# Cryogenic CO2 Parts Cleaning Technology (ESHC001): Final Report

**SEMATECH**
**Technology Transfer 97053286A-TR**

# Cryogenic CO2 Parts Cleaning Technology (ESHC001): Final Report

Technology Transfer # **97053286A-TR**
**SEMATECH**
*May 31, 1997*

**Abstract:** This document reports the results of a project to measure the performance of a cryogenic $CO_2$ technology using solid $CO_2$ pellets at high velocities to clean parts contaminated during semiconductor processing. Unlike traditional manual cleaning methods, the cryogenic $CO_2$ technology reduces the use of solvents and acids as well as the clean time, operating costs, and worker exposure to harmful chemicals. A secondary ion mass spectrometer (SIMS) was used to investigate contamination related to the use of dry ice pellets, block dry ice, and air. Because glycol is sometimes added to dry ice during formation, the effects of glycol-containing and glycol-free dry ice also were investigated. Costs associated with the cryogenic $CO_2$ parts cleaning were compared to the costs associated with manual cleaning on a part-by-part basis.

**Keywords:** Dry Cleaning, Wafer Cleaning, Safety, Cost Analysis, Secondary Ion Mass Spectroscopy

**Authors:** Joseph Rauchut

**Approvals:** Walter Worth, Program Manager
Courtney Murdoch, Project Manager
Scott Elrod, Director
Laurie Modrey, Technical Information Transfer Team Leader

# Table of Contents

## List of Figures

## List of Tables

# 1 EXECUTIVE SUMMARY

This document reports the results of a project to measure the performance of a technology that uses solid $CO_2$ pellets at high velocities to clean parts contaminated during semiconductor processing. Whereas traditional cleaning methods are done manually using acids, solvents, 3M Scotch Brite materials, wire brushes, and scrapers, the cryogenic $CO_2$ technology reduces the use of solvents and acids as well as the clean time, operating costs, and worker exposure to harmful chemicals. A criterion for evaluating the cryogenic $CO_2$ parts cleaning tool included the ability to return cleaned parts to original use without further cleaning.

The cryogenic $CO_2$ parts cleaning system studied consists of an exhausted glove box, a clean dry air (CDA) compressor, a CDA dryer, and a portable cleaning station (PCS). It can be operated using dry ice pellets or shavings from a block of dry ice. Based on a visual inspection of cleaned parts, pellets and block shavings were equally effective. The $CO_2$ delivery system has two options: hand-held (for low pressures) and robotic. Both methods produced similar results, but overall the most effective cleaning was achieved with the $CO_2$ blast perpendicular to the cleaning surface. The effectiveness of the clean, regardless of method, was greatly reduced when the clean blast was almost parallel to the surface being cleaned.

A secondary ion mass spectrometer (SIMS) was used to investigate the contamination effect on the cleaned parts of dry ice pellets, block dry ice, and air. The samples cleaned with air showed the highest levels of contamination by carbon, hydrocarbons, and fluorine. Because glycol is sometimes added to the dry ice during formation, the effects of glycol-containing and glycol-free dry ice also were investigated. The glycol-free dry ice displayed the most sample-to-sample variation and the highest amounts of contamination. Contamination with elemental carbon was ten times higher when using glycol-free dry ice.

Cleaning costs associated with the cryogenic $CO_2$ parts cleaning were compared to the costs associated with manual cleaning on a part-by-part basis. In all cases, net savings were achieved by using the cryogenic $CO_2$ parts cleaning tool. The total annual savings after all operating costs (labor, materials and depreciation) were estimated to be $266,339.

# 2 INTRODUCTION

## 2.1 Background

Semiconductor manufacturing equipment accumulates deposits from processing that are often difficult to remove. SEMATECH Equipment Engineering has become interested in a technology that uses solid $CO_2$ pellets at high velocities to clean contaminated parts. This cleaning process is analogous to sandblasting and has the advantage of eliminating the solvents and acids currently used for parts cleaning. The $CO_2$ pellets sublime after striking the object, leaving a residue on the bottom of the glove box that can be disposed of appropriately.

SEMATECH supported a project at AT&T (now Lucent Technologies) to measure the performance of the cryogenic $CO_2$ cleaning methodology. To simulate manufacturing-level use, marathon testing was performed in AT&T’s Allentown facility. This testing was also used to characterize equipment performance compared to standard cleaning methods.

