“A Statistical Method for Eliminating False Counts Due to Debris, Using Automated Visual Inspection for Probe Marks”

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- **Probe Debris & Challenges to Automated Inspection**
- **Statistical Probe Mark Area Filter**
- **Statistical Probe Mark Proximity Filter**

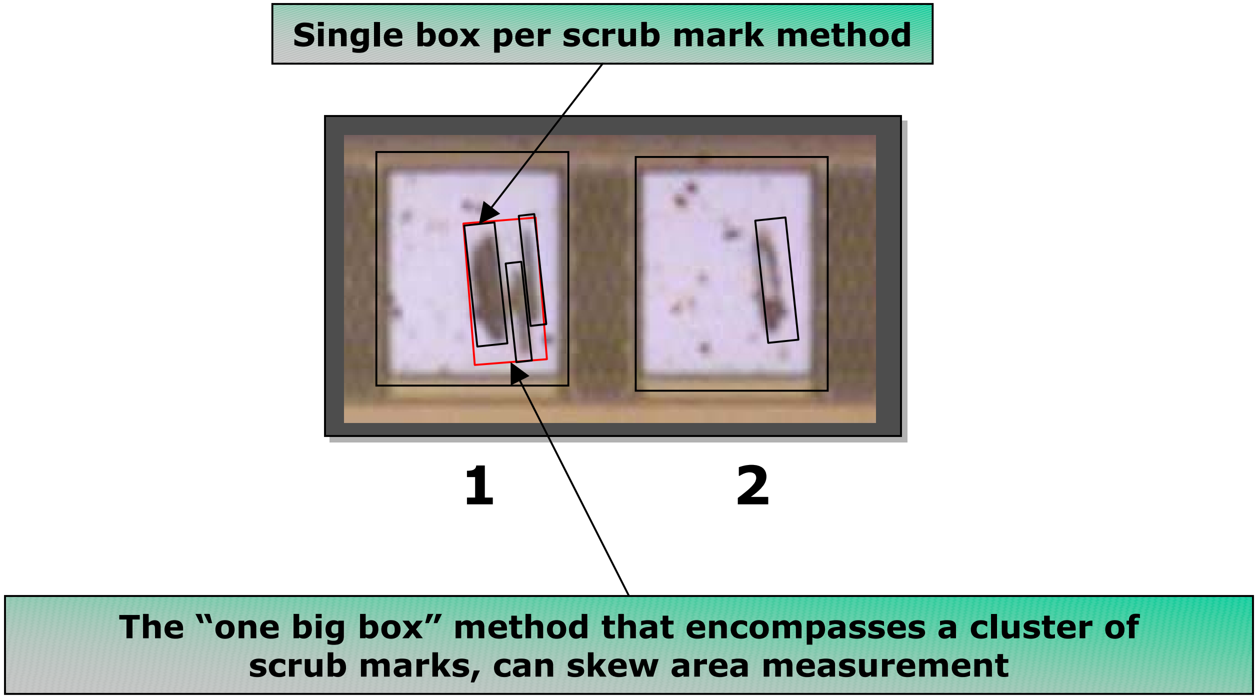
Wafer Probe Quality Control

- Quality control of the wafer probe scrub area (probe mark) is required to:
  - Ensure probe mark area is sufficient for proper forming of intermetallics during wire bonding.
  - Detect cracked passivation oxide outside the bond pad area.
- Traditionally, manual inspection, which relies on sampling by human operators, has provided this control.
- Currently, more test floors are using automatic inspection to allow 100% inspection and remove operator to operator variability.

Manual Probe Mark Inspection

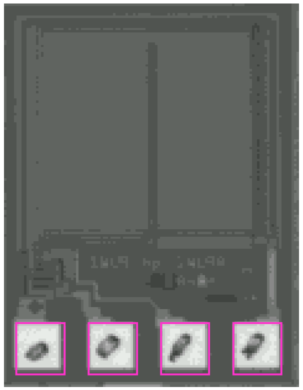
Operator uses a microscope review station to:

1. Estimate probe damage area with one or more rectangular reticles
2. Determine if the probe mark violates the boundary of the bond pad



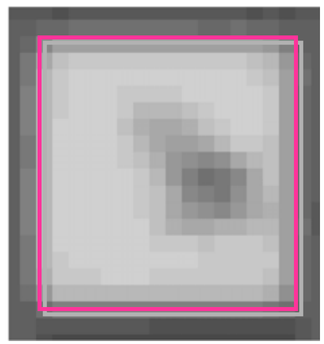
Automatic Probe Mark Inspection

Probe Debris Filter



Pixel Analysis

1. Edge search begins where bond pad masks are defined during recipe set-up

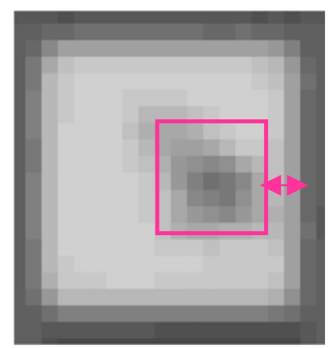


2a. Actual bond pad edges detected by pixel analysis

2b. Bond pad area calculated

3a. Dark pixels inside bond pad edges counted to calculate **area** (as % of total bond pad area – or – in um^2)

3b. Pixels from probe mark edge to nearest bond pad edge counted to calculate **proximity** (in um)

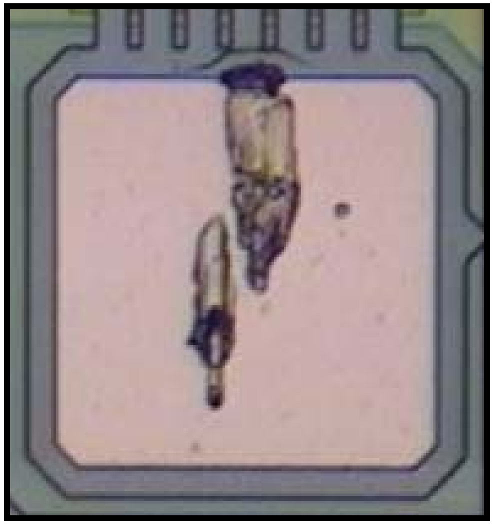


The Probe Mark Debris Challenge

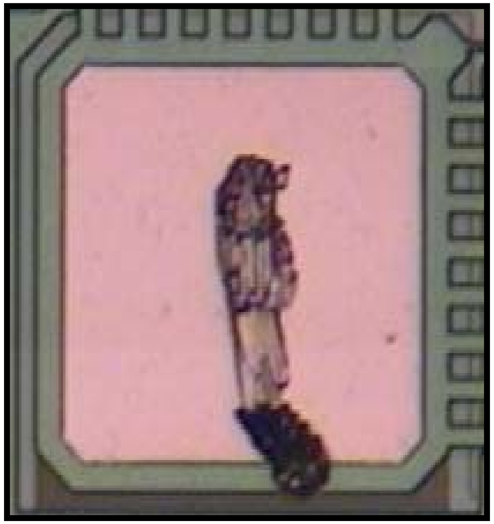
Debris is:

- A natural product of the probing process.
- Considered non-critical to device functionality

Automatic probe mark inspection systems have difficulty differentiating between defects and debris.



