DECEMBER 2006

Integrated Materials, Inc.

Cost of Ownership Impacts on LPCVD Poly Silicon Deposition

David W. Jimenez / Wright Williams & Kelly, Inc.

the future of furnaceware™

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By
David W. Jimenez
Wright Williams & Kelly, Inc.

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Background

For more than 20 years the semiconductor industry has sought a solution to the acute problems that accompany the use of quartz and silicon carbide in furnace processes. These processes, including high temperature anneal, diffusion and deposition processing, make up to 30 percent of the major process steps in wafer manufacturing.

While recent improvements in furnace cleaning have helped to remediate particle defects induced by quartz or SiC consumables, engineers still have not achieved the overall reduction of defect rates required for state-of-the-art manufacturing environments. Moreover, the cleaning process is costly; capital, chemicals and the necessary environmental safeguards drive up the cost of ownership (COO).

Additionally, IC manufacturers must cope with trace metal contamination, “slip” due to differences in the Coefficient of Thermal Expansion (CTE) between wafer support consumables and the wafer, and consumables’ structural stability in the high-temperature processes.

Now, given the demanding characteristics of advanced IC device processing as the industry continues to both shrink device architectures and move to 300mm wafers, the need for a solution to these problems grows even greater.

To address these problems, Integrated Materials recently introduced its patented SiFusion™ technology that allows for the manufacture of pure poly silicon furnaceware. SiFusion is the first proven application of poly silicon furnaceware as an alternative to current quartz and silicon carbide consumables. The suite of SiFusion products includes furnace boats, liners, injectors and pedestals. These products are designed for furnaces from the major capital equipment suppliers, Tokyo Electron, Hitachi-Kokusai, ASM, Aviza and others.

With the introduction of SiFusion as a viable alternative to traditional consumables, there is an opportunity to examine the cost of ownership for all three furnace consumable materials. Thus, Integrated Materials retained a cost of ownership modeling expert, Wright Williams & Kelly, Inc. (WWK), to examine pure poly silicon furnaceware compared to quartz and silicon carbide in both the 200mm and the 300mm environments. In the Spring of 2006, Wright Williams & Kelly, Inc. also released a white paper examining Integrated Materials’ furnaceware cost of ownership impacts on the LPCVD Nitride Deposition process utilizing the same methodology.

Cost of Ownership Defined

SEMI E35 defines cost of ownership as the full cost of embedding, operating, and decommissioning, in a factory environment, a system needed to accommodate a required volume. The significant COO inputs include:

- Equipment cost
- Operating cost
- Yield
- Down time
- Throughput rate

These factors are combined in the COO equation:

$$COO = \frac{CF + CV + CY}{TPT * L * Y * U}$$

where:

COO = Cost per good wafer
CF = Fixed Cost
CV = Variable Cost
CY = Cost of Yield Loss
TPT = Throughput Rate
L = Useful Life of Process
Y = Composite Yield
U = Utilization

Fixed costs are incurred once during the life of the process and are associated with the acquisition and installation of equipment. Fixed costs include costs such as equipment purchase, installation and setup, facility modifications, initial training, and initial qualification costs. Variable costs are incurred on an on-going basis. Variable costs such as material, labor, repair, standards, requalification, utility and overhead expenses are costs that are incurred during equipment operation. Cost of yield loss is the value of scrap caused by the process step. Process scrap identified at the step of interest but caused by prior processing is part of the prior process step COO. Thus, yield losses caused by the processing tool must be clearly separated from prior losses. The sum of these costs form the numerator of the COO equation.

The denominator of the COO equation is an estimate of the number of good wafers produced during the life of the process. Throughput rate is based on process and handling times such as job setup, loading and unloading, reporting, and other overhead operations. It excludes training, repair, and qualification times since these are included in utilization. Yield may be defined as the ratio of good units compared to the total number of units produced, including rework. Utilization is the ratio of actual usage compared to total available time. Utilization includes repair and maintenance time, both scheduled and unscheduled; setup and qualification time; and standby time. It shows the impact of non-productive time on cost and normalizes ideal throughput to a realistic estimate. Utilization is estimated using SEMI E10 definitions for availability, reliability and maintainability.