### 2.2 Objectives and Purpose

The purpose of this project was to determine if the cryogenic $CO_2$ parts cleaning tool (or "cleanblaster") is an acceptable replacement for the parts cleaning methods using acids, solvents, 3M Scotch Brite material, wire brushes, and scrapers. The parts cleaned came from a variety of tools and included transfer plates, gate valves, aluminum shields, pipes, printed circuit boards, and a variety of other components. A criterion for evaluation of the cryogenic $CO_2$ cleaning tool included the ability to return parts cleaned by the cryogenic $CO_2$ system to original use requiring no further cleaning.

## 3 PROCESS EQUIPMENT

### 3.1 Description

The system used in this project consists of one glove box[1], one clean dry air or CDA compressor, one CDA dryer, and one PCS. The glove box is a contained area where the cleaning takes place (see Figure 1). An exhaust system removes $CO_2$ gas while a trap in the bottom catches solid waste. A window in the front of the glove box allows the operator to view the progress of the clean. The glove box itself is 4 ft x 4 ft x 8.5 ft, containing a 36-inch diameter table with "hold-down" holes for parts to be cleaned. This table can be set to rotate during the clean by toggling a switch on the front of the glove box. It completes one revolution in four minutes.

**Figure 1 Front View of Glove Box (note: it is not located in a cleanroom environment)**

---

[1] Manufactured by Alpheus Cleaning Technologies Corporation, Called the "Whisperblast"

The $CO_2$ delivery system to the glove box has two options: manual and robotic. The manual version—a hand held wand or duck gun(see Figure 2)—is similar to the water sprayers used at a self-service car wash with complete manual control. The robot is a mechanical arm moved by toggling various pneumatic switches. The robotics system operates at a maximum pressure of 250 psig. The duck gun, on the other hand, offers more versatility for aiming the gun at the object being cleaned. However, safety issues limit the efficacy and ease of operating the duck gun above 75 psig. The robotic cleaning mechanism is completely air operated, which also has drawbacks. If the robot arm needs to change direction, the air in the cylinder needs to be exhausted beforehand, making the change very slow. The viewing glass does not fog during operation because the inlet port in the rear of the unit allows room temperature air to enter the chamber. The noise level during a clean is approximately 90 dB, and ear protection is recommended. The ratio of $CO_2$ to air through the delivery system is controlled by a Venturi nozzle, which can be changed as needed to protect parts with delicate coatings (such as aluminum plating).

**Figure 2** **Inside Glove Box Where A Hand-Held Duck Gun Performs The Clean**

The CDA compressor[2] (see Figure 3) placed within 50 linear feet of the glove box maintains the pressure and flow rate to the PCS. It provides a maximum operating pressure of 250 psig. It is a stationary, air-cooled, two-stage, oil-injected screw compressor rated at 150 hp. Operating costs for this compressor in loaded mode are $7.50 per hour, based on an electric rate of $0.06 per kilowatt-hour (KWH).

The SDI-5 Miniblast (see Figure 4) functions as the dry ice supply for the glove box. It can be operated with dry ice pellets or shavings from a block of dry ice. Dry ice pellets are similar to salt in texture and size. The drawback to the pellet system is that the pellets can sometimes stick to the chamber, especially if the pellets are several days old. The Miniblast is 36 in x 48 in x 44 in and is on wheels for portability. The SDI unit accepts standard size ice blocks of approximately one cubic foot, weighing about 50 pounds each. The cost of the dry ice block is $0.23 per pound, while the pellets cost $0.30 per pound. The dry ice is stored in insulated containers adjacent to the glove box (see Figure 5).

The CDA dryer[3] has two drying cylinders; it is capable of delivering a continuous supply of super dry compressed air to the downstream glove box and dry ice units (see Figure 6). Each cylinder is filled with an adsorbent drying medium that collects and holds moisture on the surface. While the compressed air is being dried in one tower, the desiccant in the off-line tower is being regenerated. This cycle repeats every four minutes. The CDA supply line has a blow-off system that evacuates the line every 20 seconds to prevent the compressor from dead ending at full pressure. The outlet dew point from this unit is -40°F at line pressure.

**Figure 3 CDA Compressor**

**Figure 4 SDI-5 Miniblast Unit**

---

[2] Manufactured by Atlas Copco, Model Number GR110

[3] Manufactured by Air Tak, Model Number HLD-250-HPM

**Figure 5** Storage Containers for Dry Ice

**Figure 6** Dual Cylinder CDA Dryer

A 9 KW CDA heating unit[4] heats the air before it enters the glove box to keep the parts being cleaned from freezing. The unit is able to maintain a constant operating temperature while air is flowing. When the airflow ceases, the temperature rises, and the heater shuts off.

The glove box, SDI-5 Miniblast, Miniblast MBL-5 pellet system, and air dryer are located along an outside wall of the building to provide a direct path for the liquid $CO_2$ line in case a $CO_2$ tank installation is needed. AT&T chose to buy the dry ice block and pellets from a local supplier for this project.

