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DIE CRACK PREVENTION AND DETECTION IN ADVANCED PACKAGING

KGD 2020

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onto innovation™

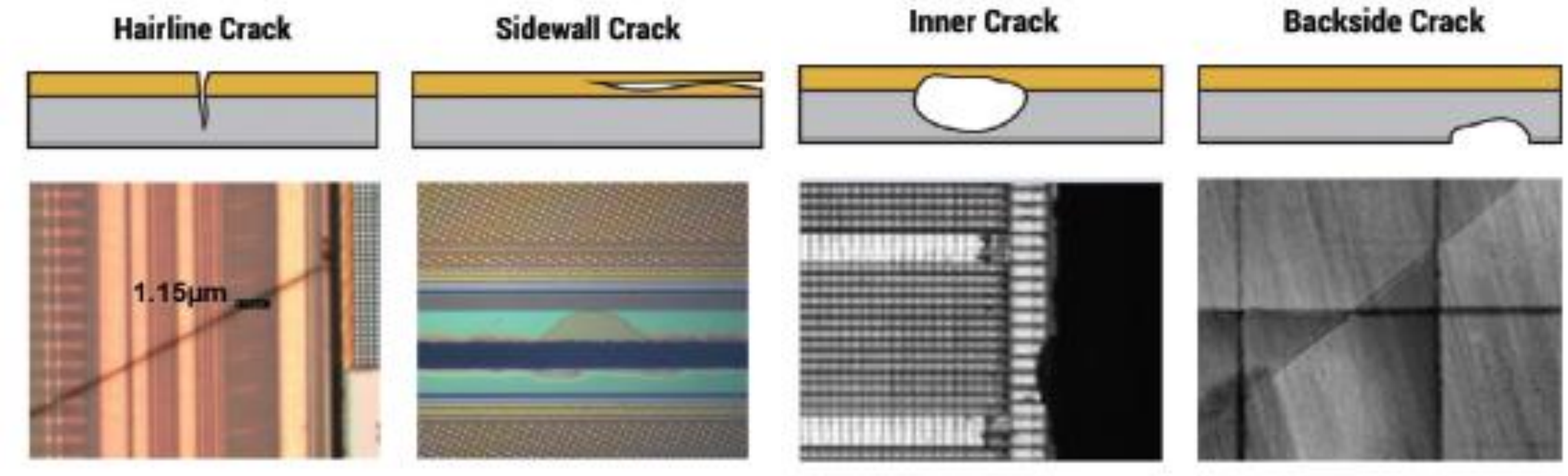
Outline/Agenda

- Introduction
- Discussion Topics
- Results of Experiments
- Conclusions
- Q & A

Introduction

- As more chips are integrated vertically, overall package thickness increased as well and the common ways to reduce the overall package thickness are by thinning chips or die and reducing bump sizes.
- As die or chips are getting thinner, they become more fragile and susceptible to cracks or chippings after sawing process.
- Wafers are grinded as thin as 50um for vertical integration currently.
- Cracks or chips can reduce the final package yields or cause long term reliability issues in the consumer devices.
- Highest possible die quality is essential to make any KGD / advanced packaging approach work.
- These cracks are not easy to detect with the traditional BF and DF illumination optics from the wafer surface. Need new imaging method to detect these types of cracks.
- The traditional method to inspect for these cracks is to take images from side on each die. Pick & Place machine picks up each die after singulation and takes images from all four sides to see if cracks can be seen.
- Time and cost can be greatly reduced if these cracks can be prevented or detected prior to pick & place operations.

Die Crack Types



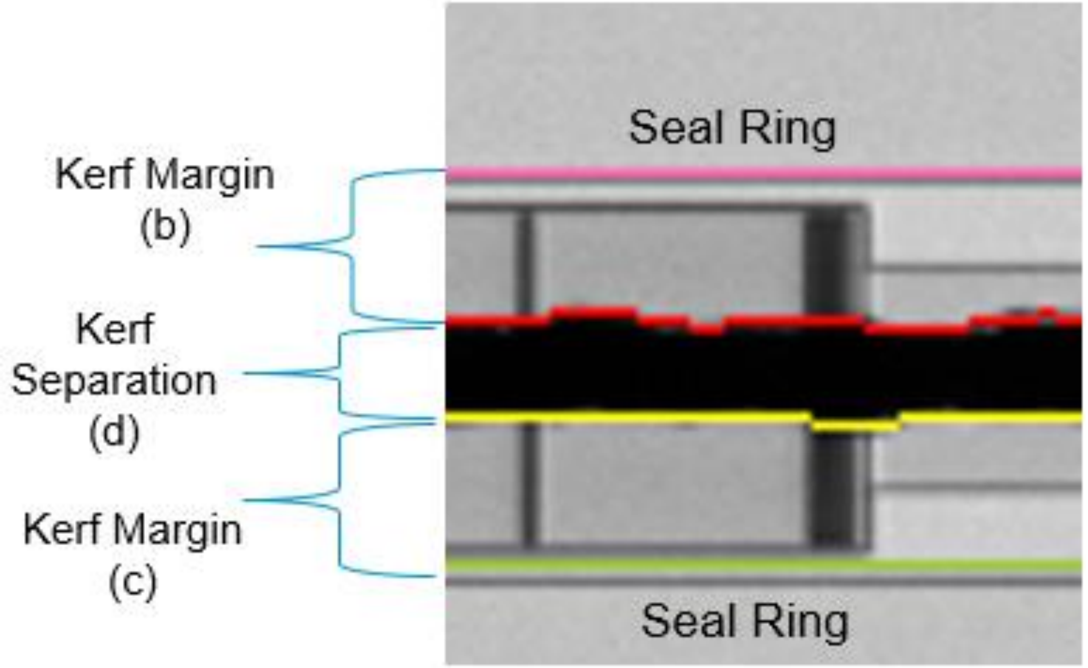
All of these cracks are initiated by sawing!