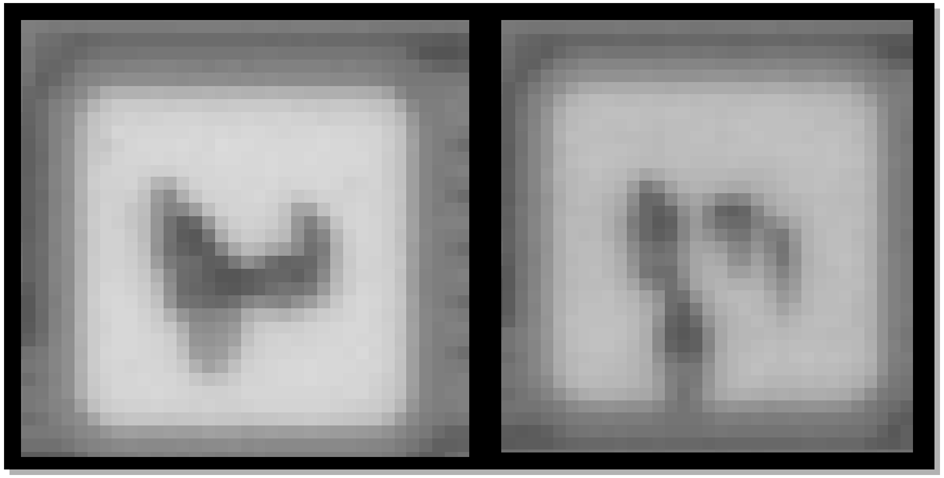
Real Probe Mark Edge Excursion



Aluminum Slag/Debris

Automatic Probe Mark Inspection for Debris

- Machine vision algorithms, using low magnification images, are not effective for distinguishing debris from probe marks.
  - At low mag, there are not enough pixels to provide enough gray scale information.



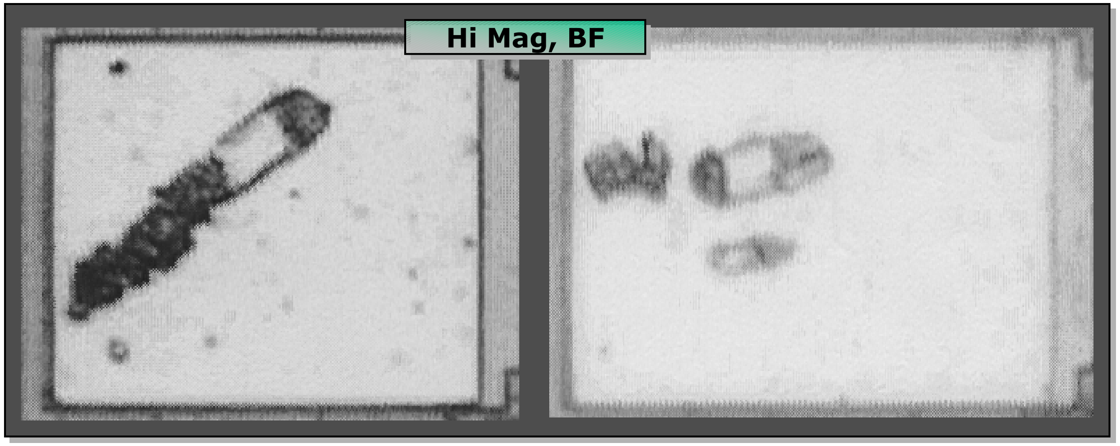
These images show low mag (3 um/pixel resolution) images of pads w/ possible size and proximity defects. It is impossible to tell whether debris is present or not.

Machine Vision-Based Debris Filter

Machine vision algorithms for differentiating debris from actual probe marks are difficult to create.

- Simple techniques based on color or brightness suffer from lack of robustness.
- Complex techniques based on shape and texture are slow and difficult for the user to tune.
- High magnification is needed, requiring a second inspection pass and reduced throughput.

Debris displays different visual characteristics

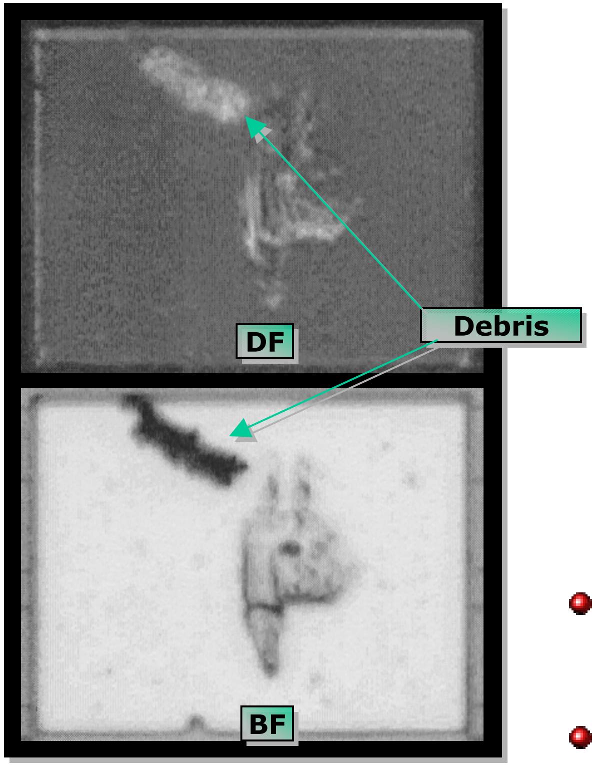


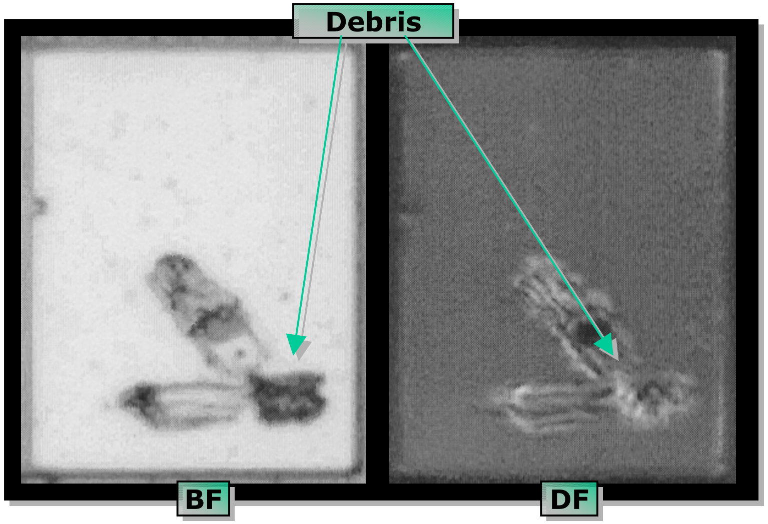
Debris is very dark & easy to distinguish from probe mark

Debris is much lighter & very similar to probe mark

Machine Vision-Based Debris Filter

Lighting techniques such as dark field illumination are generally unreliable for this type of detection.





- DF image (upper left) reflects light from debris, distinguishing it from probe mark.
- DF image (above) does not reflect light from debris, cannot distinguish debris from probe mark.

Statistical Debris Filter

Premises

1. Wafer probing excursions occur in a systematic manner as opposed to a random manner.

2. A statistical method of separating random (false) probing defects from systematic (true) probing defects can be used.

Based on these premises, two statistical debris filters were developed.

