Device Packaging 2020 - Fountain Hills, AZ USA - March 2-5, 2020
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Die Crack Prevention and Detection in Advanced Packaging

March 03, 2020

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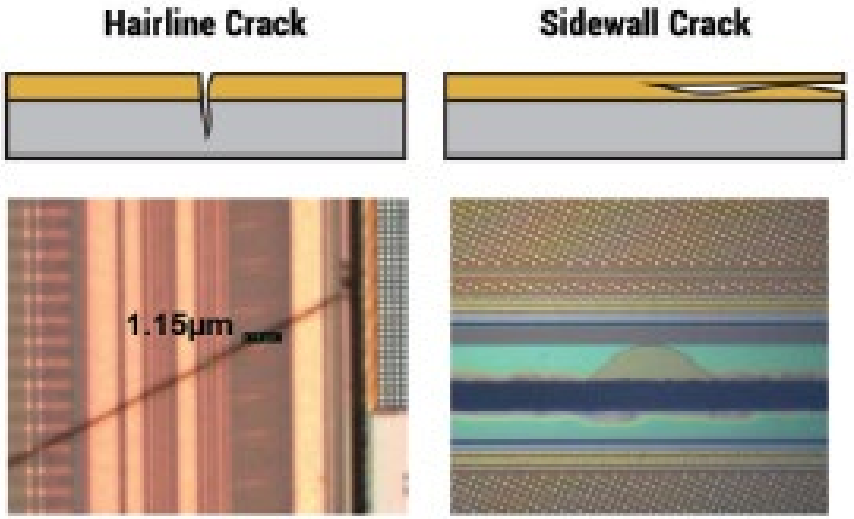
Outline/Agenda

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

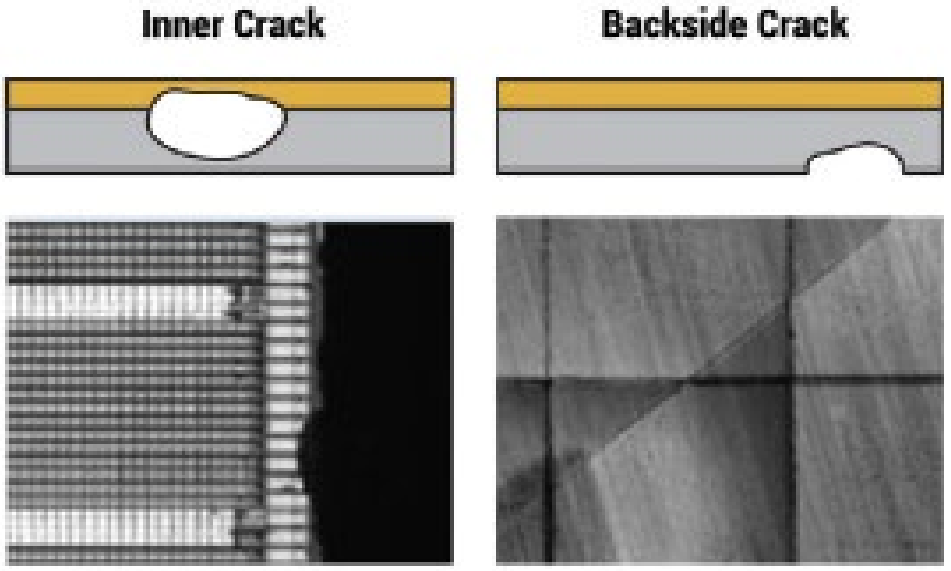
Introduction

- 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.
- 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.
- These cracks are not easy to detect with the traditional BF and DF illumination optics. Need new imaging method to detect these types of cracks.

Die Crack Types



All these cracks are initiated by sawing!



KERF Metrology / Inspection (Crack Prevention)

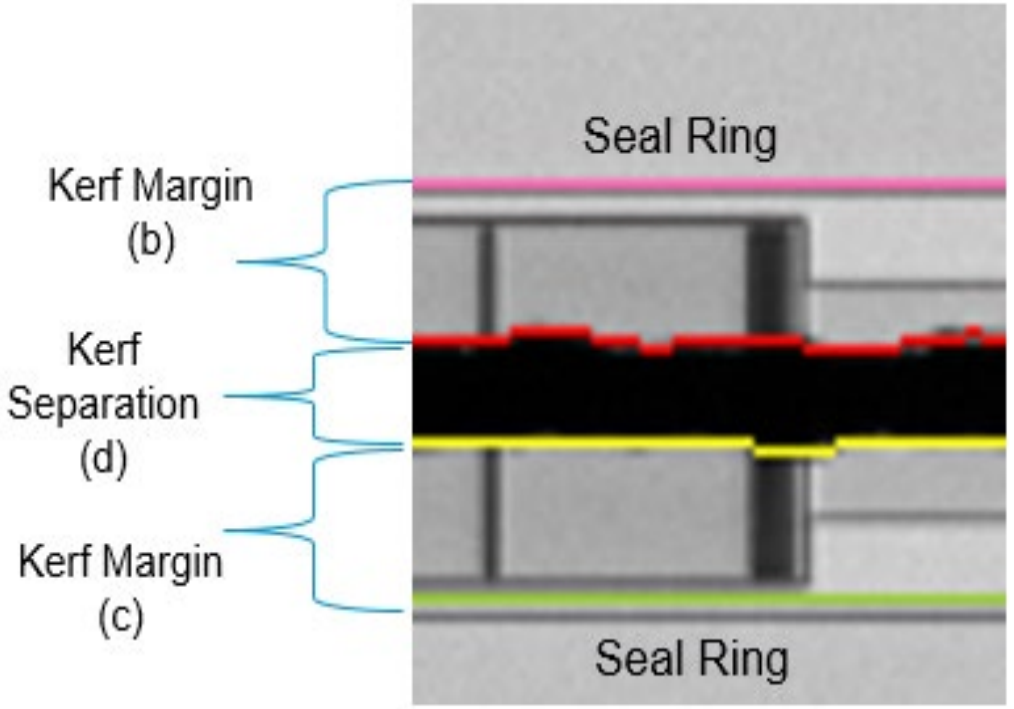
- ***The best prevention for die cracks is sawing process control.***