Cost of Ownership Overview and Methodology

Wright Williams & Kelly, Inc. (WWK) created an extensive matrix to examine materials combinations for both the 200mm and 300mm LPCVD poly silicon applications. The materials examined were quartz, silicon carbide (SiC), and pure poly silicon (SiFusion). These materials were examined for both boat and liner applications as well as quartz versus poly silicon injectors. The fundamental parameters for the vertical furnace remained constant regardless of the materials used but were updated for differences in wafer size.

The objective of this project was to estimate the operational cost differences resulting from these material combinations. Cost of ownership metrics evaluated during these analyses are shown in Tables 1 and 5.

For the following analyses, WWK utilized TWO COOL®, the semiconductor industry's cost of ownership and overall equipment efficiency (OEE) standard. TWO COOL is the only software to comply with Semiconductor Equipment and Materials International (SEMI) Standards E10, E35, and E79.

200mm Cost of Ownership Results

After the base furnace model was built, the following parameters where chosen for examination for each of the material combinations.

Table 1: COO Input Parameters

Boat	Liner
Scheduled Maintenance	Scheduled Maintenance
Purchase Price	Purchase Price
Expected Life	Expected Life
Breakage Risk	Breakage Risk
HF Cleaning Costs	HF Cleaning Costs

The following lists the assumptions for the 200mm models.

Table 2a: 200mm General COO Assumptions

General Assumptions
LPCVD poly deposition at 3.33μm/week
Outer tube cleaned 2 times per year
Cost to clean each part is $600
Outer tube PM is 24 hours
Breakage risk is 7.5% for each PM
Breakage risk is 2% for removal with no PM
100% yield

Table 2b: 200mm Specific COO Assumptions

Quartz	SiC	SiFusion
Quartz boat clean after 10µm	SiC boat clean after 20µm	SiFusion boat clean after 500µm
Quartz liner clean after 20µm	SiC liner clean after 20µm	SiFusion liner clean after 500µm
Quartz boat lasts 3 months, need 2	SiC boat lasts 2 years, need 2	SiFusion boat lasts 3 years, need 1.25
Quartz liner lasts 3 months, need 2	SiC liner lasts 2 years, need 2	SiFusion liner lasts 3 years, need 1.25
Quartz boat PM is 12 hours	SiC boat PM is 12 hours	SiFusion boat PM is 12 hours
Quartz liner PM is an incremental 12 hours	SiC liner PM is an incremental 12 hours	SiFusion liner PM is an incremental 12 hours
Quartz boat costs $2,500	SiC boat costs $15,000	SiFusion boat costs $22,000
Quartz liner costs $2,500	SiC liner costs $15,000	SiFusion liner costs $32,000

Table 3 summarizes the results of the 200mm analyses.

Table 3: 200mm COO Results

Boat/Liner Material[1]	Cost of Ownership
SiFusion/SiFusion	$3.63
SiFusion/Quartz	$3.80
SiFusion/SiC	$3.82
SiC/Quartz	$3.99
SiC/SiC	$4.00
Quartz/Quartz	$4.09

200mm COO Cost Drivers

Examination of the detailed TWO COOL[2] cost of ownership models for each material combination highlights the main cost driver differences. In the case of quartz boats and liners, the main cost drivers, aside from the equipment factors that are the same for all analyses, are the increased frequency of cleaning and the resultant decreases in equipment utilization and high cleaning costs, and the short useful life. Some of these higher costs are offset by the relatively low price for these parts.

SiC components provided an interesting analysis in that the combination of a SiC boat and a quartz liner had a lower COO than the SiC/SiC combination. This is based on the fact that SiC liners require the same amount of cleaning compared to quartz, cost significantly more to purchase, but last significantly longer. SiC boats have half the cleaning frequency of quartz.