Sample Die Crack Images (Side View)

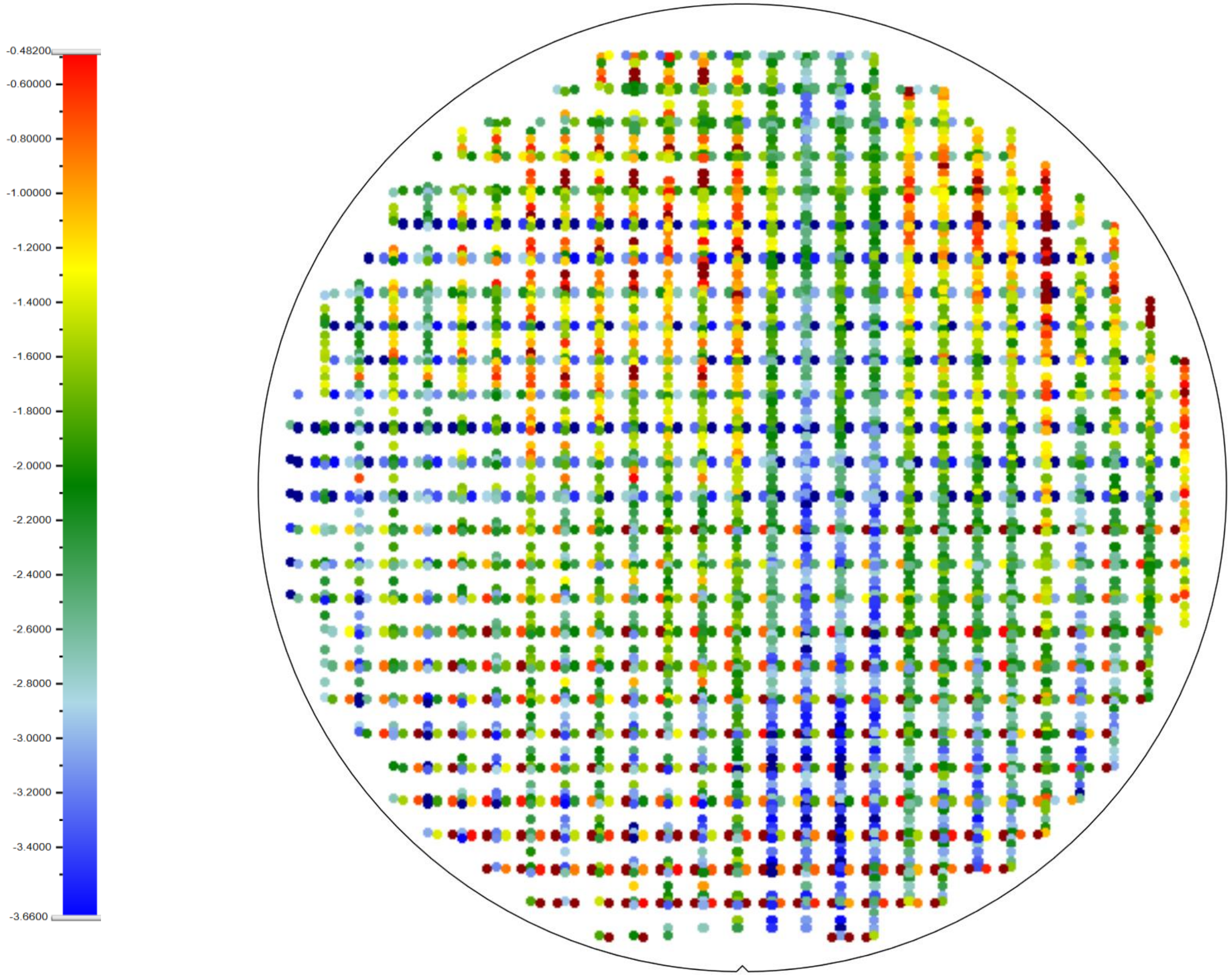
KERF Metrology / Inspection (Crack Prevention)

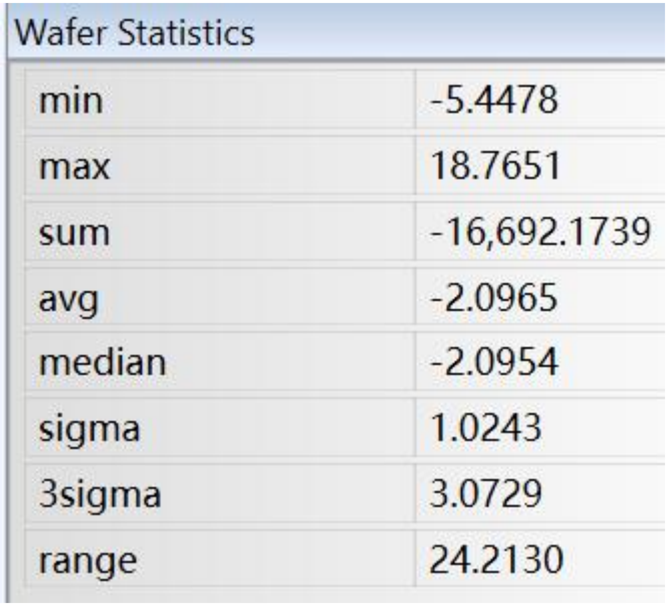
The best prevention for die cracks is sawing process control

- Kerf Margin measures how much material is left outside the die after singulation.
- Kerf Width measures how much material was removed by singulation. It requires an accurate determination of the whole wafer street width before singulation.
- Kerf Position measures the distance between the actual cut and the street center. Ideally, the cut should occur in the center of the street.
- Kerf Separation is the distance between the cut edges of two neighboring die. It indicates how far apart the two dies moved during expansion. This is sum of film expansion and how much material was removed