- Probe mark area debris filter
- Probe mark proximity debris filter

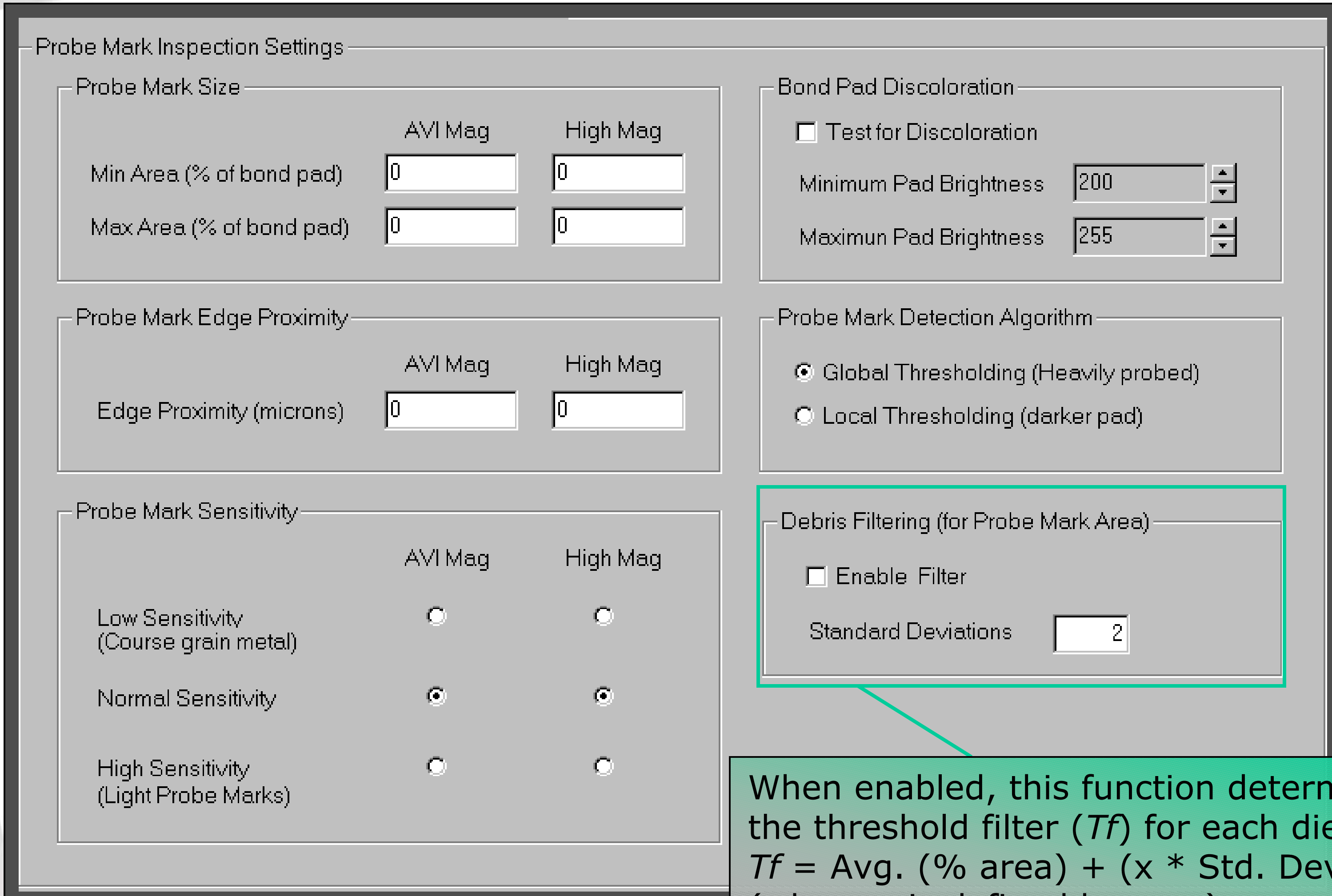
- **Probe Debris & Challenges to Automated Inspection**
- Statistical Probe Mark Area Filter
- **Statistical Probe Mark Proximity Filter**

Statistical Probe Mark Area Filter

Assumptions Made

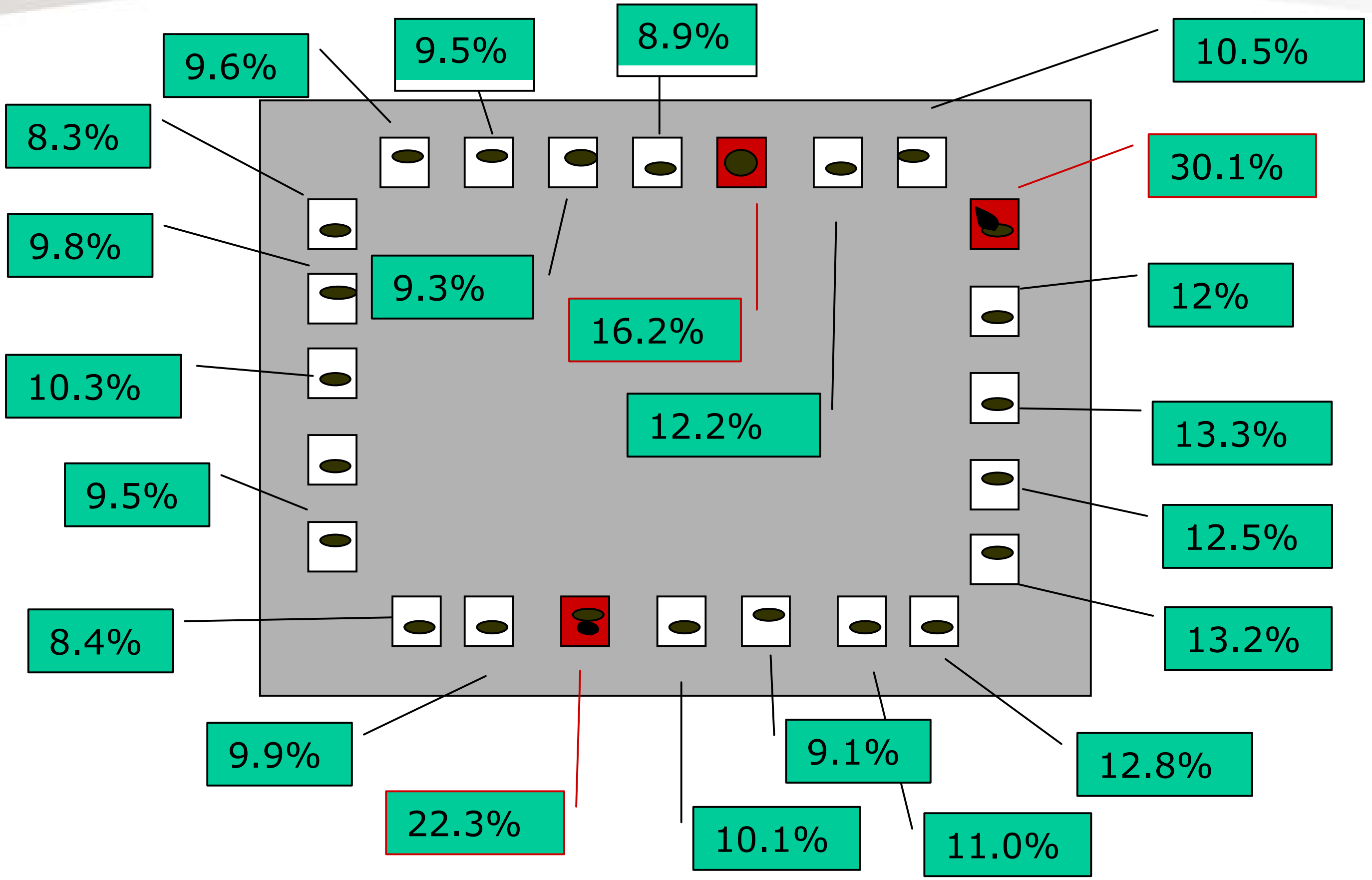
- All bond pads on one die have been subjected to the same number of touchdowns.
- There are five (5) or more bond pads on one die.
- Actual probe damage area will not differ in a statistically significant manner within one die.