- **Kerf Margin measures how much material is left outside the die after singulation.**

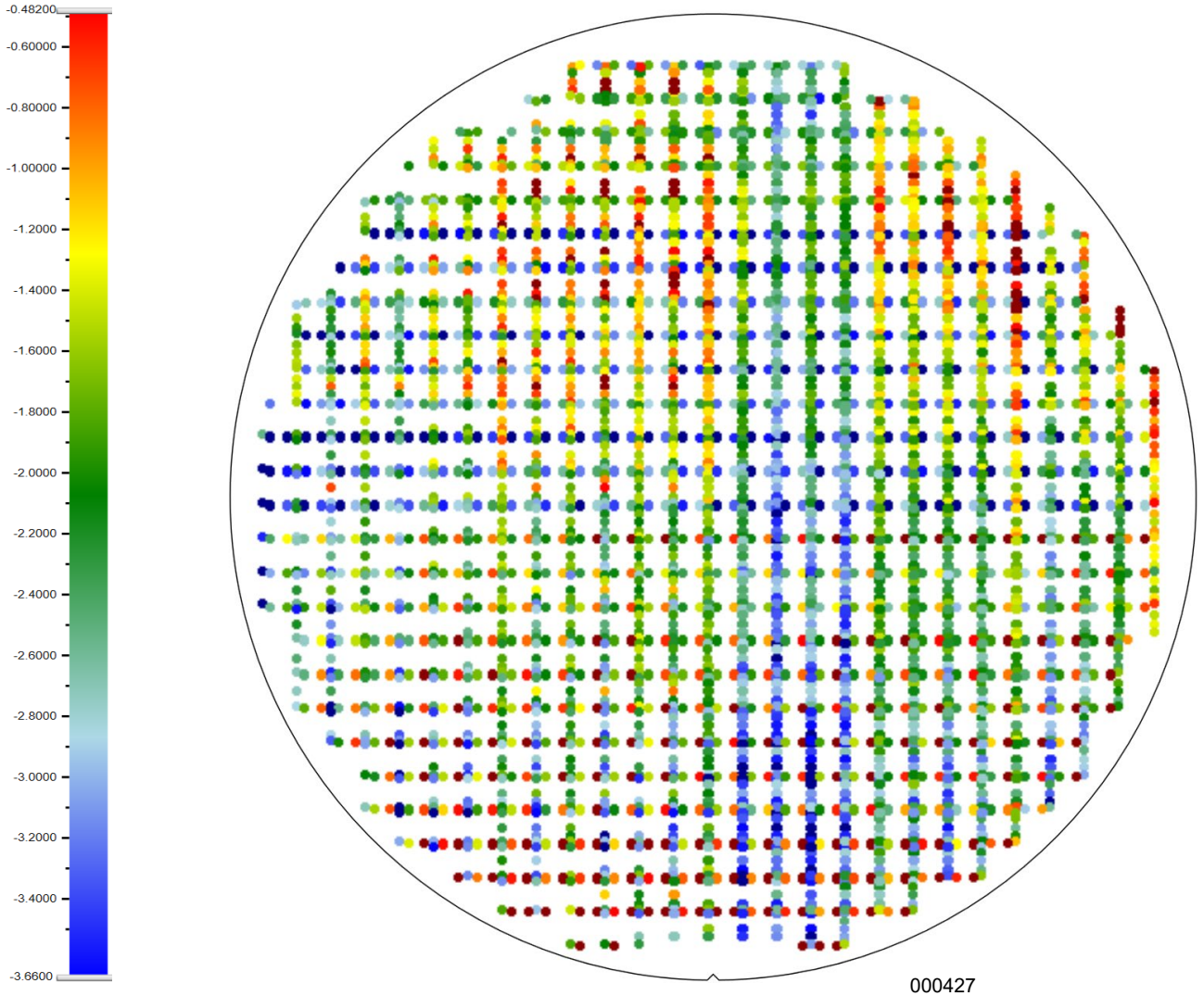
- **Kerf Width measures how much material was removed by singulation. It requires an accurate determination of the whole wafer street width before singulation.**

