ATMI AutoClean®

The First and Only In-Situ Implanter Cleaning Process.
Agenda

› Issues Impacting Implant Efficiency

› ATMI AutoClean Demonstrated Benefits

› System Features
Problems Caused by Dirty Implanters

› Short and unpredictable source life

› Beam instability due to glitching or arcing

› Extended set-up time from beam instability

› Undesired personnel exposure to toxic waste

› Lost productivity due to decreased tool availability
Problems Caused by Dirty Implanters

- Short and unpredictable source life
- Beam instability due to glitching or arcing
- Extended set-up time from beam instability
- Undesired personnel exposure to toxic waste
- Lost productivity due to decreased tool availability
Short and Unpredictable Source Life

Data Courtesy of Atmel
150mm Applied Materials XR80 with IHC source
Problems Caused By Dirty Implanters

› Short and unpredictable source life

› Beam instability due to glitching or arcing

› Extended set-up time from beam instability

› Undesired personnel exposure to toxic waste

› Lost productivity due to decreased tool availability
Beam Instability due to Glitching or Arcing

Data source: Implanter Source Life and Stability Improvement using In-Situ Chemical Cleaning
Terry Romig, Michael Mitchell, Texas Instruments Inc
David Eldridge, Jim Mayer, ATMI
http://ismi.sematech.org/smisymposium/abstracts/08051924424.pdf

Glitch occurrence increases as the source ages
Problems Caused By Dirty Implanters

- Short and unpredictable source life
- Beam instability due to glitching or arcing
- Extended set-up time from beam instability
- Undesired personnel exposure to toxic waste
- Lost productivity due to decreased tool availability
Extended Recipe Set-Up Time due to Beam Instability

Beam non-uniformity requiring multiple recipe set-ups & potential / frequent manual intervention
Problems Caused By Dirty Implanters

- Short and unpredictable source life
- Beam instability due to glitching or arcing
- Extended set-up time from beam instability
- Undesired personnel exposure to toxic waste
- Lost productivity due to decreased tool availability
Undesired Personnel Exposure to Toxic Waste

Operator exposed 2-3 times per month, per implanter
Problems Caused By Dirty Implanters

- Short and unpredictable source life
- Beam instability due to glitching or arcing
- Extended set-up time from beam instability
- Undesired personnel exposure to toxic waste
- Lost productivity due to decreased tool availability
ATMI AutoClean®
Complete System Solution to Implanter In-Situ Cleaning

Cleaning Reagent
Process Recipes & BKM
Solid Source Delivery
Customer Specific Application Development

Predictable Process.
Extended Source Life.
ATMI AutoClean Demonstrated Process Benefits

> 40% increase in source life

> 15% reduction in recipe set-up time

> 80% reduction in glitching

> 40% reduction in PM frequency

Dramatic reduction in toxic waste and cleaning time

7% improvement in implant productivity

Up to $100K annual cost savings per implanter

Implanter &/or process dependent
ATMI AutoClean Demonstrated Process Benefits

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Implanter &/or process dependent
>40% Increase in Source Life

Field Data
Multiple Tool Types, Source Types, Device Types, Wafer Sizes
Opportunity to Reduce PMs By 50%

3-week PM experiment
2-week calendar PM target
Baseline Source Life

*Source #4 experienced filament power supply failure, not source related

Source Hours

AutoClean Source Life

Source 1, Source 2, Source 3, Source 4*, Source 5, Source 6, Source 7, Source 8, Source 9, Source 10

Major Logic Manufacturing Customer

300mm mixed logic production
Varian VIISta HC with IHC source

Opportunity to Reduce PMs By 50%

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>2X Increase in Source Life

Data Courtesy of Atmel

150mm Applied Materials
XR80 with IHC source
ATMI AutoClean Demonstrated Process Benefits

>40% increase in source life

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>40% reduction in PM frequency

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7% improvement in implant productivity

Up to $100K annual cost savings per implanter

Implanter &/or process dependent
>30% Improvement in Beam Uniformity

Beam uniformity for all recipes

Average beam uniformity without AutoClean: 1.234%
Average beam uniformity with AutoClean: 0.841%

>30% reduction

32% improvement in beam uniformity on the wafer

Major Logic Manufacturing Customer
300mm mixed logic production Varian
VIIIa HC with IHC source
>15% Reduction in Recipe Set-Up Time

Set-Up Time for Multiple Recipes

Time to set up Recipe (secs)


Major Logic Manufacturing Customer

300mm mixed logic production Varian VIISta HC with IHC source

17%
ATMI AutoClean Demonstrated Process Benefits

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> 15% reduction in recipe set-up time

