SW Test Workshop

Semiconductor Wafer Test Workshop

Automated Probe-Mark Analysis

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imec

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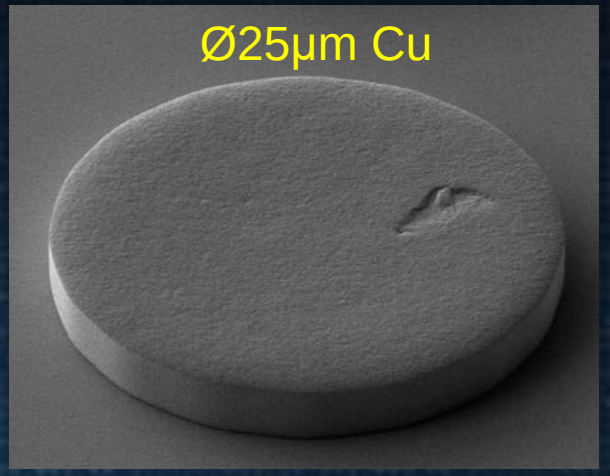
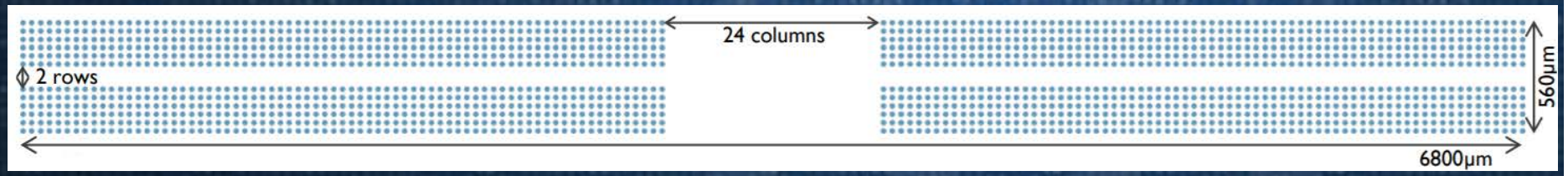
Overview

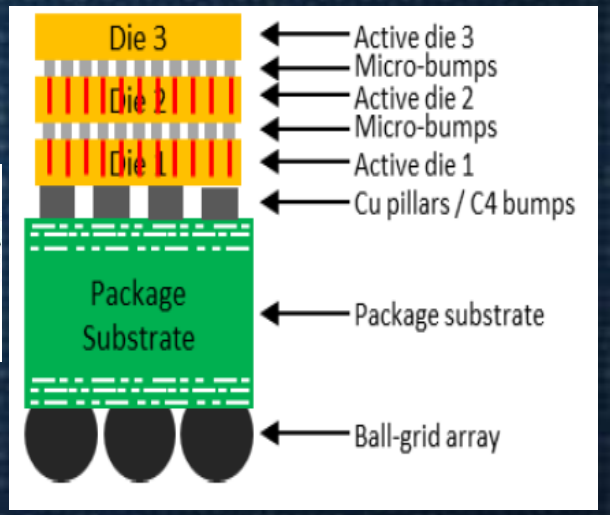
1. Introduction
2. Automated Probe Mark Recognition
3. Area of the Probe Mark
4. Results
5. Robustness of the algorithm
6. Summary

Micro-bump Probing



- **Come in different metallurgies, forms, and shapes**
- **Functional interconnects of 3D-stacked dies are formed by large arrays of fine-pitch micro-bumps**
  - JEDEC Standard
    - Wide-I/O 2: 1,752 micro-bumps @40/40μm pitch

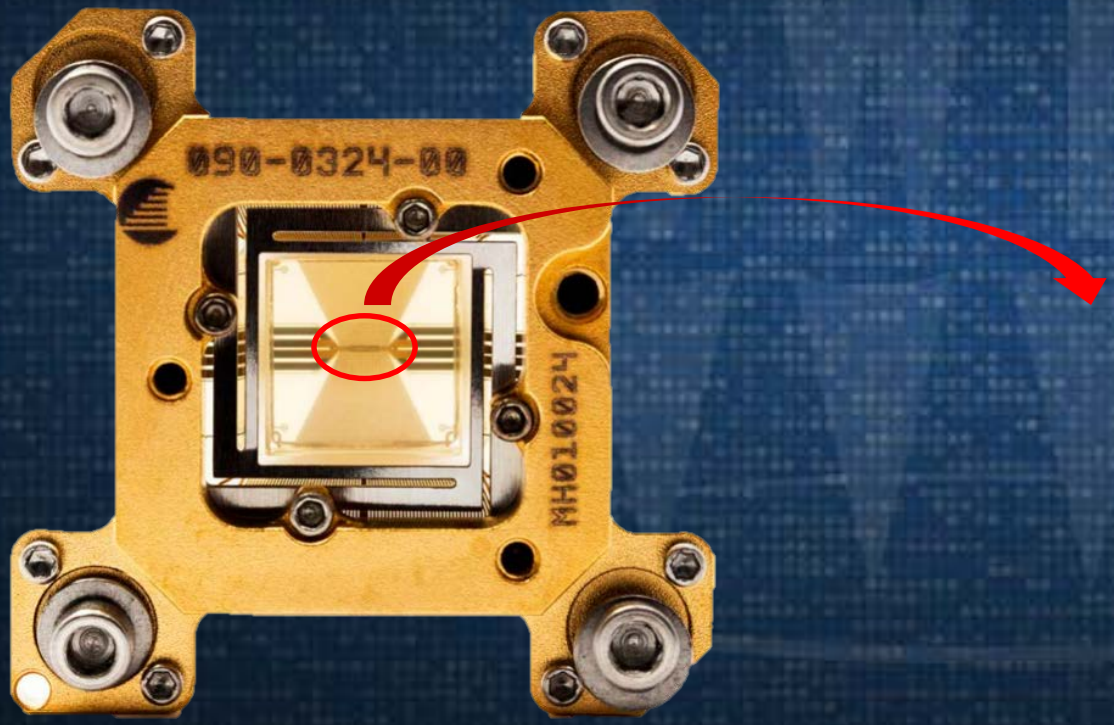




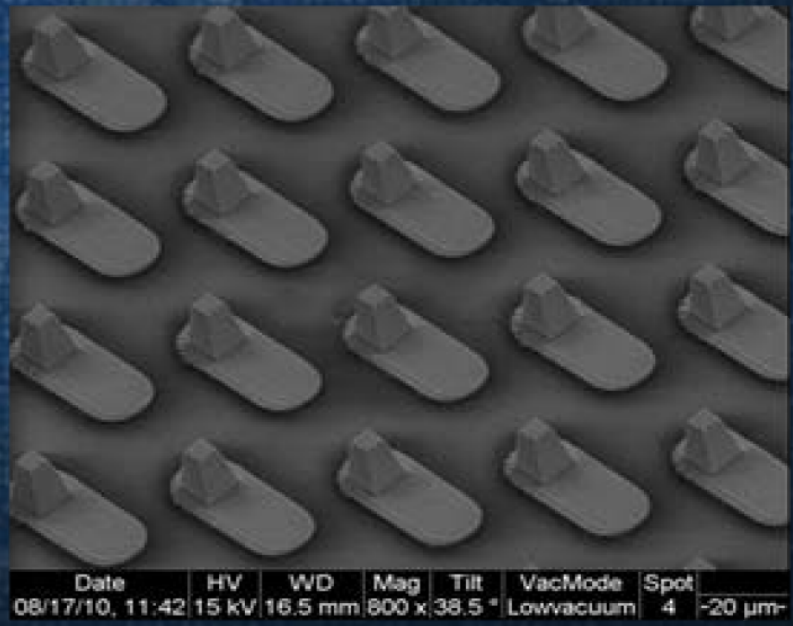
- **Previous works:**
  - It is possible to probe micro-bumps directly
    - SWTW' 13: Gunther Böhm, *et al*.
    - SWTW' 17: Erik Jan Marinissen, *et al*.

Direct Micro-Bump Probing

- **Need dedicated probe cards**
  - Pyramid® Rocking Beam Interposer Probe Cores



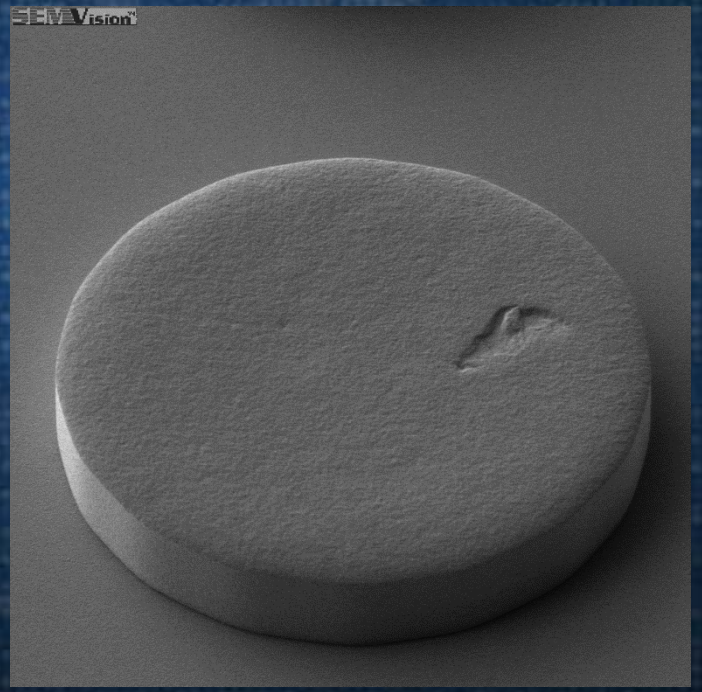
- RBI MEMS-type probe tips



Quality of Probing

- **Probing**
  - Probe tips land on the probe targets (micro-bumps)
- **Leaves the probe marks on the micro-bumps**