- **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**

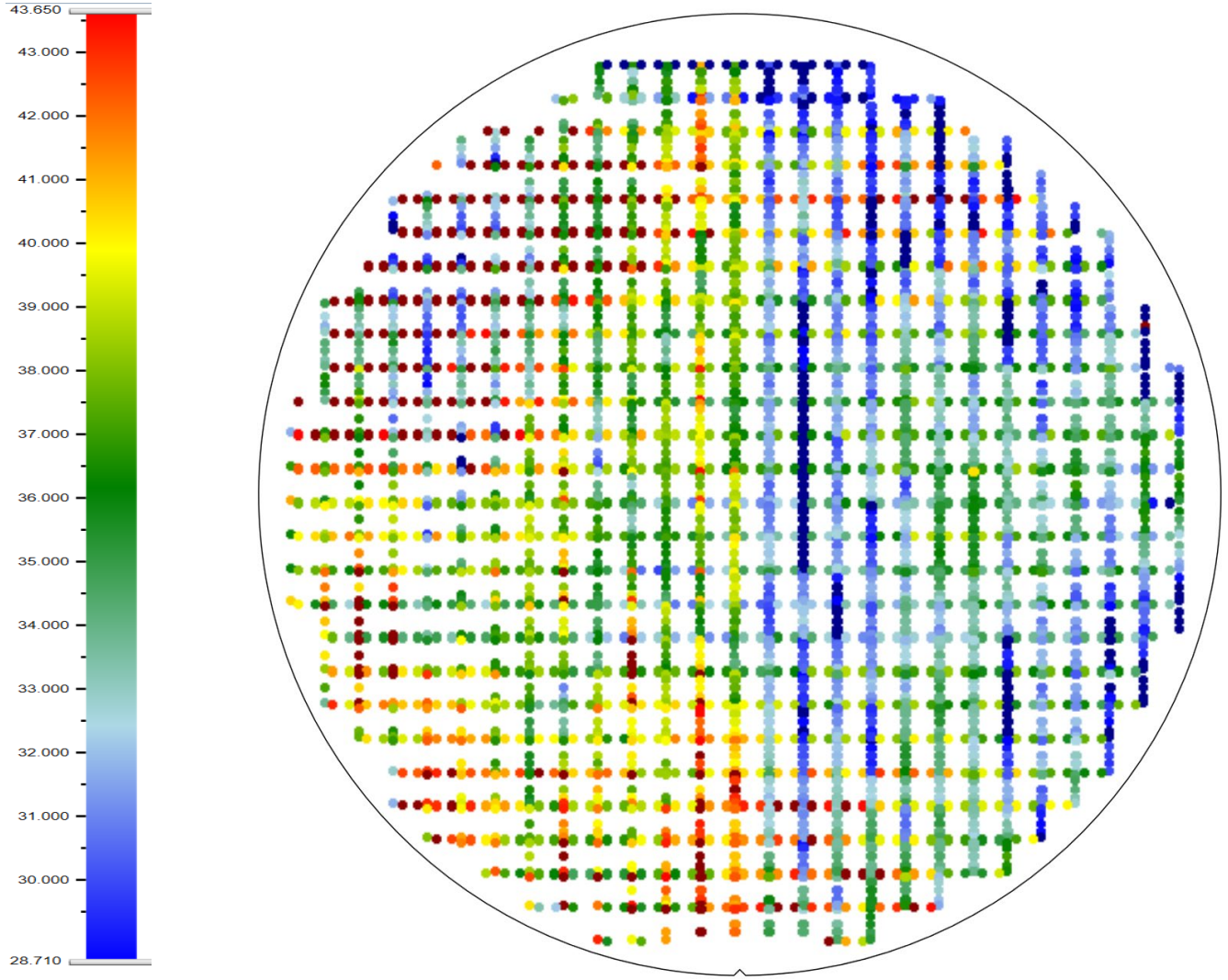


KERF Position Color Map



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

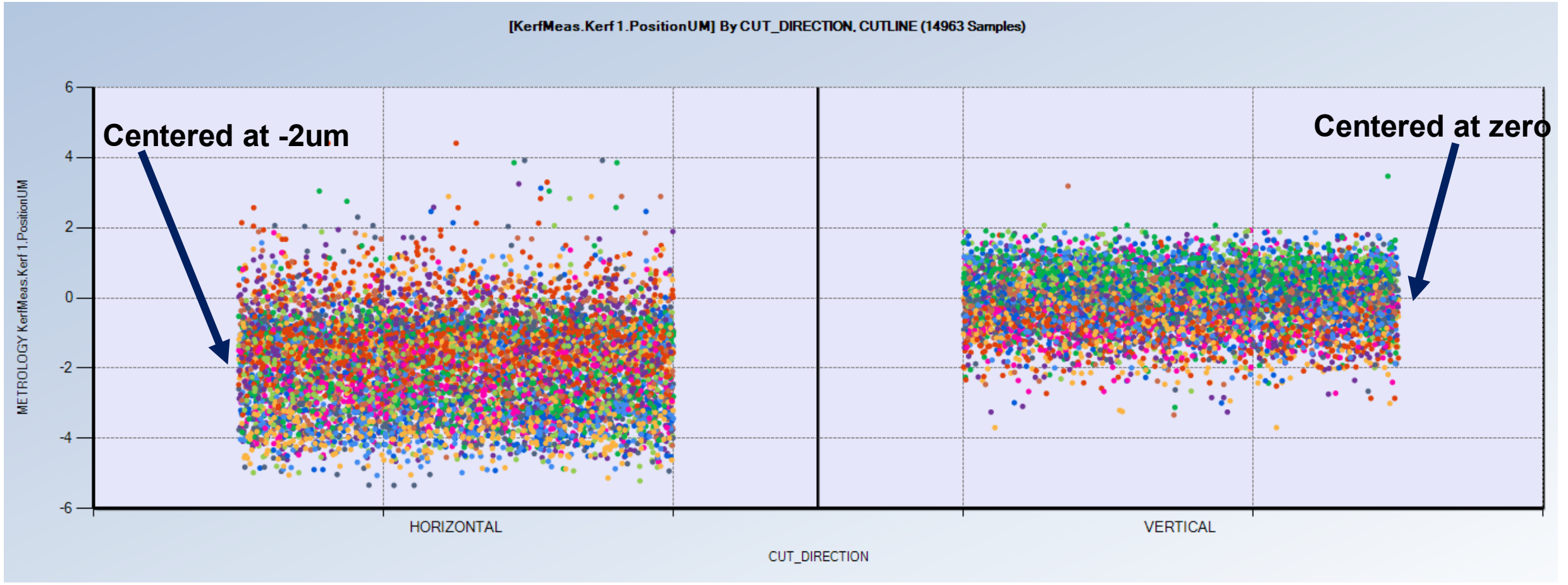
KERF Separation Color Map



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

