Tutorial:

Probe Card Evaluation Process

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- Suppliers: Cascade Microtech, Cerprobe, Custom One Design, Form Factor, Micro Probe, Probe Technology, SV Probe
Ground Rules

- Maintain an informal environment
  - Ask your questions as they arise
- Respect your colleagues
  - Keep side conversations under control
- Get out on time!
Agenda

- Acknowledgements
- Ground Rules
- Background
- Probe Card Selection Criteria
- Probe Card Specifications
- Evaluation Process
- Conclusions
Background

• Probe card industry
  – Dominated by epoxy ring cantilever needles
  – Many small suppliers, few large ones
  – Very competitive environment
  – Limited development capabilities
  – Stake in maintaining the status quo
Background (cont’d)

• Probing requirements are pushing beyond the envelope for cost effective use of needles
  – Fine pitch pads
  – Area array pads
  – Multi-die

• Building the cards is not the problem so much as using them is.
Background (cont’d)

• New technologies are appearing with key attributes:
  – Photolithographic
  – Machined
  – Manufactured

• Some new entries to the probe card market
  – Lack detailed knowledge of probing
Our situation:
- Highly competitive commodity flash memory
- Manufacturing cost is key
- Currently probing x16
  - Going wider
  - Considering full wafer ultimately
- Need to enable next generation wafer testing with probe capability
Background (cont’d)

Needle Probe Card Costs

Price per probe vs. Number of Probe Points

- Price per probe increases with the number of probe points.
- The costs are shown for different multiples: $x_1$, $x_2$, $x_4$, and $x_{16}$.

Diagram showing the relationship between the number of probe points and the price per probe.
Background (cont’d)

![Graph showing Probe Card Cost per Site vs. Number of DUTS Probed in Parallel]

- The graph illustrates the relationship between the number of devices under test (DUTS) probed in parallel and the cost per site for probe cards.
- As the number of DUTS probed in parallel increases, the cost per site also increases linearly.

*Note: The specific values are not provided in the image.*
Background (cont’d)
Candidate Technologies

- Vertical buckling beam
- Membrane
- Conglomerate bump
- Photolithographically defined beams
- others
Background (cont’d)
Candidate Technologies
Background (cont’d)

• So why are we doing this?
  – Probe technology is generally not viewed as providing a competitive advantage
  – New probe technology is expensive to develop
  – Higher volume drives lower costs
  – Suppliers cannot adequately evaluate their technologies independently
  – Sharing methods and results can accelerate learning and innovation in the market.
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- **Probe Card Selection Criteria**
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Several areas of consideration in making a selection:
- Technical
- Performance
- Commercial
- Supplier capabilities
- Financial
- Environmental Health and Safety (EHS)
Probe Card Selection Criteria (cont’d): Technical

- Does the technology meet your specifications?
  - Layout flexibility
  - Planarity
  - Contact resistance
  - Current carrying capacity
  - Pad damage
  - AC characteristics
  - etc.
Probe Card Selection Criteria (cont’d): Performance

- Does the technology work in your manufacturing process?
  - Yield
  - Bin fallout
  - Repeatability
  - MTBF, MTTR
  - Run rate
  - etc.
Probe Card Selection Criteria (cont’d): Commercial

- Is the supplier prepared to meet your needs for manufacturing quantities?
  - Delivery
  - Capacity
  - Financial health
  - Warranty
  - Service
  - etc.
Probe Card Selection Criteria (cont’d): Supplier Capabilities

- Does the supplier have the technical capabilities to support the technology?
  - Engineering organization
  - Analysis capabilities
  - R&D organization
  - Technology roadmap
  - Design capabilities
  - etc.
Probe Card Selection Criteria (cont’d): Financial

- What is the total cost of ownership of the technology?
  - Purchase price
  - Lifetime
  - Maintenance and repairs
  - Retrofits
  - Headcount
  - etc.
Probe Card Selection Criteria (cont’d): EHS

- Does the technology include any EHS concerns?
  - Final product
  - Production integration
  - Manufacturing process
  - etc.
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Probe Card Specifications

- Define the technical requirements of the probe technology
  - DC electrical: contact resistance, leakage, signal path resistance, current capacity, etc.
  - AC electrical: bandwidth, capacitance, cross talk, etc.
  - Mechanical: alignment, planarity, force, pitch, layout, etc.
  - Other: pad damage, environment, lifetime, etc.
**Probe Card Specifications (cont’d)**

- **Must be defined up front before discovery**
  - Complete and specific
- **Based on process/product requirements**
  - avoid wish lists
  - clarify between “must have” and “nice to have”
- **Avoid technology specific requirements**
  - e.g scrub mark, beam length, contact force
  - Break out of the needle mindset
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Evaluation Process

- How do we determine compliance with specifications and fit into the manufacturing process?
  - Technical
  - Performance
- How do we do this repeatedly?
- How do we do it cost effectively?
Evaluation Process (cont’d)

- What are the available resources?
  - People
  - Probers
  - Testers
  - Off-line tools
  - Wafers
  - etc.