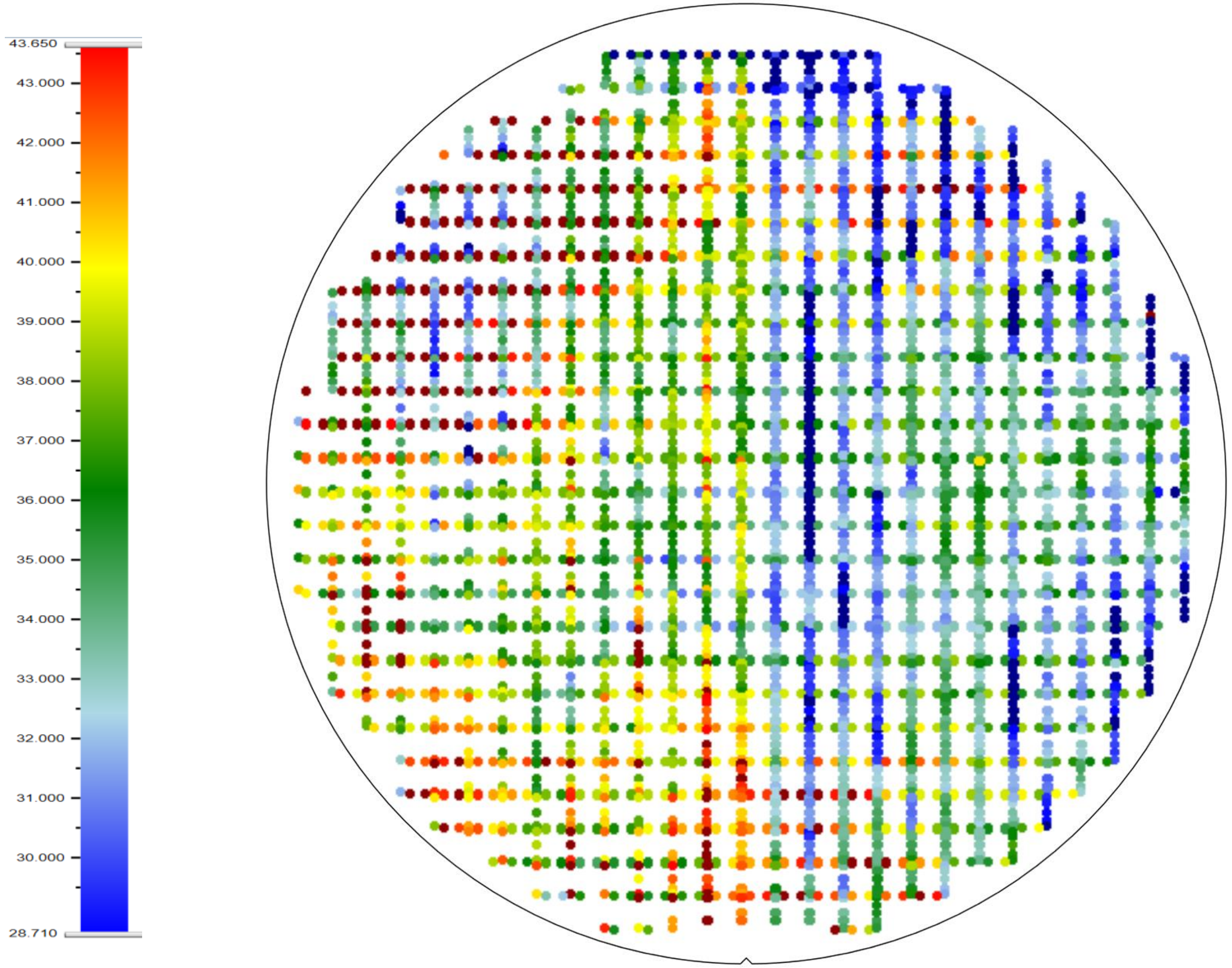
KERF Position Color Map

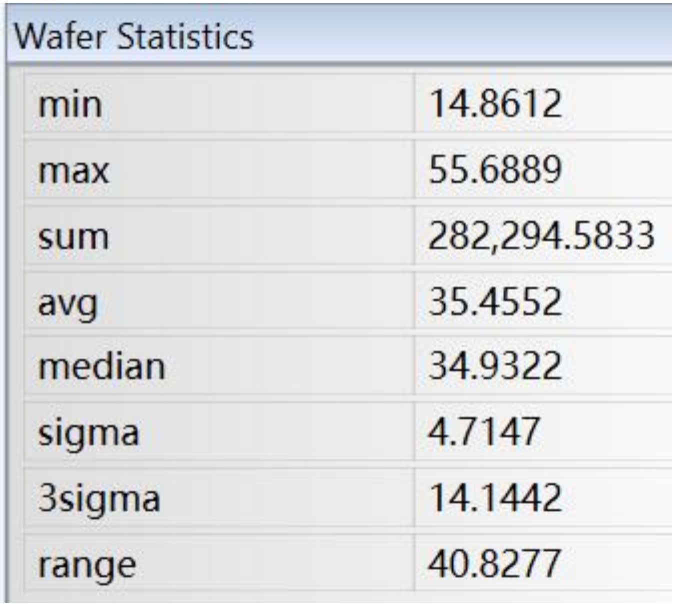




Wafer Statistics	
min	-5.4478
max	18.7651
sum	-16,692.1739
avg	-2.0965
median	-2.0954
sigma	1.0243
3sigma	3.0729
range	24.2130