[1]All results based on the use of quartz injectors.
[2] TWO COOL® is a commercial software package from Wright Williams & Kelly, Inc. and is the de facto COO standard in the semiconductor industry.

The significantly higher purchase price for SiC is mitigated somewhat by their long potential life. However, the cleaning frequencies place these high-price materials at risk of breakage on a regular basis and, thus, lead to near cost parity between SiC and quartz materials.

SiFusion boats and liners provided the lowest cost of ownership by a substantial margin. This was achieved through the near elimination of routine cleanings for both components. This increased the Production Utilization Capability by 3.3 percent and reduced lifetime costs by almost $300K. The higher purchase price of the SiFusion material is more than offset by its long life and drastically reduced risk of breakage.

Based on these results, it is estimated that the payback period for the SiFusion boat is 25 weeks ([$22,000 - $2,500]/[[$4.09 - $3.80] x 2,651 wafers out per week]) compared to quartz and half that compared to SiC. Further, the SiFusion liner has a payback period compared to quartz of 65 weeks and 33 weeks for SiC.

Table 4: 200mm COO Drivers

Item	Quartz/Quartz	SiC/Quartz	SiFusion/SiFusion
Production Utilization Capability	81.93%	83.06%	85.23%
Good Wafers Out per Week	2,581	2,616	2,772
Annual Cleaning Costs	$12,042	$6,828	$1,618
Annual Boat/Liner Consumption	$40,000	$35,000	$22,500
Annual Breakage Risk	$6,518	$13,036	$2,160

Yield Improvements Due to Defect Reduction

The above analyses were based on the assumption of 100 percent yield. This is due to the fact that defect density measurements on poly silicon films are not reliable. However, the correlation of poly process changes to yield improvements is fairly direct. Client data has indicated that the switch to SiFusion furnaceware has provided a measurable improvement in yield.

Quartz versus SiFusion Injectors

The data presented so far has been with quartz injectors, which represents over 60% of the total materials costs in the SiFusion/SiFusion example. It is estimated from client data that quartz injectors have an average deposition life of 2μm. This is due to warpage, breakage, and particle formation. With the introduction of SiFusion injectors, we can examine an alternative to this significant cost component. In the case of SiFusion injectors, it is estimated that injector life would be in excess of 1,200μm. However, we have taken a more conservative approach in our analysis and assumed that SiFusion injectors would be changed at the six month PM of the outer tube.

Based on these conservative results, it is estimated that the payback period for the SiFusion injectors is less than 9 weeks ([$10,000 - $600]/[[$3.63-$3.22] x 2,772 wafers out per week]) compared to quartz. See Report 3. The lifetime cost savings for injectors alone is nearly $300,000.

200mm Summary

WWK created an extensive matrix of materials combinations for 200mm LPCVD poly silicon applications. The materials examined were quartz, SiC, and pure poly silicon created through the SiFusion process. These materials were examined for both boat and liner applications and the results are summarized in the following reports:

Report 1: TWO COOL Management Report

	Quartz/Quartz	SiC/Quartz	SiC/SiC	
Cost Per System	1,000,000	1,000,000	1,000,000	Dollars
Number of Systems Required	1	1	1	System
Total Depreciable Costs	1,255,000	1,255,000	1,255,000	Dollars
Equipment Utilization Capability	88.18	89.31	89.31	Percent
Production Utilization Capability	81.93	83.06	83.06	Percent
Composite Yield	100.00	100.00	100.00	Percent
Good Wafer Equivalents Out per Week	2,580.77	2,616.36	2,616.36	G.W.E.'s
Good Wafer Equivalent Cost				
With Scrap	4.09	3.99	4.00	Dollars
Without Scrap	4.09	3.99	4.00	Dollars
Average Monthly cost				
With Scrap	45,862	45,333	45,476	Dollars
Without Scrap	45,862	45,333	45,476	Dollars
Process Scrap Allocation				
Equipment Yield	0.00	0.00	0.00	Percent
Defect Limited Yield	0.00	0.00	0.00	Percent
Parametric Limited Yield	0.00	0.00	0.00	Percent
Equipment Costs (Over Life of Equipment)	1,668,313	1,668,313	1,668,313	Dollars
Per Good Wafer Equivalent	1.77	1.75	1.75	Dollars
Per Good cm2 Out	0.0070	0.0070	0.0070	Dollars
Recurring Costs (Over Life of Equipment)	2,184,059	2,139,679	2,151,669	Dollars
Per Good Wafer Equivalent	2.32	2.24	2.25	Dollars
Per Good cm2 Out	0.0092	0.0089	0.0090	Dollars
Total Costs (Over Life of Equipment)	3,852,372	3,807,992	3,819,982	Dollars
Per Good Wafer Equivalent (COO)	**4.09**	**3.99**	**4.00**	**Dollars**
Per Good Wafter Equivalent Supported	4.09	3.99	4.00	Dollars
Per Good cm2 Out	0.0163	0.0159	0.0159	Dollars