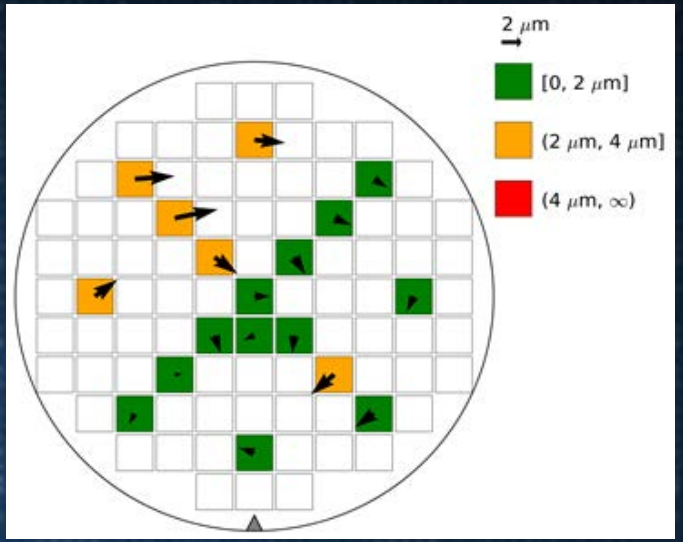
- Before probing

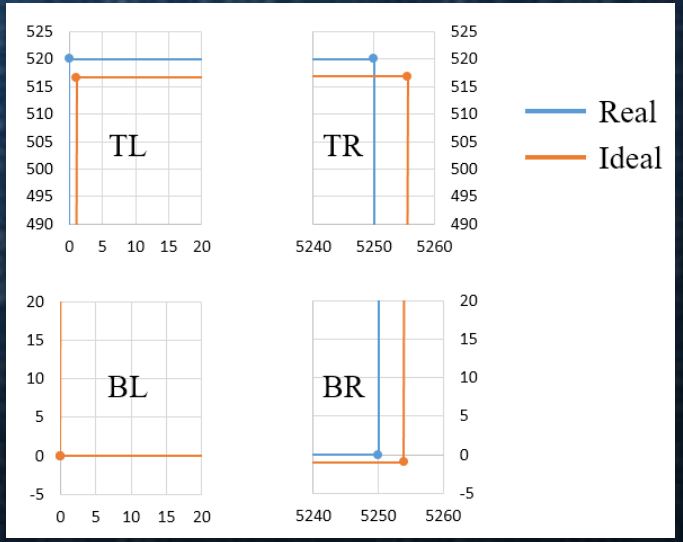


- After probing

Probe-To-Pad Alignment (PTPA) Accuracy

- **Determined by probe station and probe card**
  - Measure probe mark offsets in all four corners of the micro-bump array
- **Probe station accuracy**
  - Equals offset of BL probe mark, as BL corner is main probe training location
  - Offset is chuck-position dependent
- **Probe card accuracy**
  - Translate offsets such that BL = (0, 0)
  - Offsets of other corners are due to probe card
  - Offsets are chuck-position independent





Motivation

- **Software tool for measuring the misalignment of the probe mark w.r.t. the probe target**
- **Image processing for probe mark recognition**
  - Contours, centers and surface areas of probe marks and probe targets
- **Characterizing the quality of probing**

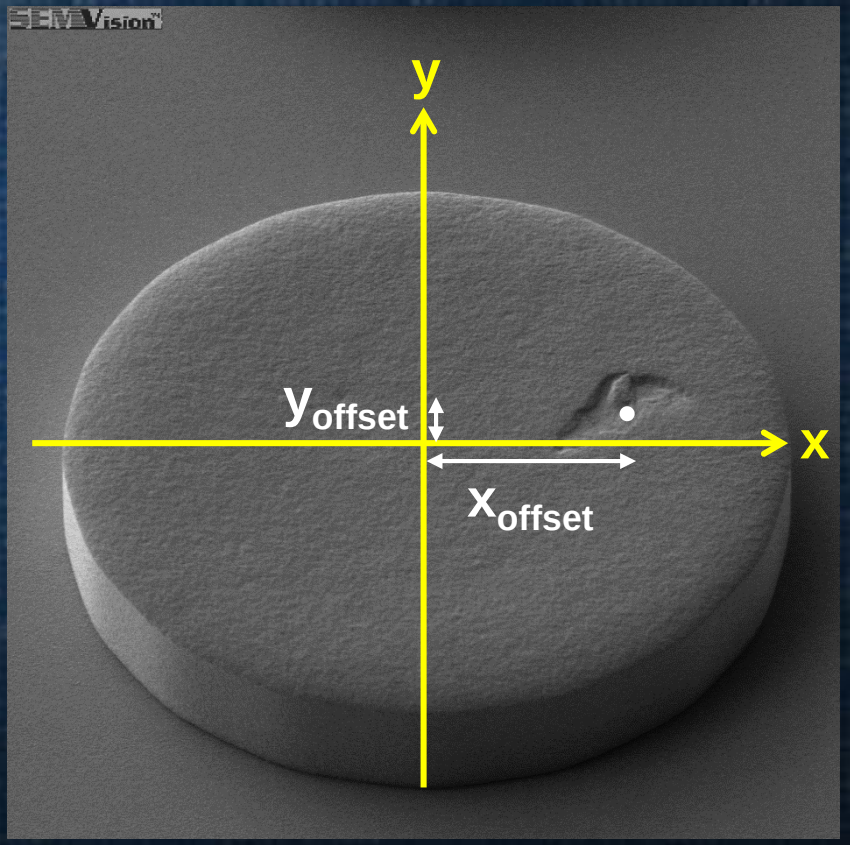


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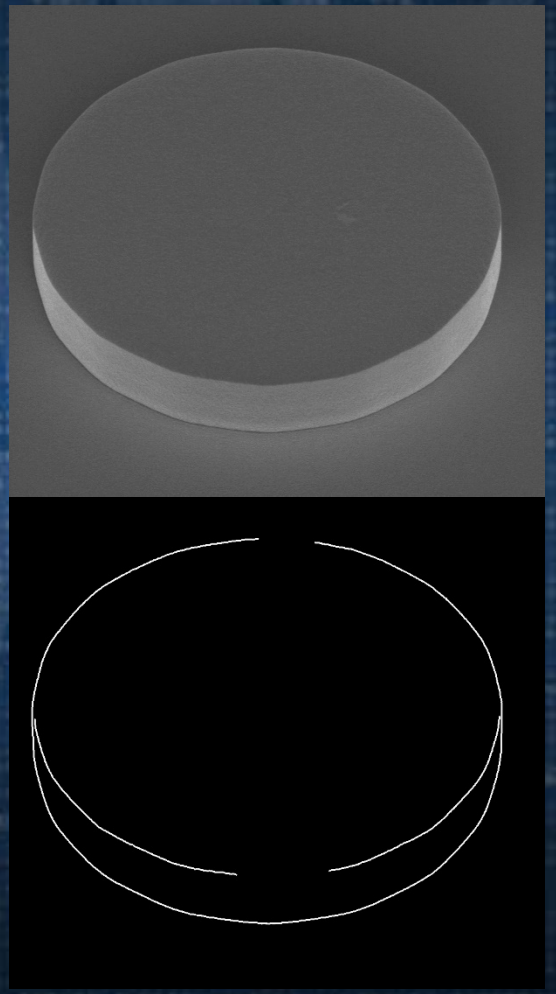
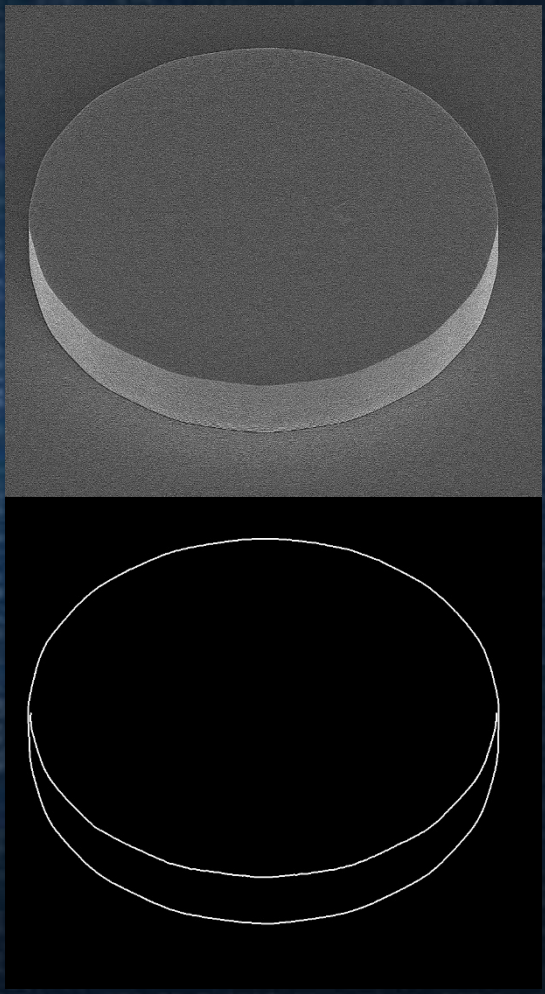
Image Processing Techniques

- **Image sharpening**
  - Technique for increasing image sharpness
- **Edge detection**
  - Algorithm: Canny[1]
    - Suitable for our algorithm