### 3.2 Installation

A cryogenic $CO_2$ parts cleaning tool was installed during the week of August 12, 1995, at AT&T's Microelectronics plant in Allentown, Pennsylvania. Two-inch diameter stainless steel pipes were used to link the compressor, air dryer, Miniblast MBL-5, and SDI-5 units. The piping divides after entry into the facility with a separate ball valve for each tool. The glove box has an additional ball valve to operate the various pneumatic parts.

### 3.3 Training

A representative from Alpheus provided training for the AT&T Maintenance and Production groups. The training exercise included all the operational components that make up the entire system. The instructions were precise and accurate, emphasizing safety. Each page of the manual supplied by Alpheus was encapsulated in plastic for cleanroom use.

## 4 EXPERIMENTAL PROCEDURES

Cleaning was performed using both the duck gun and robot delivery systems. Cleans with the duck gun used the shaved ice method exclusively, while the robot system used both shaved dry ice and dry ice pellets. The blast pressure and pellet rate for the pellet method and the blast pressure, feed pressure, and ice rate for the shaved ice method were altered according to the part being cleaned. Blast air temperature (the temperature of the heated air coming from the CDA unit) was monitored for most of the runs. Clean times were recorded when applicable and visual inspection was used to determine if the cleaned part was acceptable.

## 5 RESULTS OF CLEANING

### 5.1 Comparison of Pellets to Shavings from Dry Ice Block (Using Robot Only)

Both the pellet and shaved ice methods, although at different blast pressures, were able to effectively clean the 3180 transfer plates in 30 minutes. The shaved dry ice method used lower blast pressures and lower ice rates, and, as a result, consumed less dry ice.

---

[1] Manufactured by Watlow Corporation

## 5.2 Results from Robot

Only four of all the parts that were tried were not able to be cleaned: an aluminum shield, a pod shield from an eclipse sputter, a polysilicon carbide boat, and an eclipse sputter wafer holder. Each of these parts was tried at only one setting. Neither pellets nor the block systems would remove the aluminum film left on these 3180 aluminum shields.

Although the large transfer plate was successfully cleaned, the 30 minutes required to clean it were not justified. One problem was the slow rotational speed of the table; another problem was that the effective spot size of the blast on the surface was relatively small.

## 5.3 Results from Duck Gun

Throttle valves and screens from an Applied Materials 5000 tool were cleaned with the duck gun in one minute. The throttle valves take two hours to clean using standard methods, while the screens are normally discarded. This is a 99% reduction in clean time for the throttle valves, and a savings on equipment and disposal costs for the screens.

Only parts with baked-on photoresist could not be cleaned with the duck gun.

Table 1 shows detailed data from experiments using both the robot delivery system and the duck gun.

## 5.4 Other General Results

A printed circuit board with no components was subjected to the $CO_2$ clean using the shaved dry ice tool. The object was to remove only the residual flux from the solder joint. A relatively low pressure (100 psig) and a distance of approximately six inches between the gun nozzle and the board damaged the board. Increasing the working distance and reducing the pressure to 60 psig worked on the second try. Repeated cleans were successful in removing the flux without damaging the board.

Overall, the most effective cleaning was achieved with a $CO_2$ blast perpendicular to the cleaning surface. Cleaning inside pipes, especially in bends, was difficult. If the material being cleaned is soft and easily removed, pipe cleaning is effective. However, effectiveness was greatly reduced when the clean blast was almost parallel to the surface being cleaned.