Report 2: TWO COOL Management Report

	SiFusion/ Quartz	SiFusion/ SiC	SiFusion/ SiFusion	
Cost per System	1,000,000	1,000,000	1,000,000	Dollars
Number of Systems Required	1	1	1	Systems
Total Depreciable Costs	1,255,000	1,255,000	1,255,000	Dollars
Equipment Utilization Costs	90.39	90.39	91.48	Percent
Production Utilization Costs	84.14	84.14	85.23	Percent
Composite Yield	100.00	100.00	100.00	Percent
Good Wafer Equivalents Out Per Week	2,650.53	2,650.53	2,684.70	G.W.E.'s
Good Wafer Equivalent Cost				
With Scrap	3.80	3.82	3.63	Dollars
Without Scrap	3.80	3.82	3.63	Dollars
Average Monthly Cost				
With Scrap	43,806	43,949	42,298	Dollars
Without Scrap	43,806	43,949	42,298	Dollars
Process Scrap Allocation				
Equipment Yield	0.00	0.00	0.00	Percent
Defect Limited Yield	0.00	0.00	0.00	Percent
Parametric Limited Yield	0.00	0.00	0.00	Percent
Equipment Costs (Over Life of Equipment)	1,668,313	1,668,313	1,668,313	Dollars
Per Good Wafer Equivalent	1.72	1.72	1.70	Dollars
Per Good cm2 Out	0.0069	0.0069	0.0068	Dollars
Recurring Costs (Over Life of Equipment)	2,011,433	2,023,422	1,884,734	Dollars
Per Good Wafer Equivalent	2.08	2.09	1.92	Dollars
Per Good cm2 Out	0.0083	0.0083	0.0077	Dollars
Total Costs (Over Life of Equipment)	3,679,746	3,691,735	3,553,047	Dollars
Per Good Wafer Equivalent (COO)	**3.80**	**3.82**	**3.63**	**Dollars**
Per Good Wafer Equivalent Supported	3.80	3.82	3.63	Dollars
Per Good cm2 Out	0.0151	0.0152	0.0144	Dollars
Per Productive Minute	1.19	1.19	1.13	Dollars