- Without sharpening



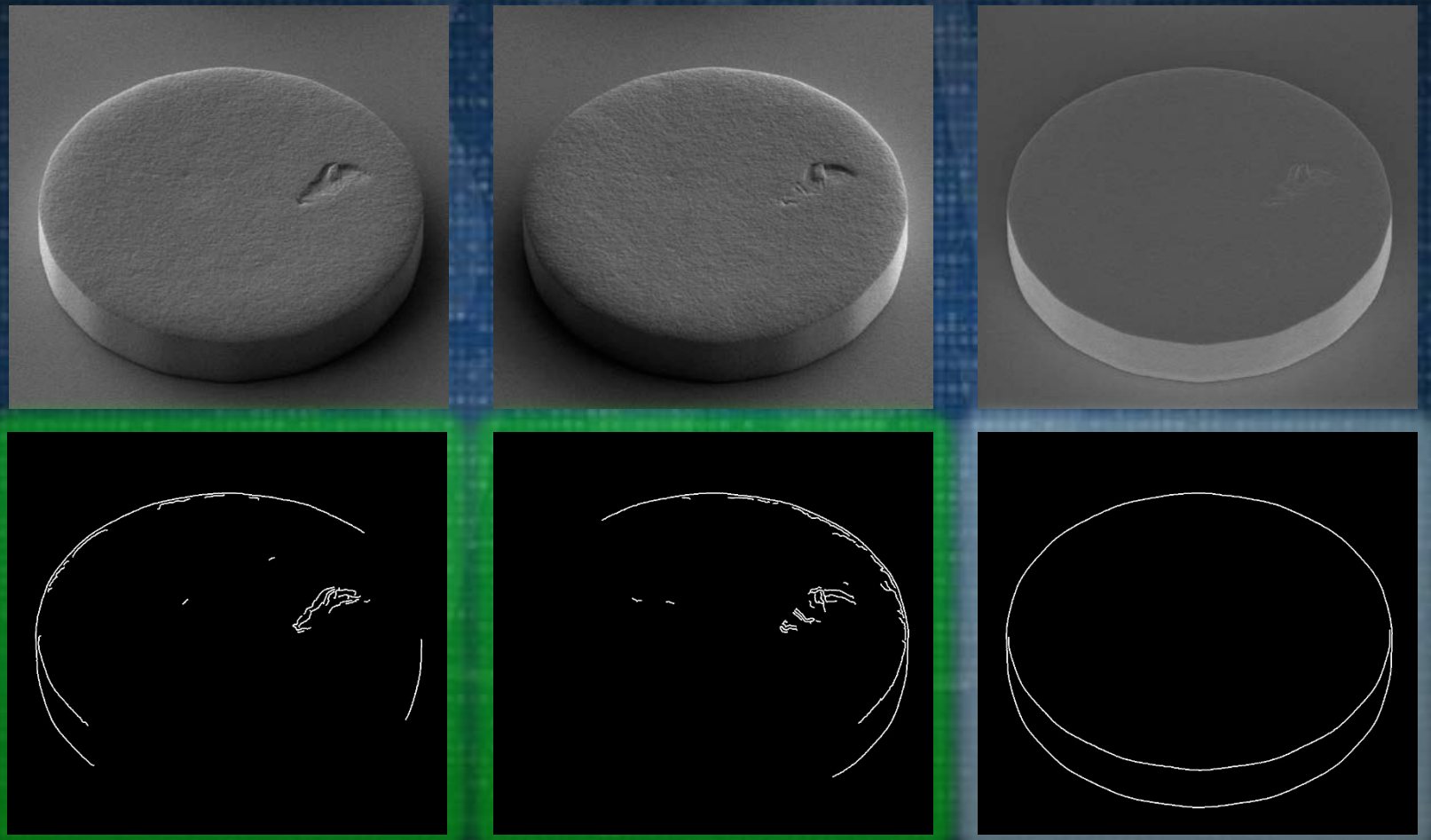
- With sharpening



[1]John Canny, “A Computational Approach to Edge Detection”, *IEEE trans. Pattern Analysis and Machine Intelligence*, 1986

Input Files: SEM Image of Micro-Bump

- **Three different conditions of images for each micro-bump**

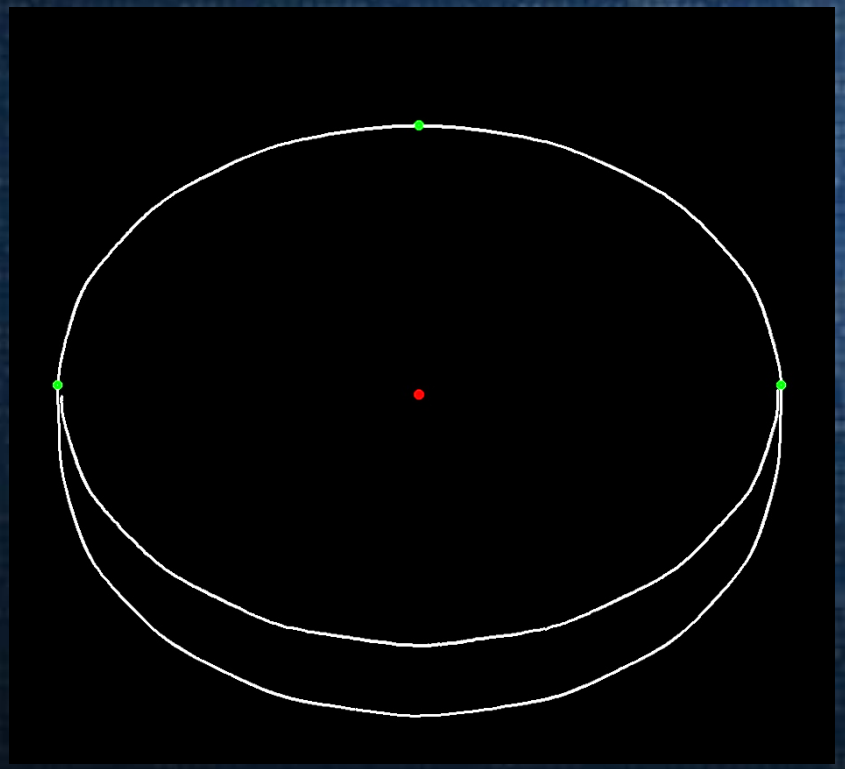


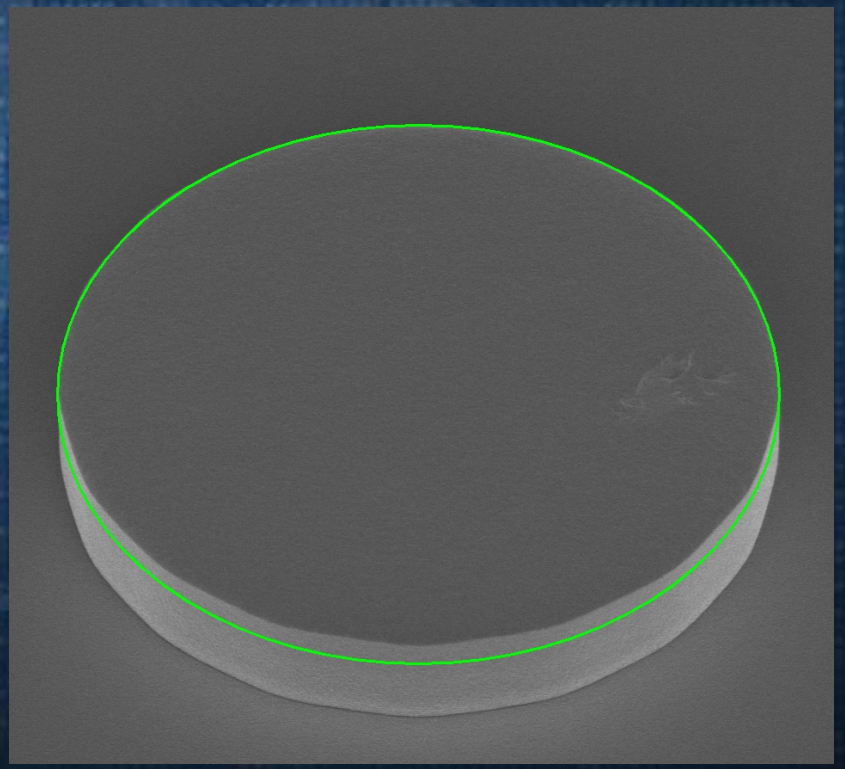
Used for probe mark recognition

Used for identifying the micro-bump contour

Contour of the Micro-Bump (1/3)

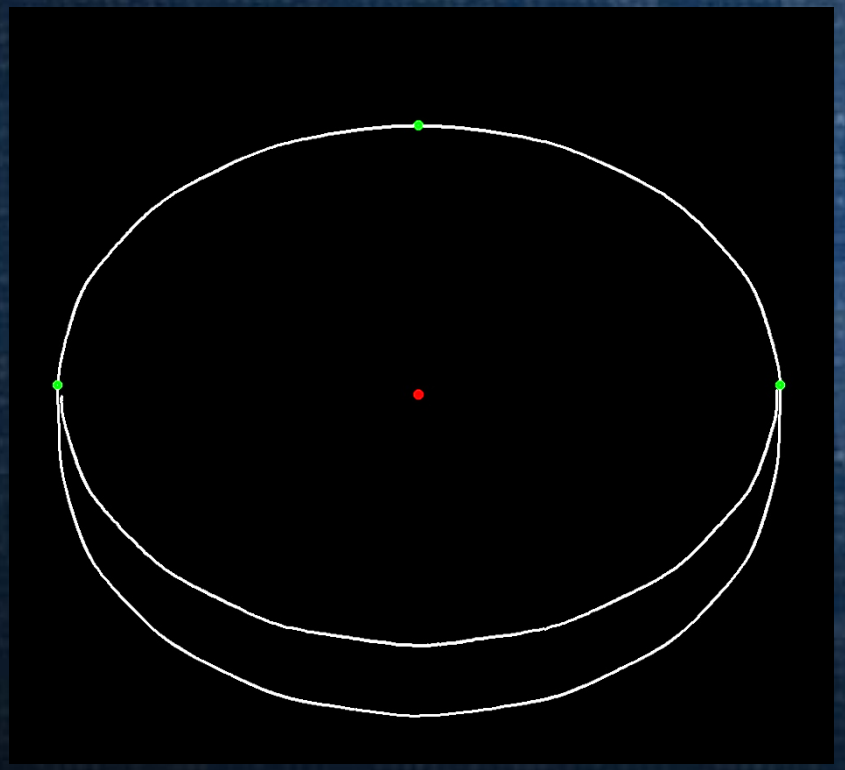
- **The midpoint between the leftmost and rightmost points**
  - In theory, the midpoint is the center point of the micro-bump contour
  - The *y* position of this midpoint is incorrect.