Statistical Probe Mark Area Filter



When enabled, this function determines the threshold filter (*Tf*) for each die.
Tf = Avg. (% area) + (x * Std. Dev.)
(where x is defined by user)

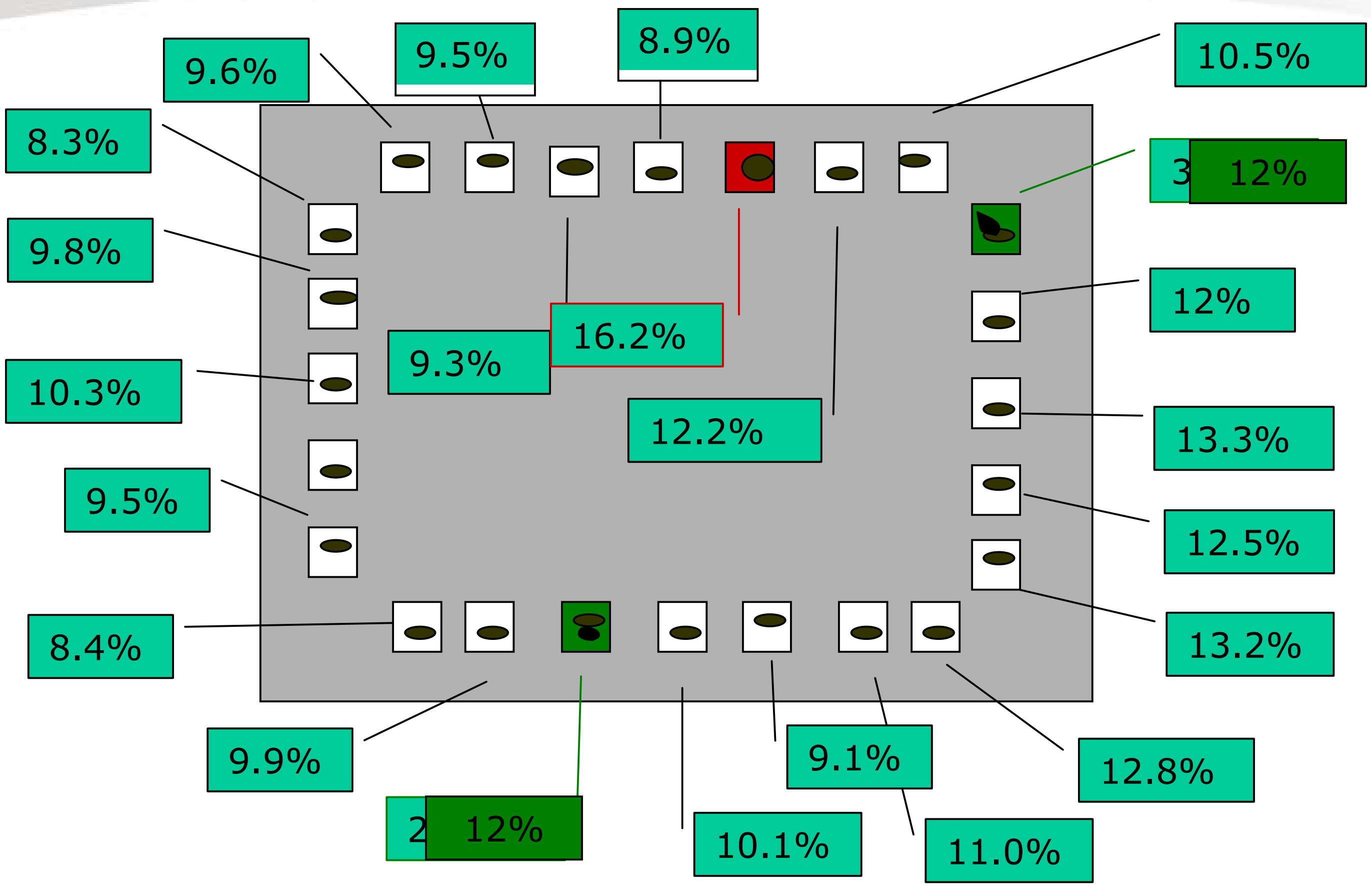
Probe Mark Area Inspection Without Filter



Max. area = 15%

Pad areas greater than max. area fail

Probe Mark Area Inspection With Filter



If pad area is greater than *Tf*, the value is changed to avg. and passed.

If pad area is less than *Tf*, but greater than max. area, the probe mark is failed.

Max. area = 15%

***Tf* = 17%**

Avg. = 12%

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Standard Deviations vs. Performance

Probe Debris Filter

Bond Pad	No Filter	2σ Filter	3σ Filter	4σ Filter
1	9.60	9.60	9.60	9.60
2	9.50	9.50	9.50	9.50
3	9.30	9.30	9.30	9.30
4	8.90	8.90	8.90	8.90
5	16.20	16.20	16.20	16.20
6	12.20	12.20	12.20	12.20
7	10.50	10.50	10.50	10.50
8	30.10	11.99	11.99	30.10
9	12.00	12.00	12.00	12.00
10	13.30	13.30	13.30	13.30
11	12.50	12.50	12.50	12.50
12	13.20	13.20	13.20	13.20
13	12.80	12.80	12.80	12.80
14	11.00	11.00	11.00	11.00
15	9.10	9.10	9.10	9.10
16	10.10	10.10	10.10	10.10
17	22.30	11.99	22.30	22.30
18	9.90	9.90	9.90	9.90
19	8.40	8.40	8.40	8.40
20	9.50	9.50	9.50	9.50
21	10.30	10.30	10.30	10.30
22	9.80	9.80	9.80	9.80
23	8.30	8.30	8.30	8.30

Average PM Damage %	11.9913
Std Deviation of PM Damage %	4.900919
Debris Filter 2 Std Deviations	21.79314
Debris Filter 3 Std Deviations	26.69406
Debris Filter 4 Std Deviations	31.59498

Choice of Std. Dev. will affect the performance of the Area Debris Filter:

- **If *Tf* is too small, there is potential for escapes.**
- **If *Tf* is too large, there is potential for false counts.**

