Advances in ion Implant and USJ Metrology

USJ Metrology
West Coast Junction Technology Group
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Outline

- Introduction
- Enhancements and Applications
  - Ion Implantation
  - USJ capability
- In-line product monitoring
- Conclusions
THERMA-PROBE Product Evolution

1984
TP-150
1st generation Implant Monitoring System

1985
TP-200
2nd generation

1987
TP-300
Automated Operation Production Control

1990
TP-320
High dose Capability

1992
TP-400
Dual Cassette

1995
TP-420
GEM Compliant SECS

1996
TP-500
200mm Increased throughput
Solid state lasers Pattern recognition Optional bulkhead mount

2001
TP-630
200/300mm system Same measurement system as TP500 Windows NT

2003
TP-500XP / TP-630XP
Xtreme Precision
90nm production
3X Enhanced dose detectability
Fiber coupled lasers
XP upgrade kits available

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SPC READY

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THERMA-PROBE – New XP Products Enable Lowest Dose Detectability
Eliminate Costly Monitor Wafers – Monitor Drift and Minimize Catastrophic Implant Failure Events
TP-XP used for Process Control

TP-XP minimizes wafer scraps from catastrophic or slow drift failure of process tool.
Therma-Probe Signal Response

PMR: Photo-Modulated Reflectance

- Temperature (Thermal-Wave) and Plasma Density (Plasma-Wave)
- Crystal Damage
- Pump (790nm)
- Probe laser (670nm)

Modulated Reflectivity

Index of Refraction Change

α

 oxide

Implant damage

Silicon

Modulated Reflectivity α. Implantation Damage
TP-XP Enhancements and Applications
Long-term Stability

- Eliminates drift
- Superior measurement stability
- Improves fab productivity and enables new applications

Dose Detectability (DD)

- 3-5x Improvement in DD
- Enables SPC for implant dose monitoring

\[
DD: \text{Dose detectability [\% dose } 3\sigma] = \frac{3 \times \% \sigma}{\text{Sensitivity}}
\]
Enabling Technology Transfer

Spatial Averaging (SA)

- 2x Improvement in DD for SPC
- Enables technology transfer

T2T Matching < 1%

Graph showing dose detection as a function of dose x 10^{12} [ions/cm^2]

- BF_2 under 50keV
- No SA

Graph showing TWI signal as a function of TWI signal (T#1)

- R^2 = 0.99
- T2T Matching < 1%

- 0.5% TWI Signal (T#2)
- 0.5% TWI Signal (T#1)
- 0.1% TWI Signal (T#1)
Ultra Shallow Junction Capability

\( x_j \) and anneal temperature

- Measured after implant and anneal
- Application specific correlation
- \(<1.5\% \ 3\sigma \) precision for <500Å
- Anneal temperature resolution <2 deg
- Enables RTP and spike anneal process monitoring
Ultra Shallow Junction Capability
Abruptness

TWI proprietary Abruptness method

- Pump laser
- Beam scanner
- Detector
- Filter
- Edge filter
- Polarizing beamsplitter
- 1/4 waveplate
- Objective
- Sample
- X-Y stage
- Signal generator
- Coherent demodulator
- Data acquisition

Resolution <0.5nm/dec
In-Line Product Monitoring Using TP-XP System
In-line Metrology for Ion Implant and USJ

- Drivers for In-line Metrology
  - Tighter control needs of evolving ITRS requirements
  - Cost of advanced technology & 300 mm scraps
    - Cost of re-work labor and materials
    - CoO decline for process tools
    - Production flow interruption
  - In-line metrology enables advanced equipment and process control
    - Identified by International SEMATECH as a key technology challenge for 2006

- In-line Ion Implant and USJ Metrology
  - Non-destructive, fast, and reliable
  - Optical methods like PMR
  - Therma-Probe\textsuperscript{XP} offers field-proven solutions
### Necessary components for Product Monitoring

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<tr>
<th>Measurement Performance</th>
<th>TP-XP</th>
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<tr>
<td>➔ Repeatability</td>
<td>✓</td>
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<tr>
<td>➔ Stability</td>
<td>✓</td>
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<tr>
<td>➔ Tool Matching</td>
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<table>
<thead>
<tr>
<th>System Performance</th>
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<tr>
<td>➔ Pattern Recognition</td>
<td>✓</td>
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<tr>
<td>➔ Throughput</td>
<td>✓</td>
</tr>
<tr>
<td>➔ Automation</td>
<td>✓</td>
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<tr>
<td>➔ Reliability</td>
<td>✓</td>
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Dynamic Repeatability on product

Repeatability Dynamic on Pattern wafer

Site by site (9 sites) dynamic repeatability <0.02% 1σ
Production Lot stability on Double Implant (one month)

Process variation ±2% dose

Error bars represent wafer uniformity ± 1σ over 9 sites

Mean TW Signal deviation suggests likely process variation
Currently more than eight tools are matched to the golden tool.
Matching results over a broad range of production wafers

Matching could be optimized in the more critical signal range without seriously impacting the rest of the signal ranges.

Range: 500 – 10000TW

>90% match at <2%

>1% and <2% 18%

<1% 25%

<0.5% 50%

>2% 7%
Conclusions

- Dose and energy detectability
  - Wide range of implant and dopant type
  - SPC ready (DD < 2.0 % $3\sigma$ with spatial averaging)
  - Tool-to-tool matching is better than 1% in a specific range

- USJ monitoring
  - Better than 1.5 % ($3\sigma$) precision
  - Simultaneous monitoring of USJ depth and abruptness

- Productivity
  - Pattern recognition with ability of 30x30micron box size
  - Excellent dynamic repeatability and stability on product
  - Unparallel matching performance in the industry
  - Fully automated, high throughput and reliability
  - TP-XP minimizes wafer scraps from catastrophic or slow drift failure of process tool