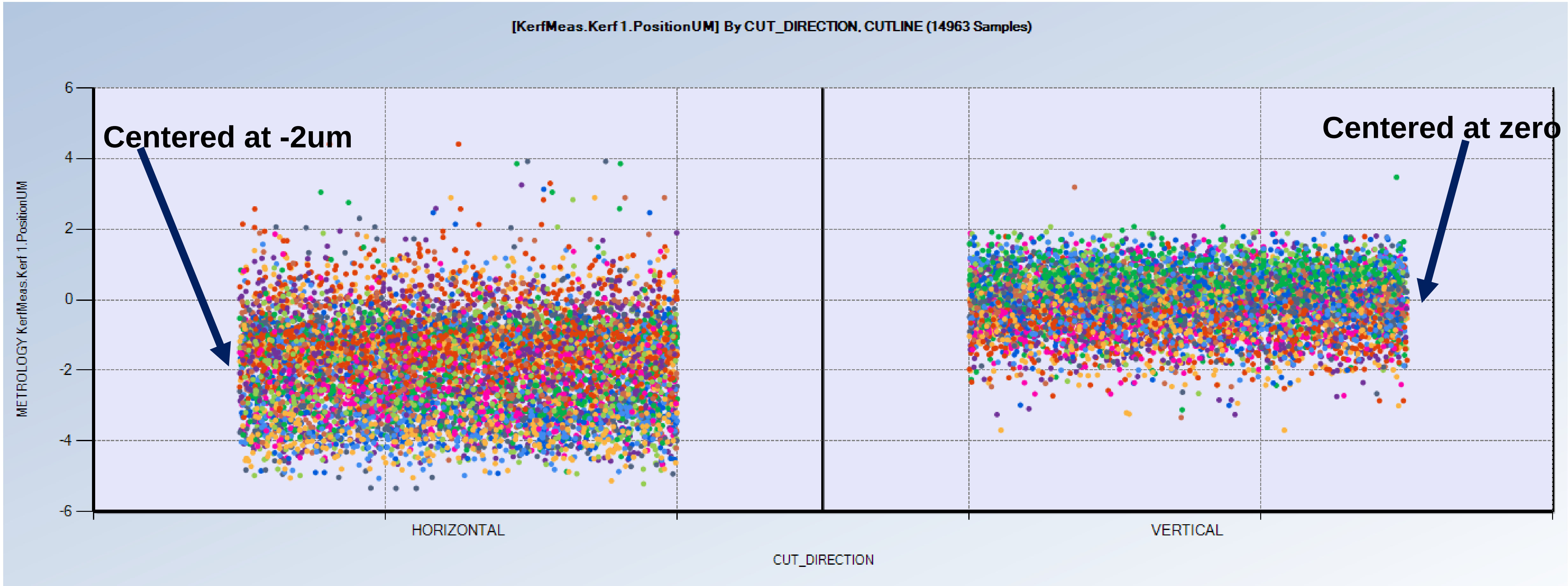
KERF Separation Color Map





Wafer Statistics	
min	14.8612
max	55.6889
sum	282,294.5833
avg	35.4552
median	34.9322
sigma	4.7147
3sigma	14.1442
range	40.8277

KERF Position Variation By Cut Direction

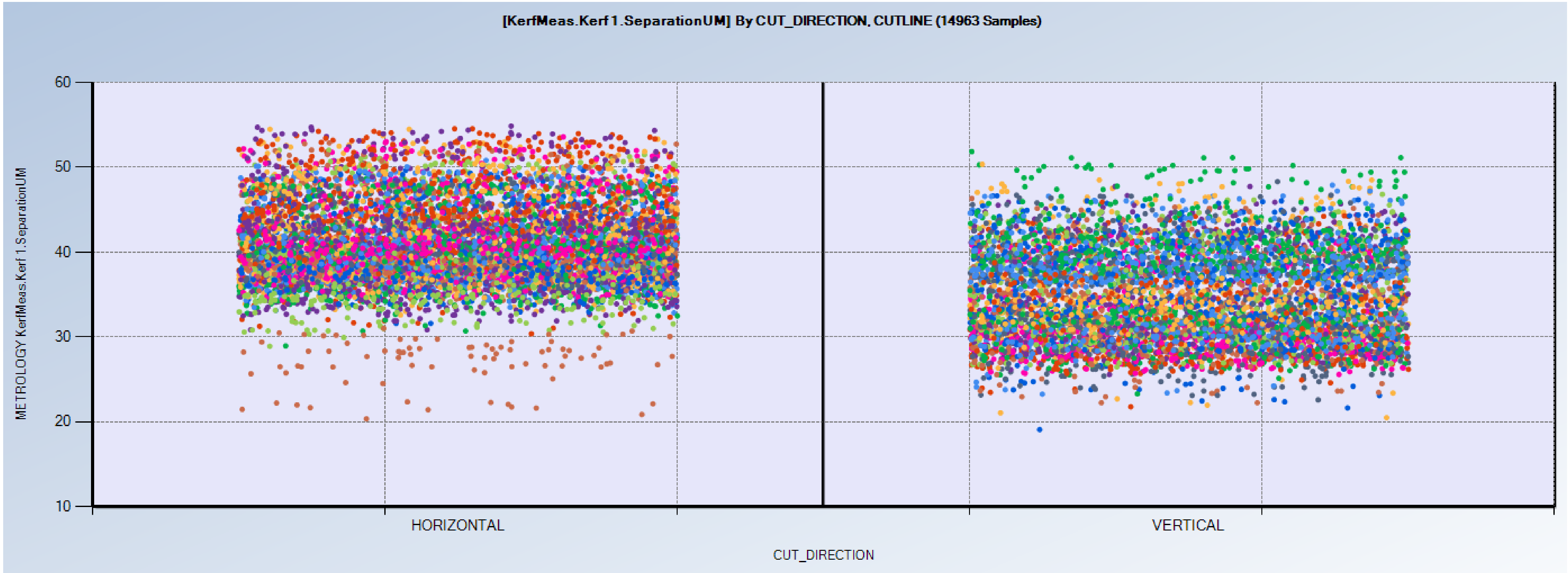


Centered at -2um

Centered at zero

It can be seen that the positional accuracy is centered at zero for vertical cuts while the horizontal cuts are centered at -2um. Also, the verticals cuts have less positional variation than the horizontal cuts.