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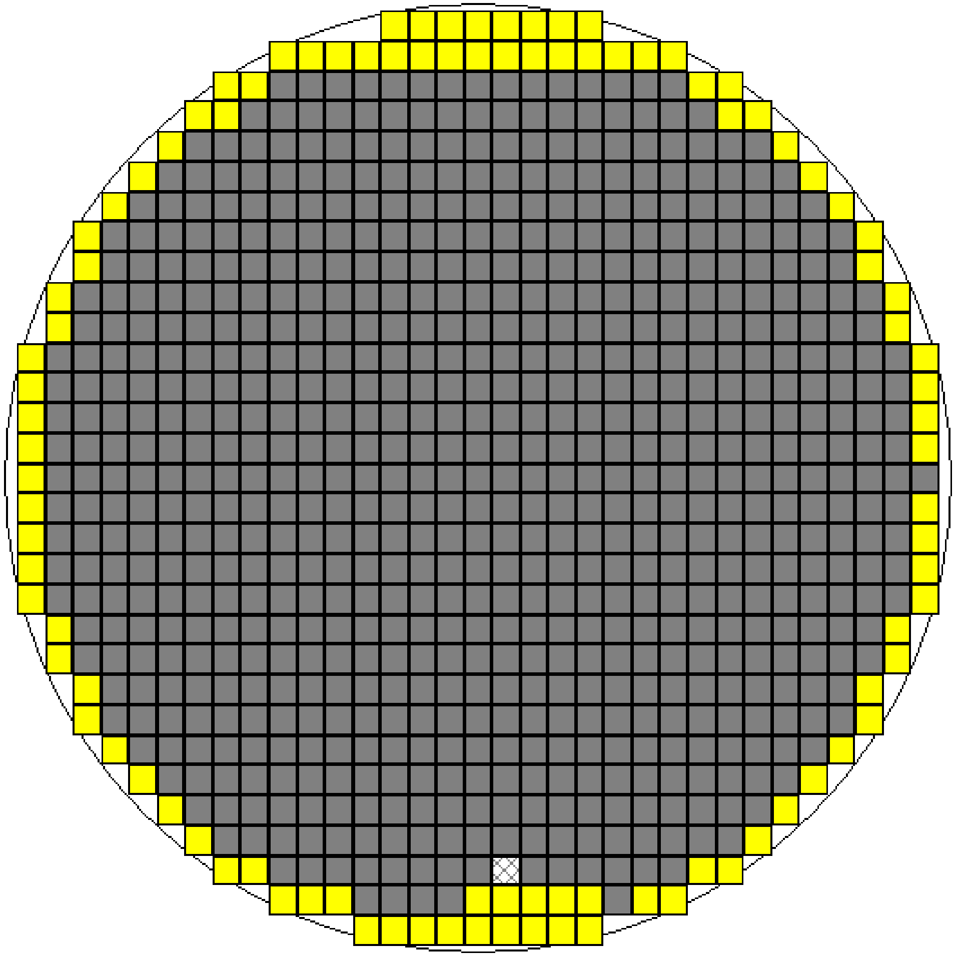
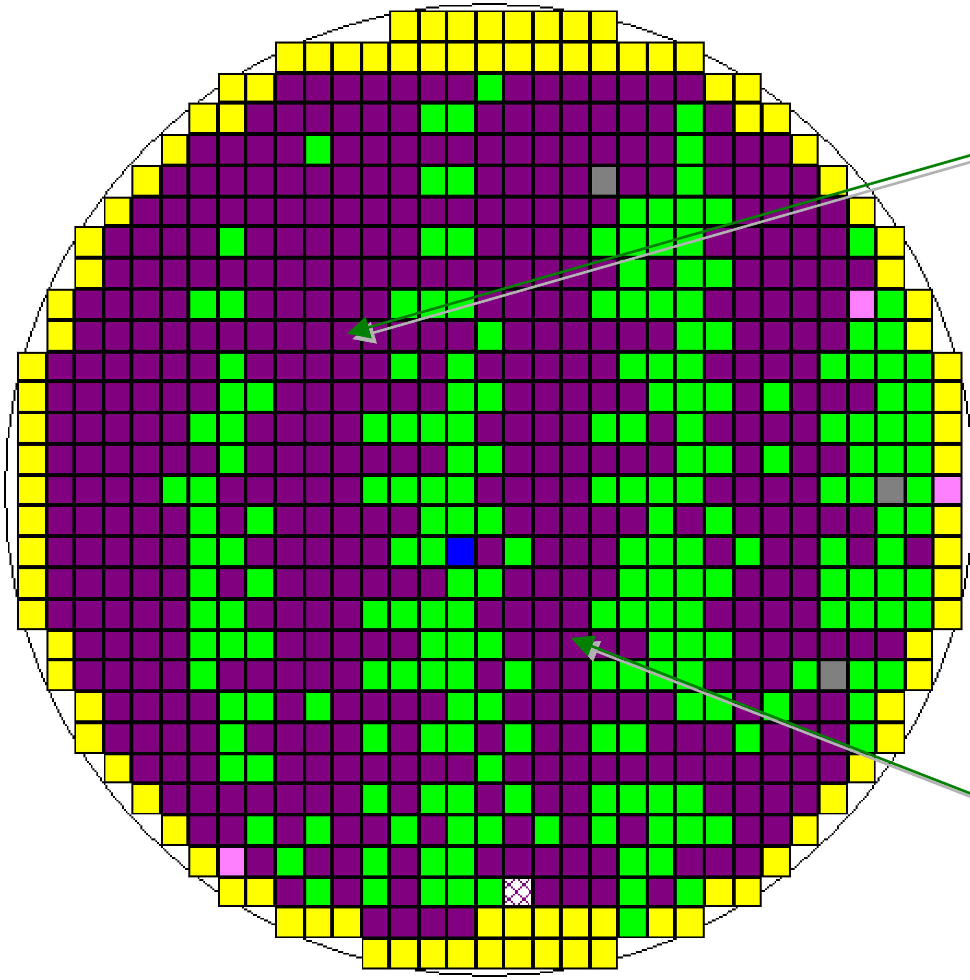
Parameters for Area Filter Test

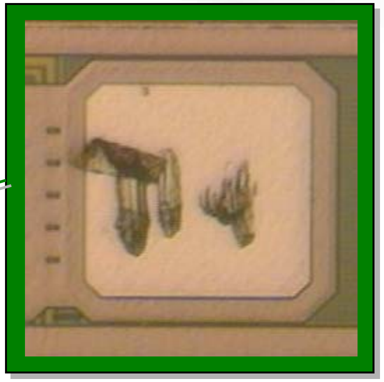


Wafer size:	**8-inch**
Inspected die:	**713**
Die size:	**5897um x 6349um**
Pads/die:	**38**
Max. area:	**25%**
Std. Devs:	**1.1**

Defect Map Without Area Filter

Probe Debris Filter





False "Too Big" Defects from Debris

Probe "Too Big"

Pass

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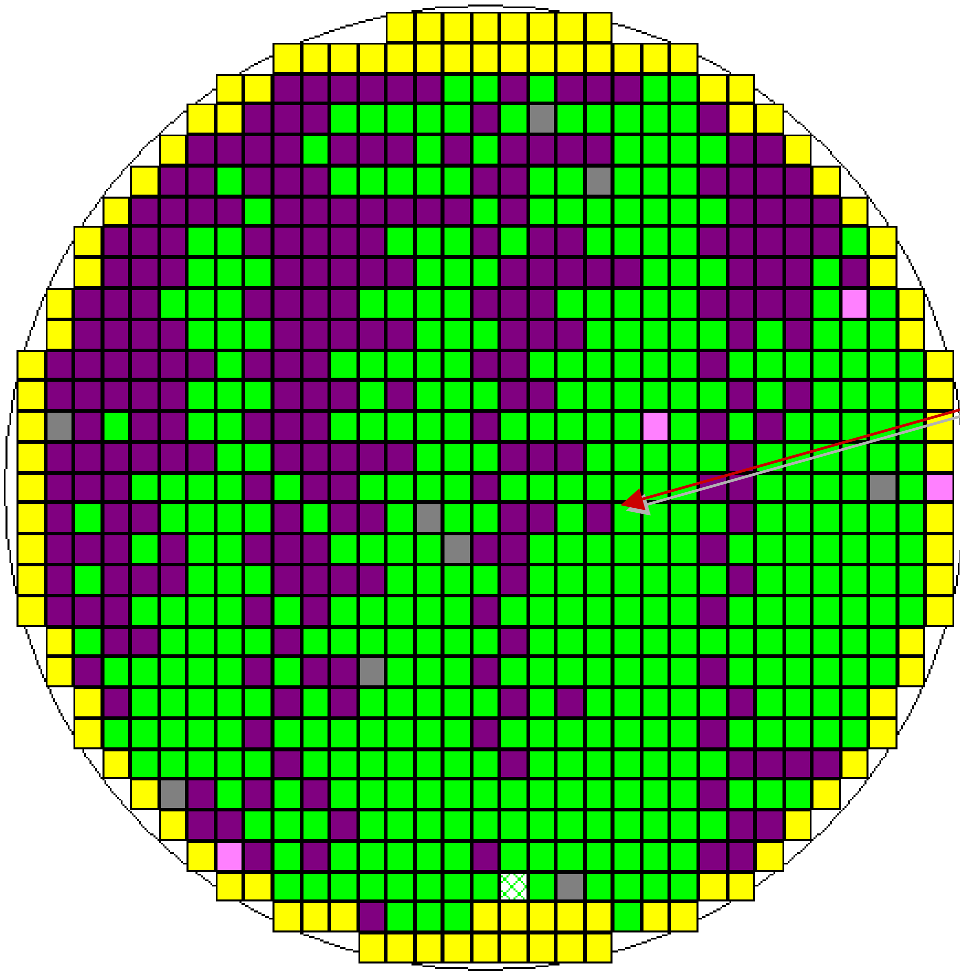
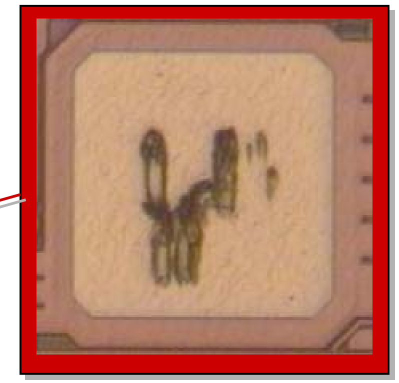
Defect Map With Area Filter

