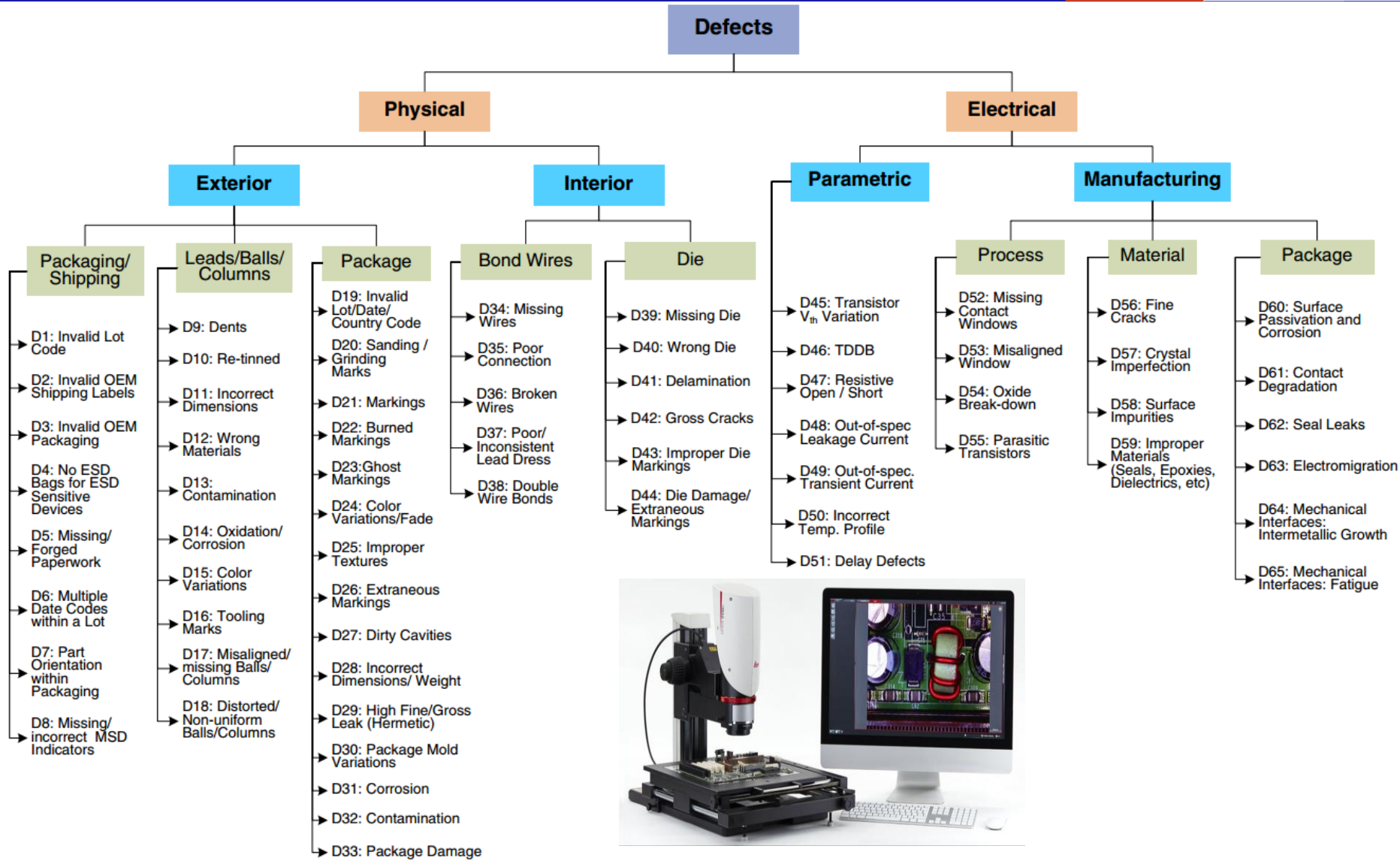
30

Different marking location

Optical Inspection Part 28



Taxonomy of Defects



Scratch Detection

Prior work

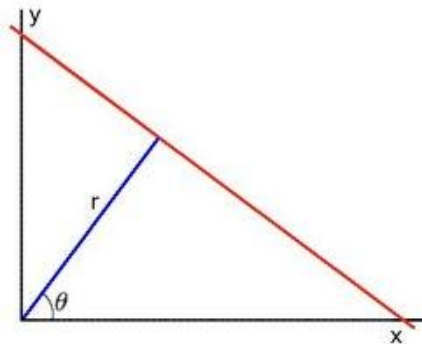
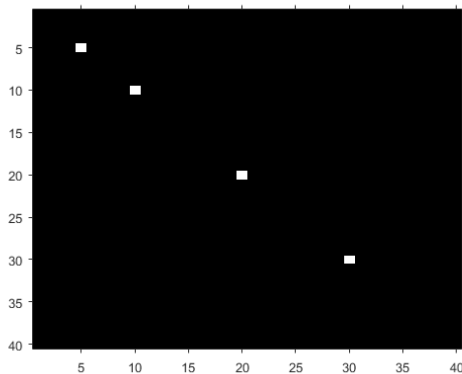
- Thresholding, Edge detection, vertical/horizontal line detection, etc.

Hough Transform

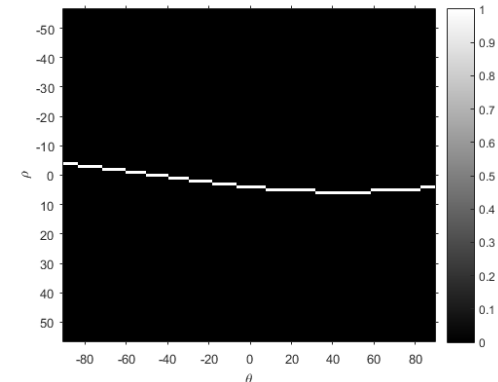
- Each white pixel in a binary image “votes” for a family of lines in an accumulator matrix
- Given a set of angles $\theta = \{-89^\circ \dots 90^\circ\}$ on some interval and a pixel (x_0, y_0) :
 - Can define the family of lines that pass through (x_0, y_0) as:
$$r = x_0 \cos\theta + y_0 \sin\theta$$
 - Each pair (r, θ) in the accumulator matrix is incremented by 1