# Table 1 Experimental Data

|  |  |  |  | *Pellets* |  | *Shaved ice* |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Item*** | ***Date*** | ***Tool*** | ***Cleaned*** | **Blast Pressure (psig)** | **Pellet Rate (lb/hr)** | **Blast Pressure (psig)** | **Feed Pressure (psig)** | **Ice Rate (lb/hr)** | **Blast Air Temp (F)** | **Clean Time (min)** |
| ***Data from Robotic Delivery System*** |  |  |  |  |  |  |  |  |  |  |
| 1 | 17-Oct-95 |  | TEOS VALVE |  |  | 130 | 56 | 50 |  | 2 |
| 2 | 17-Oct-95 | COYOTE | COYOTE PIPE |  |  | 130 | 56 | 50 |  |  |
| 3 | 17-Oct-95 | COYOTE | COYOTE PIPE |  |  | 130 | 56 | 50 |  |  |
| 4 | 17-Oct-95 |  | BELLOWS MOSII NITRIDE FURNACE |  |  | 130 | 56 | 50 |  |  |
| 5 | 17-Oct-95 | 3180 | TASI SHIELD |  |  | 130 | 56 | 50 |  | 5 |
| 6 | 18-Oct-95 | COYOTE | THROTTLE VALVE |  |  | 130 | 50 | 50 |  | 5 |
| 7 | 18-Oct-95 | SI NITRIDE | AMMONIUM CHLORIDE TRAP |  |  | 130 | 50 | 50 |  | 10 |
| 8 | 18-Oct-95 | SI NITRIDE | AMMONIUM CHLORIDE TRAP | 100 | 60 |  |  |  |  | 5 |
| 9 | 18-Oct-95 | 3180 | 3180 TARGET SHIELD |  |  | 100 | 50 | 50 |  |  |
| 10 | 18-Oct-95 | BPTEOS | THROTTLE VALVE |  |  | 100 | 50 | 50 | 180 |  |
| 11 | 18-Oct-95 | BPTEOS | THROTTLE VALVE |  |  | 130 | 50 | 60 | 180 |  |
| 12 | 18-Oct-95 | 3180 | ALUM SHUTTER | 250 | 100 |  |  |  |  | 15 |
| 13 | 19-Oct-95 | FURNACE | BLOWER SCREEN | 150 | 50 |  |  |  |  | 2 |
| 14 | 19-Oct-95 | BPTEOS | THROTTLE VALVE | 150 | 50 |  |  |  |  | 2 |
| 15 | 19-Oct-95 | 8100 | ALUMINUM ETCH SHIELD | 100 | 50 |  |  |  |  |  |
| 16 | 19-Oct-95 |  | FURNACE TRAP | 100 | 50 |  |  |  |  | 5 |
| 17 | 19-Oct-95 | NOVELLUS | SHOWER HEAD | 160 | 80 | 160 | 50 | 60 | 93 |  |
| 18 | 19-Oct-95 |  | WINDOW - HEX TRAY |  |  | 200 | 50 | 60 | 93 |  |
| 19 | 19-Oct-95 |  | BP TEOS THROTTLE VALVE / OSI VALVE | 210 | 40 |  |  |  |  | 15 |
| 20 | 25-Oct-95 | 3180 | ALUMINUM SHIELD | 210 | 60 | 200 | 50 | 70 |  |  |
| 21 | 26-Oct-95 | 3180 | TRANSFER PLATE |  |  | 200 | 50 | 70 |  | 30 |
| 22 | 27-Oct-95 | 3180 | TRANSFER PLATE |  |  | 200 | 50 | 70 |  | 30 |
| 23 | 27-Oct-95 | 3180 | RING - AFTER ETCH | 200 | 50 | 200 | 50 | 40 |  |  |
| 24 | 30-Oct-95 |  | END CAP - HIPOX FURNACE |  |  | 150 | 50 | 40 |  | 50 |
| 25 | 30-Oct-95 |  | PRINTED CIRCUIT BOARD |  |  | 100 | 50 | 40 |  |  |
| 26 | 30-Oct-95 |  | PRINTED CIRCUIT BOARD |  |  | 60 | 50 | 40 |  | 10 |
| 27 | 30-Oct-95 | 3180 | S/S/RINGS W/CLIPS #5 BARREL HI PRESS |  |  | 200 | 50 | 60 |  | 5 |
| 28 | 30-Oct-95 |  | ISOLATION VALVE | 200 | 60 |  |  |  |  | 1 |
| 29 | 31-Oct-95 | APPLIED 5000 | TURBO SCREEN |  |  | 70 | 45 | 22 | 150 | 0.5 |
| 30 | 31-Oct-95 |  | POD SHIELD - ECLIPSE SPUTTER - ALUMINUM |  |  | 250 | 45 | 70 | 150 |  |
| 31 | 31-Oct-95 | 3180 | TRANSFER PLATE - 2 SIDES | 250 | 60 | 250 | 45 | 60 | 150 | 30 |
| 32 | 2-Nov-95 | WHIRLER | PHOTORESIST BOWLS - 3 PARTS - S/S |  |  | 60 | 45 | 28 | 132 | 15 |