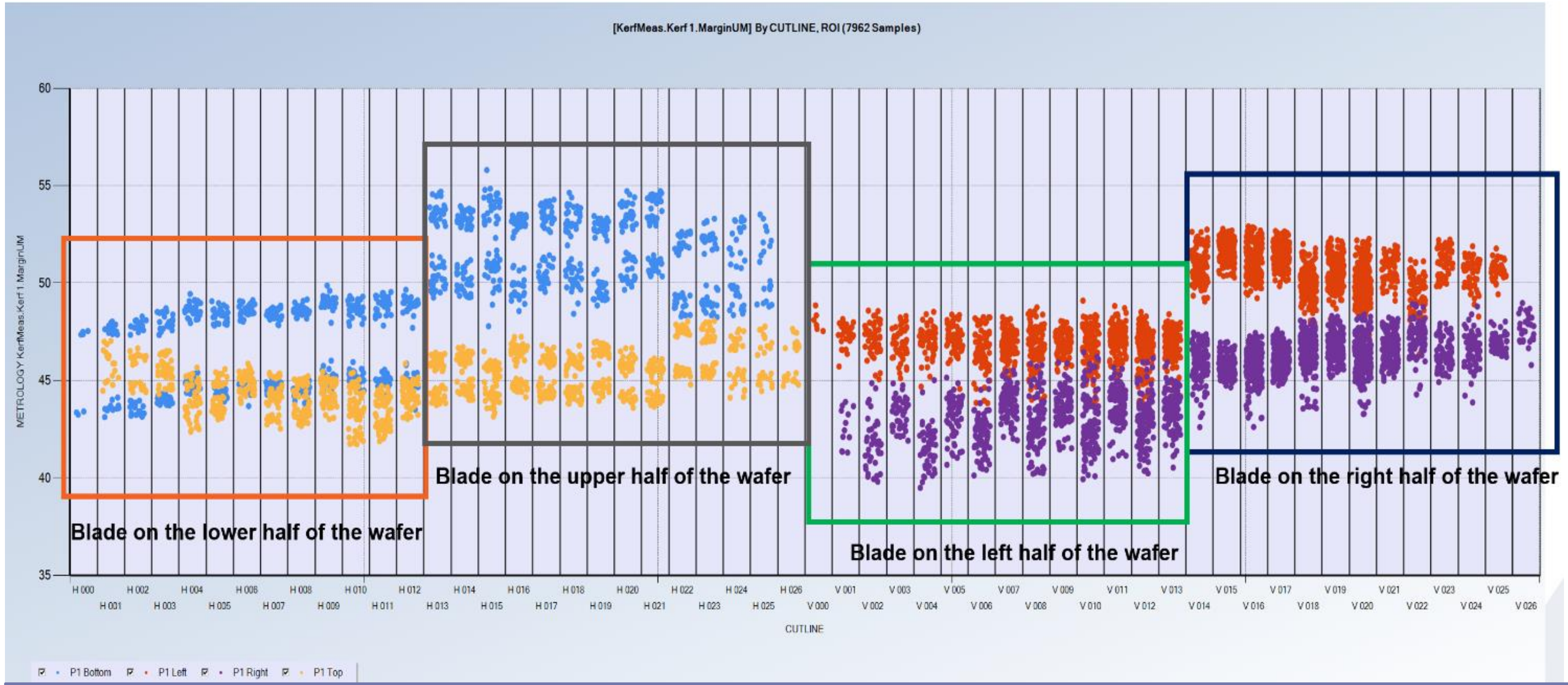
KERF Separation Variation By Cut Direction



It can be seen that the KERF separation in the vertical direction is about 10um smaller than that of the horizontal direction.