Image



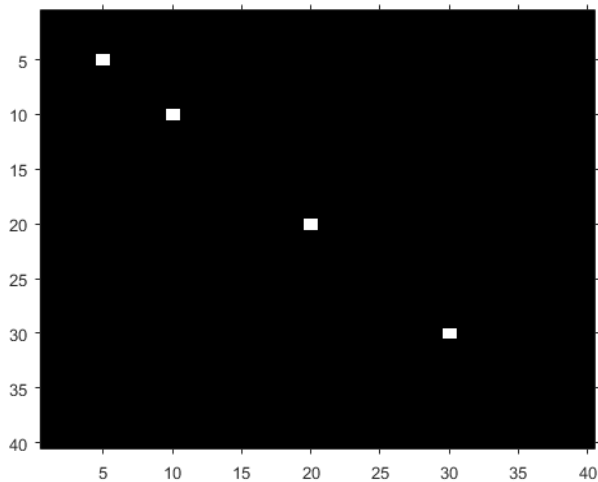
Accumulator



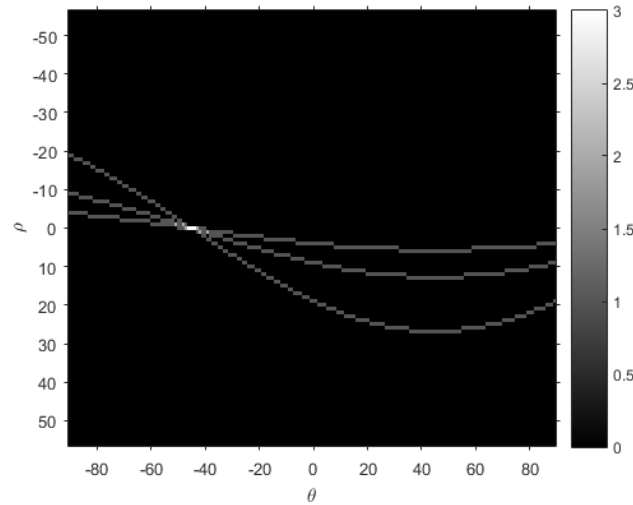
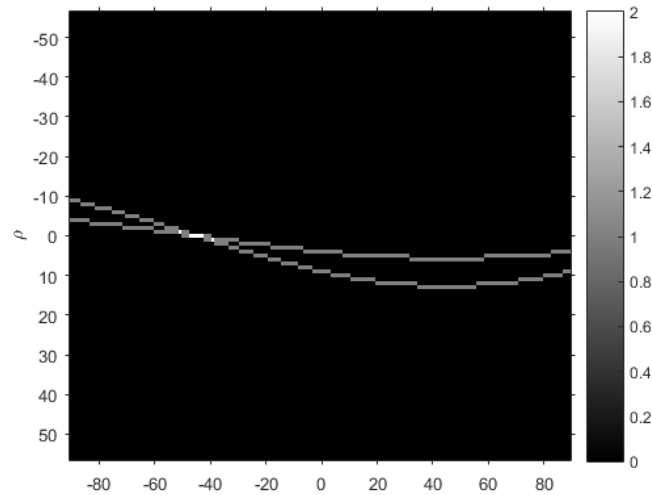
Hough Space

Hough Transform

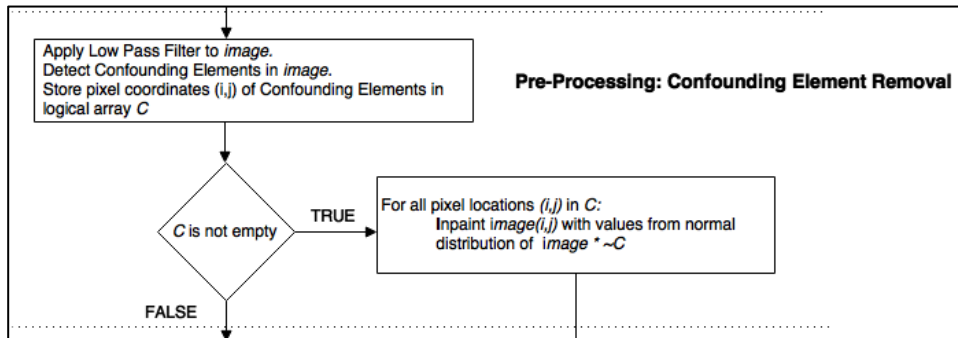
Binary Image



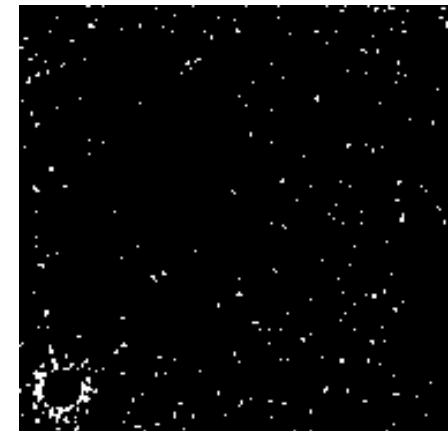
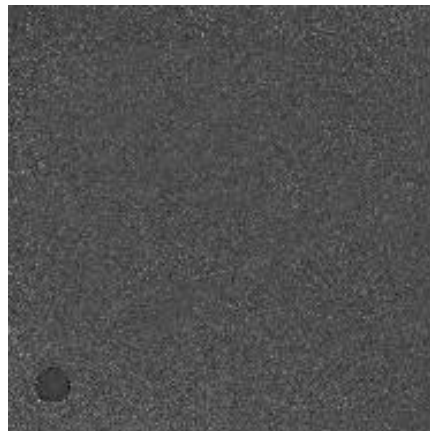
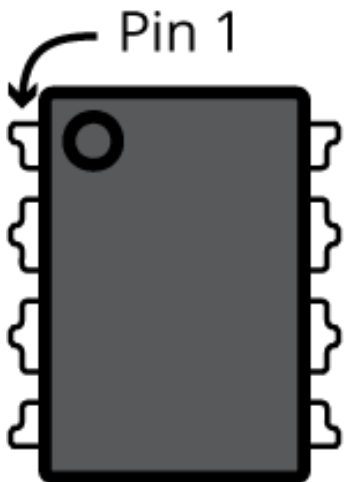
Accumulator



Preprocessing: Confounding Element Removal



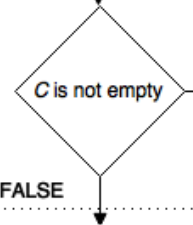
- Problem: Text, Logos, and orientation markers can create false Hough Line peaks
- Here, we assume text has already been removed



Preprocessing: Confounding Element Removal

Apply Low Pass Filter to *image*.
Detect Confounding Elements in *image*.
Store pixel coordinates (i,j) of Confounding Elements in logical array *C*