Report 3: Injector Comparison

	SiFusion/ SiFusion Quartz	SiFusion/ SiFusion/SiFusion	
Cost Per System	1,000,000	1,000,000	Dollars
Number of Systms Required	1	1	Systems
Total Depreciable Costs	1,255,000	1,255,000	Dollars
Equipment Utilization Capability	91.48	94.24	Percent
Production Utilization Capability	85.23	87.99	Percent
Composite Yield	100.00	100.00	Percent
Good Wafer Equivalents Out Per Week	2,684.70	2,771.63	G.W.E's
Good Wafer Equivalent Cost			
With Scrap	3.63	3.22	Dollars
Without Scrap	3.63	3.22	Dollars
Average Monthly Cost			
With Scrap	42,298	38,834	Dollars
Without Scrap	42,298	38,834	Dollars
Process Scrap Allocation			
Equipment Yield	0.00	0.00	Percent
Defect Limited Yield	0.00	0.00	Percent
Parametric Limited Yield	0.00	0.00	Percent
Equipment Costs (Over Live of Equipment)	1,668,313	1,668,313	Dollars
Per Good Wafer Equivalent	1.70	1.65	Dollars
Per Good cm2 Out	0.0068	0.0066	Dollars
Recurring Costs (Over Life of Equipment)	1,884,734	1,593,766	Dollars
Per Good Wafer Equivalent	1.92	1.58	Dollars
Per Good cm2 Out	0.0077	0.0063	Dollars
Total Costs (Over Life of Equipment)	3,553,047	3,262,078	Dollars
Per Good Wafer Equivalent (COO)	**3.63**	**3.22**	**Dollars**
Per Good Wafer Equivalent Suported	3.63	3.22	Dollars
Per Good cm2 Out	0.0144	0.0128	Dollars
Per Productive Minute	1.13	1.01	Dollars

300mm Cost of Ownership Results

After the base furnace model was built, the following parameters where chosen for examination for each of the material combinations.

Table 5: COO Input Parameters

Boat	Liner
Scheduled Maintenance	Scheduled Maintenance
Purchase Price	Purchase Price
Expected Life	Expected Life
Breakage Risk	Breakage Risk
HF Cleaning Costs	HF Cleaning Costs

The following table lists the assumptions for the 300mm models.

Table 6a: 300mm General COO Assumptions

General Assumptions
LPCVD poly deposition at 3.33µm/week
Outer tube cleaned 2 times per year
Cost to clean each part is $800
Outer tube PM is 24 hours
Breakage risk is 7.5% for each PM
Breakage risk is 2% for removal with no PM
100% yield

Table 6b: 300mm Specific COO Assumptions

Quartz	SiC	SiFusion
Quartz boat clean after 10µm	SiC boat clean after 20µm	SiFusion boat clean after 500µm
Quartz liner clean after 20µm	SiC liner clean after 20µm	SiFusion liner clean after 500µm
Quartz boat lasts 3 months, need 2	SiC boat lasts 2 years, need 2	SiFusion boat lasts 3 years, need 1.25
Quartz liner lasts 3 months, need 2	SiC liner lasts 2 years, need 2	SiFusion liner lasts 3 years, need 1.25
Quartz boat PM is 12 hours	SiC boat PM is 12 hours	SiFusion boat PM is 12 hours
Quartz liner PM is an incremental 12 hours	SiC liner PM is an incremental 12 hours	SiFusion liner PM is an incremental 12 hours
Quartz boat costs $5,000	SiC boat costs $38,000	SiFusion boat costs $48,000
Quartz liner costs $8,000	SiC liner costs $40,000	SiFusion liner costs $65,000

Table 7 summarizes the results of the 300mm analyses.

Table 7: 300mm COO Results

Boat/Liner Material[3]	Cost of Ownership
SiFusion/SiFusion	$4.83
SiFusion/SiC	$5.31
SiFusion/Quartz	$5.34
SiC/SiC	$5.73
SiC/Quartz	$5.76
Quartz/Quartz	$5.77

300mm COO Cost Drivers

Examination of the detailed TWO COOL cost of ownership models for each 300mm material combination highlights the main cost driver differences. In the case of quartz boats and liners, the main cost drivers, aside from the equipment factors that are the same for all analyses, are the increased frequency of cleaning and the resultant decreases in equipment utilization and high cleaning costs, and the short useful life. Some of these higher costs are offset by the relatively low price for these parts.

In the 300mm case, the SiC liner had a lower COO than the quartz liner, resulting in an SiC/SiC combination with the lowest COO after all the SiFusion combinations. This is based on the fact that SiC liners require the same amount of cleaning compared to quartz, but last significantly longer, overcoming the purchase price deltas. SiC boats have half the cleaning frequency of quartz. The significantly higher purchase price for SiC is mitigated somewhat by their long potential life. However, the cleaning frequencies place these high-price materials at risk of breakage on a regular basis and, thus, lead to near cost parity between SiC and quartz materials. The difference between the lowest COO result for SiC and the highest COO for a quartz combination was only $0.04.

