Defect Reduction and Yield Enhancement, Part 1

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OUTLINE

Particulates
- Particle Definition
- Killer Defects
- Cost of a Killer Defect
- Yield Models
- Sources of Microcontamination
- Particle Counters and Scanners
- Particle Transport Mechanisms
- Defect Test Structures

Material Defects
- Wafer Defects
- Gettering
- Oxygen Precipitation
PARTICLE DEFINITION

Stable (Non-Volatile) Conglomeration of Molecules

Diameter ~2 nm to 2 mm
KILLER DEFECTS

ANY PARTICULATE THAT CAUSES A DISRUPTION IN THE INTENDED MICROCIRCUIT PATTERN.

Size is about the minimum feature size and needs to be in a critical spot on the wafer at a critical time in the manufacturing process.

ANY CRYSTAL DEFECT THAT CAUSES A DISRUPTION IN THE INTENDED MICROCIRCUIT PATTERN.

Defect needs to be near the surface (Top 5 to 30 micrometers)
Defect needs to be in a critical device area
KILLER DEFECTS (CONTINUED)

ANY CHEMICAL CONTAMINATE THAT CAUSES A DISRUPTION IN THE INTENDED ELECTRONIC DEVICE OPERATION.

Metals such as gold, copper, platinum etc causes decrease in lifetime of minority carriers causing devices such as memory and CCD's to fail (less than 10 parts per trillion)

Metals such as sodium and potassium causes shifts in threshold voltage of MOS FET's (less than one part per billion)

Metals such as boron, phosphorous, arsenic, aluminum, indium, antimony are semiconductor dopants (less than one part per million)
THE COST OF ONE KILLER DEFECT PER WAFER

assume 5000 6 inch wafer starts per week
assume 1 cm x 1cm size chip
assume $10 selling price

\[
\text{AREA} = \pi R^2
\]
\[
(3.14)(7.5 \text{ cm})^2 = 176 \text{ cm}^2
\]

\[
\text{NUMBER OF DIE/WAFER} = \frac{\text{AREA}}{\text{DIE AREA}}
\]
\[
= 176 \text{ die}
\]

\[
\text{NUMBER OF DIE PER YEAR} = (50000 \text{ wfr/wk})(52 \text{ wk/yr})(176 \text{ die/wfr}) \]
\[
= 45,760,000 \text{ die/year}
\]

\[
\text{DOLLARS/YEAR} = 457,600,000/\text{year}
\]

\[
\text{COST OF ONE ADDITIONAL KILLER DEFECT / WFR}
\]
\[
= \frac{457,600,000}{176} = \$2,600,000/\text{year}
\]
IDENTIFY SOURCE OF CONTAMINATION

Root Cause Analysis by Blank Wafer
DRT - “O” Ring Contamination

The image shows a graph of elemental analysis with peaks for O, F, Mg, C, Na, S, and Cl. The graph suggests the presence of these elements on the wafer.

Rochester Institute of Technology
Microelectronic Engineering
COST OPPORTUNITY

SEMATECH COST RESOURCE MODEL SENSITIVITY

Probe Yield  Fab Yield  Throughput  Downtime %  Tool Capital  Consumables  Materials  Maintenance  space  Salaries  Clean Room Layout  Operators

% Cost Chang per 1 % Change in Variable
YIELD MODELS

\[ \text{YIELD} = e^{-AD} \]

WHERE
- \( A \) is the CHIP AREA \((\text{cm}^2)\)
- \( D \) is the DENSITY OF DEFECTS \((\text{#/cm}^2)\)