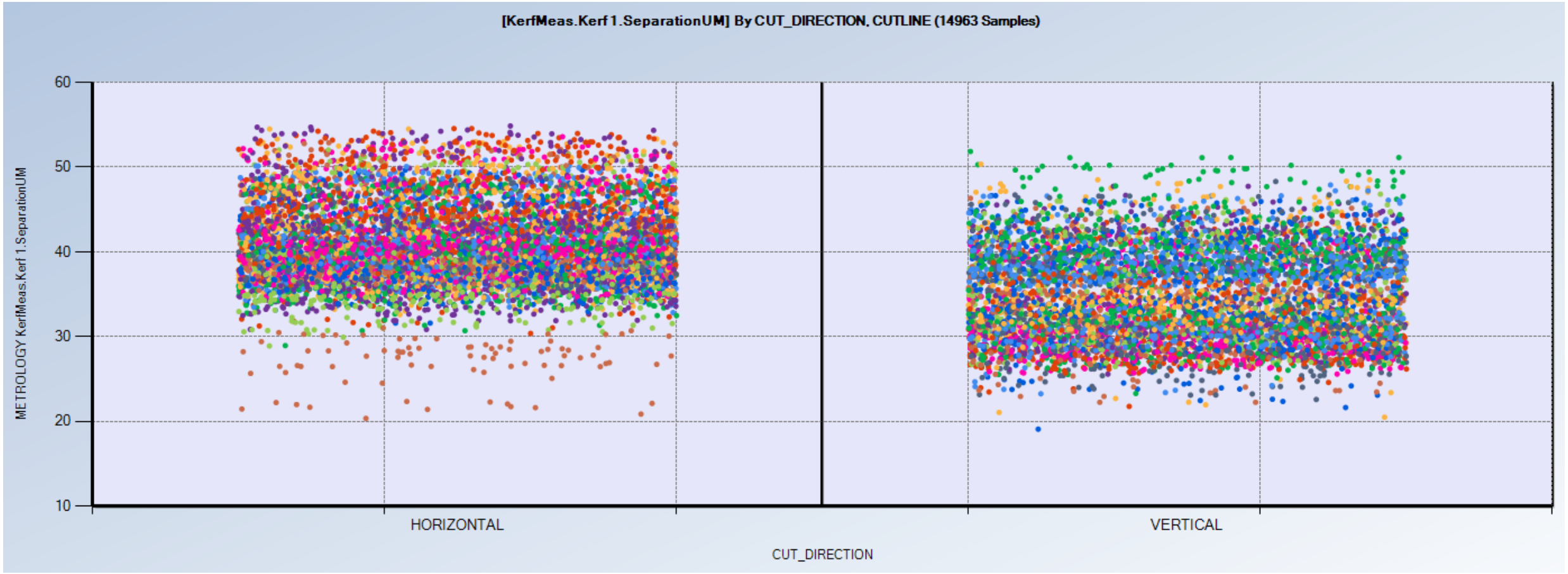
000428

KERF Position Variation By Cut Direction



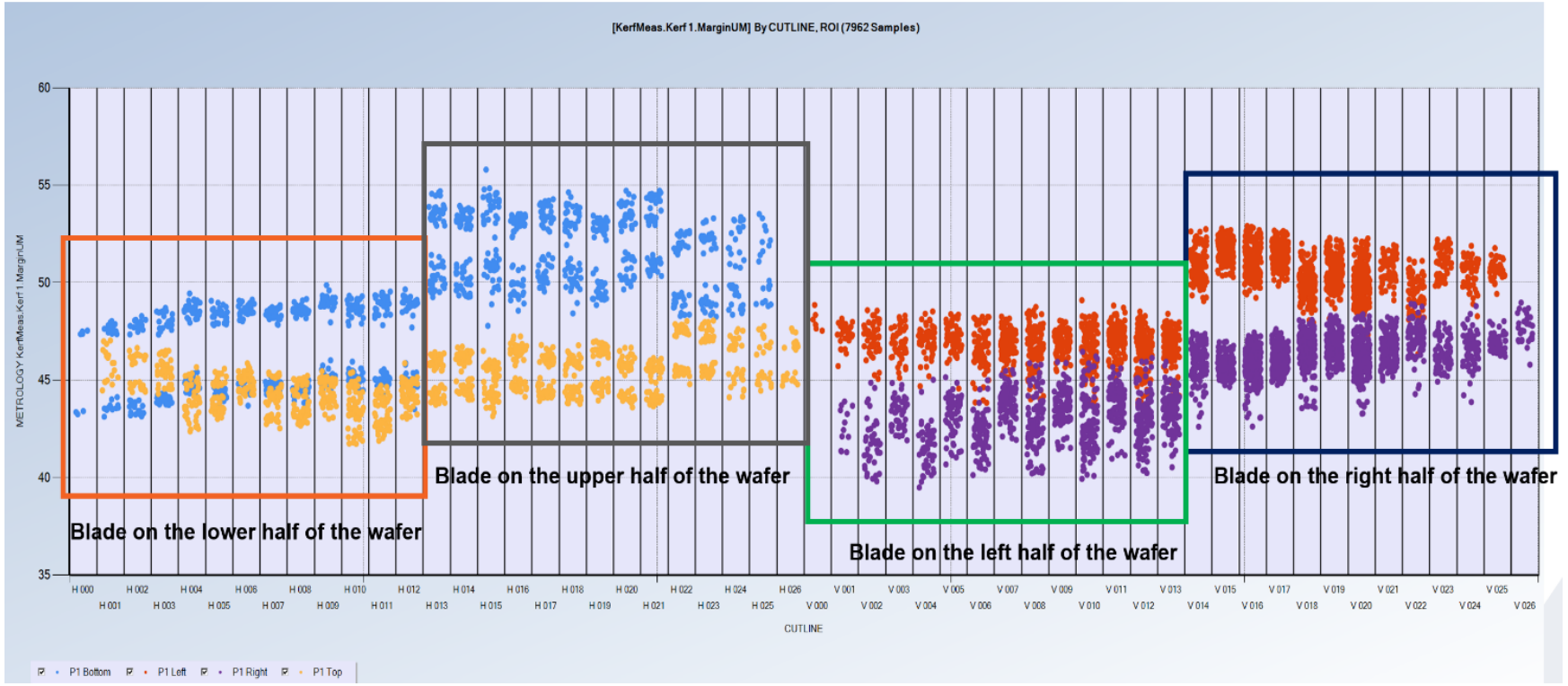
It can be seen that the positional accuracy is centered at zero for vertical cuts while the horizontal cuts are centered at -2um. Also