SiFusion boats and liners provided the lowest cost of ownership by a substantial margin. This was achieved through the near elimination of routine cleanings for both components. This increased the Production Utilization Capability by 3.3 percent and reduced lifetime costs by almost $600K. The higher purchase price of the SiFusion material is more than offset by its long life and drastically reduced risk of breakage.

Based on these results, it is estimated that the payback period for the SiFusion boat is 45 weeks ([$48,000 - $5,000]/[[$5.77 - $5.34] x 2,209 wafers out per week]) compared to quartz and under 11 weeks compared to SiC. Further, the SiFusion liner has a payback period compared to quartz of 46 weeks and 23 for SiC.

[3] All results based on the use of quartz injectors.

Table 8: 300mm COO Drivers

Item	Quartz/Quartz	SiC/SiC	SiFusion/SiFusion
Production Utilization Capability	81.93%	83.06%	85.23%
Good Wafers Out per Week	2,151	2,181	2,238
Annual Cleaning Costs	$16,056	$9,104	$2,157
Annual Boat/Liner Consumption	$104,000	$78,000	$47,083
Annual Breakage Risk	$11,732	$50,839	$4,520

Yield Improvements Due to Defect Reduction

The above analyses were based on the assumption of 100 percent yield. This is due to the fact that defect density measurements on poly silicon films are not reliable. However, the correlation of poly process changes to yield improvements is fairly direct. Client data has indicated that the switch to SiFusion furnaceware has provided a measurable improvement in yield.

Quartz versus SiFusion Injectors

The data presented so far has been with quartz injectors, which represents over 25% of the total materials costs in the SiFusion/SiFusion example. It is estimated from client data that quartz injectors have an average deposition life of 2μm. This is due to warpage, breakage, and particle formation. With the introduction of SiFusion injectors, we can examine an alternative to this significant cost component. In the case of SiFusion injectors, it is estimated that injector life would be in excess of 1,200μm. However, we have taken a more conservative approach in our analysis and assumed that SiFusion injectors would be changed at the six month PM of the outer tube.

Based on these conservative results, it is estimated that the payback period for the SiFusion injectors is less than 8 weeks ([$10,000 - $600]/[[$4.83-$4.27] x 2,310 wafers out per week]) compared to quartz. See Report 6. The lifetime cost savings for injectors alone is over $250,000.

300mm Summary

WWK created an extensive matrix of materials combinations for 300mm LPCVD poly silicon applications. The materials examined were quartz, silicon carbide (SiC), and pure poly silicon manufactured through the SiFusion process. These materials were examined for both boat and liner applications and the results are summarized in the following reports:

Report 4: TWO COOL Management Report

	Quartz/Quartz	SiC/Quartz	SiC/SiC	
Cost Per System	1,300,000	1,300,000	1,300,000	Dollars
Number of Systems Required	1	1	1	Systems
Total Depreciable Costs	1,630,000	1,630,000	1,630,000	Dollars
Equipment Utilization Capability	88.18	89.31	89.31	Percent
Production Utilization Capability	81.93	83.06	83.06	Percent
Composite Yield	100.00	100.00	100.00	Percent
Good Wafer Equivalents Out Per Week	2,151.33	2,181.00	2,181.00	G.W.E's
Good Wafer Equivalent Cost				
With Scrap	5.77	5.76	5.73	Dollars
Without Scrap	5.77	5.76	5.73	Dollars
Average Monthly Cost				
With Scrap	53,945	54,559	54,298	Dollars
Without Scrap	53,945	54,559	54,298	Dollars
Process Scrap Allocation				
Equipment Yield	0.00	0.00	0.00	Percent
Defect Limited Yield	0.00	0.00	0.00	Percent
Parametric Limited Yield	0.00	0.00	0.00	Percent
Equipment Costs (Over Life of Equipment)	2,046,582	2,046,582	2,046,582	Dollars
Per Good Wafer Equivalent	2.61	2.57	2.57	Dollars
Per Good cm2 Out	0.0046	0.0045	0.0045	Dollars
Recurring Costs (Over Life of Equipment)	2,484,775	2,536,416	2,514,415	Dollars
Per Good Wafer Equivalent	3.16	3.19	3.16	Dollars
Per Good cm2 Out	0.0056	0.0056	0.0056	Dollars
Total Costs (Over Life of Equipment)	4,531,358	4,582,998	4,560,997	Dollars
Per Good Wafer Equivalent (COO)	**5.77**	**5.76**	**5.73**	**Dollars**
Per Good Wafer Equivalent Supported	5.77	5.76	5.73	Dollars
Per Good Cm2 Out	0.0102	0.0102	0.0101	Dollars
Per Productive Minute	1.50	1.50	1.49	Dollars