EXAMPLE: CHIP AREA is 1 cm\(^2\) and DEFECT DENSITY is 1/cm\(^2\)

then \( \text{YIELD} = e^{-1} = 37\% \)
### MAXIMUM NUMBER OF PARTICLES PER CUBIC FOOT OF AIR

<table>
<thead>
<tr>
<th>CLASS</th>
<th>0.1 um</th>
<th>0.2 um</th>
<th>0.3 um</th>
<th>0.5 um</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS 1</td>
<td>35</td>
<td>7.5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>CLASS 10</td>
<td>350</td>
<td>75</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>CLASS 100</td>
<td>750</td>
<td>300</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>CLASS 1000</td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
</tr>
</tbody>
</table>

CLEANROOM DESIGN

BALLROOM DESIGN
TUNNEL AND CHASE DESIGN
MINI-ENVIRONMENT

Ballroom Design
PARTICLES AND THEIR SOURCE

Iron oxide from welding process

Fly ash from coal burning power generation

Asbestos

Ref: William Hinds, “Aerosol Technology”
MINI ENVIRONMENT

SMIF Cassette Loading Tools

Open Cassette Loading

FOUP
Front Opening Universal Pod
People can generate up to 2,000,000 particles per minute. By using white suits and other clean room protocols this number can be reduced to less than 10,000 particles per minute.
PEOPLE AND MOVEMENT

The skin we shed

Skin particles released (million/min)

- Sitting quietly: 100,000/min.
- Walking 3kph: 5.0 million/min.
- Walking 5kph: 7.5 million/min.
- Walking 8kph: 10 million/min.

Source: Dr. Ken Goldstein Cleanroom Consultants, and Mike Fitzpatrick, Lockwood Greene, Cleanrooms East 99
SPIT
TWEEZERS
Finding a 1µm particle on an 8” wafer is equivalent to finding a penny in the city of Rochester, NY.
Laser Particle Counter (LPC) 3A and 3B and Condensation Nucleation Counter (CNC) 4A all at the same location in the fab.
POSITIVE PRESSURE IN A CLEANROOM

24 HOUR TRACE OF PARTICLE COUNT AND CLEANROOM PRESSURE

Figure 8-7a. A 24-h particle concentration profile measured near the reticle cleaner.
PARTICLES NEAR PHOTORESIST SPINNER

Source: Donovan et al., 1988

Figure 9-7. Periodic bursts of particles larger than 10 nm in the vicinity of a photoresist spinner.
PARTICLE COUNTS NEAR LPCVD SYSTEM

PARTICLES NEAR LPCVD LOAD STATION

Source: Donovan et al., 1988

Figure 9-8. Particle concentration from the loading area of a low pressure chemical vapor deposition furnace.
MICRO CONTAMINATION IN IC MANUFACTURING

<table>
<thead>
<tr>
<th>RCA CLEAN AND WET ETCH</th>
<th>SCALE (0-10) IMPORTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>particles in liquids</td>
<td>2</td>
</tr>
<tr>
<td>particles on surface of baths</td>
<td>4</td>
</tr>
<tr>
<td>(langmire film deposition)</td>
<td></td>
</tr>
<tr>
<td>process design</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLASMA ETCH</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>particles formed by the process</td>
<td>10</td>
</tr>
<tr>
<td>particles from the gas source</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DIFFUSION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>particles generated in diffusion furnace</td>
<td>4</td>
</tr>
<tr>
<td>due to mechanical movement</td>
<td></td>
</tr>
<tr>
<td>particles from the gas source</td>
<td>2</td>
</tr>
</tbody>
</table>
### MICRO CONTAMINATION - EQUIPMENT & PROCESS

#### PHOTOLITHOGRAPHY
- drips: 2
- airborne dust: 2
- solids in the resist: 4
- particles from dried developer: 6
- particles from spinners: 4

#### METALIZATION
- flakes from previous depositions: 10

#### HANDELING
- marks and scratches: 4
- edge marks from boats and positioning fixtures: 4
- particles from storage boxes: 4
# Micro Contamination - Equipment & Process

