2010 Keynote Address

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REALIZING THE BENEFITS OF ADAPTIVE TEST

by

Ken Butler

Fellow

Texas Instruments

ABSTRACT

Like most of the rest of the world, the electronics industry is under extreme pressure to drive out cost wherever possible. Outsourcing has become a way of life. IDMs in the US are nearly extinct since development and manufacturing costs must be amortized over a much larger product base. The ATE industry is a shadow of its former self and everyone is looking for the least expensive platform possible. It's harder and harder to stay in business, let alone stay competitive.

We hear a lot lately about adaptive test and the potential to use it to reduce manufacturing costs, but what is it really? Will adaptive test techniques make burn-in obsolete? How do we use these ideas effectively within my manufacturing flow? How hard is it to integrate into our existing test and data infrastructure? In this talk we will look at the history and evolution of adaptive test. The concepts have been around for 10 years or more, but most are far from being considered entrenched. By comparison, on-chip scan compression techniques were introduced around 2002 and saw pervasive adoption across much of the industry almost overnight, at least for large system on chip designs. Why the difference? Can the case be made for the economic benefits of adaptive test? Of course adaptive test is no panacea, but we will see that when it is implemented correctly, it can do much to streamline a manufacturing operation, speed product ramps, and reduce costs. It will require an increased level of standardization, much improved data mining and statistical analysis techniques, and stronger and more open communication across the entire supply chain. But everyone who participates in the process will benefit.

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Realizing the Benefits of Adaptive Test

Ken Butler

TEXAS INSTRUMENTS

2010 BiTS Workshop
March 7 - 10, 2010

Outline

- Historical Perspective
- ITRS Roadmap
- Applications
- Industry needs and future trends

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The Latest Buzz Word?

Kazuo Nakajima, "A New Approach to System Diagnosis", Proc. *19th Annual Allerton Conf. Comm. Contr. Comput.*, Sep. 1981.

Texas Tech (now Maryland College Park)

"Nakajima was the first to suggest a departure from this practice [fixed test sequence]. He proposed to adaptively choose the tests and to seek their results until one can identify a fault-free unit. This fault-free unit may then be used as a tester to identify all faulty units."

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What is Old is New Again

- Common themes between Nakajima's work and more recent ideas
  - Fixed testing isn't always the best answer
    - Learn more about the product
    - Learn it faster, more efficiently
  - Use information across devices to aid in disposition

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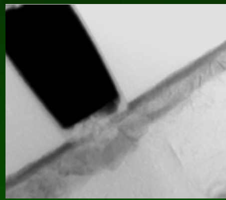
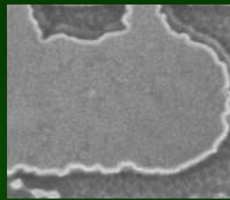
And Some New Things too

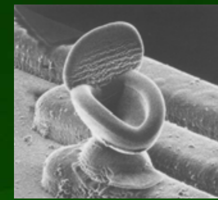
- Variability everywhere…
  - Smaller dimensions, but same ol' wavelength of litho light source
  - Film thicknesses at atomic scale
- Implication: Variation happens



Resistive via



Line edge roughness



"Toilet bowl"

ITRS Adaptive Test Section

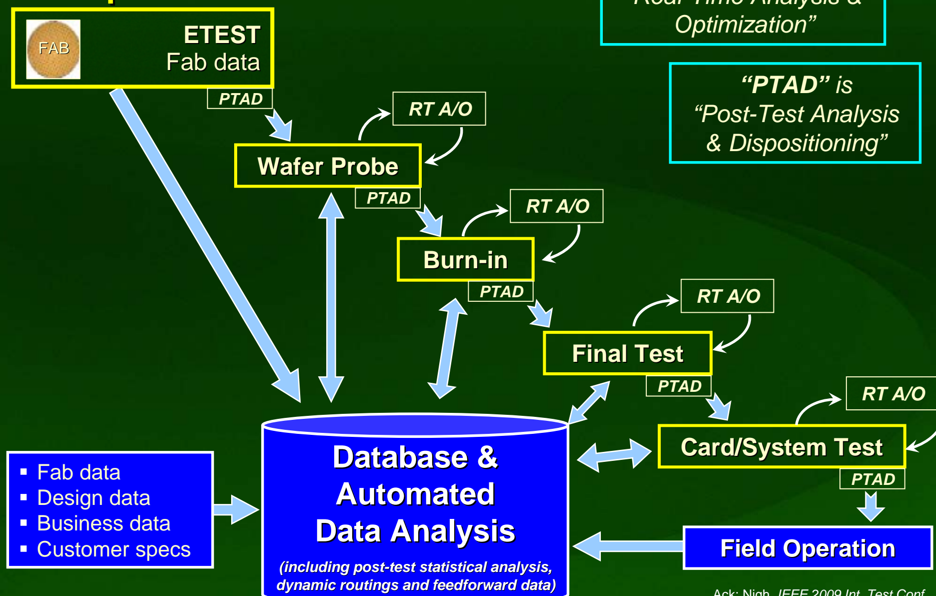
- Led by Phil Nigh at IBM, 50 contributors
- Defines terminology
- Lists example applications
- Challenges
- Trends
  - Implications for industry segments (e. g., ATE, software/automation, others)
  - Future directions