Report 5: TWO COOL Management Report

	SiFusion/Quartz	SiFusion/SiC	SiFusion/ SiFusion	
Cost Per System	1,300,000	1,300,000	1,300,000	Dollars
Number of Systems Required	1	1	1	Systems
Total Depreciable Costs	1,630,000	1,630,000	1,630,000	Dollars
Equipment Utilization Capability	90.39	90.39	91.48	Percent
Production Utilization Capability	84.14	84.14	85.23	Percent
Composite Yield	100.00	100.00	100.00	Percent
Good Wafer Equivalents Out Per Week	2,209.48	2,209.48	2,237.96	G.W.E’s
Good Wafer Equivalent Cost				
With Scrap	5.34	5.31	4.83	Dollars
Without Scrap	5.34	5.31	4.83	Dollars
Average Monthly Cost				
With Scrap	51,248	50,986	46,975	Dollars
Without Scrap	51,248	50,986	46,975	Dollars
Process Scrap Allocation				
Equipment Yield	0.00	0.00	0.00	Percent
Defect Limited Yield	0.00	0.00	0.00	Percent
Parametric Limited Yield	0.00	0.00	0.00	Percent
Equipment Costs (Over Life of Equipment)	2,046,582	2,046,582	2,046,582	Dollars
Per Good Wafer Equivalent	2.54	2.54	2.51	Dollars
Per Good cm2 Out	0.0045	0.0045	0.0044	Dollars
Recurring Costs (Over Life of Equipment)	2,258,217	2,236,216	1,899,316	Dollars
Per Good Wafer Equivalent	2.80	2.77	2.33	Dollars
Per Good cm2 Out	0.0050	0.0049	0.0041	Dollars
Total Costs (Over Life of Equipment)	4,304,800	4,282,799	3,945,899	Dollars
Per Good Wafer Equivalent (COO)	**5.34**	**5.31**	**4.83**	**Dollars**
Per Good Wafer Equivalent Supported	5.34	5.31	4.83	Dollars
Per Good Cm2 Out	0.0094	0.0094	0.0085	Dollars
Per Productive Minute	1.39	1.38	1.26	Dollars