| 33 | 7-Nov-95 |  | ISOLATION VALVE - A3 FURNACE - MOSV |  |  | 150 | 50 | 30 | 150 |  |
| 34 | 7-Nov-95 |  | POLY SI CARBIDE BOATS - BICII |  |  | 100 | 50 | 30 | 150 |  |
| 35 | 7-Nov-95 |  | TEOS ELBOW (FORELINE) |  |  | 125 | 50 | 20 | 150 |  |
| 36 | 7-Nov-95 |  | NITRIDE ELBOW |  |  | 125 | 50 | 20 | 150 |  |
| 37 | 7-Nov-95 |  | THROTTLE VALVE |  |  | 70 | 50 | 35 | 150 |  |
| 38 | 7-Nov-95 |  | SLOW START |  |  | 70 | 50 | 35 | 150 |  |
| 39 | 7-Nov-95 |  | ECLIPSE SPUTTER WAFER HOLDER |  |  | 250 | 50 | 40 | 150 |  |
| 40 | 27-Nov-95 |  | THROTTLE VALVE - TEOS |  |  | 160 | 45 | 55 | 180 | 5 |
| 41 | 1-Dec-95 |  | 2 THROTTLE VALVES, 1 ISO VALVE |  |  | 150 | 45 | 70 | 180 | 15 |
| 42 | 2-Dec-95 |  | ISO VALVE - TEOS |  |  | 150 | 45 | 70 | 180 | 15 |
| 43 | 3-Dec-95 |  | THROTTLE VALVE & ISO VALVE |  |  | 150 | 45 | 70 | 180 | 75 |
| 44 | 11-Dec-95 |  | 3180 TRANSFER PLATE | 200 | 50 |  |  |  | 135 | 30 |
| 45 | 12-Dec-95 |  | 3180 TRANSFER PLATE |  |  | 150 | 45 | 45 |  | 30 |
| 46 | 19-Dec-95 |  | T4 - VALVES & PIPE |  |  | 150 | 45 | 45 | 135 | 2.5 |
| 47 | 19-Dec-95 |  | BPTEOS VALVE ELBOW, THROTTLE |  |  | 150 | 45 | 45 | 135 | 1 |
| 48 | 5-Jan-96 |  | 3180 XFER PLATE |  |  | 120 | 45 | 50 |  | 1 |
| 49 | 9-Jan-96 |  | 5000 THROTTLE & TURBO SCREEN - POLY |  |  | 120 | 45 | 50 |  | 5 |
| 50 | 10-Jan-96 |  | 5000 SLIT VALVE - POLY |  |  | 120 | 45 | 50 |  | 1 |
| 51 | 10-Jan-96 |  | 3180 XFER PLATE |  |  | 120 | 45 | 50 |  | 30 |
| 52 | 17-Jan-96 |  | 5000 THROTTLE - POLY |  |  | 120 | 45 | 50 |  | 15 |
| 53 | 20-Jan-96 |  | THROTTLE VALVE |  |  | 160 | 45 | 55 | 180 | 5 |
| 54 | 20-Jan-96 |  | NECK & THROTTLE VALVE - BPTEOS |  |  | 150 | 50 | 40 | ROOM | 60 |
| 55 | 21-Jan-96 |  | 3 THROTTLE & 3 ISO VALVES - BPTEOS |  |  | 150 | 50 | 40 | ROOM | 120 |
| 56 | 14-Apr-96 |  | QUARTZ LINER 5000 ETCH |  |  | 155 | 35 | 60 | ROOM | 10 |
| 57 | 15-Feb-96 | X4 | NITRIDE END PLATE |  |  | 150 | 50 | 55 | ROOM | 20 |
| ***Data from Duck Gun Delivery System*** |  |  |  |  |  |  |  |  |  |  |
| 58 | 13-Mar-96 |  | ISO VALVE |  |  | 50 | 30 | 45 | ROOM | 10 |
| 59 | 13-Mar-96 |  | BELLOWS FROM U1 FURNACE |  |  | 50 | 30 | 45 | ROOM | 5 |
| 60 | 14-Mar-96 |  | THROTTLES - APPLIED 5000 normally 2hrs |  |  | 50 | 30 | 45 | ROOM | 1 |
| 61 | 14-Mar-96 |  | THROTTLES - APPLIED 5000 normally 2hrs |  |  | 50 | 30 | 45 | ROOM | 1 |
| 62 | 14-Mar-96 |  | THROTTLES - APPLIED 5000 normally 2hrs |  |  | 50 | 30 | 45 | ROOM | 1 |
| 63 | 14-Mar-96 |  | THROTTLES - APPLIED 5000 normally 2hrs |  |  | 50 | 30 | 45 | ROOM | 1 |
| 64 | 14-Mar-96 |  | APPLIED 5000 SCREENS normally junked |  |  | 50 | 30 | 45 | ROOM | 1 |
| 65 | 15-Mar-96 |  | APPLIED 5000 SCREENS normally junked |  |  | 50 | 30 | 45 | ROOM | 1 |
| 66 | 16-Mar-96 |  | 1 VALVE- 2 TURBO SCREENS |  |  | 50 | 30 | 45 | ROOM |  |
| 67 | 18-Mar-96 |  | ISO VALVE -SOFT START |  |  | 50 | 30 | 45 | ROOM | 20 |

