Industrial Transition to 450mm Notchless Wafers

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Global 450mm Consortium (G450C)

Semiconductor Technology Symposium
SEMICON West, 7/10/14
Overview of 450mm notchless wafers

• 450mm notchless wafer task - innovation and collaboration
  - Innovation: New wafer geometry, new tool design, new detection device, and new detection methods
  - Effective collaboration among IC makers, tool suppliers, subsystem suppliers, and wafer manufacturers
  - Only 14 months to complete all technical designs and tests (Feb. ‘13 to Mar. “14)

• Four key dates
  - November 2012
  - May 2013
  - November 2013
  - March 2014
Establishing Notchless Work Group

- Tool suppliers requested evaluation of notchless wafers in Nov. ’12
- SEMI members expressed many notch-related problems: stress, non-symmetry, non-uniformity, complicated tool parts, and edge exclusion
- G450C members agreed to explore in Jan. ‘13.
- Established Work Group and defined schedule at G450C in Feb. ‘13.

**Objective:** to explore the 450mm notchless wafers and to assist the standardization of potential fiducial marks

- **Notchless Representatives**
  - Members: member company representatives
  - Review data
  - Provide guidance

- **Notchless Execution Team**
  - Members: wafer & tool suppliers, member company home teams.
  - Execute experiments
  - Collect data

- **G450C Coordination Team**
  - Members: G450C program staff
  - Create plans & schedule
  - Coordinate activities

- **SEMI Committee**
  - Si wafer committee
  - Standardization process

Member company representatives:
- GLOBALFOUNDRIES: Dave Gross
- Intel: John Williams
- IBM: Gerd Pfeiffer
- Samsung: Samjong Choi, Tae-Hyoung Koo
- TSMC: Vincent YH Chou
- G450C staff: Mike Goldstein, Les Marshall
- Felix Ku, CK Huang, Vincent Huang

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Laser-inscribed Fiducial Marks

- Understand the characteristics of laser marks (accuracy, repeatability, etc.)
- Tool suppliers recommended trying new marks and not using T7 as the orientation fiducial mark

**Laser mark measurement (300mm)**

- The hole size and depth measurement for the reference point of T7 code
  - Average hole diameter (N=41): 110.6 um
  - Standard deviation: ±1.4 um
  - Average hole depth (N=41): 70.8 um
  - Standard deviation: ±1.0 um
- Determining the coordinate of wafer by the hole location is achievable.
Phase 1 Test Results

- Phase 1 test wafers (May to Oct. ’13)
  - 35 designs of fiducial marks; testing methods defined.
- SNARF approved at SEMICON West in July 2013.
  - Sharing notchless technical progress at SEMICON West (Jul.), Taiwan (Sep.), Japan (Dec.), and Korea (Feb. ’14).
  - Presenting progress at many SEMI TF meetings and ITG-J meeting.

Test Wafers for Fiducial Marks

- Designs and inputs collected from G450C member companies, tool suppliers, and optical detection suppliers.
- Total 35 locations (10° apart) on 300mm wafers
  - Locations A to I
- Two hole depth (35 μm & 60 μm)
  - 25 marks with 35μm
  - 10 marks with 60μm

- Objectives in tests: X-Y accuracy, θ angle accuracy, repeatability, and throughput rate.
- Outputs: laser hole depth effect, slanted lines vs. straight lines, distance between dots, number of dots, etc.

- Process effects on wafers
  - low reflectivity tests: Oxide (850A) ~12%; Nitride (600A) ~3%;
  - Entire IC baseline processes at CNSE

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Development of Test Methods

- Encouraging results from various detection devices
- Achieving the necessary requirements for accuracy and speed
  - Design concepts narrowed down from test results

Highlight - Line Camera results

- 1D line camera (2048 pixels) for 20mm length
  - 10 microns per pixel
  - 2.5 sec for a rotation (0.4 rps, 300 mm wafer)
  - Analyze the gray value in the image

- Observations:
  - Location repeatability ± 10 μm (1σ)
  - 205 μm pitch would be better than 125 μm pitch
  - Out of focus by 1mm would reduce the contrast, but results are still ok.

Fine Measurement Evaluation

- Repeatability depends on number of dots in a vertical line
- Achieved the desired repeatability on the marks of bare Si wafers using existing camera technology
  - 3 dots (3σ = ±0.8μm); 4 dots (3σ = ±0.4μm)

<table>
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<th>Mark Type</th>
<th>Dot Depth</th>
<th>Dot # (Vertical)</th>
<th>Repeatability (Horizontal)</th>
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</table>

Data Source: Tokyo Electron

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Phase 2 Test Results

- Phase 2 test wafers (Nov. ‘13 to Feb. ‘14)
  - 9 fiducial marks on 3 different test wafers.
  - Verifying the fiducial design concepts to fit all tool requirements (e.g. litho, metrology, handling, and processing tools)
  - Selecting the final 3 fiducial marks based on test results

Design Concept Update

- Optimizing the detectability
  - Vertical lines with 4 dots; horizontal lines with ≥ 7 dots.
  - Different patterns at 3 locations for robustness and speed
  - Unequal spacing (119-120-121 degree apart) among 3 patterns
  - Mark width ≥ 2mm. Line interval ≥ 2 dots.

- Optimizing silicon wafer quality
  - Off crystal plane, fewer dots, and shallower dots to minimize Si crystal damage
  - Dot size: 100 ± 5 μm; dot pitch: 200 ± 10 μm pitch; dot depth: 45 ± 10 μm
  - Fiducial marks are mainly located within the 1.5 mm EE region
Process Effects on Fiducial Marks

• Fiducial marks passed the tests throughout the IC processes
  • The fiducial marks were detectable throughout the IC processes at CNSE R&D fab and a HVM commercial fab.

Process effect on fiducial marks

• Survivability test: 30 wafers went through IC process at CNSE without issues
• Results - fiducial marks still meet detection requirements

Data source: Nikon
Final Set of Orientation Fiducial Marks

- Final 3 orientation fiducial marks selected in March ’14
- Potential backend solutions after grinding explored.
- Ballot for cycle 4 approved at SEMI NA meeting in April ‘14
- Ballot received 100% acceptance and Committee approval; M1 standards expected to pass at SEMICON Europe (Oct. ‘14)
Next Steps

- Start notchless transition from July 2014
  - G450C will provide suppliers 450mm wafers with new orientation fiducial marks
  - Expect some tool modification for notchless wafers beginning in early 2015
- Small quantity of pure 450mm notchless wafers available for tool development by the end of 2014
- Continue other SEMI standards (Coordinate system simplification, 1.5mm EE, M76, etc.)
Acknowledgement

• Thank my team and General Managers at G450C
• Thank participating companies including Applied Materials, Nikon, ASML, Canon, Hitachi, KLA-Tencor, Lam Research, Tokyo Electron, Sumco, LG Siltron, GSI Group, Recif Technology, PVA TePla, Mitsui Chem, Disco, Cognex, Sinfonia, Keyance, and Brooks.

Member company representatives:
GLOBALFOUNDRIES    Dave Gross
Intel                John Williams
IBM                  Gerd Pfeiffer
Samsung              Samjong Choi, Tae-Hyoung Koo
tsmc                 Vincent YH Chou
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