Probe Debris Filter



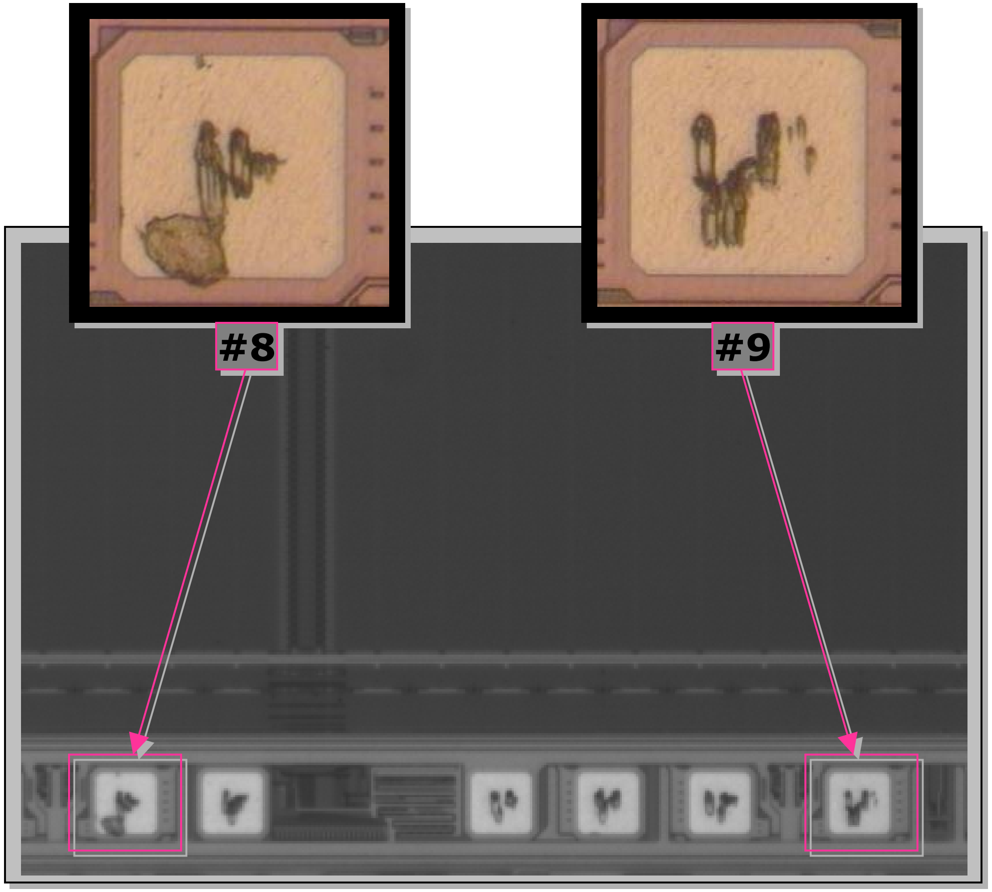


True "Too Big" Defect

Probe "Too Big"

Pass

Pad Areas Before & After Filter



Before Filter:
Pad #8 Fails
Pad #9 Fails

Measurement	Die	Area %	Area um square
6	0	23.203909	1409.305542
7	0	21.484575	1314.597412
8	0	28.773952	1746.843262
9	0	25.316364	1537.989868

After Filter:
Pad #8 Passes
Pad #9 Fails

Measurement	Die	Area %	Area um square
6	0	23.203909	1409.305542
7	0	21.484575	1314.597412
8	0	21.993752	1746.843262
9	0	25.316364	1537.989868

Statistical Probe Mark Area Filter

Advantages

- Easy to use – user only specifies filter threshold level
- Fast – filter does not reduce machine throughput
- Effective – debris which significantly increases the perceived probe damage area is automatically cleared
- Automatically adjusts to variability of probing process - a well controlled process will have a lower standard deviation, resulting in a tighter debris filter threshold.

Disadvantages

- Not effective for small debris which does not significantly increase the probe damage area but does occlude the bond pad edge. This can create false probe mark position rejects.
- May cause escapes if one probe needle creates a significantly larger damage area than other probe needles.

- **Probe Debris & Challenges to Automated Inspection**
- **Statistical Probe Mark Area Filter**
- **Statistical Probe Mark Proximity Filter**

Statistical Probe Mark Proximity Filter

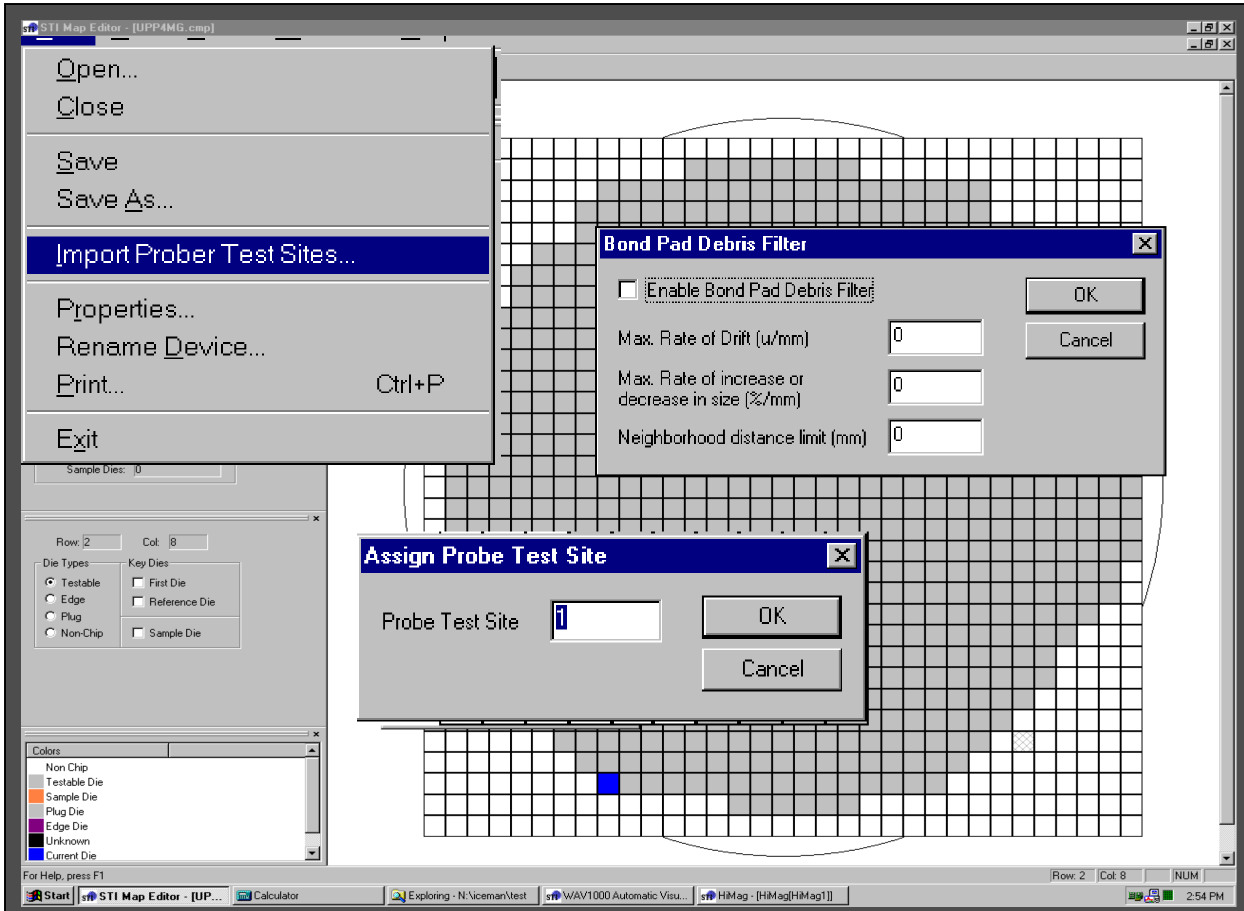
Assumptions Made

- The probe mark created by a particular probe needle will not vary significantly in size or position within a small index distance on the wafer.
- A large variation in probe mark position or size within a small index distance on the wafer is caused by debris.

Statistical Probe Mark Proximity Filter

Probe Debris Filter

Software algorithm compares die to “adjacent” die of same probe site based on probing configuration.