Report 6: Injector Comparison

	SiFusion/ SiFusion/Quartz	SiFusion/ SiFusion/SiFusion	
Cost Per System	1,300,000	1,300,000	Dollars
Number of Systems Required	1	1	Systems
Total Depreciable Costs	1,630,000	1,630,000	Dollars
Equipment Utilization Capability	91.48	94.24	Percent
Production Utilization Capability	85.23	87.99	Percent
Composite Yield	100.00	100.00	Percent
Good Wafer Equivalents Out Per Week	2,237.96	2,310.43	G.W.E's
Good Wafer Equivalent Cost			
With Scrap	4.83	4.37	Dollars
Without Scrap	4.83	4.37	Dollars
Average Monthly Cost			
With Scrap	46,975	43,905	Dollars
Without Scrap	46,975	43,905	Dollars
Process Scrap Allocation			
Equipment Yield	0.00	0.00	Percent
Defect Limited Yield	0.00	0.00	Percent
Parametric Limited Yield	0.00	0.00	Percent
Equipment Costs (Over Life of Equipment)	2,046,582	2,046,582	Dollars
Per Good Wafer Equivalent	2.51	2.43	Dollars
Per Good cm2 Out	0.0044	0.0043	Dollars
Recurring Costs (Over Life of Equipment)	1,899,316	1,641,477	Dollars
Per Good Wafer Equivalent	2.33	1.95	Dollars
Per Good cm2 Out	0.0041	0.0034	Dollars
Total Costs (Over Life of Equipment)	3,945,899	3,688,059	Dollars
Per Good Wafer Equivalent (COO)	**4.83**	**4.37**	**Dollars**
Per Good Wafer Equivalent Supported	4.83	4.37	Dollars
Per Good Cm2 Out	0.0085	0.0077	Dollars
Per Productive Minute	1.26	1.14	Dollars

Conclusions

Integrated Materials proposes these advantages for IC manufacturers when using SiFusion-produced pure poly silicon furnaceware, as compared to quartz or silicon carbide consumables:

1. No other material used in semiconductor processes can compare to the purity of Integrated Materials' poly silicon fixtures. Integrated Materials components are clean to <1.0 E10 / cm2 for all trace metals.

2. In LPCVD processes, the close match of Coefficients of Thermal Expansion (CTE)

between Integrated Materials' component and the LPCVD film and Integrated Materials' patented surface preparation result in the elimination of fixture-generated particles.

Long-term production use of Integrated Materials' pure poly silicon boats in LPCVD poly silicon confirms that almost no scheduled cleaning is needed. Benefits from the near elimination of cleaning include:

1. Significant cost savings by the significant reduction of hydrofluoric acid (HF) and other chemicals used for cleaning.
2. Environmental benefits from the minimization of toxic chemical disposal.
3. Fewer process interventions resulting in more stable furnace operation.

At temperatures to 1375°C, Integrated Materials' pure poly silicon boats do not deform. Integrated Materials' poly silicon products are thermal shock resistant: they maintain their mechanical tolerances at temperatures far above those experienced by IC wafers. SiFusion fixtures exposed to 1350°C in excess of 12 months have maintained tolerances and exhibited no structural degeneration from their original form.

The Coefficient of Thermal Expansion (CTE) for the wafer and Integrated Materials' poly silicon boat match, allowing for increased thermal ramp rates and reduced thermal stabilization times while eliminating damage to the wafer and eliminating boat-inducted slip. Integrated Materials' poly silicon boats are transparent to infrared (IR) which reduces thermal "shadowing" and causes more uniform heating within the hot-zone.

Integrated Materials' precision manufacturing tolerances provide for a more efficient robotic interface that speeds up wafer load/unload time. Integrated Materials' precision standards provide for true "plug-and-play" use.

Integrated Materials' pure poly silicon components deliver equal or longer useful life than those made from silicon carbide.

About Wright Williams & Kelly, Inc.

With more than 3,000 users worldwide, Wright Williams & Kelly, Inc. is the largest privately held operational cost management company serving technology-dependent and technology-driven companies. WWK maintains long-term relationships with prominent industry resources including International SEMATECH, SELETE, Semiconductor Equipment and Materials International (SEMI), and national labs and universities. Its client base includes most of the top 20 semiconductor manufacturers and equipment and materials suppliers as well as leaders in nano-technology, MEMS, thin film record heads, magnetic media, flat panel displays, and solar panels.

WWK's product line includes TWO COOL® for detailed process step level cost of ownership (COO) and overall equipment efficiency (OEE), PRO COOL® for process flow and test cell costing, Factory Commander® for full factory capacity analysis and activity based costing, and Factory Explorer® for cycle time reduction and WIP planning. Additionally, WWK offers a highly flexible product management software package that helps sales forces eliminate errors in product configuration and quotation processes.