## Facilities Problems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of positive pressure</td>
<td>5</td>
</tr>
<tr>
<td>Dirty equipment</td>
<td>8</td>
</tr>
<tr>
<td>Dirty areas</td>
<td>8</td>
</tr>
<tr>
<td>People</td>
<td>8</td>
</tr>
<tr>
<td>HEPA filter failure</td>
<td>2</td>
</tr>
<tr>
<td>Air flow problems</td>
<td>8</td>
</tr>
<tr>
<td>Procedures</td>
<td>10</td>
</tr>
</tbody>
</table>

## LPCVD

- Flakes from previous depositions: 10
- Particles formed by the process: 10
- Particles from the gas source: 2

## Ion Implant

- Basically clean: 0
- Mechanical movement: 2
REVIEW

TODAY REDUCTION IN PARTICULATE CONTAMINATION IS CENTERED AROUND IMPROVEMENTS IN EQUIPMENT AND PROCESSES.

THE CLEANROOM CAN SHOW PARTICLE BURSTS MANY ORDERS OF MAGNITUDE ABOVE THE NOMINAL BACKGROUND PARTICULATE LEVEL.

MINI-ENVIRONMENTS OFFER FURTHER IMPROVEMENTS IN CLEANROOM ENVIRONMENTS.
PARTICLE COUNTERS

- Scattered Light Counters Give Size and Count and Are Accurate down to 0.3 um
- Particle Size is related to scatter angle
- Condensation Nucleus Counter can be used for particles smaller than 0.3 um
  - particles are drawn through a saturated vapor (often alcohol) making the particles large enough to be counted
  - particle size is not easy to determine once nucleation is used
AIR BORN PARTICLE COUNTER

INPUT AIR SAMPLE

LASER

DETECTOR ARRAY AND COUNTER

PARTICLE SIZE IS RELATED TO SCATTER ANGLE

PUMP
(LPC) Laser Particle Counter counts air born particles <0.3, 0.5, 1.0, 2, 5, >10 µm sizes. System also measures temperature, humidity and air flow.
### EXAMPLE PARTICLE COUNT DATA

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temp</th>
<th>Hmd</th>
<th>10µm</th>
<th>5µm</th>
<th>2µm</th>
<th>1µm</th>
<th>0.5µm</th>
<th>0.3µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-17-96</td>
<td>1.18</td>
<td>66.4</td>
<td>37.4</td>
<td>1</td>
<td>1</td>
<td>41</td>
<td>84</td>
<td>278</td>
<td>348</td>
</tr>
<tr>
<td>1-23-96</td>
<td>1.42</td>
<td>65.8</td>
<td>46.6</td>
<td>3</td>
<td>6</td>
<td>40</td>
<td>69</td>
<td>325</td>
<td>467</td>
</tr>
<tr>
<td>1-25-96</td>
<td>1.18</td>
<td>66.6</td>
<td>47.3</td>
<td>0</td>
<td>0</td>
<td>101</td>
<td>205</td>
<td>1111</td>
<td>1592</td>
</tr>
<tr>
<td>1-26-96</td>
<td>9.28</td>
<td>66.4</td>
<td>47.3</td>
<td>6</td>
<td>10</td>
<td>71</td>
<td>129</td>
<td>460</td>
<td>572</td>
</tr>
<tr>
<td>1-29-96</td>
<td>12.28</td>
<td>66.1</td>
<td>50.5</td>
<td>2</td>
<td>3</td>
<td>32</td>
<td>47</td>
<td>137</td>
<td>156</td>
</tr>
<tr>
<td>1-30-96</td>
<td>1.53</td>
<td>67.2</td>
<td>47.3</td>
<td>2</td>
<td>3</td>
<td>20</td>
<td>47</td>
<td>209</td>
<td>280</td>
</tr>
<tr>
<td>2-1-96</td>
<td>1.03</td>
<td>68.9</td>
<td>45.5</td>
<td>3</td>
<td>4</td>
<td>30</td>
<td>66</td>
<td>240</td>
<td>289</td>
</tr>
<tr>
<td>2-5-96</td>
<td>12.28</td>
<td>67.6</td>
<td>47</td>
<td>11</td>
<td>11</td>
<td>47</td>
<td>86</td>
<td>267</td>
<td>343</td>
</tr>
<tr>
<td>2-6-96</td>
<td>12.26</td>
<td>67.4</td>
<td>46.7</td>
<td>0</td>
<td>1</td>
<td>30</td>
<td>52</td>
<td>190</td>
<td>259</td>
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<tr>
<td>2-7-96</td>
<td>1.05</td>
<td>66.8</td>
<td>53.4</td>
<td>1</td>
<td>1</td>
<td>26</td>
<td>44</td>
<td>177</td>
<td>248</td>
</tr>
<tr>
<td>2-8-96</td>
<td>12.23</td>
<td>66.4</td>
<td>52.1</td>
<td>5</td>
<td>7</td>
<td>119</td>
<td>227</td>
<td>870</td>
<td>1199</td>
</tr>
<tr>
<td>2-9-96</td>
<td>12.23</td>
<td>66.3</td>
<td>51.1</td>
<td>3</td>
<td>6</td>
<td>64</td>
<td>111</td>
<td>467</td>
<td>653</td>
</tr>
<tr>
<td>2-12-96</td>
<td>11.14</td>
<td>65.2</td>
<td>49.1</td>
<td>3</td>
<td>3</td>
<td>55</td>
<td>106</td>
<td>506</td>
<td>700</td>
</tr>
<tr>
<td>2-13-96</td>
<td>10.33</td>
<td>64.1</td>
<td>52</td>
<td>2</td>
<td>7</td>
<td>45</td>
<td>122</td>
<td>717</td>
<td>1181</td>
</tr>
</tbody>
</table>
SURFACE PARTICLE SCANNER