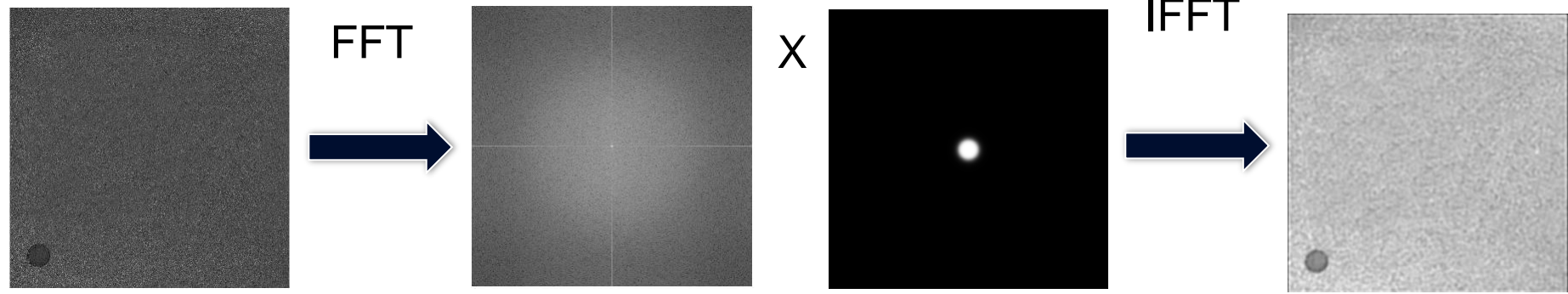
Pre-Processing: Confounding Element Removal



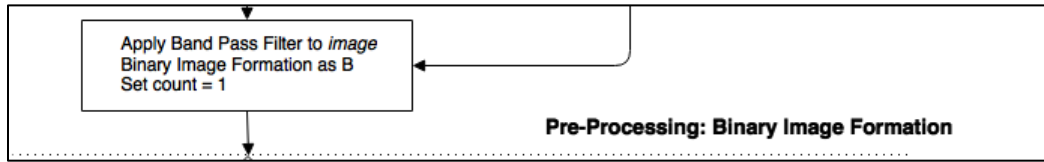
For all pixel locations (i,j) in *C*:
Inpaint *image*(i,j) with values from normal distribution of *image* * ~*C*

Apply Low Pass Filter in Frequency Domain:

$$H(u, v) = \frac{1}{1 + \left(\frac{D(u, v)}{C_L}\right)^{2n}}$$



Binary Image Formation



- Low Pass filter is applied to highlight scratches, blend together pixels into more uniform lines

Binary Threshold:

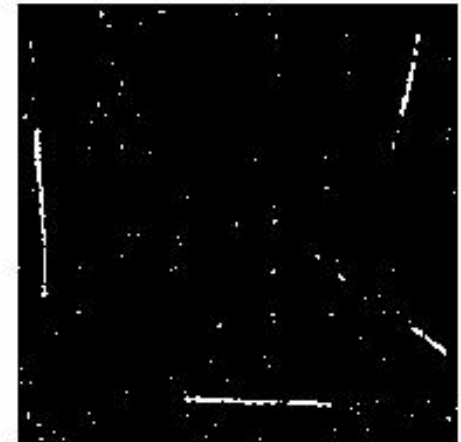
For all pixels (i,j) in Filtered Image :

$$B(i,j) = \begin{cases} 1 & \text{if } F(i,j) > \mu + 3\sigma \\ 0 & \text{Otherwise} \end{cases}$$

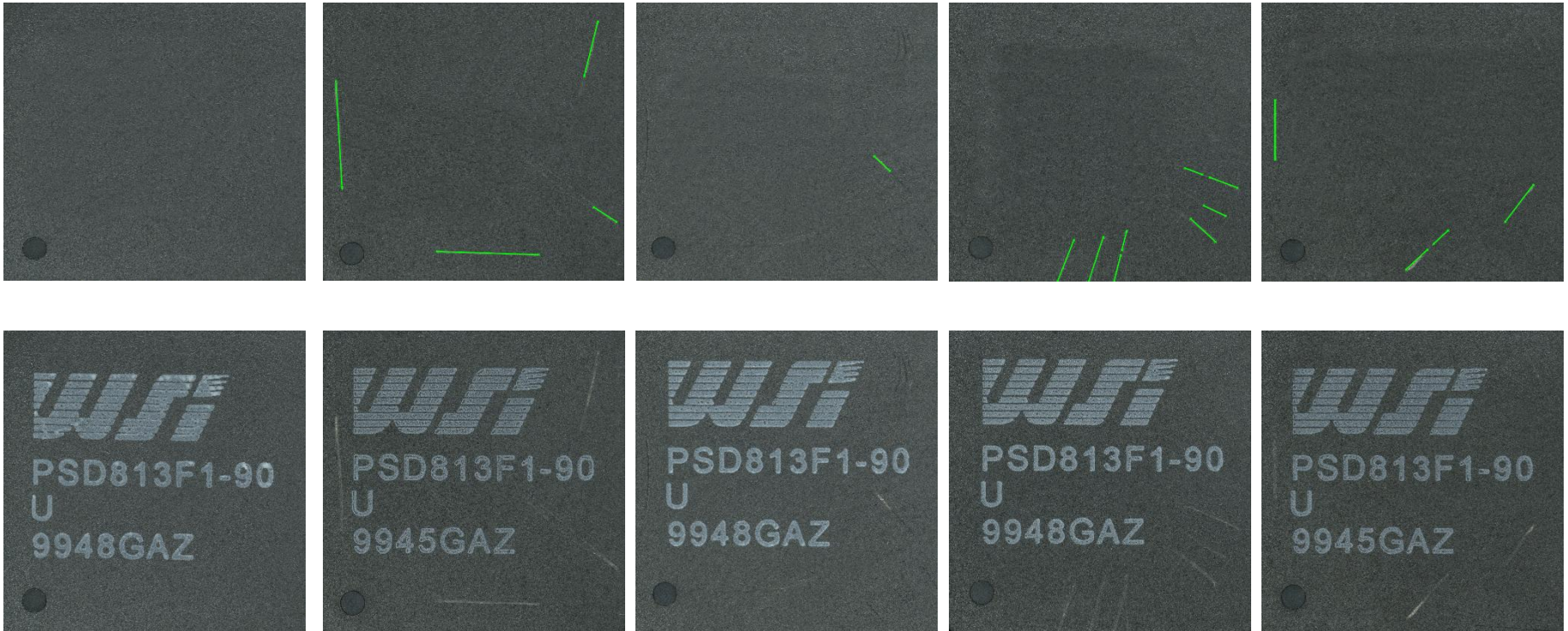
Original Image



Resulting Binary Image



Results



Average(s)	Standard	1	2	3	4
Detected Scratches	0	4	1	6	3
False Positives	0	0	0	2	1
True Scratches	0	4	8	6	4
Accuracy	100.00	100.00	0.13	0.75	0.60

$$Accuracy = \frac{Detected\ Scratches}{True\ Scratches + False\ Positives}$$

Defect Detection Automation

1. Image processing and filtering

- Image filtering, with a modified Hough transform to detect circles
- Sobel filter and canny edge detection algorithm to detect the scratches

Sudden change in the gradient will represent an edge or scratch.