> 80% reduction in glitching

> 40% reduction in PM frequency

Dramatic reduction in toxic waste and cleaning time

7% improvement in implant productivity

Up to $100K annual cost savings per implanter

Implanter &/or process dependent
>80% Reduction in Glitching

Major Logic Manufacturing Customer

300mm mixed logic production Varian VIIsta HC with IHC source
>80% Reduction in Glitching

Glitch Count

No AutoClean

AutoClean

7720

1485

81% Reduction

Major Logic Manufacturing Customer

300mm mixed logic production Varian VIISta HC with IHC source
With AutoClean Glitching Decreases As Source Ages

<table>
<thead>
<tr>
<th>Source Life (hrs)</th>
<th>Glitch Count</th>
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<tr>
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<tr>
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<td>600</td>
<td>6</td>
</tr>
<tr>
<td>700</td>
<td>7</td>
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</tbody>
</table>

No AutoClean

6 Source Changes

AutoClean

4 Source Changes

Data source: Implanter Source Life and Stability Improvement using In-Situ Chemical Cleaning
Terry Romig, Michael Mitchell, Texas Instruments Inc, David Eldridge, Jim Mayer, ATMI
http://ismi.sematech.org/ismisymposium/abstracts/08051924424.pdf
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Up to $100K annual cost savings per implanter

Implanter &/or process dependent
>40% Reduction in PM Frequency

Maintenance frequency is determined by source life

<table>
<thead>
<tr>
<th>Without AutoClean</th>
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<tbody>
<tr>
<td><strong>February</strong></td>
</tr>
<tr>
<td>S M T W Th F Sa</td>
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<tr>
<td>1 2 3 4 5 6 7</td>
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<tr>
<td>8 9 10 11 12 13 14</td>
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<td>15 16 17 18 19 20 21</td>
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<tr>
<td>22 23 24 25 26 27 28</td>
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<tr>
<td>29 30 31 1 2 3 4 5</td>
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</tbody>
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| **March**         |
| S M T W Th F Sa  |
| 1 2 3 4 5 6 7    |
| 8 9 10 11 12 13 14 |
| 15 16 17 18 19 20 21 |
| 22 23 24 25 26 27 28 |
| 29 30 31 1 2 3 4 5 |

| **April**         |
| S M T W Th F Sa  |
| 1 2 3 4 5 6 7    |
| 8 9 10 11 12 13 14 |
| 15 16 17 18 19 20 21 |
| 22 23 24 25 26 27 28 |
| 29 30 31 1 2 3 4 5 |

<table>
<thead>
<tr>
<th>With AutoClean</th>
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<tbody>
<tr>
<td><strong>June</strong></td>
</tr>
<tr>
<td>S M T W Th F Sa</td>
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<td>1 2 3 4 5 6 7</td>
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<tr>
<td>22 23 24 25 26 27 28</td>
</tr>
<tr>
<td>29 30 31 1 2 3 4 5</td>
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| **July**        |
| S M T W Th F Sa |
| 1 2 3 4 5 6 7  |
| 8 9 10 11 12 13 14 |
| 15 16 17 18 19 20 21 |
| 22 23 24 25 26 27 28 |
| 29 30 31 1 2 3 4 5 |

| **August**      |
| S M T W Th F Sa |
| 1 2 3 4 5 6 7  |
| 8 9 10 11 12 13 14 |
| 15 16 17 18 19 20 21 |
| 22 23 24 25 26 27 28 |
| 29 30 31 1 2 3 4 5 |

- Unscheduled maintenance now becomes scheduled maintenance.
- More predictable fab operations.
- Less personnel exposure.
- Increased implanter availability.

Data Courtesy of Atmel

150mm Applied Materials XR80 with IHC source
Source Stays Cleaner... Longer

270 hours without AutoClean
636 hours with AutoClean

In many cases only requiring a DI-H2O wipe

Photos courtesy of Atmel
Mid-current source chamber at source PM
ATMI AutoClean Demonstrated Process Benefits

- >40% increase in source life
- >15% reduction in recipe set-up time
- >80% reduction in glitching
- >40% reduction in PM frequency

Dramatic reduction in toxic waste and cleaning time

7% improvement in implant productivity

Up to $100K annual cost savings per implanter

Implanter &/or process dependent
7% Improvement in Implant Productivity

“Throughput modeling estimates approximately 2,000 wafers per tool in increased wafer output.”