http://icdt.ece.pdx.edu/~icdt/cgi-bin/adaptive.cgi/AdaptiveTest

Definition of Adaptive Test

*Adaptive Test is a broad term used to describe methods that change test conditions, test flow, test content and test limits **(potentially at the die/unit or sub-die level)** based on manufacturing test data and statistical data analysis.*

Ack: Nigh, *IEEE 2009 Int. Test Conf.*



Important Questions

- Adaptive test makes burn-in obsolete?
- Adaptive test = Test time reduction?
- Do we have everything we need?

Adaptive Test & Burn-in

- TI co-developed with PSU TI-specific implementation of PSU/LSI “Location Averaging” technique
- Initial application: Burn-in
- TI tends to describe it in terms of “burn-in elimination”, but it should be “burn-in optimization” – Use it where it serves best
  - Burn-in needed at first for product learning, development of statistical screens
  - Need continuous sample burn-in to monitor

Burn-in Optimization Case Study

- Device Information
  - 90nm Wireless SOC
  - Post burn-in fails obtained from a large sample of production material
  - Fails analyzed to identify potential probe-visible fails
- Outlier Analysis
  - Analysis started with 400 parameters
  - Analysis performed to identify outlier screens so that post burn-in fails can be screened at wafer sort
  - Eliminate >50% burn-in fails with 2.5% outlier rate (15 parameters total)
- Outlier unit disposition
  - Burn-in
  - Scrap
- Determined by many factors, e. g.,
  - Customer quality requirements
  - Hardware cost and availability
  - Die, package costs
  - Schedules, delivery commitments

Ack: Nahar et al., *IEEE 2009 Int. Conf. Computer Design*

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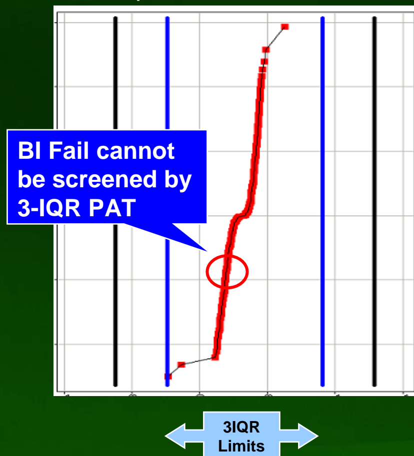
Why Location Averaging?

BI fail in middle of PAT distribution is an outlier to LA

Part Average Test

One parameter, one wafer

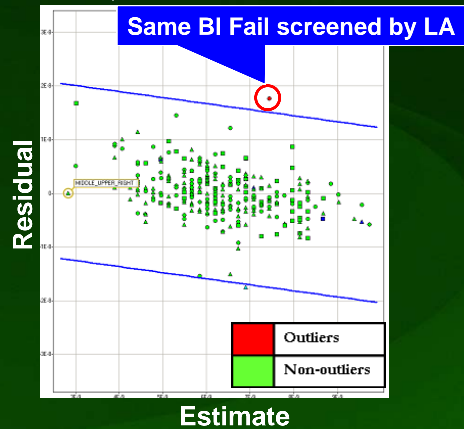


BI Fail cannot be screened by 3-IQR PAT

3IQR Limits

LA

One parameter, one wafer



Same BI Fail screened by LA

Residual

Estimate

Ack: Nahar et al., *IEEE 2009 Int. Conf. Computer Design*

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Using Testing to Enable Product Mix

Wafers | Reels of Dice | Packaging

Mobile package

Desktop package

Power

OLB & OLF

- Die level cherry pick allows routing of die to optimal package, test
- Deferred bin and configuration allows configuring devices to meet fluctuating demand for particular configurations
- Requires traceability and corresponding information systems