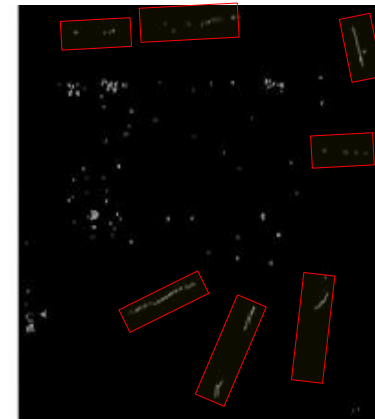
2. Machine Learning

- Similar to human brain structure
- Information is stored in interconnections between layers
- Traditional and modern ML

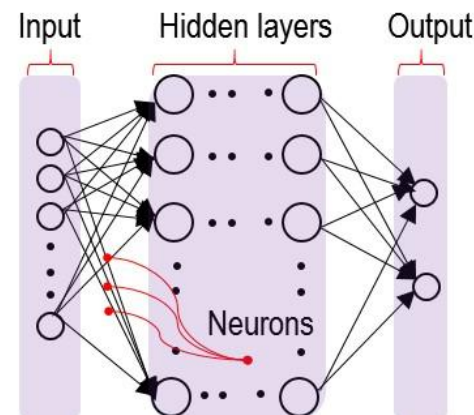
Counterfeit IC with scratch defect



original image



after image processing

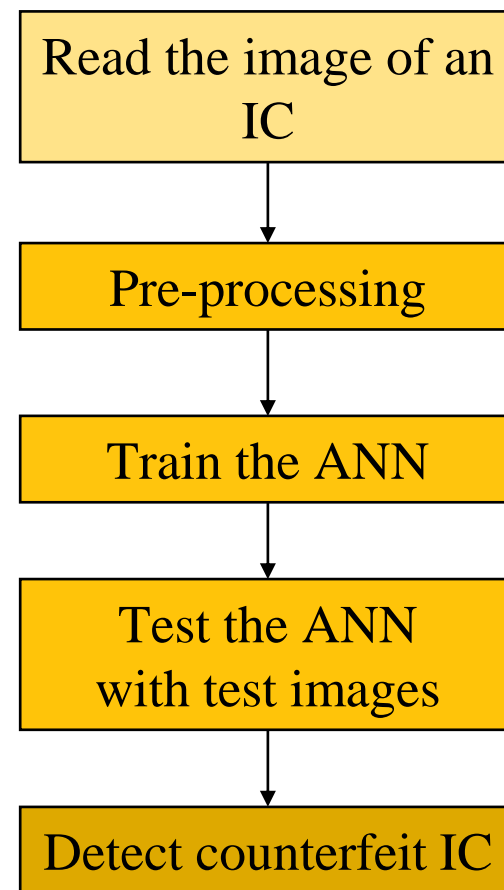


Artificial Neural Network

ANN Principles:

- Information is stored in the interconnections between neurons
- Each neuron in **input layer** is connected to all neurons in **hidden layer**.
- **Weighted matrix** decides the input for each neuron in hidden layer
- Output of a neuron is calculated based on an appropriate **activation function** (tanh, step function, etc.)
- During training the expected output is **compared** with the output obtained.

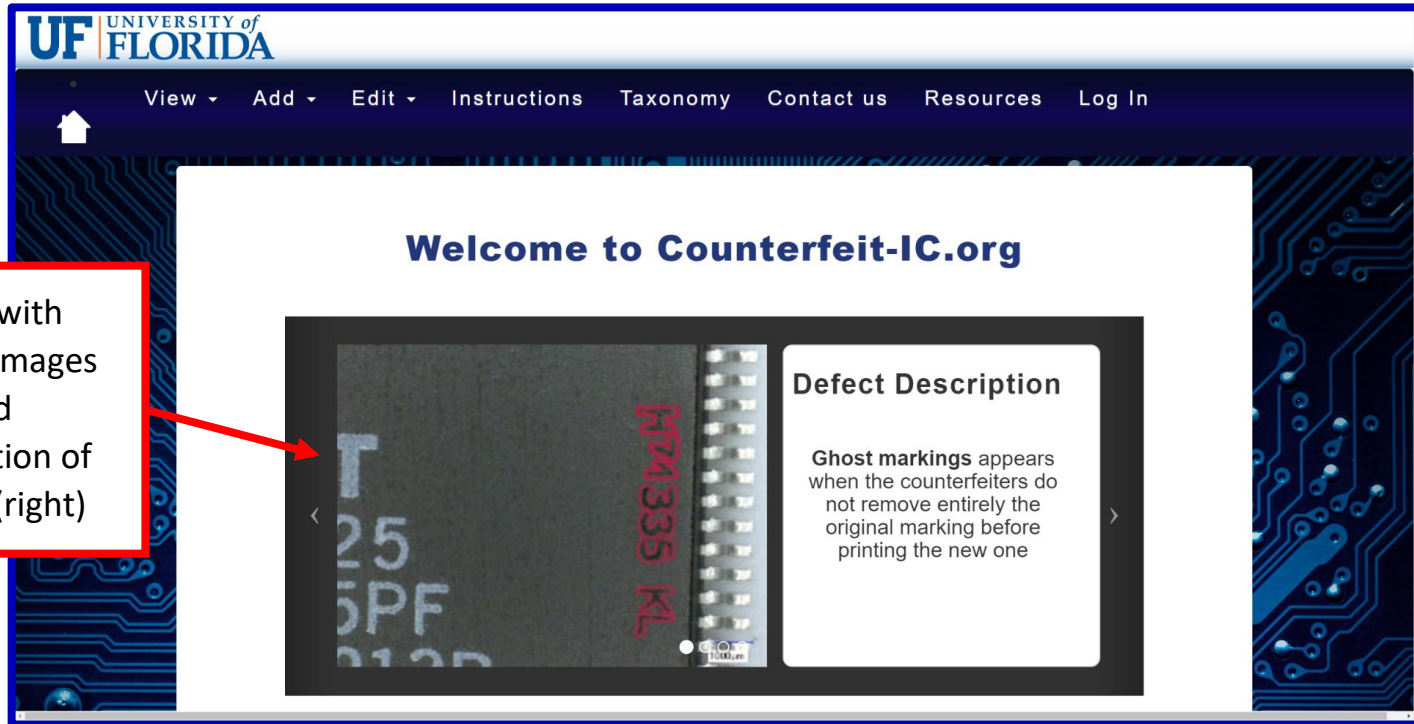
Flowchart for the counterfeit IC detection using neural network





A resource sponsored by the National Science Foundation (NSF) to

- *VIEW and EXPORT* images and statistical information related to counterfeit defects
- *UPLOAD* images of defects found by physical inspection of counterfeit ICs
- *DEVELOP* automated counterfeit IC detection techniques
- *LEARN* more about the defects found in counterfeit ICs and counterfeit IC detection



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Learn more about counterfeit defects



Scroller with sample images (left) and explanation of defects (right)

Register and log in for full access

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Learn more about counterfeit defects