the verticals cuts have less positional variation than the horizontal cuts.

KERF Separation Variation By Cut Direction



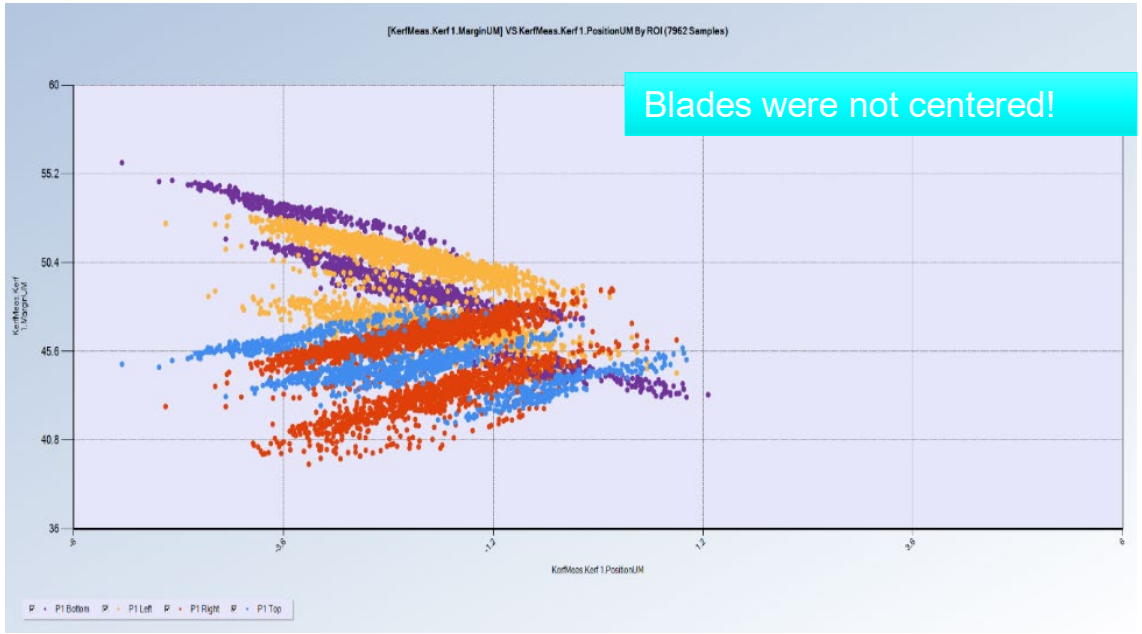
It can be seen that the KERF separation in the vertical direction is about 10um smaller than that of the horizontal direction.

