Process impacts of chemistry preparation on DHF process

Thomas Kopp

Levitronix User Conference
Zürich, April 11th 2013
Agenda

- Company
- Products & Applications
- Products - Impressions
- Motivation
- Initial situation
- Root cause analysis
- New solution
- Test results
- Summary
Worldwide Locations in Europe & Asia

AP&S International GmbH
Obere Wiesen 9
D-78166 Donaueschingen
Germany

www.ap-s.de | www.ap-s.cn | www.ap-s.sg | www.semi-parts.com
Products & Applications

Clean
- SC1
- TMAH/H₂O₂
- DSP
- EKC / ACT a.o.
- SOM, DIO3
- SPM
- Scrubber
- Post CMP
- Megasonnic
- Etc.

Etch
- DHF
- BOE
- HF 49%
- DHF/HCl
- KOH
- H₃PO₄
- P-Etch
- Etc.

Metal etch
- Poly-Si
- Alu
- Ti, TiN
- Ni, NiCr
- BiSb
- Co
- CoSi
- Cu
- Etc.

PR Strip
- SPM
- SOM
- Etc.

Eless Plating
- Nickel-Gold
- Nickel-Palladium-Gold

Metal etch
- Poly-Si
- Alu
- Ti, TiN
- Ni, NiCr
- BiSb
- Co
- CoSi
- Cu
- Etc.

Lift-off
- Metal
- Etc.

Dryning
- Marangoni
- Spin
- Hot air

Coating and Developing
- Positive resist
- Negative resist
- SU8

Wet bench
- Single wafer
- Parts cleaning
- Facility

Refurbishment
- Lotus systems products
- Customized solutions
Products - Impressions
DHF process in semiconductor industry

DHF  ≡  Diluted Hydro-Fluoric Acid

DHF is used in various applications in semiconductor industry. Most important applications are:

• Removal of natural Si-Oxide from wafer surface (natural etch stop when Si-Oxide is removed)
• Etching of a defined layer-size of Si-Oxide (controlled by time)
• Saturation of wafer surface with hydrogen
Motivation

Delta Etch rate \sim p \times \Delta T

- Etch rate
- Uniformity

Process parameters

temperature

DHF concentration

Etch rate vs. DHF concentration

etch rate vs. process time
Motivation

In standard wet process equipment, mostly the SiO2-layer removal is controlled by the etch time (process time). This requires a very exact etch rate and therefore a stable status for:

- DHF concentration
- DHF mixture homogenity
- Temperature
Problems, that could be seen in this process:

- Etch rate fluctuation over days; the etch rate differs between different days
- Etch rate fluctuation over lots; the etch rate differs between different lots
- Uniformity of etched wafer surface within a wafer or within one lot of wafers doesn’t fulfill the requirements
Initial situation - Hardware setup

Preparation tank
5% HF dilution

Spiking pump

DIW

Facility supply

5% HF dilution

Static mixer

0.5%/0.2% HF dilution

Static immersion tank
Initial situation – Measurement results

Fluctuation of oxide-removal day to day

Etch rate fluctuation day to day


$\Delta \sim 20 A^\circ$

std. dev.: > 0.5

avg. etch rate [$A^\circ$] vs. different days [date]
Root cause analysis

Following possible root causes where verified:

- Process time – OK; no fluctuation
- Temperature fluctiation – OK; no fluctuation that could cause the fluctuation of the etch rate
- HF concentration preparation tank (5%) – OK; measured with online analytic measurement device
- HF concentration in bath (0.5%/0.2%) – NOK; fluctuation observed
- DIW supply – NOK; significant fluctuation of DIW input pressure & flow observed
Fluctuation of DIW input flow was caused by very high fluctuation of DIW input pressure at process module between approx. 1 bar and 3,5 bar.
New solution - requirements

1. Suitable for wide input pressure range 0,8 to 3,7 bar
2. Variable mixing rates (500:1; 200:1)
3. Repeatability of Mixing Ratio ±1%
4. Absolute Accuracy of Mixing Ratio ±2%
5. Compact design
6. Extremely low particle generation
7. Homogeneous mixture of DIW and 5% DHF dilution
8. Smooth, continuous flow without pressure pulsation
Pre mixing of Chemistry in additional tanks