View and upload

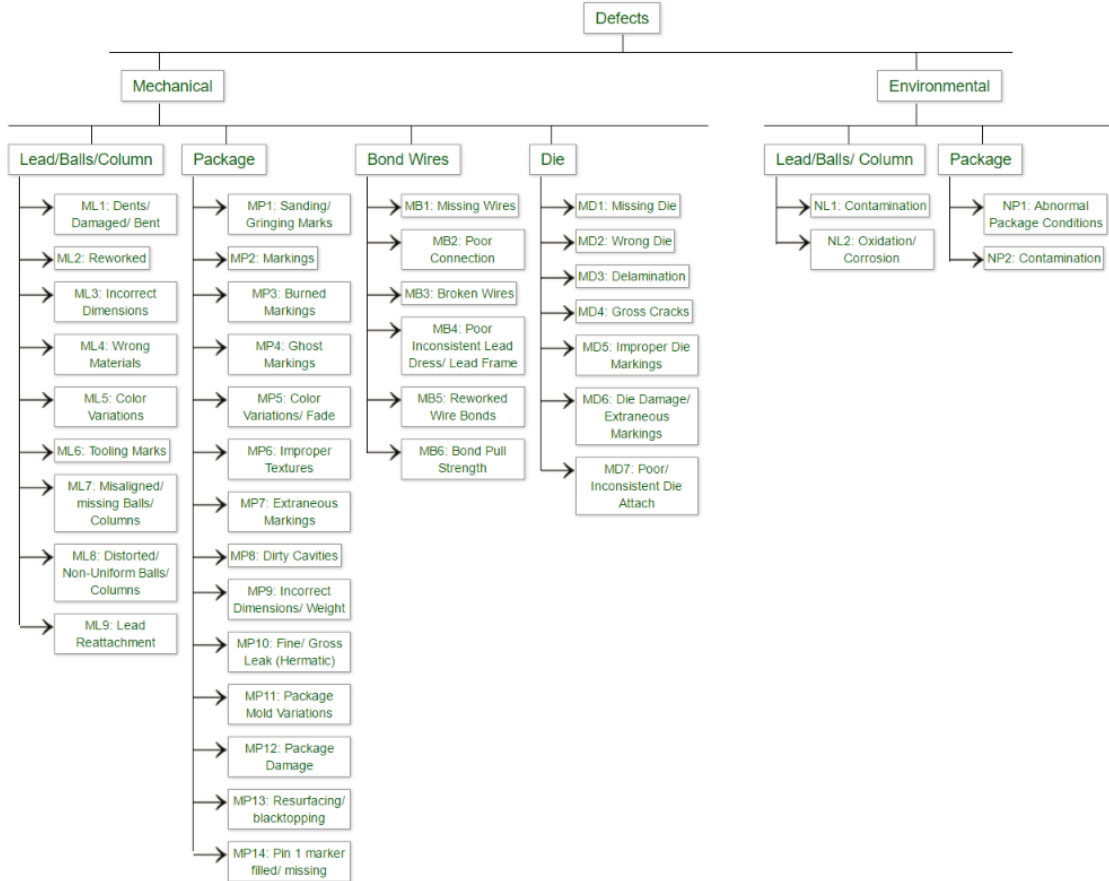
Scroller with sample images (left) and explanation of defects (right)

Register and log in for full access

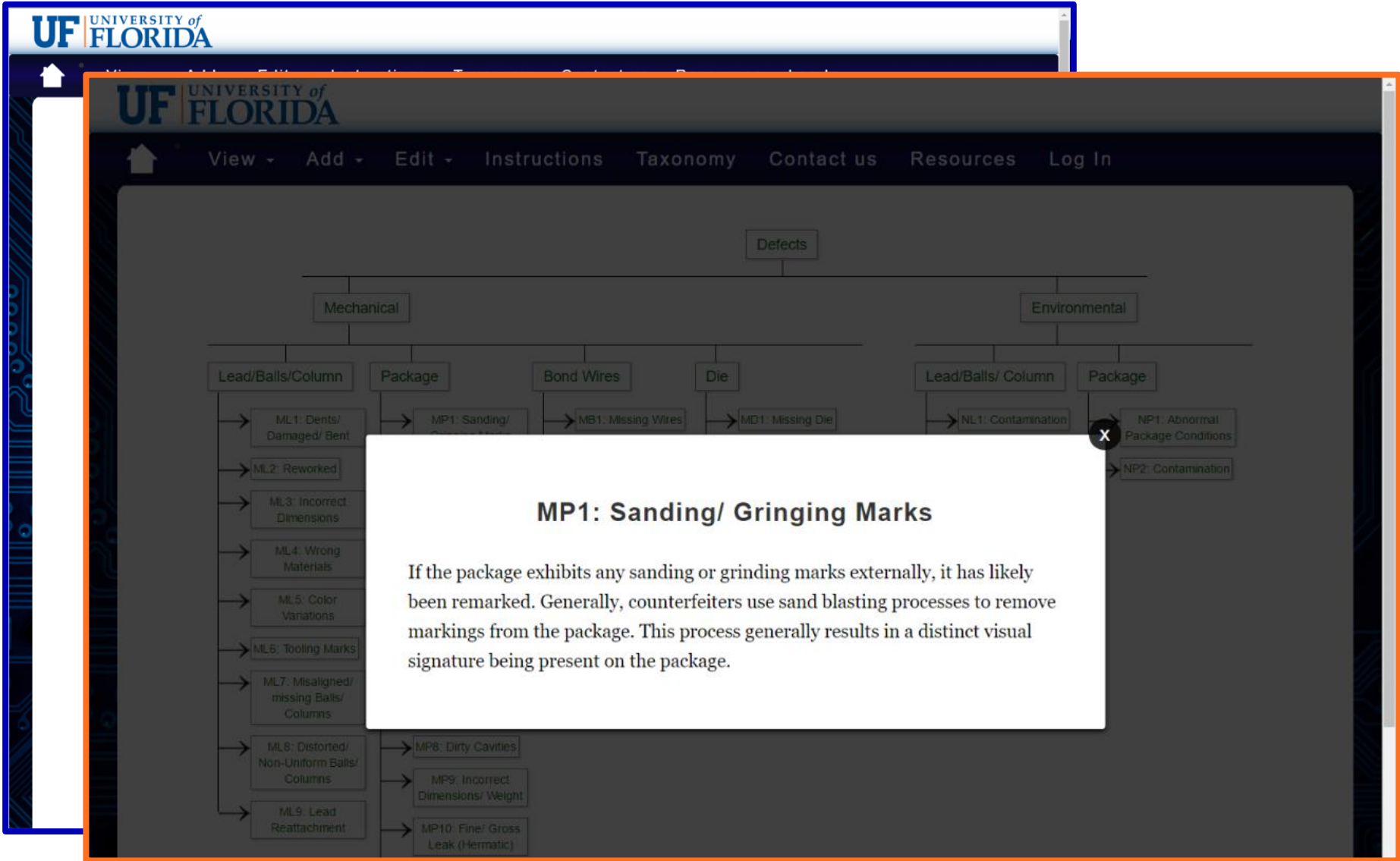
A resource sponsored by the National Science Foundation (NSF) to