- Where is the likely bottleneck?
Evaluation Process (cont’d)

- Manage the bottleneck
  - Minimize demand
  - Maximize efficiency
- Warning--the bottleneck may change!
Evaluation Process (cont’d): Our Resources

- **People**
  - probe engineers shared with production

- **Equipment**
  - probers (shared)
  - IC testers (shared)
  - probe card analyzers (shared)
  - probe mark analyzer (shared)
  - microscopes (shared)

- **Wafers:** bare Al, probe test chip, and product
• Test chip provides for multiple touchdowns on a single die site. 30+ wafers worth of TDs per wafer.

• Allows for single probe card for both test chip and product.
Evaluation Process (cont’d)
Our Bottlenecks

• Initial pass showed IC testers as bottleneck
• Evaluation protocol developed to minimize requirements for testers
• Learn all we can before putting card on the tester
  – Alignment, planarity, tip geometry, prober compatibility, probe mark characteristics, operating conditions
• Understand the starting state \( (t_0) \) of the card
Evaluation Process (cont’d)
Protocol Phase 1

PB3000 time zero → PCR uScope tip size, t0 → TEL P8i Vision → TEL P8i, AL Rc vs. OT → TEL P8i/PMA
Evaluation Process (cont’d)
Performance Characterization

• How does the technology perform
  – right out of the box
  – throughout its useful lifetime

• Metrics
  – Yield, bin fallout
  – Contact resistance
  – Pad damage (bondability)
  – Planarity, alignment, leakage, etc.
Evaluation Process (cont’d)
Protocol Phase 2

- Two-way correlations
- Multiple temperatures
- Acknowledge that cleaning frequency and requirements are unknown

-- generate assy wafer
-- possible clean cycle
Evaluation Process (cont’d)

Lifetime performance

• How does the technology perform and evolve with continued use?
  – Simulated useful lifetime with bare Al wafers
  – Electrical and mechanical characteristics
  – Test chip for contact resistance, PMA
• Is useful lifetime limited by the technology, the process, or the product life cycle?
Evaluation Process (cont’d)
Protocol Phase 3

PB3000 55k TD → PCR uScope tip size, 55k → TEL P8i, Al 45k TD → TEL P8i, 2PCJ16 5k TD, Hot Rc → PCR uScope tip size, 205k

PB3000 105k TD → TEL P8i, Al 95k TD → TEL P8i, 2PCJ16 5k TD, Hot Rc → PB3000 205k TD

Correlation

-- generate assy wafer
-- possible clean cycle

TEL P8i, 2PCJ16 5k TD, Hot Rc

**Note:** The diagram shows the correlation between different processes and equipment, indicating potential clean cycle and assembly wafer generation.
Evaluation Process (cont’d)

- How much margin to the useful lifetime does this technology provide?
  - Assumes probe life exceeds useful lifetime
Evaluation Process (cont’d)
Protocol Phase 4

- TEL P8i, Al 295k TD
- TEL P8i, 2PCJ16 5k TD, Hot Rc
- PB3000 505k TD
- PCR uScope tip size, 505k

--- possible clean cycle

--- generate assy wafer
Evaluation Process (cont’d)

Technical Protocol

- Phase 1: $t_0$ characterization
- Phase 2: Early life characterization
- Phase 3: Lifetime characterization
- Phase 4: Lifetime margin

Does this technology meet our technical requirements?
Completing the evaluation protocol:
- addresses technical concerns
- touches on performance concerns
Sufficient to weed out would-be contenders
Probably not sufficient to identify a single “winner”
Production pilot completes the performance evaluation
Evaluation Process (cont’d)  
Production Pilot

- Multiple cards
- In parallel with current technology
- Extended time
- On-going detailed analysis of results
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- New technology concepts to address the evolving probing requirements (pitch, arrays, multi-die) are out there.
- Converting concepts into hardware is a challenge for developers
- Validating the concepts is a challenge for potential users
  - Close cooperation with suppliers in needed
Conclusions (cont’d)

- Understanding your contacting requirements is a pre-requisite to technology evaluations
  - Clear, complete specifications
- Establishing a repeatable, cost effective process for evaluating contact technologies is critical for a successful selection
- Sharing of methods and results is key to quickly getting up the learning curve and down the cost curve.