KERF Metrology –

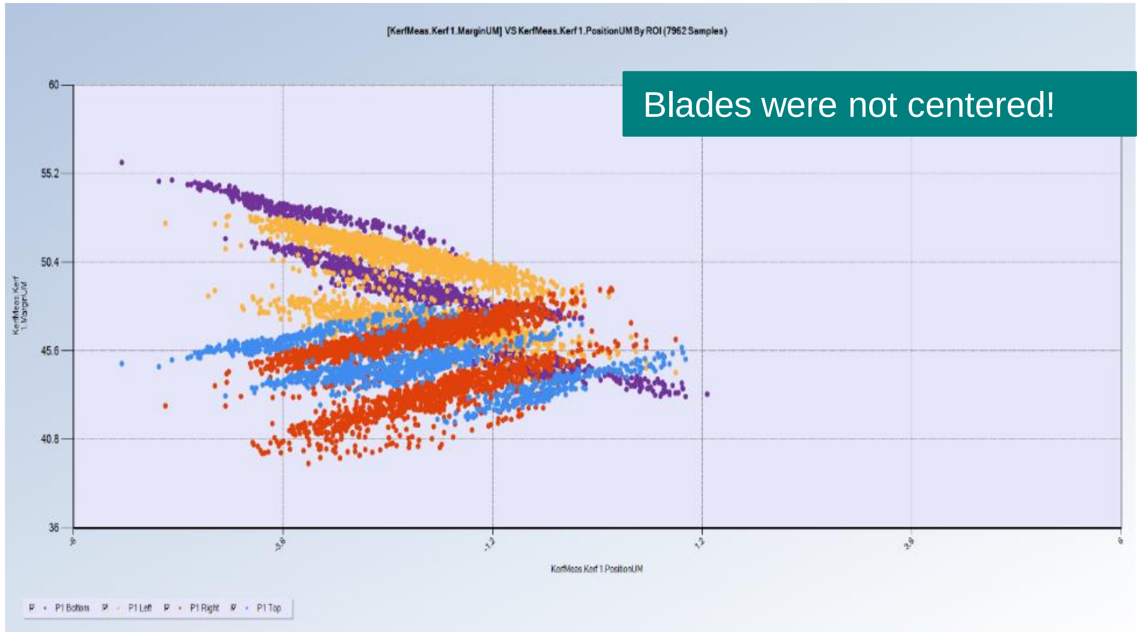
Kerf margin distribution by cut lines



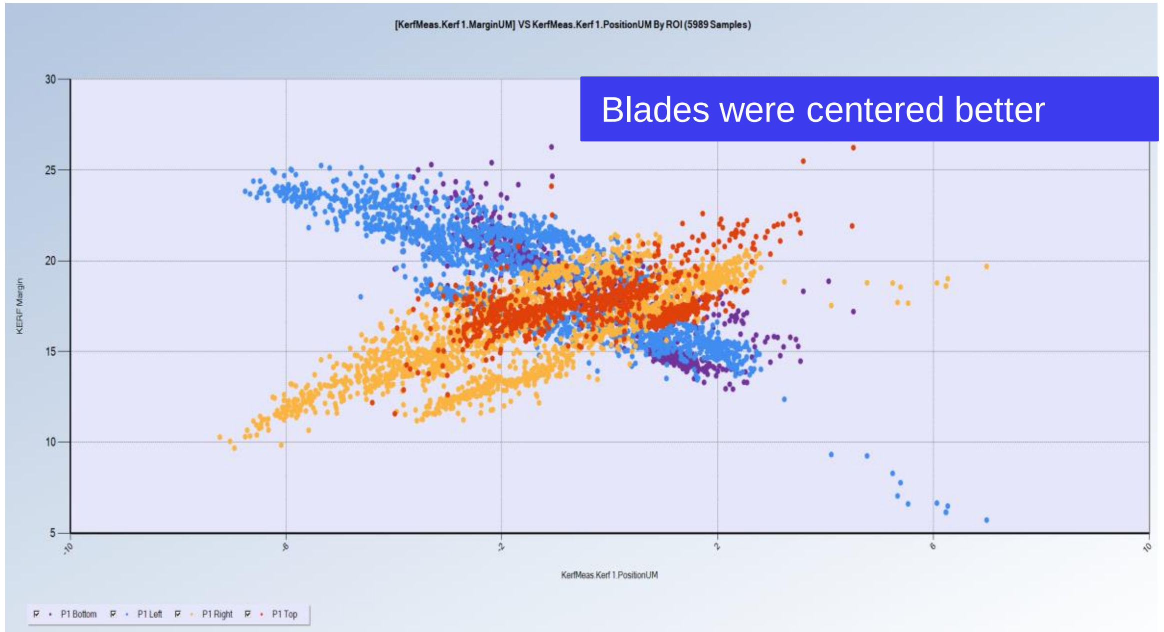
Clear signature of two blades (vertical cuts) between the left and the right side of the wafer can be seen here.
The blade on the left side of the wafer was better centered in the middle of KERF compared to the blade on the right side of the wafer.
The margins between the left and right side are closer to each other on the left side compared to the margins on the right side of the wafer. Also, it can be seen that more raw materials were removed on the left half of the wafer compared to the right half of the wafer.

KERF Metrology

Correlation between KERF margin and KERF position



Blades were not centered!



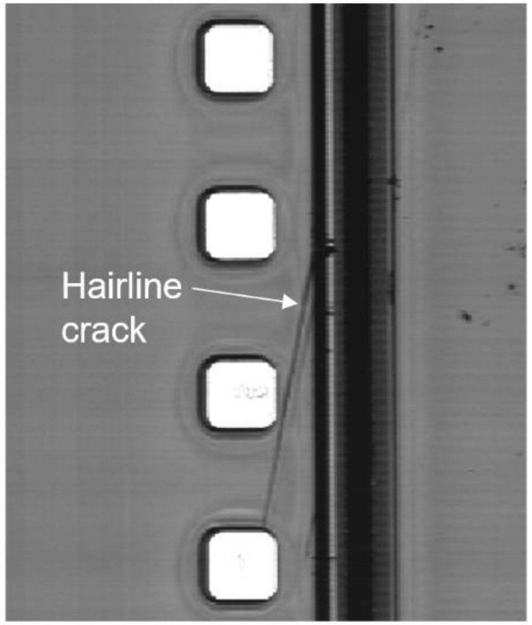
Blades were centered better

It can be seen that all the data has negative values for KERF position.
It is indicating that the blades were not centered in the center of KERF for both cut directions.
For horizontal cuts, the blades were placed slightly higher than the center of KERF.
For vertical cuts, the blades were placed slight right to the center of KERF.

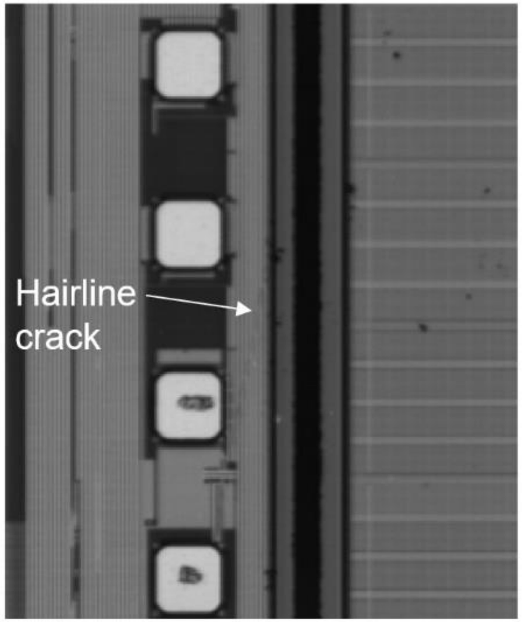
Hairline Cracks

Topography-based image can improve the apparent size and the contrast of the hairline cracks.