- *VIEW and EXPORT* images and statistical information related to counterfeit defects
- *UPLOAD* images of defects found by physical inspection of counterfeit ICs
- *DEVELOP* automated counterfeit IC detection techniques
- *LEARN* more about the defects found in counterfeit ICs and counterfeit IC detection

Learn- Defect Taxonomy



Learn- Defect Definitions



The screenshot displays a web-based taxonomy of defects. The main menu includes 'View', 'Add', 'Edit', 'Instructions', 'Taxonomy', 'Contact us', 'Resources', and 'Log In'. The taxonomy is structured as follows:

- Defects
 - Mechanical
 - Lead/Balls/Column
 - ML1: Dents/ Damaged/ Bent
 - ML2: Reworked
 - ML3: Incorrect Dimensions
 - ML4: Wrong Materials
 - ML5: Color Variations
 - ML6: Tooling Marks
 - ML7: Misaligned/ missing Balls/ Columns
 - ML8: Distorted/ Non-Uniform Balls/ Columns
 - ML9: Lead Reattachment
 - Package
 - MP1: Sanding/ Gringing Marks
 - MP8: Dirty Cavities
 - MP9: Incorrect Dimensions/ Weight
 - MP10: Fine/ Gross Leak (Hermetic)
 - Bond Wires
 - MB1: Missing Wires
 - Die
 - MD1: Missing Die
 - Environmental
 - Lead/Balls/ Column
 - NL1: Contamination
 - Package
 - NP1: Abnormal Package Conditions
 - NP2: Contamination

MP1: Sanding/ Gringing Marks

If the package exhibits any sanding or grinding marks externally, it has likely been remarked. Generally, counterfeiters use sand blasting processes to remove markings from the package. This process generally results in a distinct visual signature being present on the package.

View a Product Report



The screenshot shows a web application interface for viewing a product report. At the top left is the University of Florida logo. A navigation bar contains a home icon, a search icon, and menu items: View, Add, Edit, Instructions, Taxonomy, Contact us, Resources, and Log In. The main content area is titled "Product Report for SB80L188EC13". Below the title, it shows "Managing Group: admin". A table lists product details: Manufacturer (Intel), Product Specification (View), Product Image (View), and Total Number of Components in Database (5). A section titled "Most Common Identified Defects in SB80L188EC13" contains a table with 5 rows of defect data. At the bottom left of the content area is an "Edit this page" button.

Product Report for SB80L188EC13

Managing Group: [admin](#)

Manufacturer	Intel
Product Specification:	View
Product Image:	View
Total Number of Components in Database:	5

Most Common Identified Defects in SB80L188EC13

Defect Name	Example	Occurrences in Product	Frequency: Within Product	Frequency: All Tested Products
Reworked	View	5	100.0000	43.3628
Tooling Marks	View	5	100.0000	34.5133
Markings	View	4	80.0000	26.5487
Package Mold Variations	View	4	80.0000	31.8584
Oxidation/Corrosion	View	1	20.0000	26.5487
Package Contamination	View	1	20.0000	17.6991

[Edit this page](#)

View a Defect Report

Defect Report for Sanding/Grinding Marks

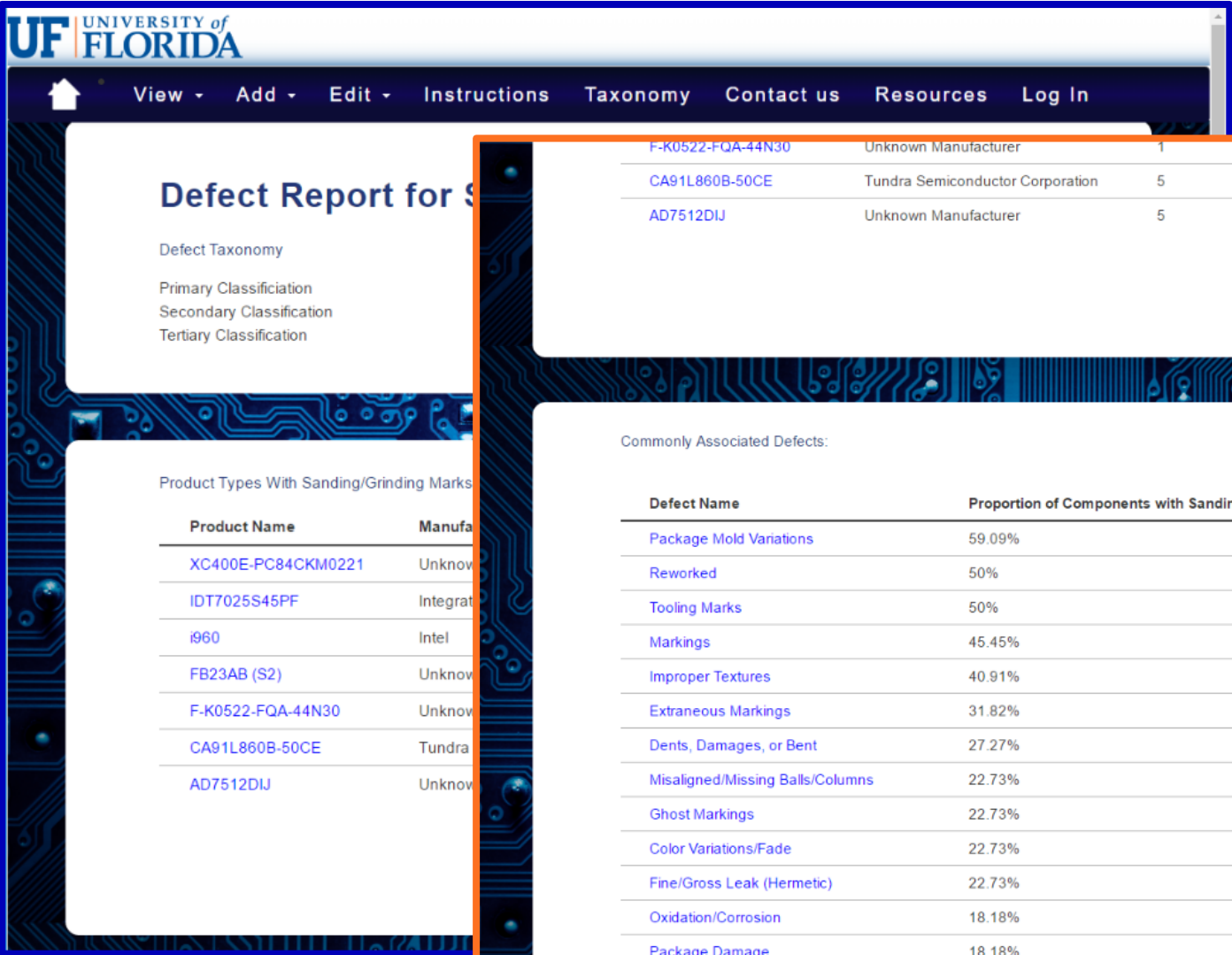
Defect Taxonomy

Primary Classification	Mechanical
Secondary Classification	Package
Tertiary Classification	N/A