PARTICLE SIZE IS RELATED TO SCATTER ANGLE

DETECTOR ARRAY AND COUNTER

ROTATING MIRROR SCANNER

LASER

WAFER WITH PARTICULATES
TENCORE SURF SCAN

Gives total surface particle count and count in 4 bins <0.5, 0.5 to 2.0, 2.0-10, >10. Bin boundary can be selected. Edge exclusion eliminated count from near the edge of the wafer.
### EXAMPLE SURFACE PARTICLE COUNT DATA

<table>
<thead>
<tr>
<th>Size Range (µm)</th>
<th>Count Before Cleaning (75 mm)</th>
<th>Count After Cleaning (75 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 - 0.5</td>
<td>104</td>
<td>10</td>
</tr>
<tr>
<td>0.5 - 2.0</td>
<td>562</td>
<td>4</td>
</tr>
<tr>
<td>2.0 - 10</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>&gt;10</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
RAINDROP MODEL (NOT ACCURATE)

\[ F = C \cdot V \]

- \( F \) = DEPOSITION FLUX (# / sec / unit area)
- \( C \) = PARTICLE CONCENTRATION (# / ft\(^3\))
- \( V \) = AIR VELOCITY (ft / sec)

EXAMPLE: Class 100 clean room with air velocity of 100 ft/min

\[ F = \frac{(100)(100)}{60} \left(\frac{(2.54)(12)}{2}\right)^2 = 0.02 \text{ particles/cm}^2 / \text{sec} \]

This is close but overestimates the number of particles because some do not adhere to the surface. The relationship can be useful if \( v \) is replaced by an effective velocity \( v_{eff} \) called the aerosol particle deposition velocity.
PARTICLE DEPOSITION MODELS

\[ V_{eff} = \text{Aerosol Particle Deposition Velocity (number of particles / time)} \]

\[ F = C \times V_{eff} \]

or

\[ V_{eff} = \frac{F}{C} \]

Where we find \( F \) from monitor wafers using a surface particle counter and \( C \) is measured using an Airborne Particle Counter.