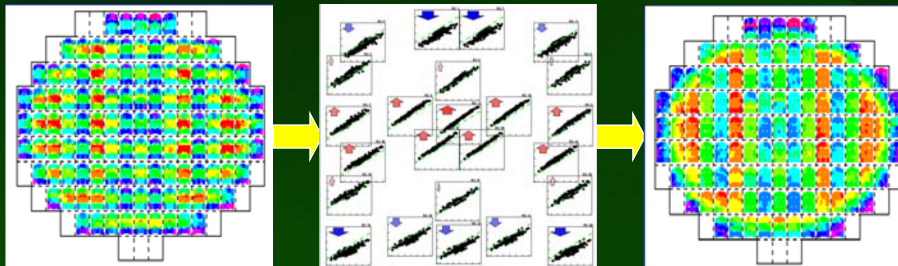
Ack: Mayberry et al., *IEEE 2006 VLSI Test Symp.*

Adaptive Test = Test Time Reduction?

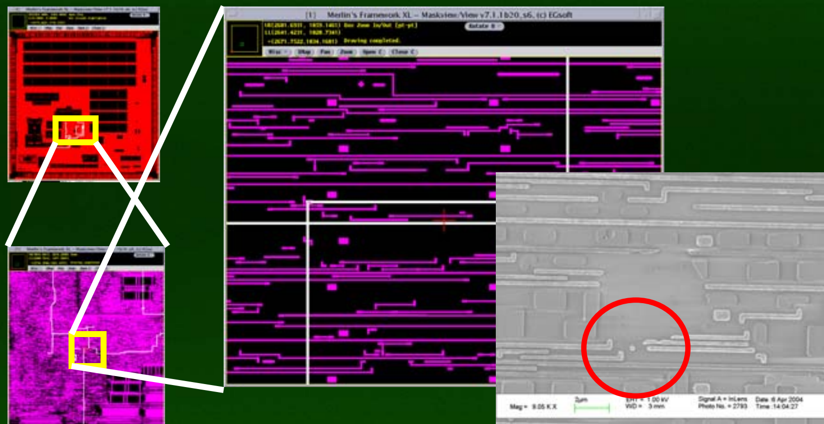
- There are many other non-TTR apps
- Address various needs
  - Process learning
  - Device debug
  - Quality improvement
- All of these more important in the era of fabless and fab-lite
- Some examples follow

Adaptive Test for Process Ramp, Debug

- Gattiker, ITC 2008
- Variation has multiple systematic and random components
- Often difficult to separate the contributing factors
- Use test results, data analysis to de-convolve them
- Feedback to fab for process learning, corrective action



Adaptive Test for Diagnosis



Where a single failure appears as multiple defects in the same general area, the location of the failure can be narrowed by generating additional patterns.

Ack: Gopu et al., *ASM 2006 Int. Symp. on Testing & FA*

Adaptive Test for Improved Screening

Probe fails
Outliers
Non-Outliers

Edge die correlated to returned units

Reticle issue correlated to probe fails

- Nahar, et al., ICCD 2009, D3T 2009
- Post-process wafer data
  - Model good die statistically
  - Correlate to any "fails" of interest

Burn-in fails correlated to probe measurement

Edge die correlated to probe fails

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Meeting the Challenge

- Test infrastructure designed ATE-based rapid go/no-go dispositions
- Moving forward, decisions deferred to take advantage of more information
- It's all about the data…
  - Data acquisition
  - Data movement
  - Data analysis
- Over time, retool infrastructure for these goals

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Software Infrastructure Improvements

- ATE
  - Modular test programs
  - On-the-fly ordering
  - Rapid in situ die history access
  - Adaptive searches
  - Standards for adaptive test data
- Analysis techniques
  - Better algorithms
  - Automated algorithm selection
  - Triggers for test content changes

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Hardware Infrastructure Improvements

- ATE, boards, ovens
  - Per-die test
  - Rapid data movement
  - Enhanced controllers for on-ATE decisions
- DFT
  - On-die monitors of all types
  - Test access mechanisms
  - On-die thermal control

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Summary

- Variation is now a way of life
- Test has to be adaptive because the devices we test are so variable
- Requires infrastructure improvements and collaboration on a grand scale, but it can be done
- There are benefits for all the players

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Fun with Quotes (http://www.brainyquotes.com)

Most of the vices and mortal sins condemned today correspond to inclinations that were purely **adaptive** or at least harmless in primitive man.
Konrad Lorenz, Austrian Nobel Prize winning Zoologist

You have to be fast on your feet and **adaptive** or else a strategy is useless.
Charles de Gaulle, French WWII General, President

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