Product Types With Sanding/Grinding Marks

Product Name	Manufacturer	Number of Occurrences	Frequency
XC400E-PC84CKM0221	Unknown Manufacturer	1	100%
IDT7025S45PF	Integrated Device Technology Inc.	5	100%
i960	Intel	2	66.667%
FB23AB (S2)	Unknown Manufacturer	3	50%
F-K0522-FQA-44N30	Unknown Manufacturer	1	20%
CA91L860B-50CE	Tundra Semiconductor Corporation	5	100%
AD7512DIJ	Unknown Manufacturer	5	100%

View a Defect Report



The screenshot shows a web application interface for viewing a defect report. At the top, there is a navigation bar with a home icon and menu items: View, Add, Edit, Instructions, Taxonomy, Contact us, Resources, and Log In. The main content area is titled "Defect Report for S" and includes sections for "Defect Taxonomy" (Primary, Secondary, and Tertiary Classification) and "Product Types With Sanding/Grinding Marks". A table lists product names and manufacturers. A modal window is open, displaying a table of defect details with columns for defect ID, manufacturer, count, and percentage. Below the modal, a section titled "Commonly Associated Defects:" contains a table listing various defect types and their proportions.

Defect ID	Manufacturer	Count	Percentage
F-K0522-FQA-44N30	Unknown Manufacturer	1	20%
CA91L860B-50CE	Tundra Semiconductor Corporation	5	100%
AD7512DIJ	Unknown Manufacturer	5	100%

Product Types With Sanding/Grinding Marks

Product Name	Manufacturer
XC400E-PC84CKM0221	Unknown
IDT7025S45PF	Integrated
i960	Intel
FB23AB (S2)	Unknown
F-K0522-FQA-44N30	Unknown
CA91L860B-50CE	Tundra
AD7512DIJ	Unknown

Commonly Associated Defects:

Defect Name	Proportion of Components with Sanding/Grinding Marks
Package Mold Variations	59.09%
Reworked	50%
Tooling Marks	50%
Markings	45.45%
Improper Textures	40.91%
Extraneous Markings	31.82%
Dents, Damages, or Bent	27.27%
Misaligned/Missing Balls/Columns	22.73%
Ghost Markings	22.73%
Color Variations/Fade	22.73%
Fine/Gross Leak (Hermetic)	22.73%
Oxidation/Corrosion	18.18%
Package Damage	18.18%
Burned Markings	4.55%

View a Sample Report



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View ▾ Add ▾ Edit ▾ Instructions Taxonomy Contact us Resources Log In

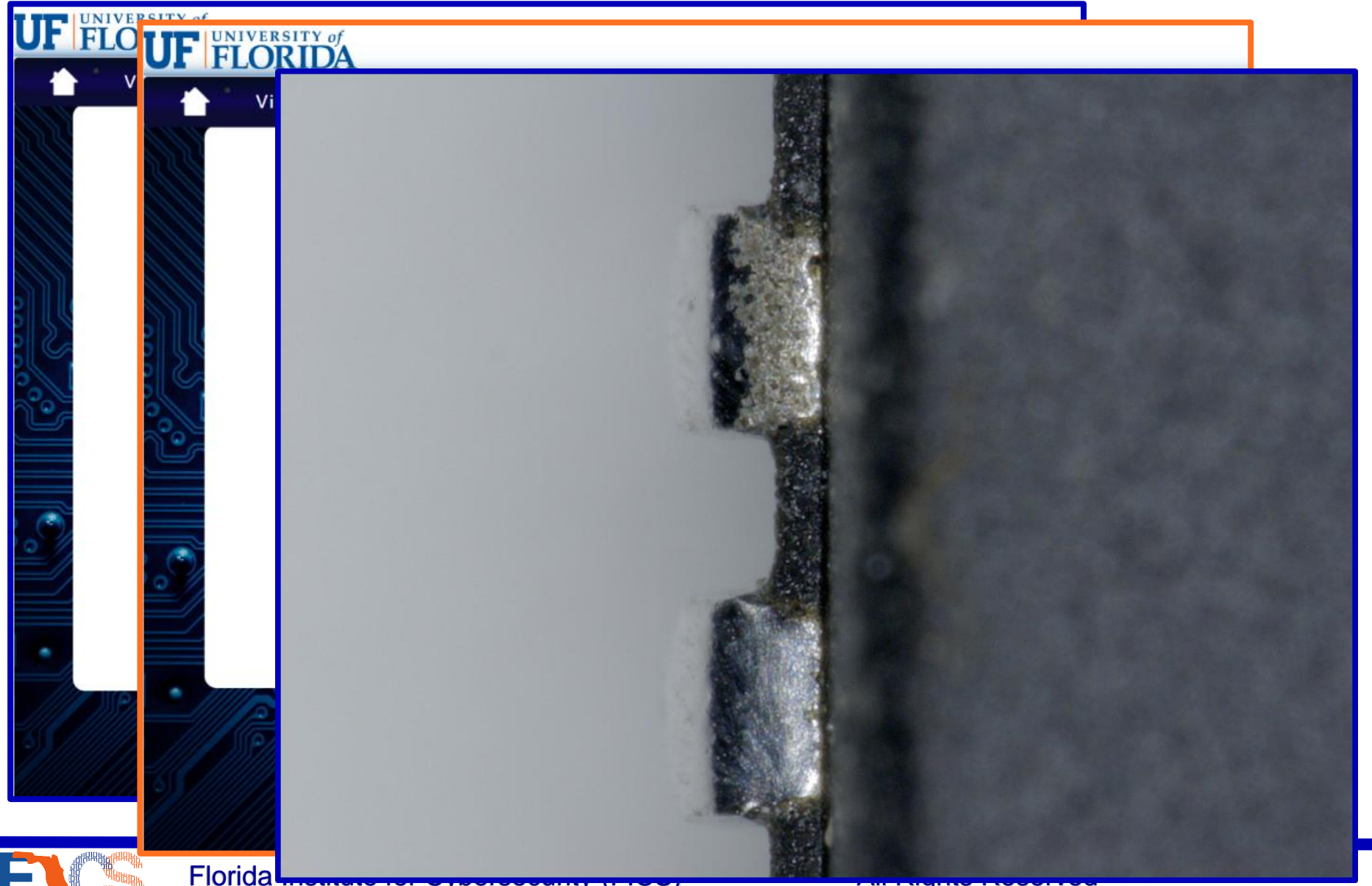
Component #78:

Product Type: i960
Product Specification: Not available
Product Image: Not available

Sample Group: Initial
ID Within Sample: 1

Defect Name	Image	Primary Class	Secondary Class	Tertiary Class
Reworked	View	Mechanical	Lead/Balls/Columns	N/A
Tooling Marks	View	Mechanical	Lead/Balls/Columns	N/A
Misaligned/Missing Balls/Columns	View	Mechanical	Lead/Balls/Columns	N/A
Package Mold Variations	View	Mechanical	Package	N/A
Package Damage	View	Mechanical	Package	N/A

View a Sample Defect Image



Uploading a New Sample Group

To upload using an Excel File, first download the form below. Each row of the form represents one defect of one component of the sample. For each row:

1. Enter the sample ID number of the component
2. Select the desired defect
3. If applicable, create a hyperlink to the corresponding image of the defect.