Example: After 8 hours in a class 100 clean room a 4 inch monitor wafer shows an increase in surface particle count from 50 to 550 particles.

\[ V_{eff} = \frac{(550-50)}{(8\times60\times60)((\pi \times (2/12)^2)) \text{ particles/ ft}^2\text{sec} / 100 \text{ particles/ft}^3} \]

\[ = 0.12 \text{ ft/min} \quad \text{or} \quad 0.61 \text{ cm/sec} \]
Veff VERSUS SIZE AND PRESSURE

Increasing Air Velocity

Aerosol Region

Gravitational Region

100 f/m

50

25

12

0.01um 0.1um 1um 10um

PARTICLE SIZE

Veff cm/sec

10^0

10^{-1}

10^{-2}

10^{-3}
Defect Reduction and Yield Enhancement

ELECTRIC FIELD EFFECTS

Increasing Particle Charge

\[ V_{\text{eff}} \text{ cm/sec} \]

\[ 10^0 \qquad 10^{-2} \qquad 10^{-4} \]

0.01um \quad 0.1um \quad 1um \quad 10um

Surface at 100 V/cm
TEMPERATURE EFFECTS

- $V_{eff}$ (cm/sec)
- Temperature (°C)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>$V_{eff}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>$10^{-4}$</td>
</tr>
<tr>
<td>80°C</td>
<td>$10^{-1}$</td>
</tr>
</tbody>
</table>
TIME TO SETTLE VERSUS PRESSURE

TIME

10^0 10^2 10^4 10^6

PRESSURE

LOW 10 um
1 um
0.1 um
HIGH 10 um
ELECTRICAL EFFECTS CAN INCREASE THE DEPOSITION VELOCITY BY 2-3 ORDERS OF MAGNITUDE, EVEN FOR LOW FIELDS OF 100 V/M.

HEATING THE WAFER CAN HELP PROTECT IT FROM PARTICULATES, 50 C CAN HELP BY ONE ORDER OF MAGNITUDE.

WAFERS SHOULD BE FACE DOWN IN VACUUM SYSTEMS. WHERE GRAVITY IS THE IMPORTANT PARAMETER. (CAUTION: IN PLASMA SYSTEMS ELECTRIC FIELD IS MORE IMPORTANT THAN GRAVITY).

AEROSOL PARTICLE DEPOSITION RATE IS A FUNCTION OF PARTICLE SIZE.
STATIC CHARGE

Static Charge causes a surface to be positive or negatively charged. This surface will attract oppositely charged particles and neutral particles from the air.

Sources of Static Charge:
- Triboelectric or Friction Charging
- Charging through Induction
- Ion implant, SEMs or plasma processes

AIR IONIZATION

All air ionization systems work by flooding the atmosphere with positive and negative ions. When ionized air comes in contact with a charged surface, the charged surface attracts ions of the opposite polarity. As a result, the static electricity that has built up on products, equipment and surfaces is neutralized.

Ions are created by high electric fields (a combination of high voltages and sharp emitter tips). The voltage can be AC (60 Hz), DC, or Pulsed. In the case of AC the air near the tips must be moving fast enough to not recombine with oppositely charged ions generated 1/60 sec later from the same tip. In DC systems a continuous high voltage is applied generating equal numbers of + and - ions. Pulsed systems apply pulsed DC high voltages. Each pulse can be negative or positive and can have separately adjusted duty cycle. Pulsed systems allow more flexibility.
Pulsed DC systems use positive and negative emitter points that are turned on and off alternately to create clouds of positive and negative ions. Cycle timing and polarity can be adjusted to provide the required balance and level of static control needed in a specific environment.
A charged plate monitor is an instrument that has an isolated conductive plate (~ 4 inches square) that can be charged to 1000 volts and the time it takes to discharge to 10% (100 volts) is determined. In normal air at 60% humidity the decay may take 12 hours. An ionization system can reduce the decay time to less than one minute.
Via chain is sensitive to contact cut problems.