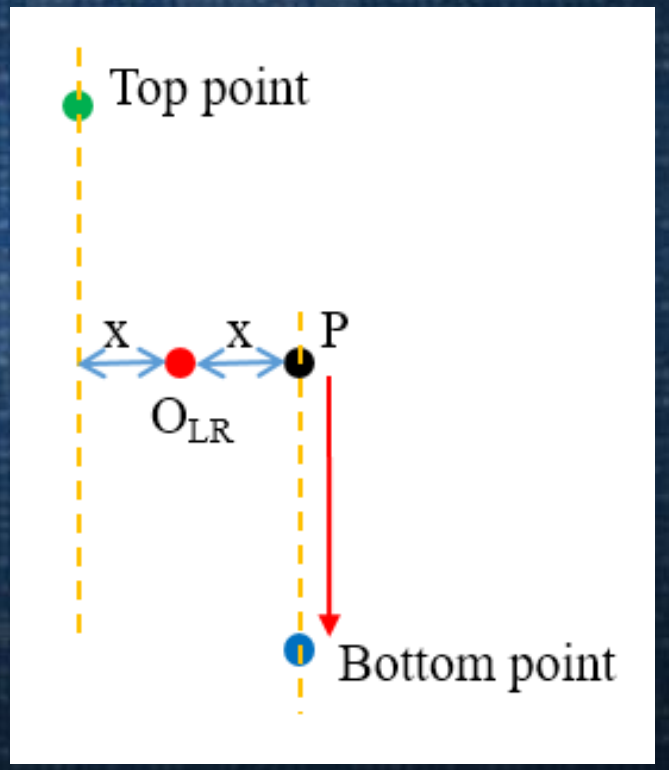




Contour of the Micro-Bump (2/3)

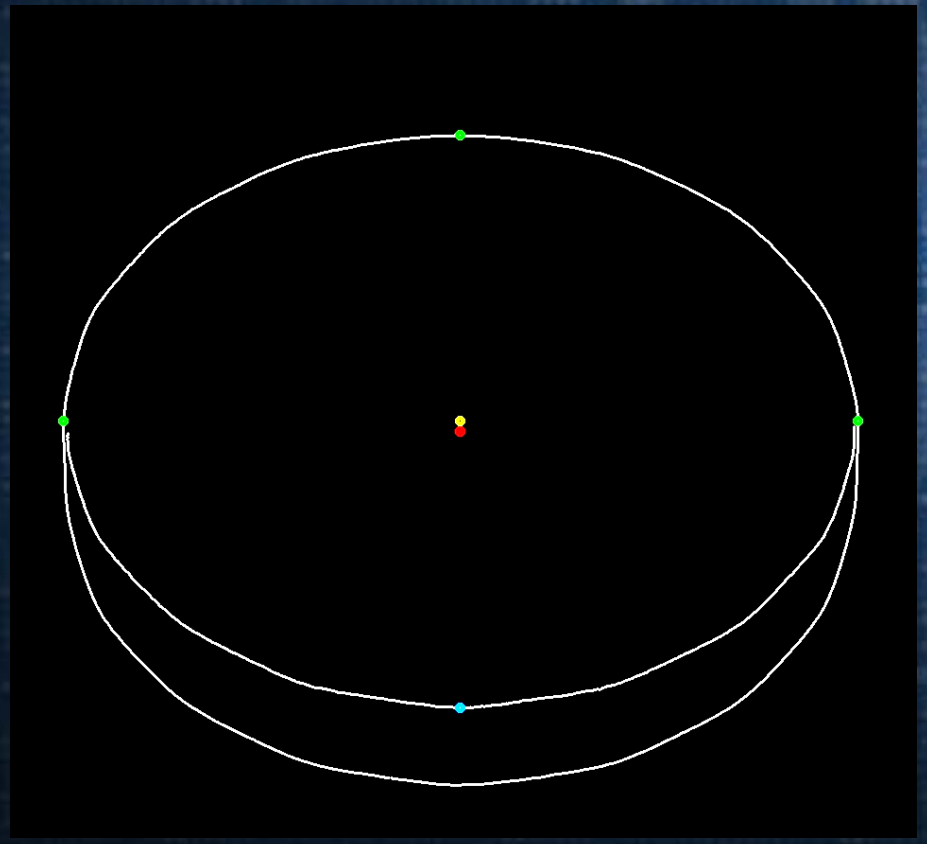
- **The contour of the micro-bump is an ellipse**
  - We use the symmetrical property of an ellipse to determine the contour

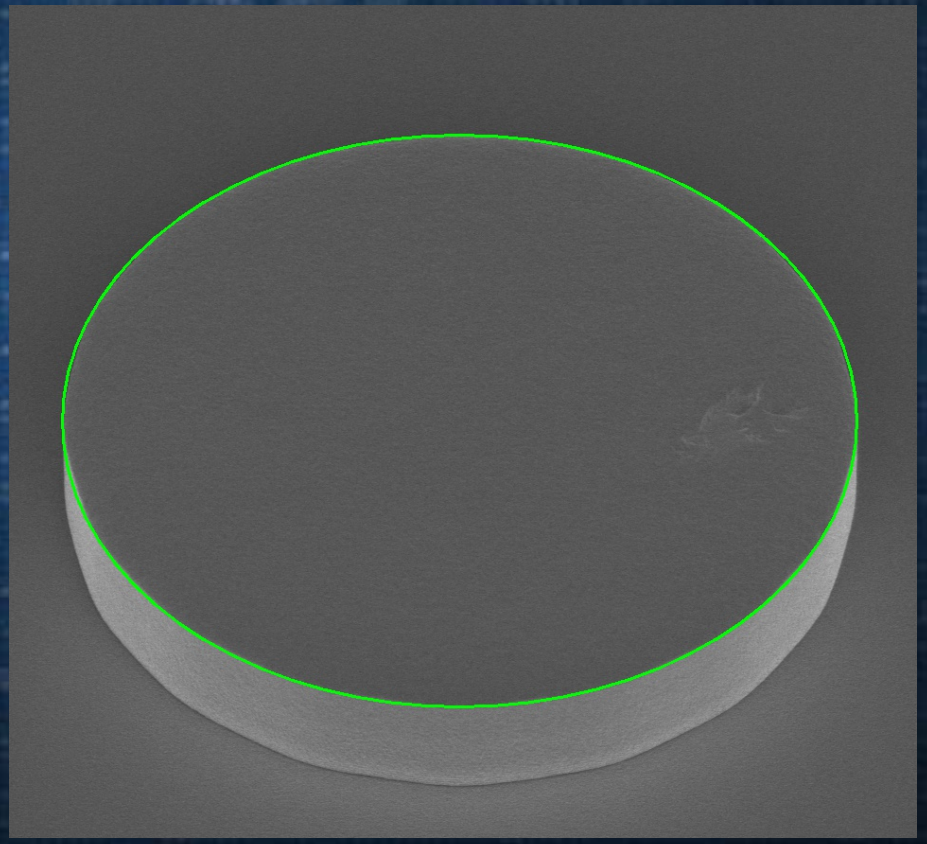




Contour of the Micro-Bump (3/3)

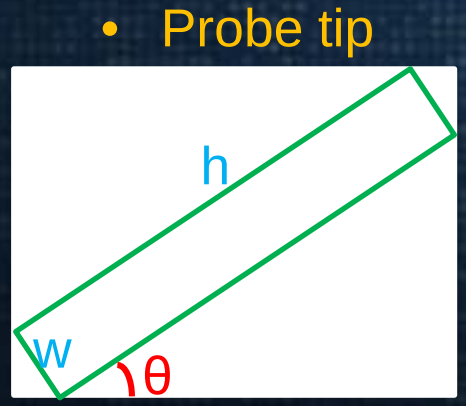
- **Center point of the contour of the micro-bump**





Probe Mark Identification

- **Many white pixels on the edge of the probe mark**
  - White pixels on the micro-bump's contour negatively affect the result
- **The position of the rectangle that encloses the largest amount of white pixels**