Do not skip rows when entering data. When finished, create a zip archive containing the images, and the Excel file, taking care to preserve the file system structure between the images and the Excel file.

Maximum file Upload is 100MB.

[See example here](#)

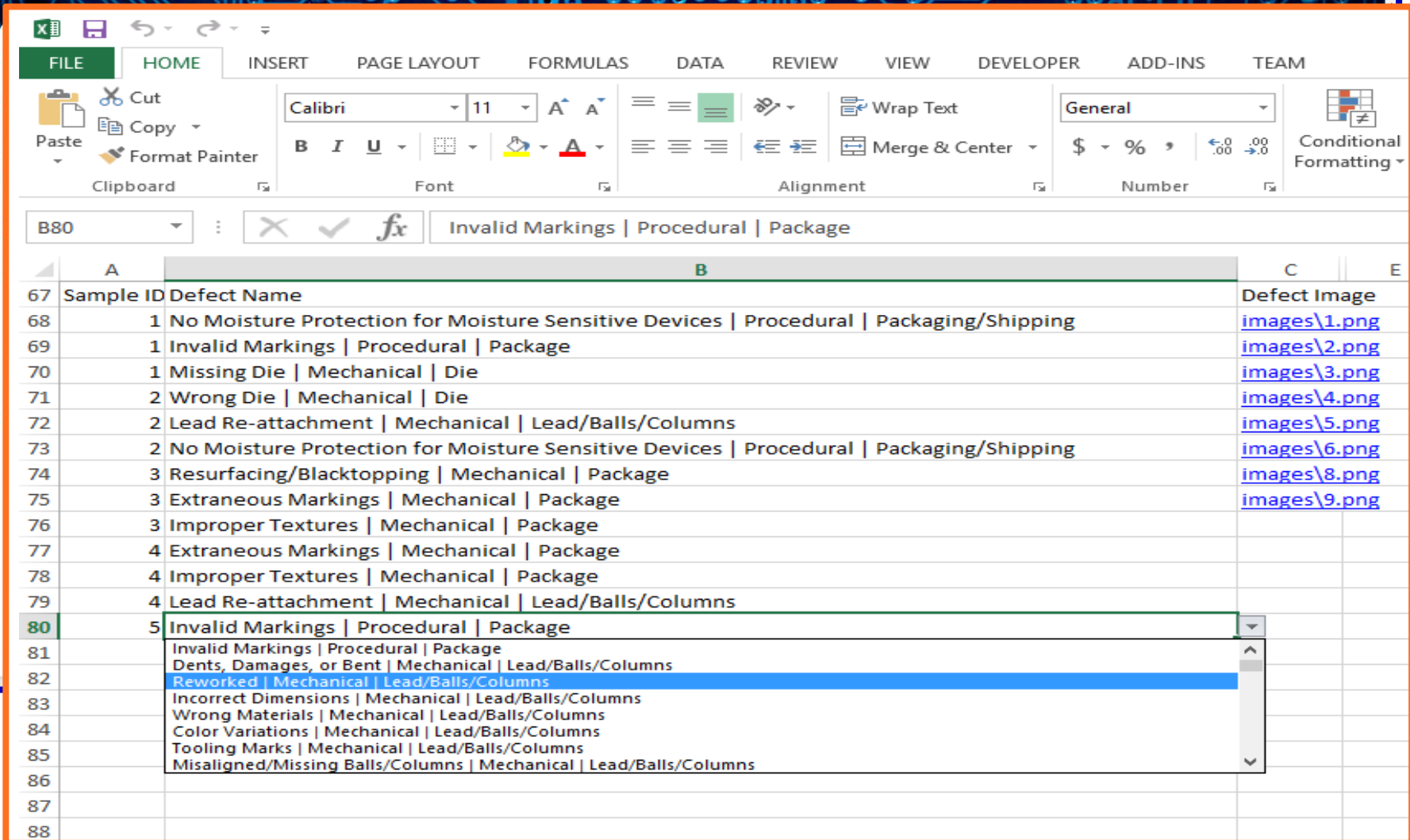
Download Excel Form

Upload the Zip Archive Below:

Click Here or Drag Files to Upload

Submit Zip file

Uploading a New Sample Group



	A	B	C	E
67	Sample ID	Defect Name	Defect Image	
68	1	No Moisture Protection for Moisture Sensitive Devices Procedural Packaging/Shipping	images\1.png	
69	1	Invalid Markings Procedural Package	images\2.png	
70	1	Missing Die Mechanical Die	images\3.png	
71	2	Wrong Die Mechanical Die	images\4.png	
72	2	Lead Re-attachment Mechanical Lead/Balls/Columns	images\5.png	
73	2	No Moisture Protection for Moisture Sensitive Devices Procedural Packaging/Shipping	images\6.png	
74	3	Resurfacing/Blacktopping Mechanical Package	images\8.png	
75	3	Extraneous Markings Mechanical Package	images\9.png	
76	3	Improper Textures Mechanical Package		
77	4	Extraneous Markings Mechanical Package		
78	4	Improper Textures Mechanical Package		
79	4	Lead Re-attachment Mechanical Lead/Balls/Columns		
80	5	Invalid Markings Procedural Package		
81		Invalid Markings Procedural Package		
82		Dents, Damages, or Bent Mechanical Lead/Balls/Columns		
83		Reworked Mechanical Lead/Balls/Columns		
84		Incorrect Dimensions Mechanical Lead/Balls/Columns		
85		Wrong Materials Mechanical Lead/Balls/Columns		
86		Color Variations Mechanical Lead/Balls/Columns		
87		Tooling Marks Mechanical Lead/Balls/Columns		
88		Misaligned/Missing Balls/Columns Mechanical Lead/Balls/Columns		

Readings

- IDEA-STD-1010-B
- Counterfeit-ic.org
- Book chapter: Counterfeit Integrated Circuits: Detection, Avoidance, and the Challenges Ahead
- ISTFA paper: A Database for Counterfeit Electronics and Automatic Defect Detection Based on Image processing and Machine Learning