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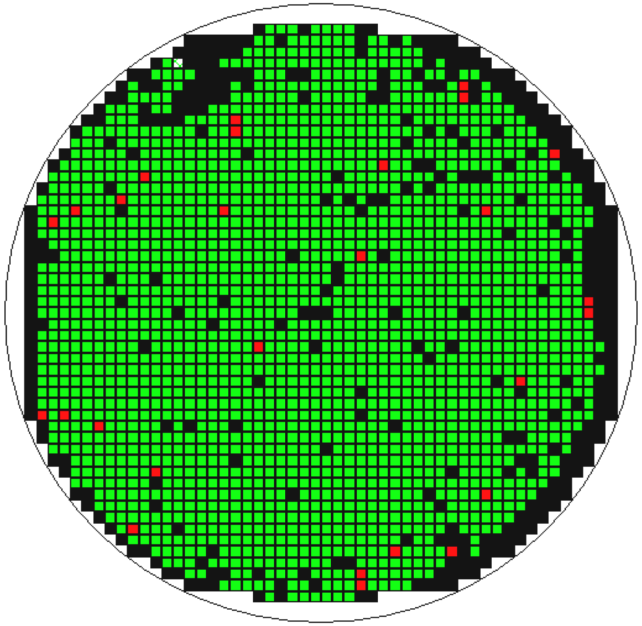
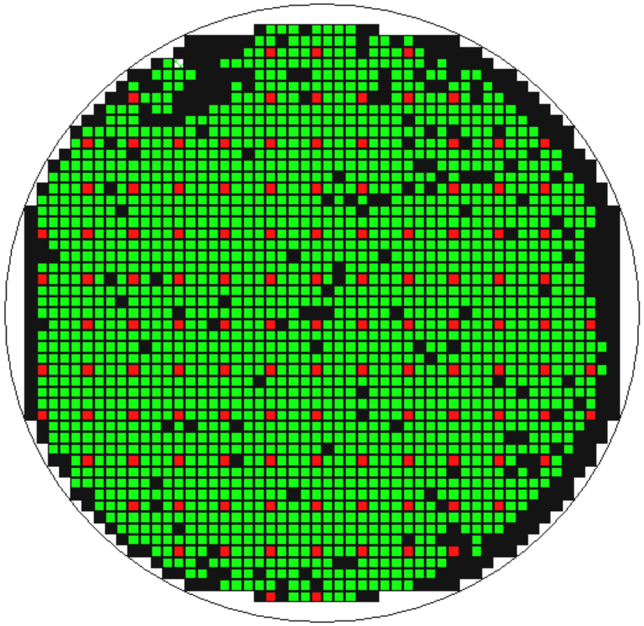
Statistical Probe Mark Proximity Filter

- If the defect is caused by a needle error, it will occur in the probe configuration pattern across the wafer
- If the defect is caused by slag/debris, it will be a random occurrence and will not match the probe mark signatures of the adjacent die of the same probe site

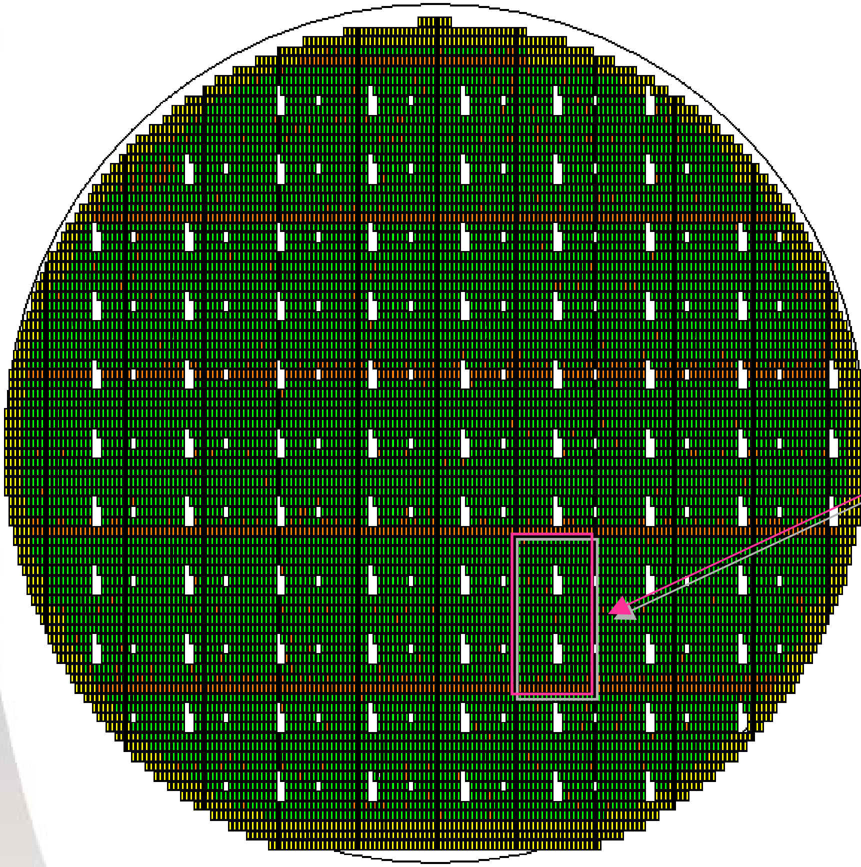


Random Occurrence



4,4 Probe Configuration Pattern

Parameters for Proximity Filter Test



Wafer Size:	**6-inch**
# of Inspected Die:	**11633**
Die size:	**762um x 1702um**
Edge Proximity:	**15um (inside edge)**
Probe Test Site:	**16**
Max. Rate of Drift:	**1um/mm**
Max. Rate of Increase/decrease:	**1%/mm**
Neighborhood Distance Limit:	**30mm**