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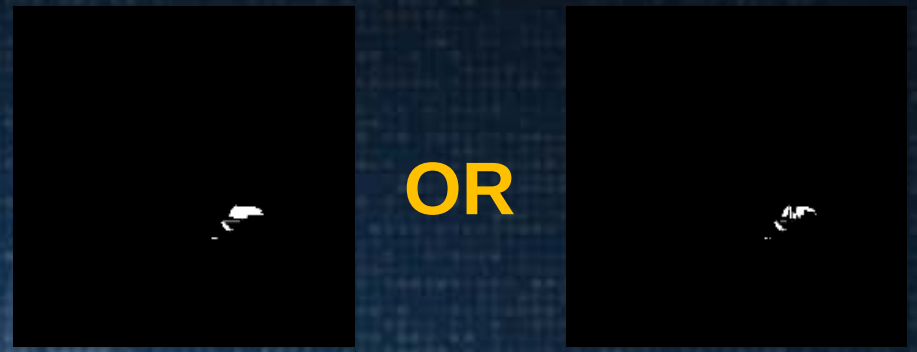
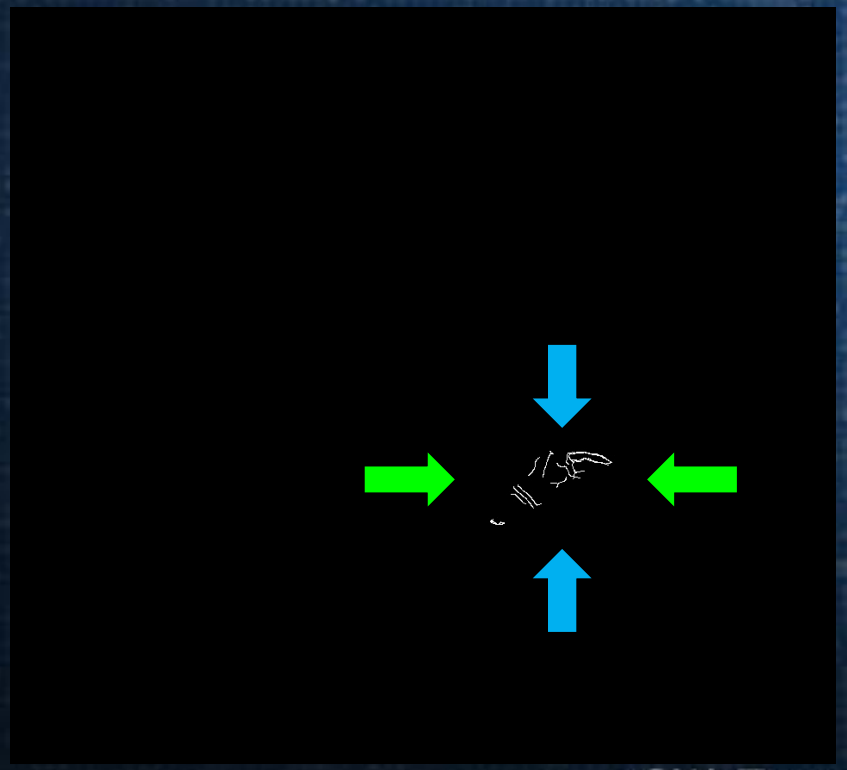
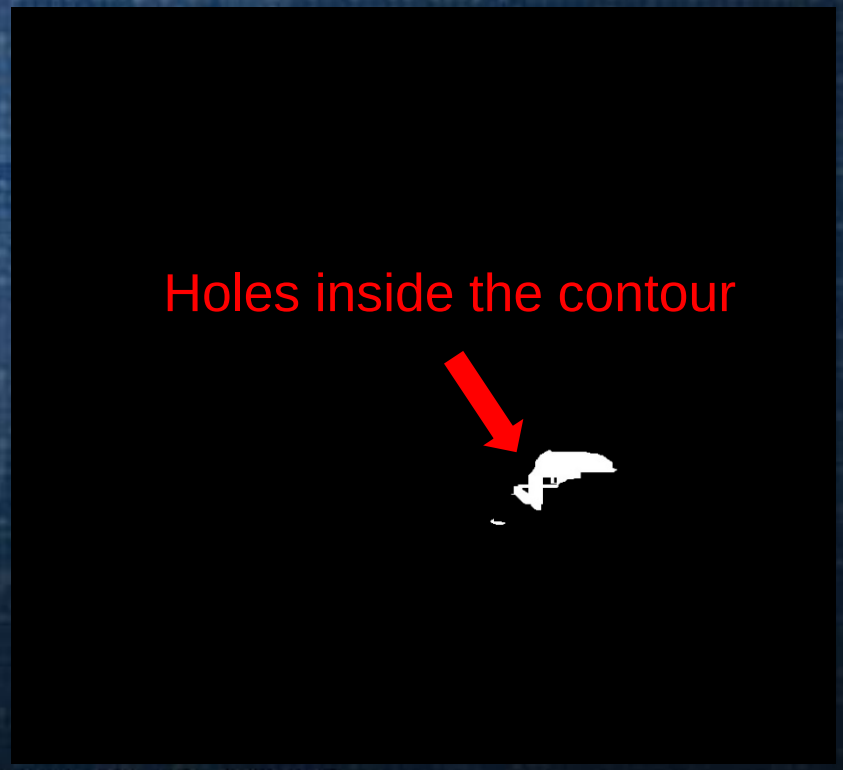
Area of Probe Mark