Comb Structure is sensitive to Shorts and less sensitive to opens if $W > S$. 

$W$ $S$
DEFECT TEST STRUCTURES

Serpentine Structure is sensitive to opens and less sensitive to shorts if $S > W$

No Defects
$R = R_1$

Short
$R << R_1$

Short
$R <= R_1$

Open
$R >> R_1$

$R = (\text{Rhos}) \times \frac{L}{W}$
Defect density (in #/cm²) = (# defective x 1612) / (# tested)

Line width = 15 μm
Line Space = 30 μm
L/W = 269
Area Covered by metal = 62050 μm²

R = Rhos L/W
<table>
<thead>
<tr>
<th></th>
<th>SERPENTINE</th>
<th>METAL</th>
<th>POLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINE WIDTH (µm)</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>SPACE (µm)</td>
<td>9</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>AREA (µm²)</td>
<td>27117</td>
<td>23820</td>
<td>24147</td>
</tr>
<tr>
<td>DEFECTS FOUND</td>
<td>34</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>DEVICES MEASURED</td>
<td>53</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>YIELD</td>
<td>36%</td>
<td>96%</td>
<td>98%</td>
</tr>
<tr>
<td>DEFECTS/cm²</td>
<td>2366</td>
<td>158</td>
<td>78</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
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<th>METAL</th>
<th>POLY</th>
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<tbody>
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<td>18</td>
<td>27</td>
</tr>
<tr>
<td>SPACE (µm)</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>AREA (µm²)</td>
<td>25389</td>
<td>24396</td>
<td>22788</td>
</tr>
<tr>
<td>DEFECTS FOUND</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>DEVICES MEASURED</td>
<td>53</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>YIELD</td>
<td>98%</td>
<td>100%</td>
<td>98%</td>
</tr>
<tr>
<td>DEFECTS/cm²</td>
<td>70</td>
<td>0</td>
<td>83</td>
</tr>
</tbody>
</table>
1. interstitial impurity
2. edge dislocation
3. self-interstitial
4. precipitate of substitutional atoms
5. small dislocation loop formed by agglomeration of self-interstitials
6. substitutional impurity, widening lattice
7. vacancy
8. dislocation loop formed by agglomeration of vacancies
9. substitutional impurity, compressing lattice
10. Schottky defect
11. interstitial arriving from surface
12. Frenkel defect
INFLUENCE OF CRYSTAL DEFECTS ON DEVICES

Leakage Currents in PN Junctions
  Precipitates, Dislocations
Collector-Emitter Leakage in BJTs
  Precipitates, Dislocations
Minority Carrier Lifetime
  Point Defects, Point-Defect Clusters
Gate Oxide Quality, Oxide leakage, Oxide Breakdown Voltage
  metallic contamination, defect density on surface, oxygen precipitates at the surface
Threshold Voltage Control
  surface state density

2. Remove Existing Crystal Defects by High Temperature Annealing or Creation of Oxygen Denuded Zones at the wafer surface, removing Oxygen precipitates near the surface.

3. Remove Point Defects by Gettering (capturing contaminates at locations away from device locations)

Yield Improvements Can Be Made
REDUCTION OF MOBILE METAL CONTAMINATES

Cu, Ni, Au, Fe are highly mobile and diffuse long distances at moderate temperatures, find defects and are captured.

Cu can diffuse 600 um in 1 min at 900 C
Fe can diffuse 100 um in 1 min at 1000 C

Low Temperature Processes introduce fewer impurities from the furnace.