Bright Field Color Image



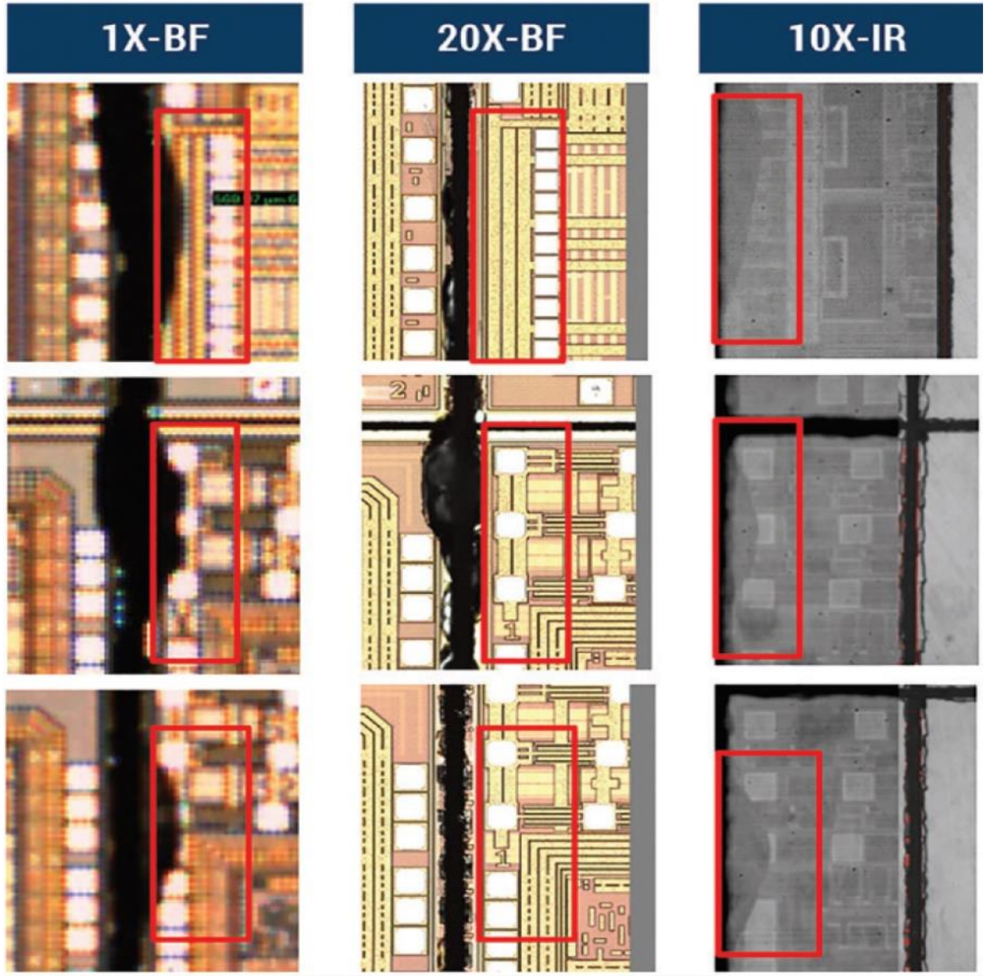
Height Topography Image



IR Image

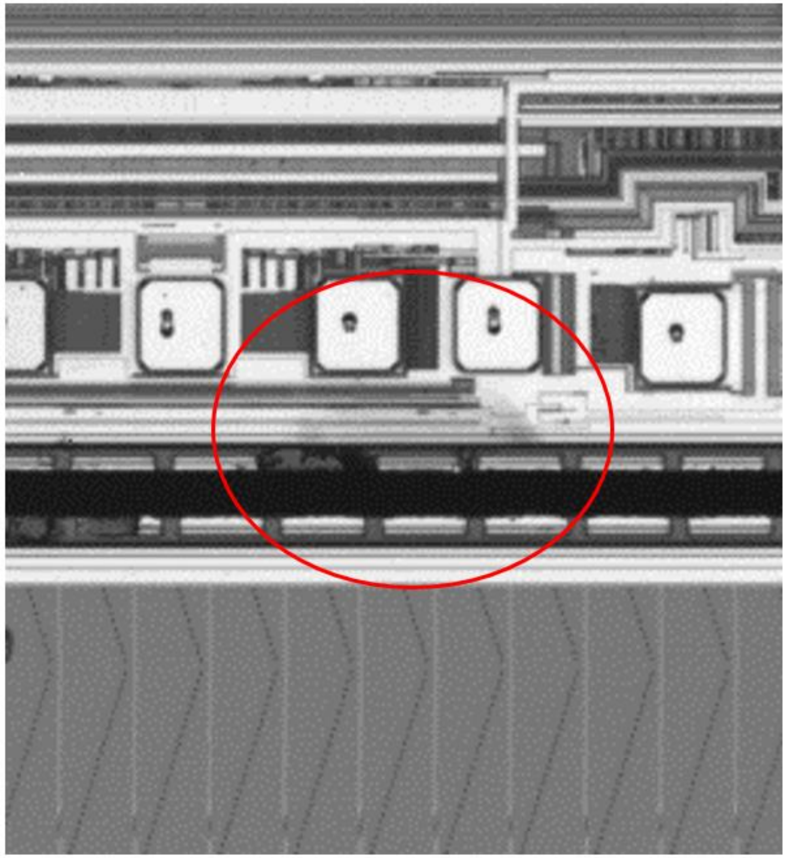
The image on the left is raw bright field color image of the hairline crack. The crack has less than 3 GSV contrast from the background. The image in the middle is the same crack captured with the new height topography sensor and it has over 70 GSV contrast. The image on the right is an IR image of the same crack and it confirmed that the crack is real.