- **Determine the shape of the probe mark**
  - Scan the edge of the probe mark

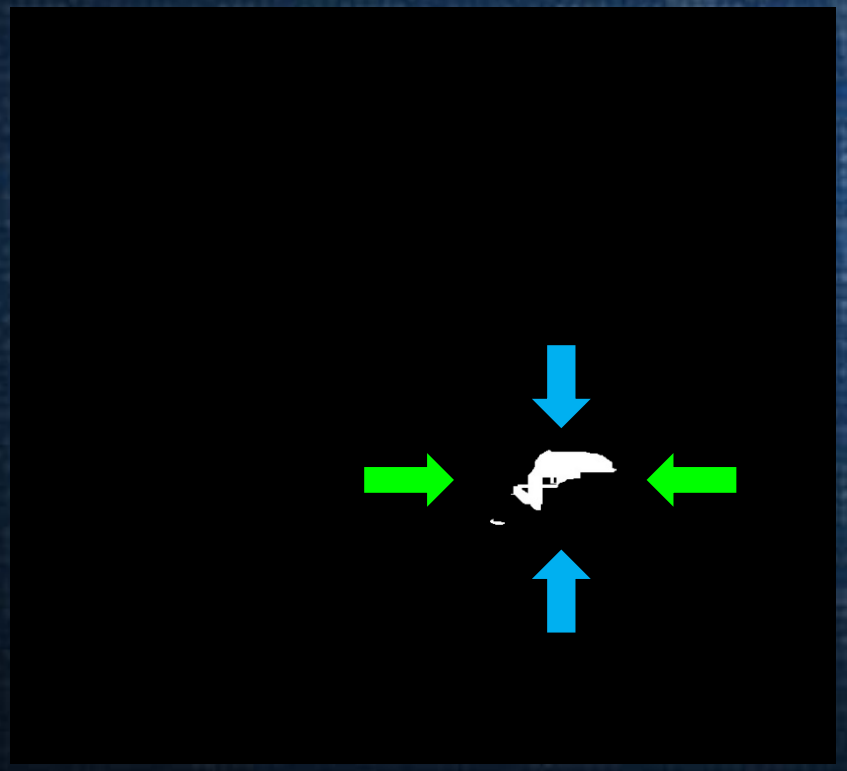


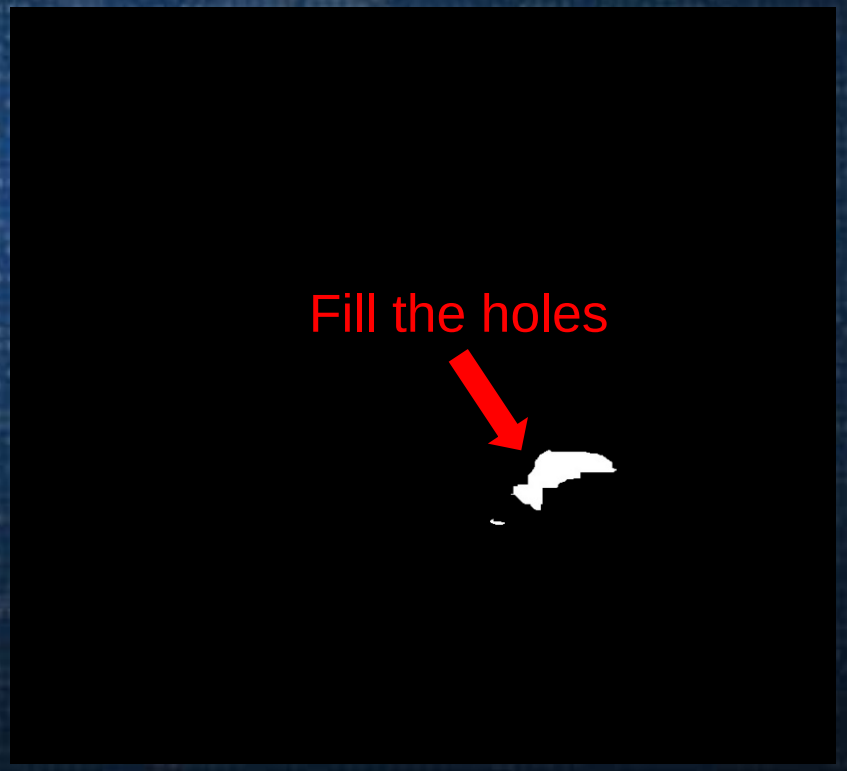




Area of Probe Mark

- **Fill up the holes**
  - Scanning along two directions





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- **Results**
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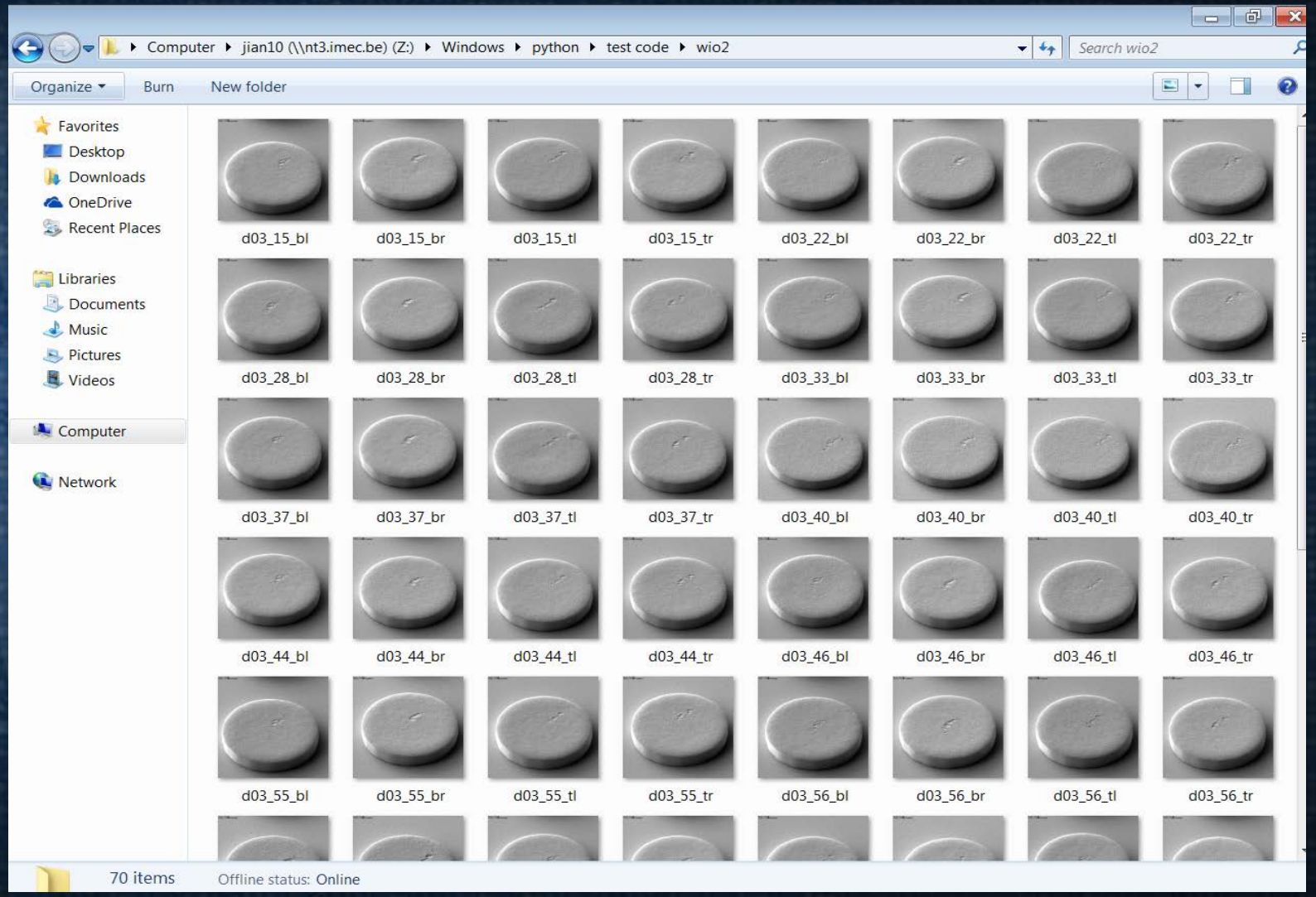
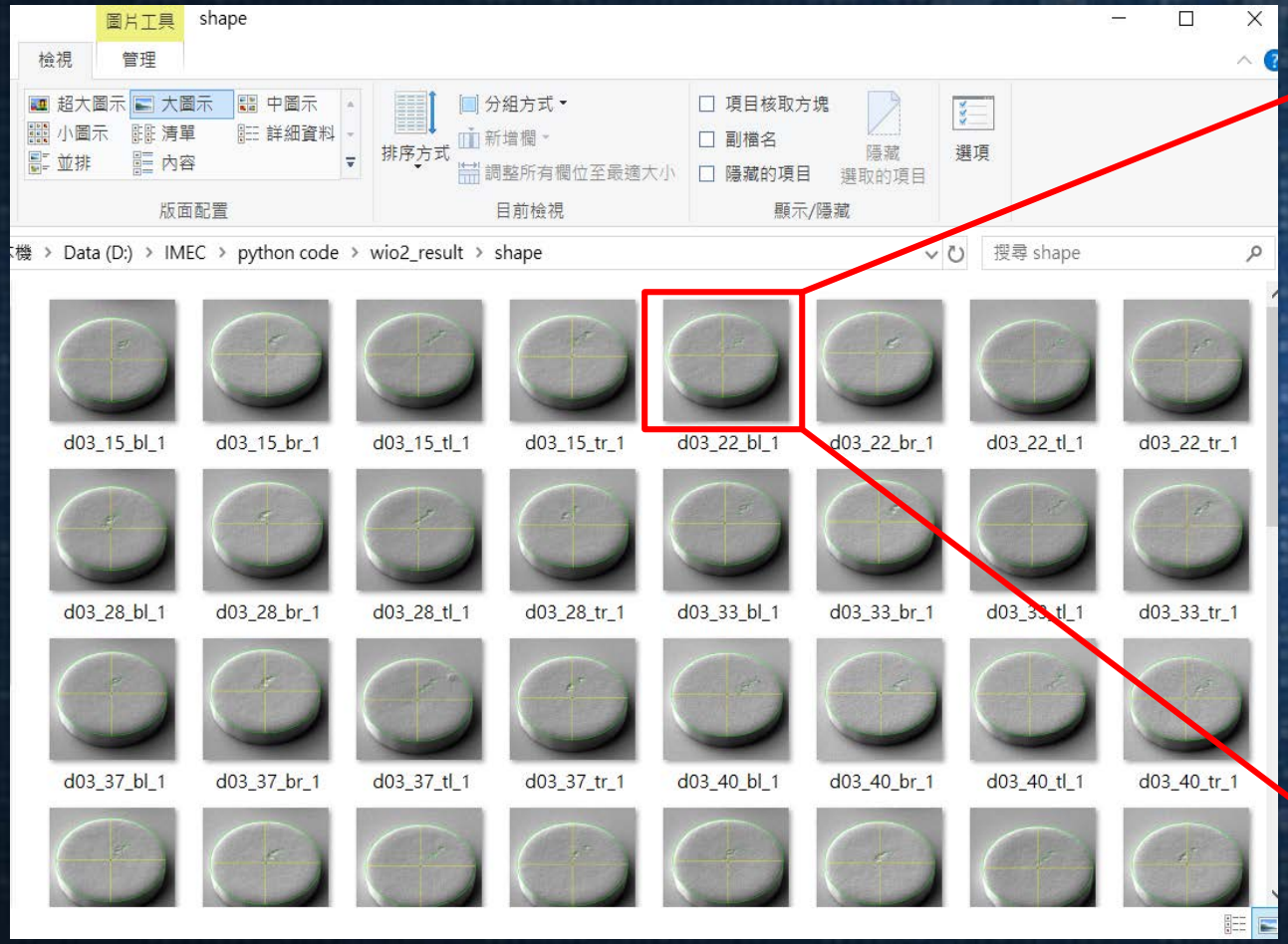
Experimental Results

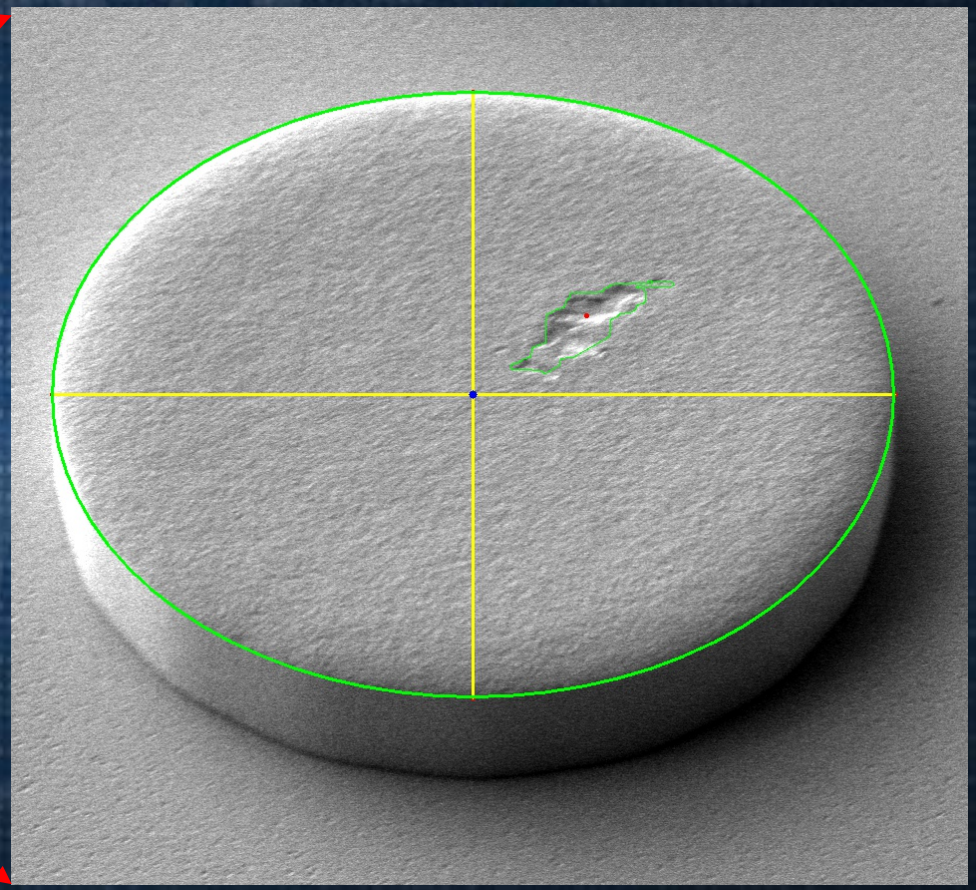
- **Input**
  - Wide-I/O 2 Probe Card
  - 70 micro-bumps