Presentation by Major 300mm Logic Customer at ISMI, Oct 24, 2007

What’s a 13th month of production worth?
ATMI AutoClean Demonstrated Process Benefits

- >40% increase in source life
- >15% reduction in recipe set-up time
- >80% reduction in glitching
- >40% reduction in PM frequency
- 7% improvement in implant productivity
- Up to $100K annual cost savings per implanter

Implanter &/or process dependent
$61,728 - $94,776 Savings Annually per Implanter

High Case Benefit:
- Reduced Glitching: $6,083
- Quicker Species Change: $162
- Fewer PM's: $2,295
- PM Labor: $911
- Source Consumables: $2,869

Low Case Benefit:
- Reduced Glitching: $4,056
- Quicker Species Change: $122
- Fewer PM's: $2,034
- PM Labor: $812
- Source Consumables: $2,543

Cost:
- AutoClean Cost: $2,800
- AutoClean Process: $1,622

High Case Improvements Target:
+60% life time source, -20% source PM time, -20% species change time, +60% glitch reduction.
Implanter Assumptions:
20 min of cleaning/day each implanter, Base Source life=240h, uptime 80%, Ion Source cost= $1,500, Source Pmt: 4h

Low Case Improvements Target:
+40% life time source, -15% source PM time, -15% species change time, +40% glitch reduction.
Implanter Assumptions:
20 min of cleaning/day each implanter, Base Source life=240h, uptime 80%, Ion Source cost= $1,500, Source Pmt: 4h
ATMI AutoClean

Complete system solution to implanter in-situ cleaning
AutoClean Process using XeF2
Engineered cleaning reagent first introduced by ATMI

Increased effectiveness
- Strong fluorinating agent → volatile fluorides of As, P, B, Si, W
- No need for plasma activation (NF₃ requires plasma activation)

Ease of Use
- Can use a simple, pressure-based, delivery system (SDS® gas stick)

Enhanced safety
- No need for dangerous high pressure gas
- Always sub-atmospheric for enhanced safety
- High density fluorine source; likely the safest source of fluorine

Reactant flows just like dopant

Physical Properties
White/Colorless Crystalline Powder
MW=169.29, Density=4.32g/l, Melting Point
135°C, Vapor Pressure 0.5kPa (3.8 torr) @ 25°C

Source
Vacuum Chamber

Ion Source

To Pump

Xe⁺ Beam

Reactant flows just like dopant
**XeF₂ Solid Delivery System**

Tailored delivery system developed by ATMI

Vapor is delivered at room temperature. No heating means no condensation inside the implanter.

Ensures that vapor delivery from the solid material is consistent and reliable (no lumps!)

### XeF₂ Flow Comparison

- **AutoClean Cylinder**
- **Conventional Cylinder**

- 75g fill weight
- Smaller than SDS® cylinder
- Installs on any spare SDS slot
- " MVCR connector
XeF2 Solid Delivery System
Tailored delivery system developed by ATMI

Vapor is delivered at room temperature. No heating means no condensation inside the implanter.

Ensures that vapor delivery from the solid material is consistent and reliable (no lumps!)

XeF$_2$ powder is distributed within the matrix of a porous aluminum material, ensuring good thermal contact and maximum solid surface area for vaporization.
AutoClean

Complete system solution to implanter in-situ cleaning
Process BKM’s and Recipes
Implementation Strategy

Running multiple species on same implanter requiring lengthy set-up or prep.
Implement AutoClean to replace Argon recipe between dopant changes.

Short source life, high glitch-rate, or high consumable costs.
Implement AutoClean recipe to automatically run for 10-15 minutes every 8 hours.

Unstable source performance due to process by-product accumulation or…?
Implement AutoClean “recovery” recipe to recover from source instability.

Multiple approaches to address variety of customer issues
Process BKM’s and Recipes
(Customer Examples)

- Implement AutoClean recipe to automatically run for 10-15 minutes every 12 hours.

- Implement AutoClean “recovery” recipe to recover from source instability.

- Replace Argon recipe with AutoClean.
AutoClean™

Complete system solution to implanter in-situ cleaning

Customer Specific Application Development
Customer Specific Considerations

**Situational Considerations**
- Tool types in installed base
- Implant process types
- Manufacturing protocols
- Production Mix

**Situational Response**
- Flow of XeF2
- Duration of clean process
- Plasma intensity & source parameters
- Frequency of Clean
Customer Specific Applications
Major 300mm Logic Customer

Needs
- Improved PM cycles on IHC source (less frequent)
- Improved Beam instability recovery
- High consumable costs – throwing away costly 300mm parts because there is no way to clean up

Situation
- 300mm mixed logic production
- Varian VIISta HC with IHC source
- 2 week PM schedule interrupted by early source failure (240 hours average)