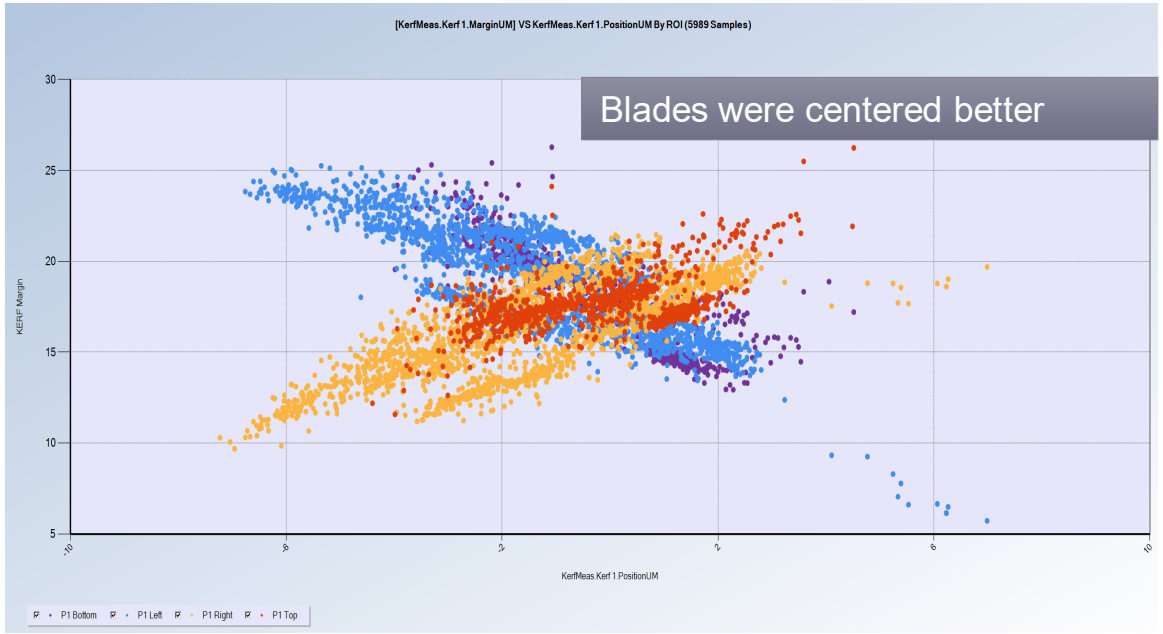
KERF Metrology – Kerf margin distribution by cut lines



Graph showing Kerf Margin distribution by cut lines on wafer.
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.

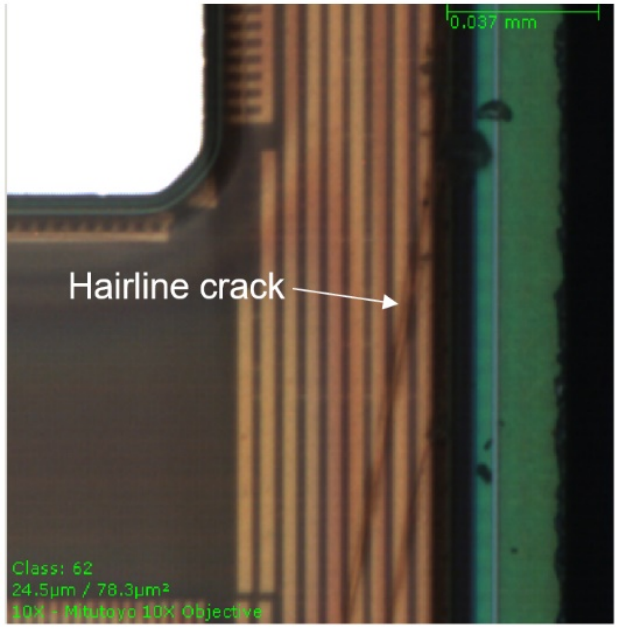
KERF Metrology – Kerf Margin VS Kerf Position



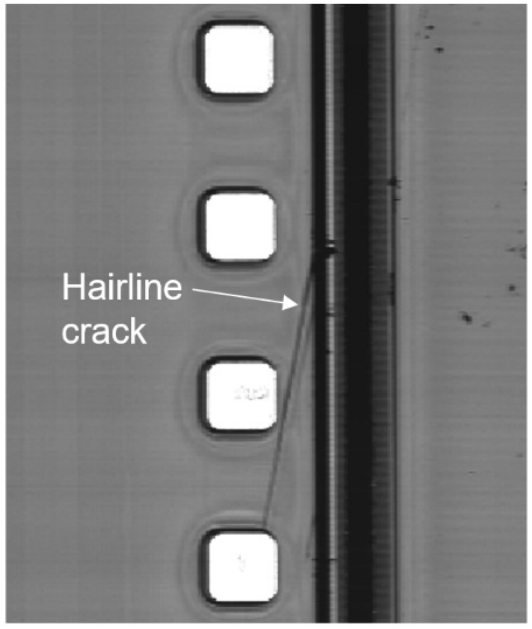


Correlation graph between KERF Margin and KERF Position.
It can be seen that all the data has negative values for KERF position.
It is indicating that the blades were not centered in the center of KERF for both cut directions.
For horizontal cuts, the blades were placed slightly higher than the center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