HCl Cleaning of Furnace Tubes
Double Wall Furnace Tubes
Eliminate Metal Tweezers
Replace Stainless Steel with Silicon, Carbon and Aluminum Parts
EXTRINSIC GETTERING

HEAVY PHOSPHOROUS DIFFUSION OF THE BACKSIDE OF THE WAFER WILL CAUSE DEFECTS THAT CAN CAPTURE METAL CONTAMINATES

MECHANICAL DAMAGE TO BACKSIDE OF THE WAFER, ABRASION, SANDBLASTING

LASER DAMAGE

ION IMPLANT DAMAGE

DEPOSITION OF POLYSILICON ON BACK OF WAFER
INTRINSIC GETTERING

STARTING WAFERS WITH 15-19 PPMA OXYGEN CONCENTRATION

1. DENUDED ZONE FORMATION - HIGH TEMPERATURE STEP TO REDUCE OXYGEN CONCENTRATION NEAR WAFER SURFACE

2. NUCLEATION OF SiO2 CLUSTERS - LOWER TEMPERATURE STEP

3. PRECIPITATE GROWTH AND GETTERING - HIGH TEMPERATURE STEP FOR GROWING SiO2 CLUSTERS AND FORMING DISLOCATION LOOPS, GETTERING SITES
**INTRINSIC GETTERING**

### 15-19 ppm Oxygen Starting Wafers

- **T1 = 1100 C, t1 = 240 min.**, give 10-40 um Denuded Zones
- **T2 = 600 C, 4 to 64 hours**, nucleate 50 A radius sites
- **T3 = 1100 C, 4 to 16 hours**, Grow 1000 A radius sites

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**Microelectronic Engineering**

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Contamination from high temperature furnace operation

Furnace tube used for p-type or n-type diffusion will dope bare wafers simply by transfer of dopant molecules from the furnace wall to the wafers.

In the case of Boron, B2O3, Boric Oxide, from spin on glass and glass transferred from solid sources

In the case of Phosphorus, P2O5, melts at 360 C and is a gas at high temperatures. This glass is a vapor at 900 C and can move from surface to surface and dope a bare silicon substrate.
REMEDIES FURNACE CONTAMINATION

Ceramic Liners
Chlorine
Procedures to Prevent Contamination
When solids are heated they will go to the liquid state (Hg is already liquid at room T) at the melting point. Solids will also go to the gas state at the correct combination of temperature and pressure. This is the vapor pressure and is often given as a function of temperature. As pressure is decreased the temperature at which solids will vaporize lowers and if this temperature is below the melting point then the material will sublime (go to gas state without going through the liquid state). In our LPCVD systems and sputtering systems temperatures around 400 C and pressures below 1x10^-5 Torr are common. At these temperatures and pressures many metals sublime and can be a source of contamination for the next users of the system. For example Zinc is a component of brass, cadmium is used to plate steel screws, sulfur and selenium are used in stainless steel ver-#303. These materials all sublime at 400 C and 1x10^-5 Torr and will contaminate the equipment as a result.
### MELTING POINT & VAPORIZATION PRESSURE DATA FOR VARIOUS MATERIALS

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<th>Material</th>
<th>Melt Point</th>
<th>Vapor Pressure</th>
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</table>

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Via Failure

A slew of detailed process problems can lead to via failures.

Vias can pull away from the metal layer.
REFERENCES

4. VLSI Technology, Ch. 14 - “Yield and Reliability”, Sze.
11. Ion Systems, 1005 Parker Street, Berkeley A 94710, ionsys@ion.com.
1. Calculate the defect density for the following examples:
   (a) 256K DRAM with die size 0.4 cm by 0.4 cm and Yield of 75%
   (b) 1M DRAM with die size of 1.4 cm by 0.4 cm and Yield of 55%,
   (c) 4 M DRAM with die size of 1.4 cm by 1.4 cm and Yield of 20%.
2. What defect density will be needed to give a 85% Yield on 16M devices with area four times the 4 M DRAM in problem 1.
This homework refers to the following articles and abstracts:

Generate a set of two questions and answers that illustrate the main points of each article. (total of 10 questions with answers)