Advantages:
• Accuracy an Repeatability
• Independend of DIW input pressure

Disadvantages:
• No compact design
• No mixing function/inhomogeneous mixture of HF and DIW
• For variable mixing rates  a) different pre-mixing tanks or 
b) waste of chemistry
New solution (2) – Pressure regulator

Pressure regulator for DIW

Advantages:
• Compact design
• Very stable output pressure

Disadvantages:
• Only stable output pressure within a small range of input pressure variation
• No linearity over complete area of operation
• No mixing function
New solution (3) – Blending system

Single Pump system for DIW

Advantages:
• Compact design
• Very stable flow

Disadvantages:
• Only stable output flow for one fluid
• No mixing function
New solution (4) – Blending system

Double Pump system for DIW&HF5%

**Advantages:**
- Compact design
- Very stable flow
- Two flows controlled
- Mixing function

**Disadvantages:**
- Costs

**Control loop 1:** DHF delution
   => Part flow (300-700 ml/min)

**Control loop 2:** DIW
   => Main flow (4-21 l/min)

to static immersion tank
# New solution – Overview

<table>
<thead>
<tr>
<th>Solution</th>
<th>DIW input pressure 0,8 – 3,7 bar</th>
<th>Variable mixing rates</th>
<th>Repeatability / Accuracy</th>
<th>Compact design</th>
<th>Mixing function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-preparation tank</td>
<td>OK</td>
<td>a) different tanks for pre mixture</td>
<td>NOK</td>
<td>NOK</td>
<td>NOK</td>
</tr>
<tr>
<td></td>
<td>Premixing not depending on DIW pressure</td>
<td>b) Waste of chemistry in case of using one tank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precision pressure regulator</td>
<td>For stable output pressure 2,5 – 4,5 bar required</td>
<td>OK (spiking pump)</td>
<td>OK</td>
<td>OK</td>
<td>NOK</td>
</tr>
<tr>
<td>Blending system with one pump</td>
<td>OK</td>
<td>OK</td>
<td>NOK</td>
<td>OK</td>
<td>NOK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Only one chemistry flow controlled.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blending system with two pumps</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on:
• system requirements
• specifications of blending systems with one and two control loops

Decision:
Solution 4 (Blending System with two pumps/control loops) will be used for further tests.

Hardware:
LeviFlowsensors (Levitronix):  LFS-50-Z; LFS-04-Z; 2x LFC-1C
Pumps (Levitronix):  BPS-600.2; BPS-200.2; LPC-600; LPC-200
Test results – Etch rate stability

Etch rate stability over different days can be improved significantly

Std.dev.: < 0.18

Std.dev.: > 0.5

Avg. Etch [Å°] rate vs. different days [date] with Blending System

Avg. etch [Å°] rate vs. different days [date] - original
Test results – Etch rate linearity

Stability of oxide-removal can be improved significantly


Δ < 1 Å


Δ ~ 20 Å
Summary

Etching a defined oxide layer in a DHF process, only controlled by time, requires an absolute stable process environment.

The blending system in this test showed

- Repeatability of Mixing Ratio better than ±1%
- Absolute Accuracy of Mixing Ratio better than ±2%
- Homogeneous mixture of DIW and 5% DHF dilution guaranteed
- Variable mixing rates (requires fluid calibration)

Thanks to Levitronix for providing hardware and technical support for these tests!
Thank you...

Please, contact us for more information!

Europe
AP&S International GmbH
Obere Wiesen 9 . Aasen
78166 Donaueschingen . Germany
Phone  +49-771-8983-0
Fax    +49-771-8983-100
info@ap-s.de
www.ap-s.de

Europe
SemiParts
An AP&S Business Unit
Obere Wiesen 9 . Aasen
78166 Donaueschingen . Germany
Phone  +49-771-8983-200
Fax    +49-771-8983-100
info@semi-parts.com
www.semi-parts.com

China
AP&S Semiconductor Equipment (Shanghai) Co., Ltd.
Phone  +86-21-5042-9053 ext. 107
Fax    +86-21-5042-9053 ext. 105
info@ap-s.cn
www.ap-s.cn

Singapore/Malaysia
AP&S Asia Pte. Ltd.
Phone  +60-403-9007
Fax    +60-408-0031
info@ap-s.sg
www.ap-s.sg