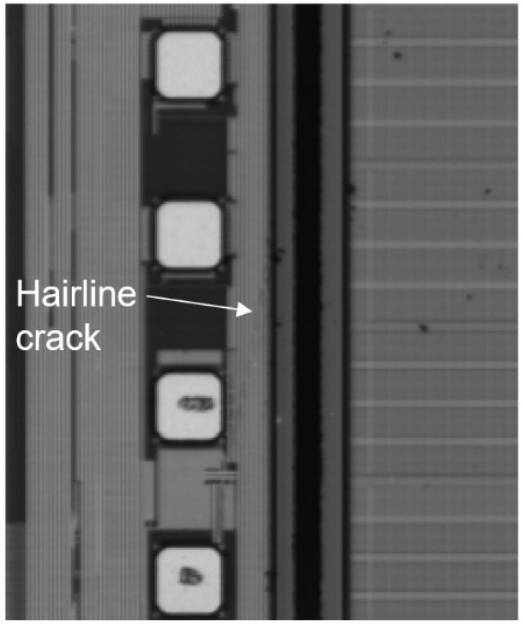
Hairline Cracks



Bright Field Color Image



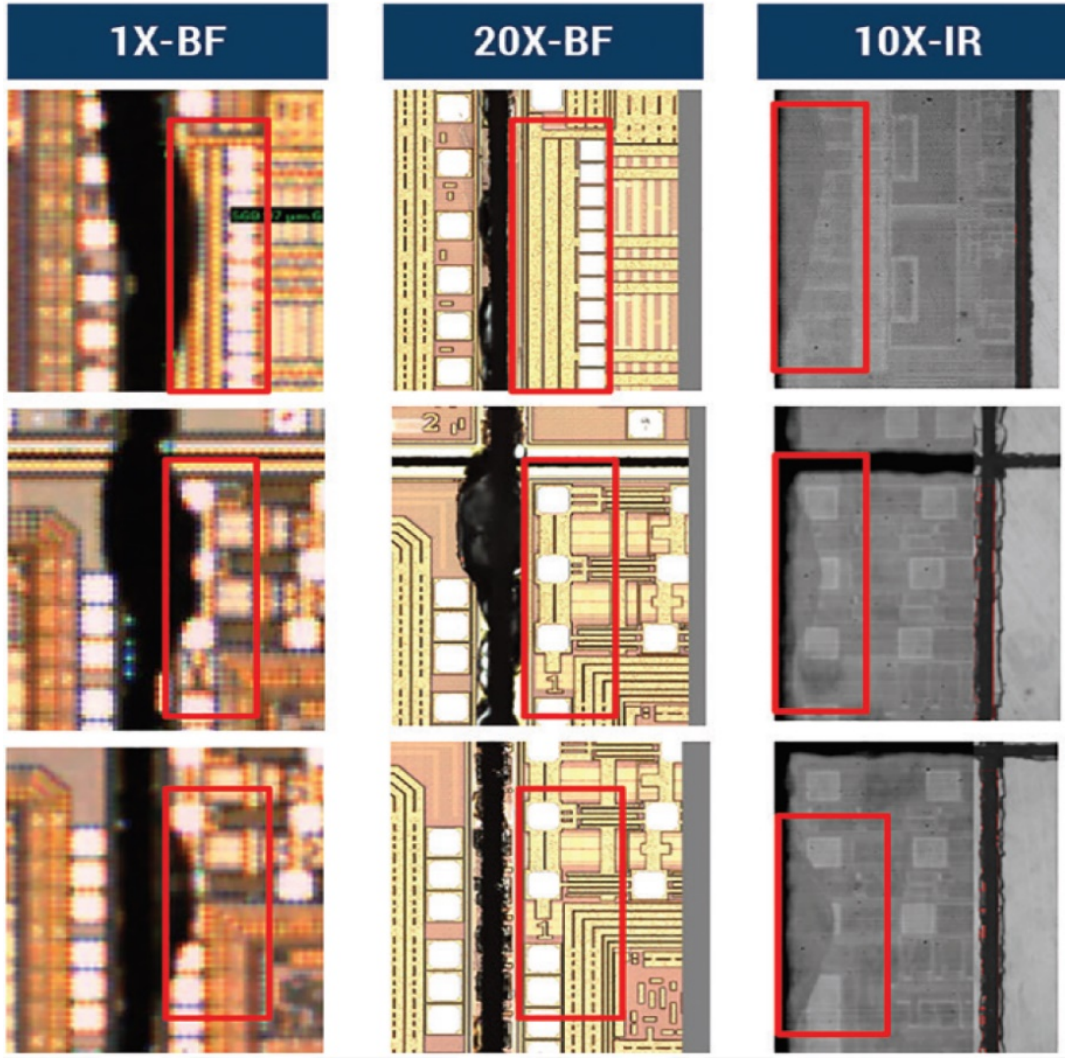
Height Topography Image



IR Image

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

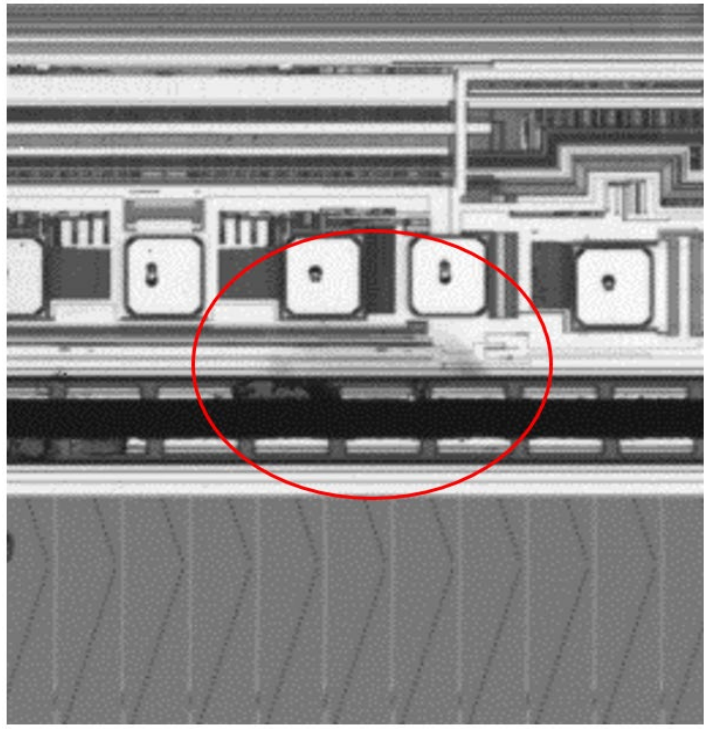


Sidewall or inner cracks can be challenging to detect because they mostly occur below the die surface.