Experimental Results

- **Output**





Experimental Results

- **Output**

offset - Notepad

File Edit Format View Help

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filename: d03_15_br, x_offset: 2.22684, y_offset: 4.27632, area_perct = 1.14631%
filename: d03_15_tl, x_offset: 3.59264, y_offset: 5.28053, area_perct = 0.695444%
filename: d03_15_tr, x_offset: 2.13777, y_offset: 5.52805, area_perct = 0.944976%
filename: d03_22_bl, x_offset: 4.038, y_offset: 4.00165, area_perct = 0.513286%
filename: d03_22_br, x_offset: 3.34716, y_offset: 3.13531, area_perct = 1.06098%
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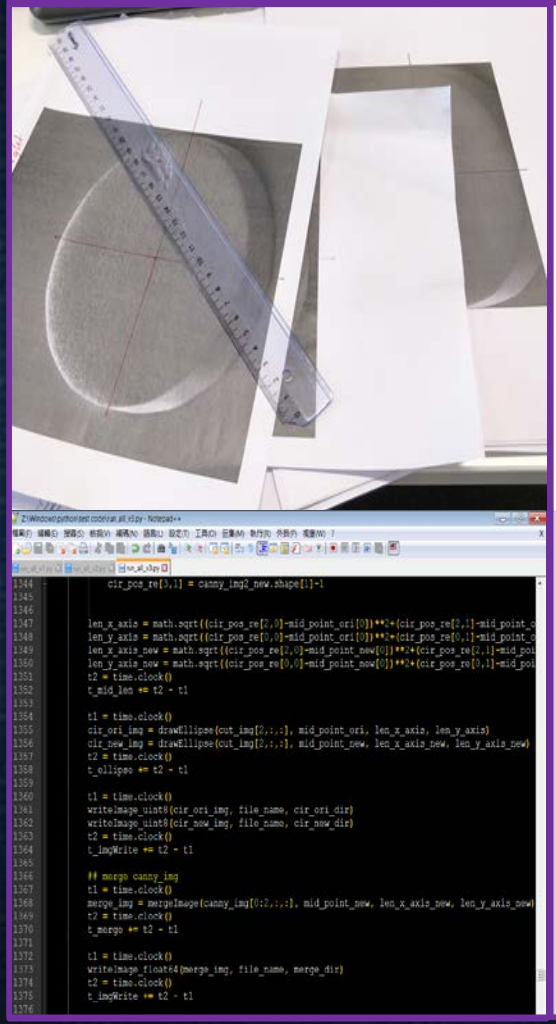
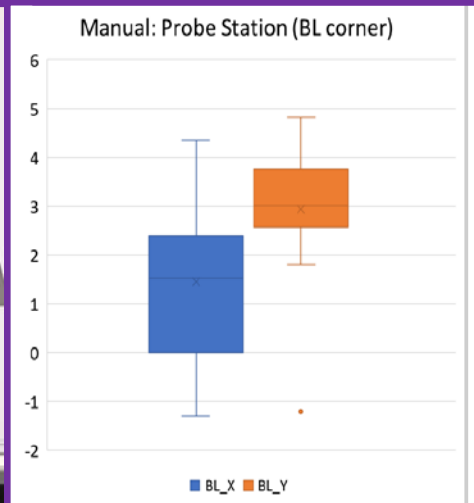
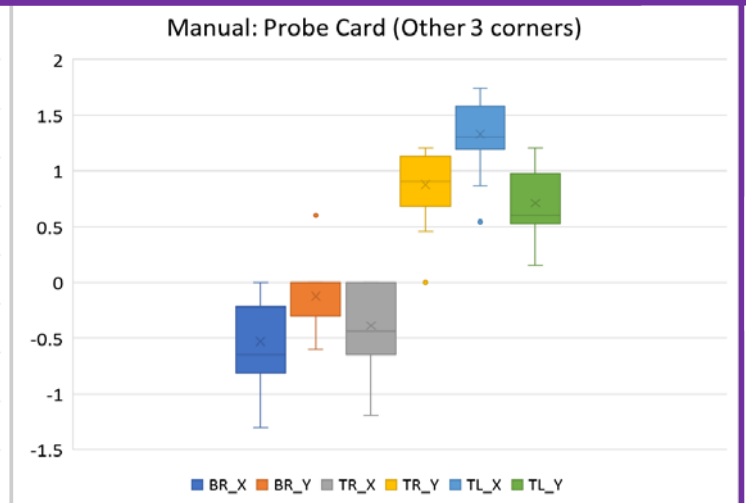
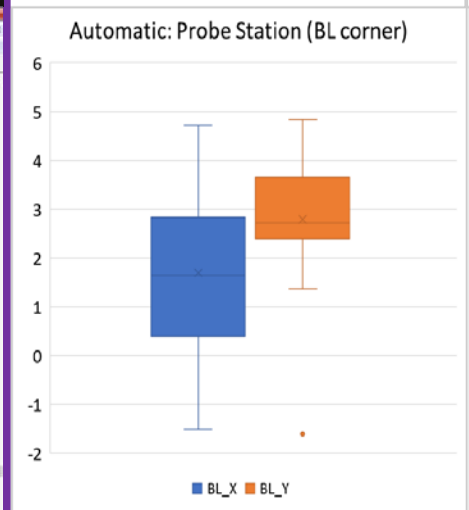
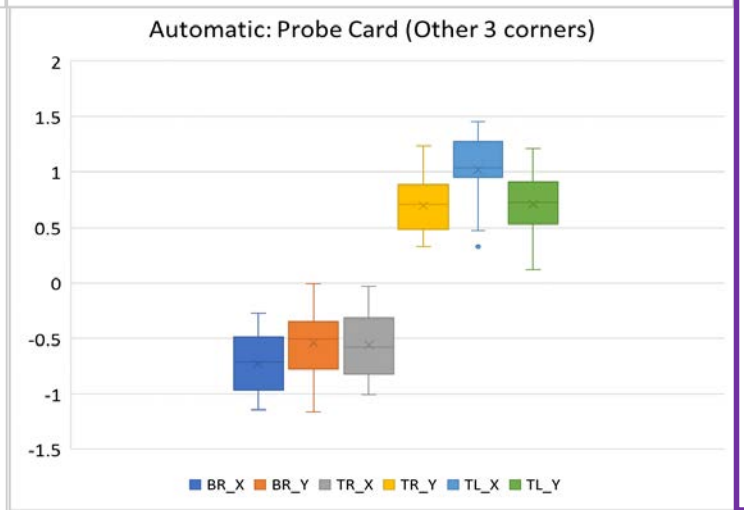
```

Automatic vs. Manual Probe Mark Analysis

Method	Results	Time
	   	3 hours (154s / µbump) 182 seconds (2.6s / µbump)

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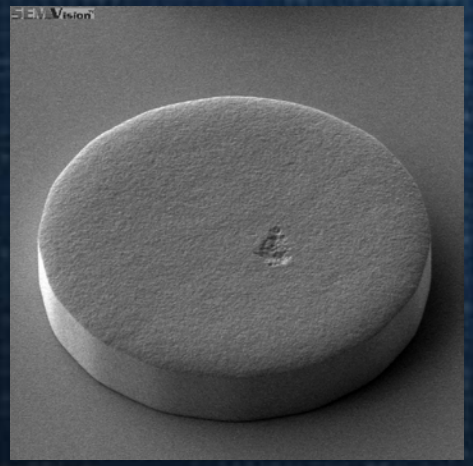
Different Conditions of the Micro-Bump Images

- **SEM tool has adjustable conditions to enhance the quality of images**
- **Common conditions we tried:**
  - 5 contrasts: dbcc_fine, dbcc_on, dbcc_off, dbcce, eiq
  - 3 voltages: 2,000V, 5,000V, 10,000V
  - 2 frame numbers: 32 frames, 128 frames
- **Goal: to check the robustness of the algorithm**

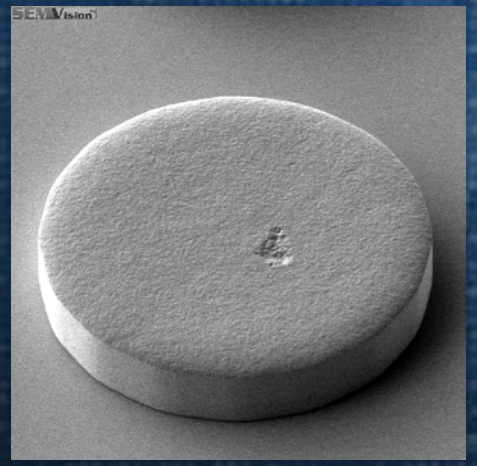
Different Conditions

- **Contrast**
  - Voltage: 2,000V
  - Frame: 32 frames

- **dbcc_fine**

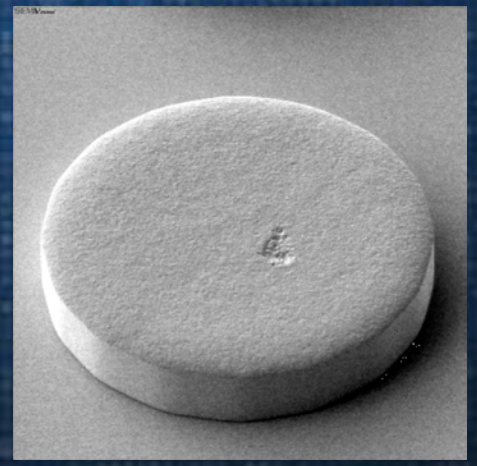


- **dbcc_on**

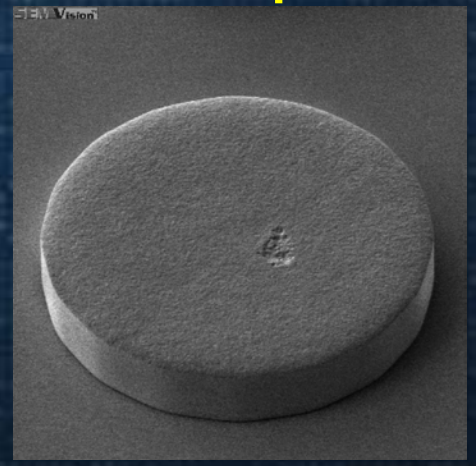


- **dbcc_off**

- **dbcce**