## 6 CONTAMINATION TESTING

A test to determine the level of contamination from the system was performed on silicon wafers with $CO_2$ pellets, block dry ice, and the air from the compressor only. Two test wafers and one control wafer were run for each test to observe any wafer-to-wafer variation. The wafers were secured with vacuum on a wafer chuck while blasting the surface from a distance of approximately 12 inches perpendicular to the gun output.

The analyses were made on a Secondary Ion Mass Spectrometer[2] (SIMS) with an $O_2^+$ primary beam. The wafers showed contamination from hydrogen, lithium, boron, carbon, hydrocarbons, fluorine, sodium, chlorine and possibly aluminum, potassium, and calcium. The air samples showed the highest level of contamination from carbon, hydrocarbons and fluorine as noted in Figure 7 below.

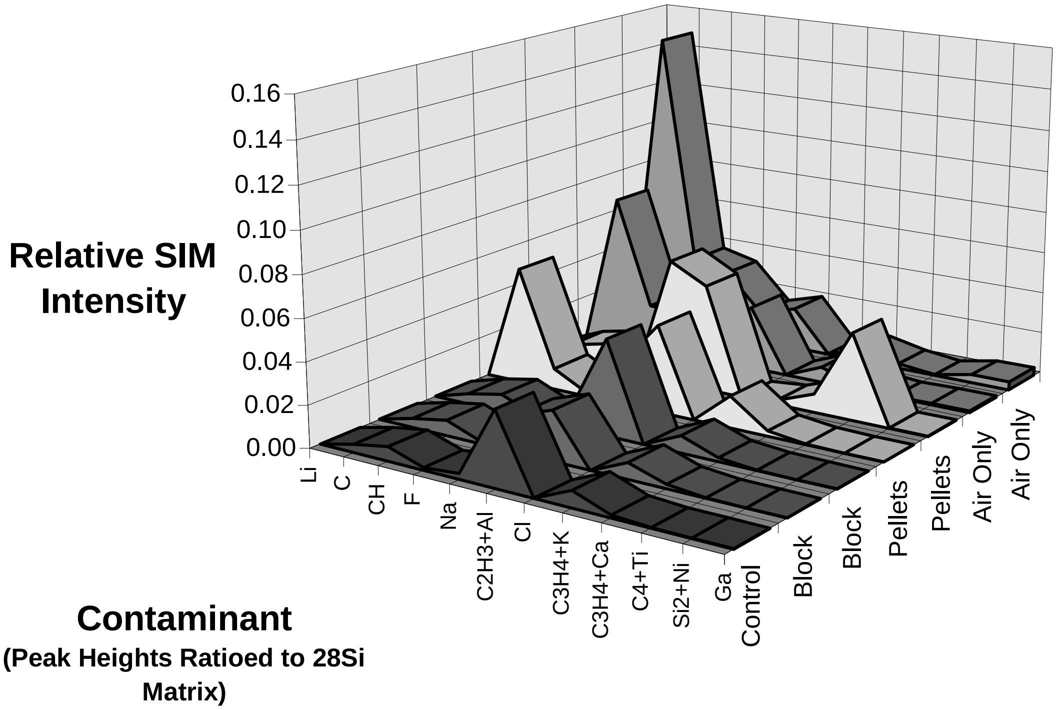

**Figure 7 Comparison of Contamination When Using $CO_2$ Pellets, Dry Ice Shavings, and Air (contains control sequence)**

---

[2] Manufactured by Perkins Elmer, Model Number PHI6300

Because glycol is sometimes added to the dry ice during manufacture to accelerate production, the effects of glycol-containing and glycol-free dry ice were investigated. The test consisted of blasting the surface of two wafers with regular (glycol-containing) dry ice and two wafers with glycol-free dry ice (see Figure 8). In addition, small pieces of glycol-containing and glycol-free dry ice were placed on the wafer surfaces until fully sublimed. Hydrogen, boron, carbon, hydrocarbons, fluorine, and sodium contamination were found on these wafer surfaces. The glycol-free dry ice displayed the most sample-to-sample variation and the highest amounts of contamination. In the case of the glycol-free $CO_2$ blast, a ten-fold increase in contamination with elemental carbon was observed. This analysis was performed twice, and the results were verified.