Sidewall / Inner Cracks

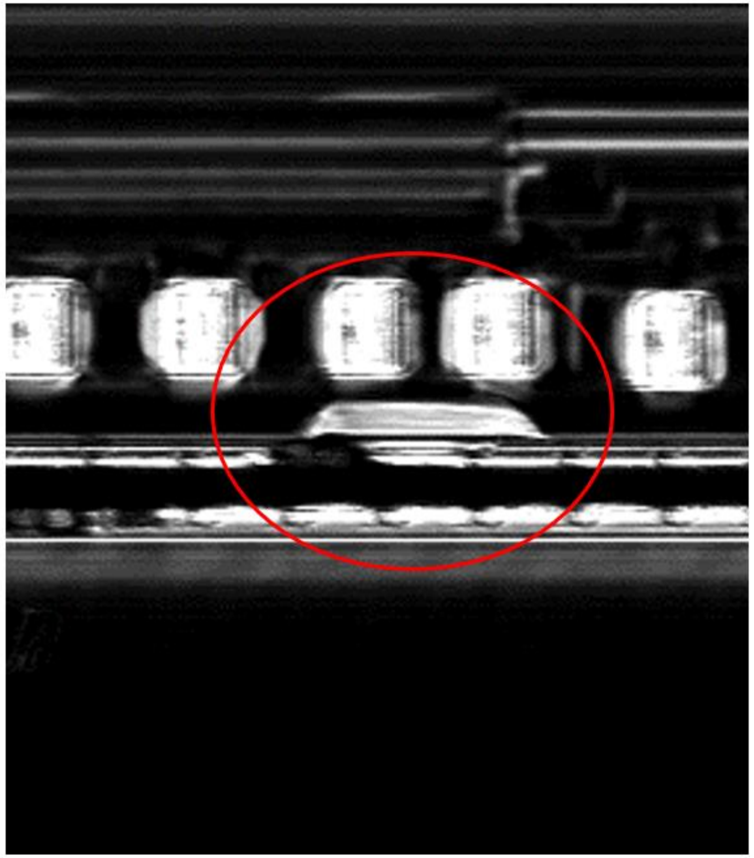


- Sidewall or inner cracks can be challenging to detect because they mostly occur below the die surface.
- In these images, their appearance changes with magnification, seeming to be more extensive at 1X and smaller at 20X.
- IR images look through the pattern on top of die and can provide crucial confirmation of their existence and extent.

Sidewall / Inner Cracks



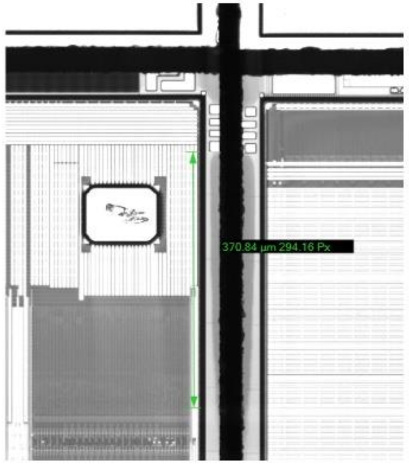
IR Image



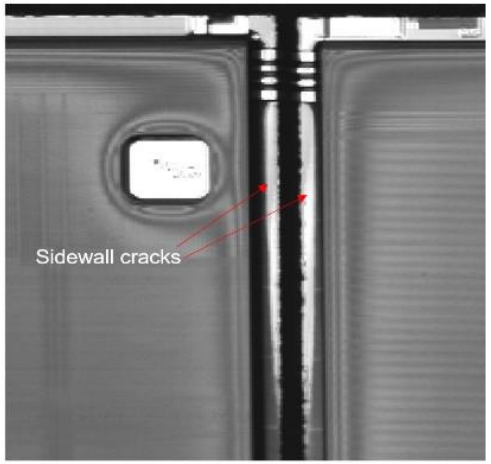
Height Topography Image

Presence of an inner crack underneath the die surface can be confirmed with the IR image. However, the contrast of the inner crack is very low since it is underneath the surface and such defects are difficult to detect.
Unlike the IR image, the same inner crack has over 200 GSV contrast.

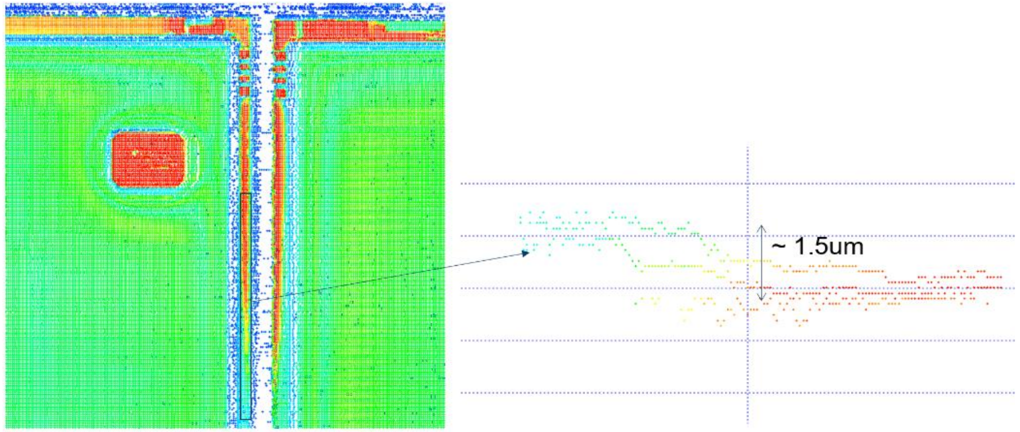
Sidewall / Inner Cracks



Brightfield Image



Height Topography Image



Height Topography Raw Plot (Top View)

5X Height Topography Raw Plot (Side View)

Sidewall cracks can be seen on both the bright field image on the left and the new height topography image on the right.

However, the contrast of the cracks are much greater on the topography-based image than the contrast on the brightfield image.

The side view of the crack confirmed that the cracked area is about 1.5µm lower than the non-cracked area of the street.

Conclusion

- Die cracks such as hairline cracks, sidewall cracks, and backside cracks may not show up during electrical tests but such cracks can cause field failures and adversely impact real world reliability issue.

- With introduction of advanced packaging and vertical stacking of dies, wafers are grinded to below 50um and susceptible to cracks more than ever.

- Highest possible die quality is essential to make any KGD / advanced packaging approach work.

- Detecting die cracks is essential in high reliability applications like automotive where there are significant safety and liability concerns.

- Proven solutions exist for in-line crack detection in high volume manufacturing. The solutions described in this presentation such as KERF metrology/inspection, hairline crack, inner crack, backside crack inspection, IR image sensor, topography based image sensor combine software and hardware to improve the wafer sawing process control and increase the sensitivity to detect such cracks with minimal nuisance defects.

Thank You

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