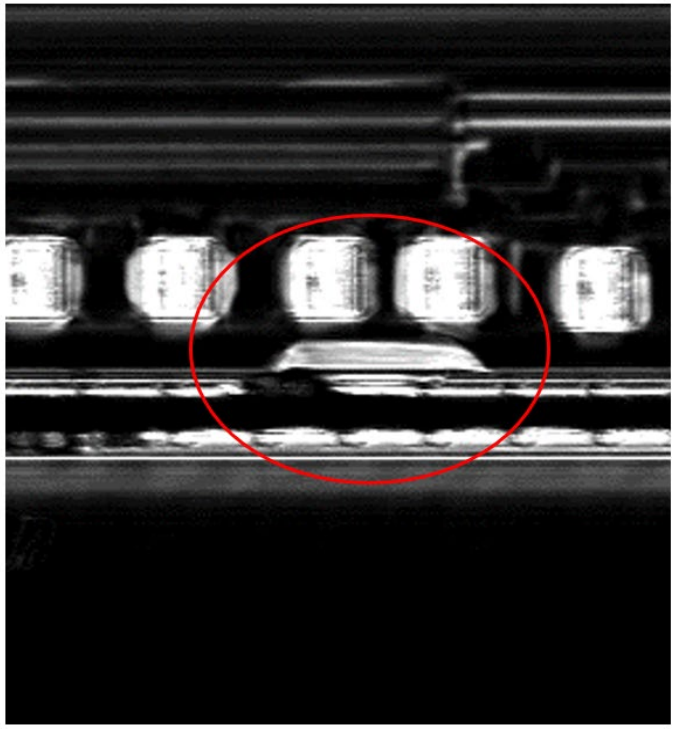
In these images, their appearance changes with magnification, seeming to be more extensive at 1X and smaller at 20X.

IR images look through the pattern on top of die and can provide crucial confirmation of their existence and extent.

Sidewall / Inner Cracks



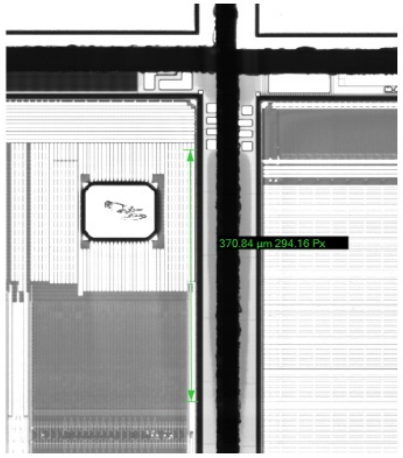
IR Image



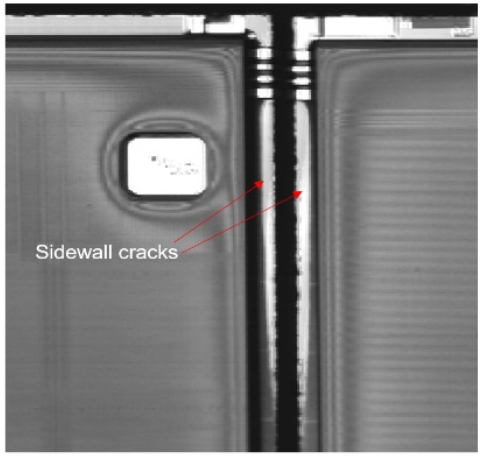
Height Topography Image

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



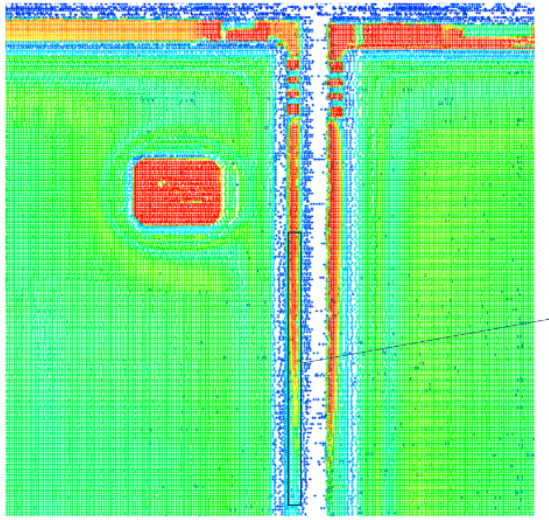
Brightfield Image



Height Topography Image

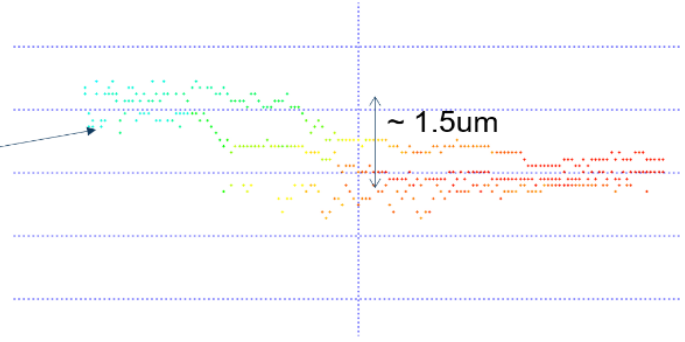
Sidewall cracks can be seen on both the bright field image on the left and the new height topography image on the right.

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



Height Topography Raw Plot (Top View)

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



5X Height Topography Raw Plot (Side View)

Conclusion

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

- **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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