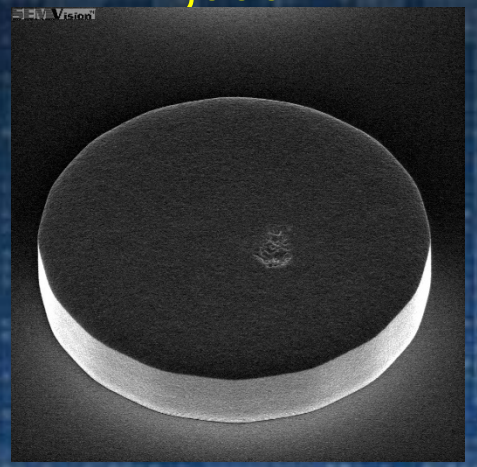
- **eiq**



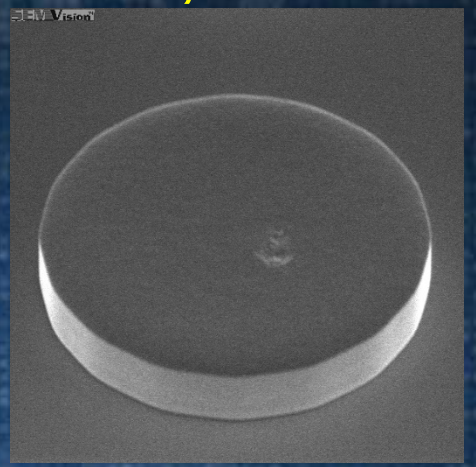
Different Conditions

- **Voltage**
  - Contrast: dbcc_on
  - Frame: 32 frames

2,000V



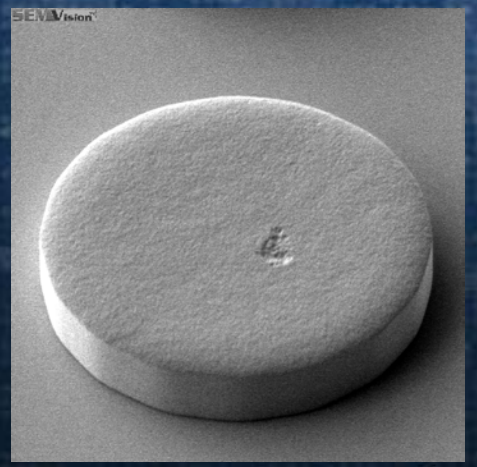
5,000V



10,000V

- **Frame**
  - Contrast: dbcc_on
  - Voltage: 2,000V

32 frames



128 frames

Results

Voltage\Contrast	dbcc_fine	dbcc_on	dbcc_off	dbcce	eiq
2,000V	C PM	C PM	C PM	C PM	C PM
5,000V	C PM	C PM	C PM	C PM	C PM
10,000V	C PM	C PM	C PM	C PM	C PM

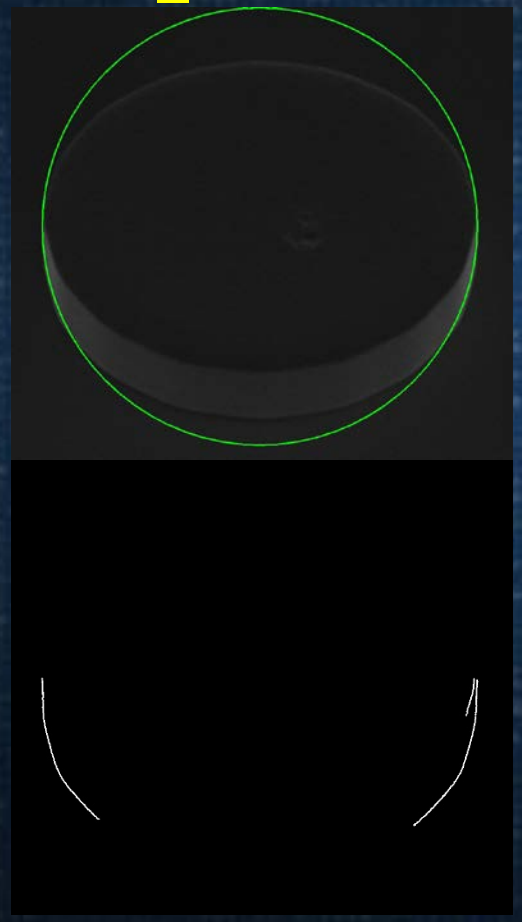
C = micro-bump contour / PM = probe mark found / not found

- Default frame setting: 32 frames
- dbcc_on + 2,000V + 128 frames: C PM
- All conditions use the same parameters

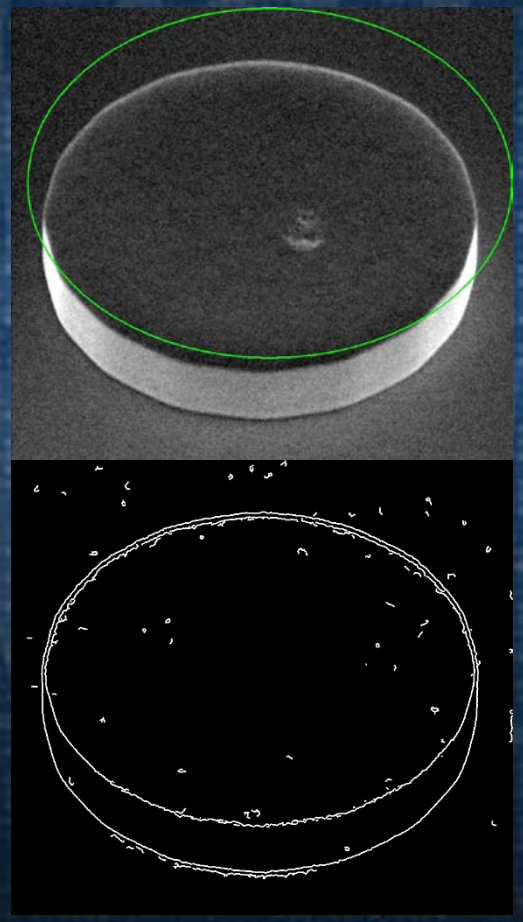
Unable to handle (1/2)

- **Identify the contour of the micro-bump**

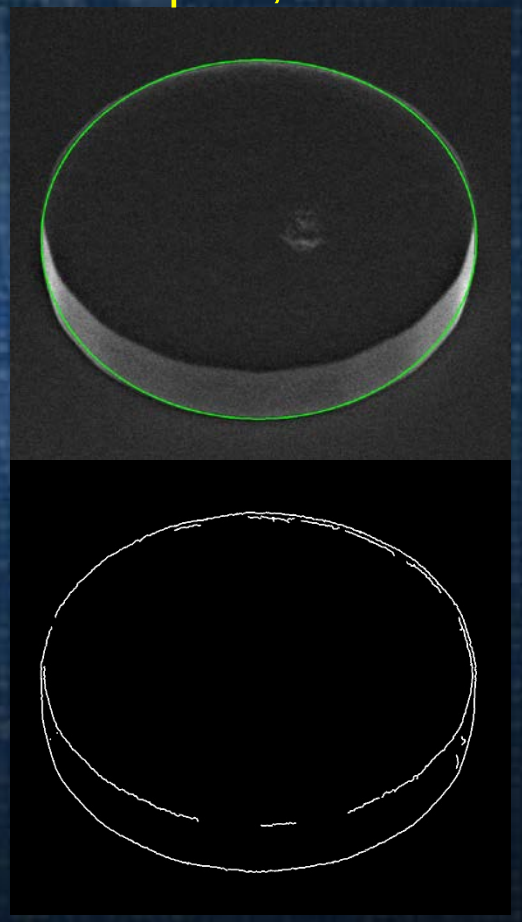
dbcc_off + 5,000V



dbcce + 5,000V

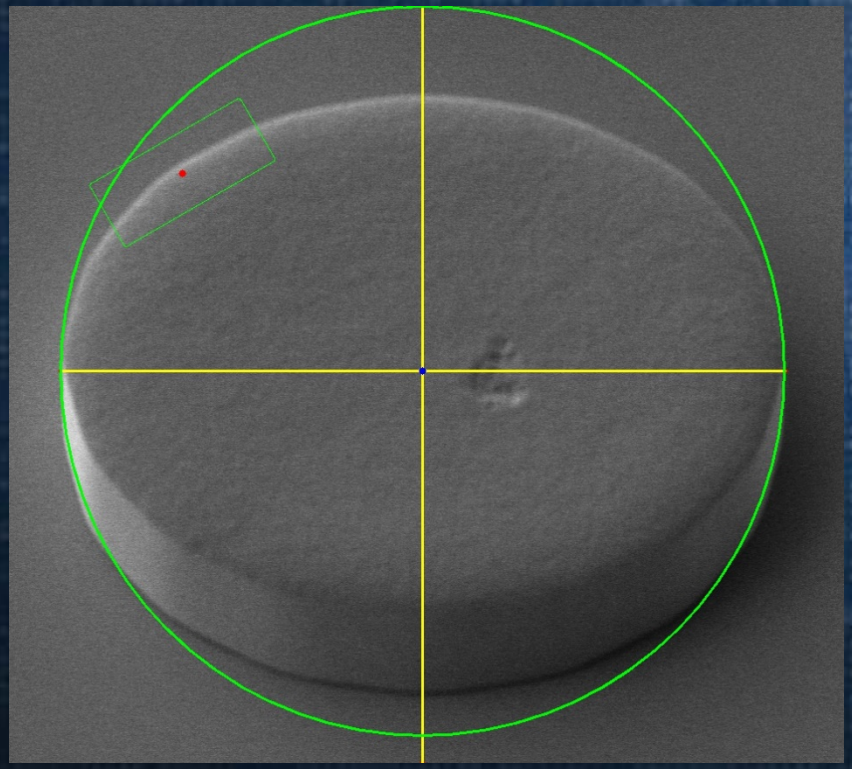


eiq + 5,000V



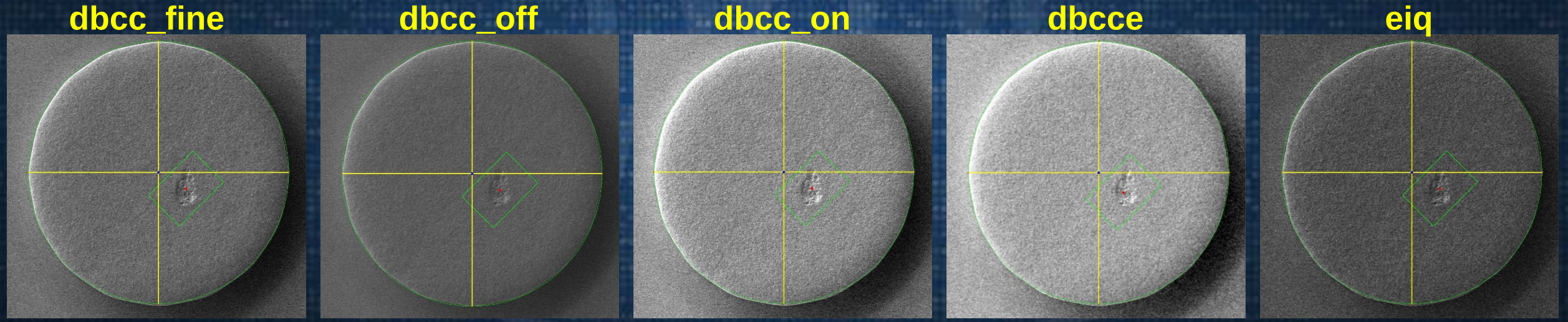
Unable to handle (2/2)

- **Identify the probe mark**
  - Caused by wrong contour of the micro-bump



Top-View of Micro-Bump Image

- **Conditions**
  - Different contrasts with 2,000V and 32 frames



Overview

- Introduction
- Automated Probe Mark Recognition
- Area of the Probe Mark
- Results
- Robustness of the algorithm
- **Summary**

Summary

- **Software tool for probe mark analysis**
  - Find the contour and center of the micro-bump and probe mark, and then calculate the offset between them
- **Comparison with manual measurements:**
  - More reliable
  - Faster
  - Comes with additional features (area of probe mark)
- **Robustness of the algorithm checked by using SEM images with different conditions**