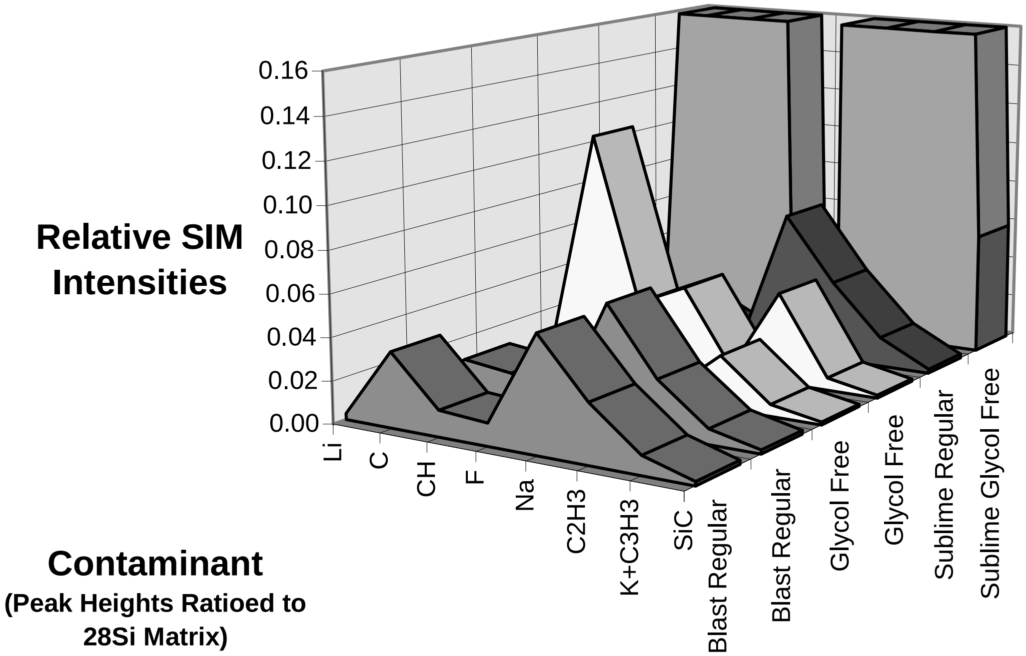

**Figure 8** **Comparison of Contamination Effects When Using Glycol-Containing and Glycol-Free $CO_2$ in Both Dry Ice (Solid) and Sublimed States**

## 7 ECONOMIC ANALYSIS

Annual operating and equipment costs were calculated for the cryogenic $CO_2$ parts cleaning tool (Items A and B in Table 2). Operating costs included electricity required to power the system's compressor for one full year (100% uptime), the cost of the dry ice, and maintenance and exhaust charges. Total equipment costs for the entire cryogenic unit ($111,000) and installation costs ($35,508) were divided into five equal annual installments, assuming a five-year equipment life.

Cleaning costs associated with the dry ice method (Item C in Table 2) were compared to costs of manual cleaning on a part-by-part basis. In all cases, a net savings was incurred from the dry ice method. Equipment installation, operation, and maintenance costs were subtracted from the annual savings to calculate a total net savings of $266,339.

**Table 2 Economic Evaluation**

| | | | |
|---|---|---|---|
| ***Item A.*** | ***Operating Costs for Cleanblaster*** | | **ANNUAL COSTS** |
| | Power (compressor) - 150hp x 750w/hp x 1kw/1000w x $.06/kw-hr x hr/yr | | $58,968 |
| | Block Ice - 10 blocks/yr x $.23/# x 50#/block | | $5,980 |
| | Maintenance Agreement | | $3,500 |
| | Exhaust (glove box) - $4.00 x 1290cfm x 1 yr | | $5,160 |
| | | **TOTAL ANNUAL OPERATING COSTS** | **$73,608** |
| ***Item B.*** | ***Equipment Costs for Cleanblaster*** | | **ANNUAL COSTS*** |
| | Dry Ice Tool (purchase) Note - not included in associated costs | | $22,200 |
| | Installation costs | | $7,102 |
| * Assuming Five Year Life | | **TOTAL ANNUAL EQUIPMENT COSTS** | **$29,302** |
| ***Item C.*** | ***Associated Savings*** | | **ANNUAL COSTS** |
| **Item 1.** | **Coat Track Assembly** | | |
| | **Manual clean** | | |
| | Acetone - # gal/yr @ $/gal | | $4,992 |
| | Disposal costs # gal/yr @ $/gal | | $2,600 |
| | Exhaust costs @ $4.00 x 775cfm x 1yr | | $3,100 |
| | Time to clean - 1 hr/set of 3 components | | |
| | clean # sets/yr x 1hr/set x labor rate | | $31,668 |
| | | Manual Clean Cost | $42,360 |
| | **Dry Ice Method** | | |
| | Time to clean - 5 min (0.083 hr)/set of 3 components | | |
| | # sets/yr x .083hr/set x labor rate | Dry Ice Method Cost | $2,628 |
| | | **Annual Savings** | **$39,732** |
| **Item 2.** | **Throttle Valve Assembly** | | |
| | **Manual clean** | | |
| | Time to clean - 2 hr/unit x # units/yr x labor rate | Manual Clean Cost | $84,240 |
| | **Dry Ice Method** | | |
| | Time to clean - 2 min/unit x # units/yr x labor rate | Dry Ice Method Cost | $1,404 |
| | | **Annual Savings** | **$82,836** |