Solution
- AutoClean 15 mins every 12 hours

Results / Proof
- >336 hour source life on 6 sources
- 40% improvement
- PM schedule changed from 2 weeks to 3 weeks
- Beam instability after 100 hours recovered and source run to 2 weeks
- Customer noticed cleaner manipulator and bushing
- Glitching (beam interruption) reduced 80%
Customer Specific Applications
Major 300mm Memory Customer

Needs
- Improved PM cycles on IHC & Bernas sources
- Improved Beam instability recovery

Situation
- 300mm memory production
- Varian VIISta HC with IHC and Bernas sources
- Average source life 240 hours

Solution
- Autoclean 10-15 minutes every 8-12 hours

Results / Proof
- 1st source (IHC) ran 450 hrs (average life without AutoClean 200 hrs)
- AutoClean then moved to VIISta with Bernas source
  - 1st source (Bernas) was glitching after 200 hrs.
  - Source life extended to 248 hrs with 30 mins AutoClean conditioning recipe.
  - 2nd source (Bernas) ran to 260 hours, well above average life (190 hrs).
Customer Specific Applications

Atmel

Needs

- Improved PM cycles on IHC source (less frequent)
- Improved Beam instability recovery

Situation

- 150mm simulated production
- Applied XR80 HC with IHC source
- Average source life was 165 hours

Solution

- AutoClean 15 minutes every 8 hours

Results / Proof

- Source lifetimes with AutoClean were 250, 310 and 323 hours
- 78% average improvement
AutoClean

Complete system solution to implanter in-situ cleaning

Predictable Process.
Extended Source Life.
AutoClean Process Development

1) Dynamic clean – ion source focused (currently released for customers)

2) Static clean – scheduled with PM; focus on source housing, extraction assembly, etc. (currently in field alpha testing, not released)

3) Ex-situ – stand alone process chamber for cleaning parts, validating capabilities and materials compatibilities (currently in R&D use, exploring customer interest; not released)
Predictable Process. Extended Source Life. Cleaning of Bernas Source Alumina Insulators with XeF₂
Predictable Process. Extended Source Life. Cleaning Bernas Source Repeller Plate With AutoClean

New / Unused → Used, before AutoClean → After AutoClean
AMAT Extraction Manipulator Bellows

Pre-Clean

XeF2 Clean 1 Cycle

XeF2 Clean 4 Cycles
Conclusions:
Viton, Vespel and Teflon are inert with XeF$_2$ – no weight loss, visual surface degradation or RGA / IR reaction products were observed.

Teflon Sample

Before

After

Vitont O-ring

Before

After

Vespel Sample

Before

After
Customer Feedback
Atmel

“Our initial testing demonstrated the outstanding cleaning properties of ATMI’s AutoClean system.”

“Regular periodic use of AutoClean for in-situ cleaning of the ion source resulted in a 40% - 50% increase in source life.”

“It also improved fab predictability and productivity by eliminating ion source failures due to beam instability and high suppression leakage current.”

“In addition, based on our initial data, our regular preventative maintenance activities will be easier and require less tool downtime as a result of using AutoClean.”

Jim Dunn
Implant Equipment Engineering Section Manager
Atmel
Colorado Springs, CO
Customer Feedback
Major 300mm Logic Customer

“AutoClean operation resulted in consistent source performance with zero unscheduled downtime caused by early source failure”

In side-by-side testing, the AutoClean system experienced 25-30% fewer source changes than the standard system.”

“Data shows clearly that the AutoClean process significantly reduced the glitch rate as the source ages, producing glitch rates at the end of source life that are comparable to new source performance.”

“Enhanced Safety with reduction in personnel exposure to hazardous materials & process byproducts = parts were cleaner and required less scrubbing during PMs.”

“Throughput modeling estimates approximately 2000 wafers per tool in increased wafer output.”
Implant Platform Experience

› AMAT, XR80, Quantums X, 1-3

› Axcelis, GSD E², Ultra, Optima MD
› Hi Energy tools – moving towards evaluations

› Japan - SEN, Nissin – initiating evaluations

› VSEA, VIISta’s - 80, HCP, HCS, 810, 900, etc
› VSEA, E500/220, VIISion 80/200

› Note: ion source types, both IHC and Bernas.
**AutoClean®**


- 30% increase in Beam uniformity
- 80% reduction in glitching
- 40% reduction in PM frequency
- Increased implanter availability
- More predictable fab operations
- Less personnel exposure
- Unscheduled maintenance now becomes scheduled maintenance

Data Courtesy of Atmel

150mm Applied Materials XR80 with IHC source

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**Winner of 2008 R&D 100 Award:** A distinction known to industry, government, and academia as proof that the goods or service is among 100 of the most innovative ideas of the year, focusing on products and processes that change people's lives for the better, improve the standard of living for large numbers of people, save lives, promote good health, and/or clean up the environment.