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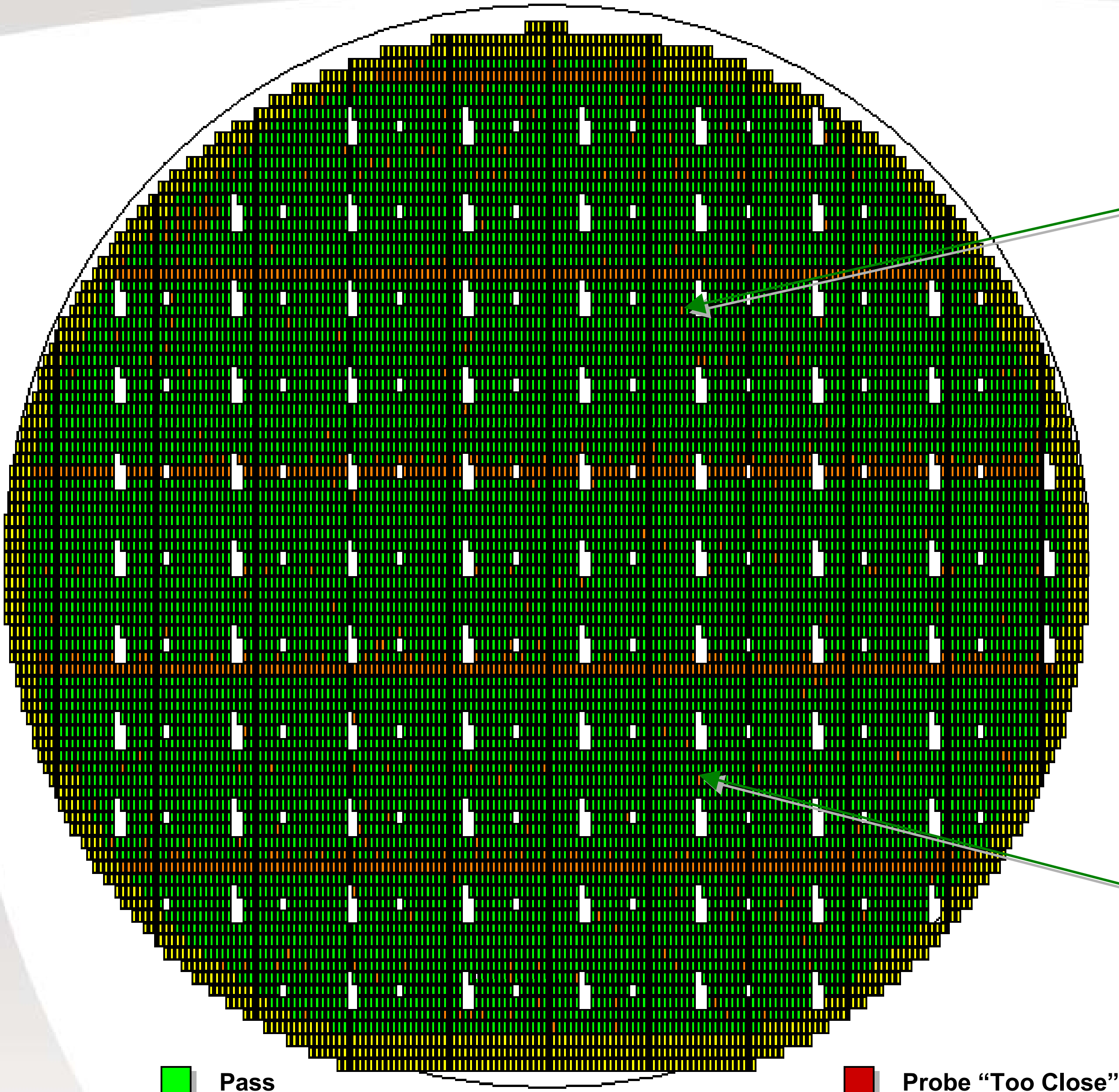
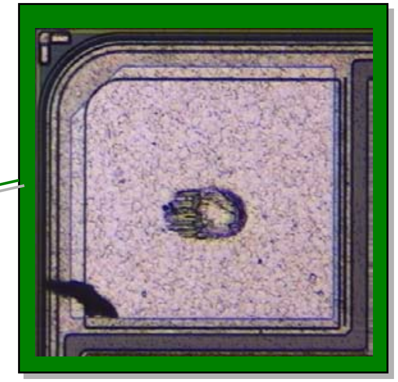
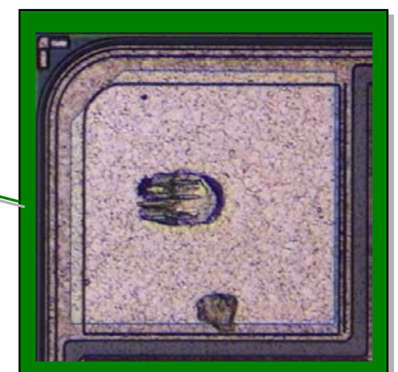
Probe Debris Filter

Defect Map Without Proximity Filter



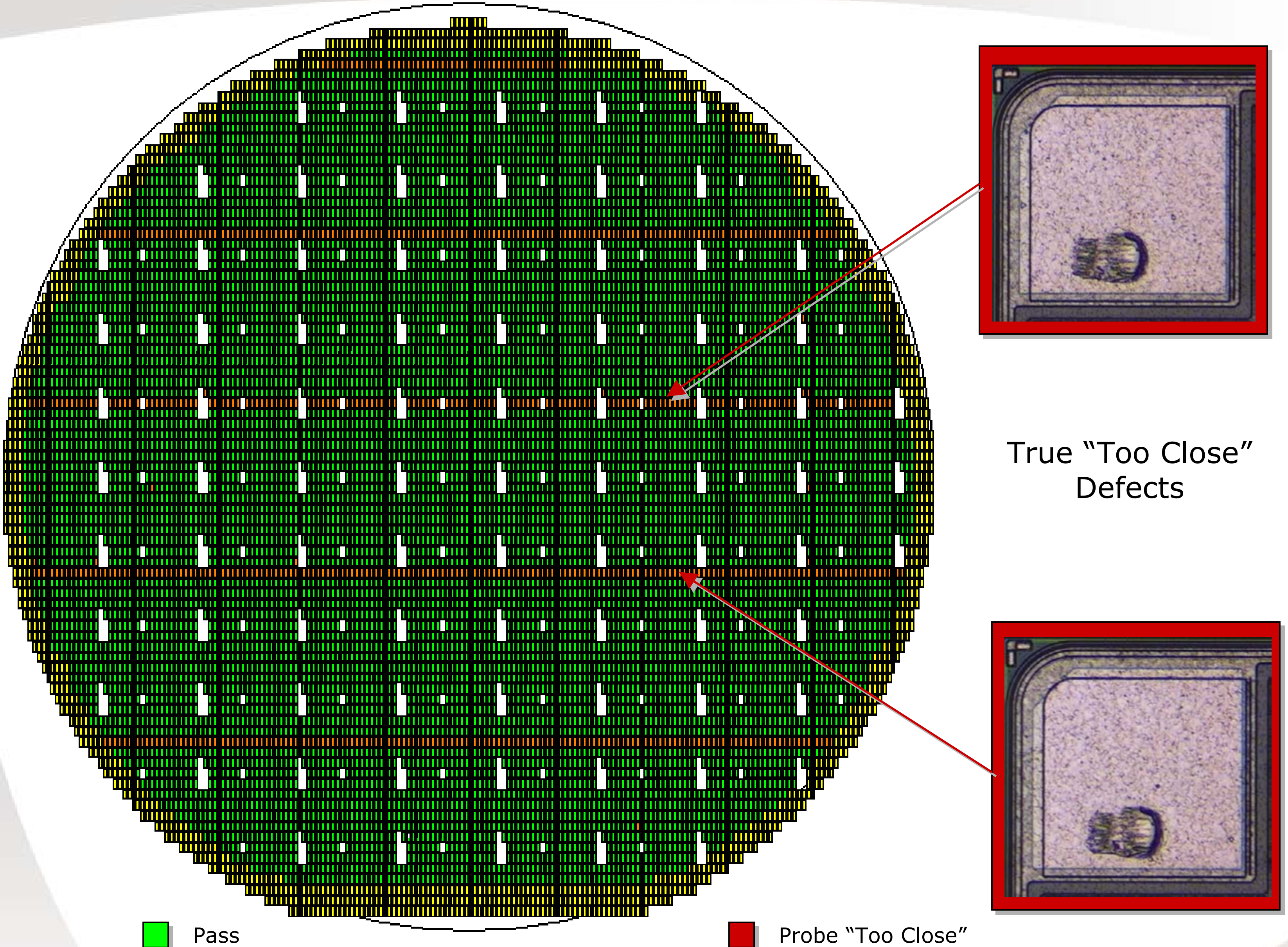


False “Too Close” Defects from Debris



Defect Map With Proximity Filter

Probe Debris Filter



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Statistical Probe Mark Proximity Filter

Advantages

- Fast – filter does not reduce machine throughput
- Effective for large and small debris – debris which does not significantly increase the probe damage area but does occlude the bond pad edge is automatically cleared based on position variation.
- Does not cause escapes if one probe needle creates a significantly larger or out of position mark compared to other probe needles.

Disadvantages

- More difficult to set-up than area filter - requires test site information to be imported from prober map file or manually entered.
- Not easily implemented for wafer probing processes which use multiple probing steps and multiple probe card configurations.
- Not statistically accurate if very large-array probing patterns are used (i.e., 4 – 6 touchdowns per wafer).
- Random sampling may not work with this filter if the sample plan is too sparse.

Acknowledgements

- These data were generated on a WAV 1000 Sprint automated inspection system.
  - Magnifications for inspections before & after debris filter were at 3µm/pixel for Area Debris, 5µm/pixel for Proximity Debris.
  - Algorithms used for statistical debris filtering are present on the WAV 1000 Sprint in the software option “Probe Debris Filter” (PDF)

WAV 1000 Sprint

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