

SW Test Workshop Semiconductor Wafer Test Workshop

Advances in Metrology for Guide Plate Analysis



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June 3-6, 2018

Overview

- Context and motivation
- Latest advances:
 - Automatic entrance hole measurement
 - Hole shape analysis
 - Debris detection
 - File format

• We're building our own system!

- Why not use what's already out there?
- What have we learned?

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Image analysis software

Image analysis software

Automatic image capture

Metrology system

Microscopes and operators

Context: guide plates

- What are we measuring? Guide plates for ProbeCards.
- What do customers care about?
 - Hole size: accuracy and repeatability
 - Taper
 - Corner radius
 - Position accuracy
 - Exit shape

Position Hole size Entry rounding Hole taper **Corner radius**

Motivation

• Why is metrology so important?

- Quality Assurance data for customers
- Feedback for process improvement
- Why make our own system?
 - Nothing suitable out there
 - Complete control of hardware and software
 - Identify error sources

Latest metrology advances

Capability features that have been developed since SW Test 2017

Automatic entrance measurement

- We need entrance data to help drive towards small pitch arrays.
- Pitch breakdown test (top):
 - Drill array of holes
 - Decrease pitch, drill again
 - Find breaking point
 - Time-consuming!
- Image processing alternative:
 - Backlight doesn't work: soft edges
 - Use toplight instead
 - Same contour algorithm as exits



Hole shape analysis

- We have adapted our Fourier methods:
 - Radius vs angle doesn't always work
 - Instead use x and y vs distance along contour perimeter
- Fourier coefficients = shape vector
- Target shape: anything you want
- Shape metric = distance between shape vector and target
- Good holes: shorter distance and smaller spread



Debris detection

- Shape vector also helps to find debris
- Target hole:
 - In previous example, ideal square
 - Here: average shape
- Again, distance is key idea here
- Good holes clustered near target (blue)
- If distance > threshold: debris



File format and storage

- We needed a file format to store and share data
- Raw data are images, but hard to search and query
- Chose JSON:
 - Plain text
 - Web standard
- Nested structure: see right
- Compression: reduces file sizes by ~90% (compared to images)

• Guide plate

- Image 1
 - Hole 1
 - Position
 - Size
 - Shape
 - Etc.
 - Hole 2
- Image 2Image 3

...

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Automatic Measurement System

Development of a custom system specifically for guide plate analysis

Evolution of metrology process

- Began with operators using microscopes
 - Prone to human error
 - Inconsistent (focus, illumination)
 - Time-consuming

First we automated the analysis

- Always same output for given image
- Richer information (shape, position)
- But capture still time-consuming
- Now the capture also



Hardware

Z axis (focus)

Microscope objective

Backlight illumination



Camera

Toplight illumination

Air bearing XY stages

Autofocus

Eliminates subjective user choice
Scan Z axis, measure contrast
Choose position with peak (below)



Position data

Hole positions are combined from:

- Position within an image (already did this for microscope images)
- Image position relative to XY stages,
 i.e. encoder readings
- Now all holes in same coordinates
- Find errors by fitting to target positions Q:
 - Scale s, rotation R, translation t
 - Measured positions P
 - Q = s(RP + t), errors = Q Q'



Position error breakdown

• With complete access to the system, we can minimise position error contributions from:

- XY stage calibration
- Microscope calibration (µm/px)
- Part rotation
- Camera rotation

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part

camera

Future challenges

What functionality are we adding?

Partial obstruction

- What if the debris is not at the exit?
- If material gets stuck inside plate, blocks light.
- Algorithms will report incorrect hole size.
- Possible solutions:
 - Measure intensity inside contour, compare average.

Entrance

Exit

Adaptive thresholding algorithm.

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light

Automatic illumination

• Light intensity is crucial.

- Saturation: can't use the images at all.
- Too dark: contour algorithm breaks down.
- Use the intensity histogram as feedback in illumination control loop.
- Challenge: multiple hole sizes. Separate exposures?



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intensity

Entrance breakdown

- Customers want no breakdown between hole walls.
- Example right:
 - Top surface is in focus
 - Breakdown is blurred

• Adapt the autofocus algorithm:

- Already measures surface focus Z
- Find focus position for every part of the image, rather than global only
- If position deeper than surface:
 broken



Conclusion

Guide plate specifications get tighter all the time

• This makes metrology more important

We are building our own system to provide the data we need

This is a powerful tool in our drive to improve our product

Thank you for your time and attention

Mike Cullimore