**Table 2 Economic Evaluation (continued)**

| | | | | |
|---|---|---|---|---|
| **Item 3.** | **Applied 5000 Screens** | | | |
| | **Manual clean** | | | |
| | | Time to clean - none - unit junked - # units/yr x $/unit | Manual Clean Cost | $22,500 |
| | **Dry Ice Method** | | | |
| | | Time to clean - 2 min/unit x # units/yr x labor rate | Dry Ice Method Cost | $27 |
| | | | **Annual Savings** | **$22,473** |
| **Item 4.** | **Throttle Valve** | | | |
| | **Manual clean** | | | |
| | | Time to clean - 2 hr/unit x# units/yr x labor rate | Manual Clean Cost | $112,320 |
| | **Dry Ice Method** | | | |
| | | Time to clean - 7min/unit x # units/yr x labor rate | Dry Ice Method Cost | $6,552 |
| | | | **Annual Savings** | **$105,768** |
| **Item 5.** | **Isolation Valves** | | | |
| | **Manual clean** | | | |
| | | Time to clean - 2 hr/unit x # units/yr x labor rate | Manual Clean Cost | $112,320 |
| | **Dry Ice Method** | | | |
| | | Time to clean - 7min/unit x # units/yr x labor rate | Dry Ice Method Cost | $6,552 |
| | | | **Annual Savings** | **$105,768** |
| **Item 6.** | **Blower Flanges** | | | |
| | **Manual clean** | | | |
| | | Time to clean - 2 hr/unit x # units/yr x labor rate | Manual Clean Cost | $13,824 |
| | **Dry Ice Method** | | | |
| | | Time to clean - 10 min/unit x # units/yr x labor rate | Dry Ice Method Cost | $1,152 |
| | | | **Annual Savings** | **$12,672** |
| ***Item D.*** | ***Net Savings*** | | | |
| **Item 7.** | **Sum of Items 1 through 6** | | | |
| | | | **TOTAL ANNUAL SAVINGS** | **$369,249** |
| **Item 8.** | **Total of Items A and B** | | | |
| | | | **LESS ANNUAL EQUIPMENT AND OPERATING COSTS** | **$102,910** |
| **Item 9.** | **Item 8 from Item 7** | | | |
| | | | **TOTAL ANNUAL NET SAVINGS** | **$266,339** |

## 8 LESSONS LEARNED

Since cryogenic $CO_2$ parts cleaning is a relatively new technology, some deficiencies in the system still must be worked out. Problems and potential solutions were noted during the course of this project. These are listed below:

- The pellets in the container stick together two days after delivery, making the pellet transfer difficult. The ice pellets have to be separated before being transferred to the unit. The dry ice block ice sublimes to approximately 80% of the original size after two days in the container. This does not create an operational problem, but the material is wasted too quickly.
- The air regulator at the glove box failed twice. The air cylinders that operate the nozzle movement and table rotation failed once due to leaks at the seals. The operation of the unit was not affected by this, but the loud noise from the escaping air was greater than the 85 dB design limit.

- The pneumatic controls that operate the robotic nozzle cause the robot to respond erratically to directional changes.
- Cleaning large parts is time-consuming because of the slow rotation of the table and the small cleaning spot size.
- The compressor was installed without a storage tank. When air pressure reaches 250 psig, a solenoid releases the excess air, reducing the pressure to 180 psig, and the cycle is repeated.
- The condensate from the compressor contains oil from the compressor and could be an environmental problem if the oil/water combination is allowed to drain onto the ground. A water-oil separator was installed to allow only the water component to be released. The oil is currently separated into a receiver.
- The compressor outside the plant is placed in stand-by when not in use to reduce operating costs. Future operations should include a remote control panel that can be used to place the compressor in stand-by when not in use.
- The CDA heater overshot the temperature set-point after the air was turned off. During the clean operation, however, the heater maintained a constant temperature.

## 9 CONCLUSIONS

Successful cleaning has been performed on throttle valves, bellows, and positive resist track bowls. The cryogenic $CO_2$ tool cleans the valve assembly in approximately five minutes compared to two hours for the manual procedure (including throttle alignment). The cryogenic $CO_2$ parts cleaning method accelerates parts cleaning and increases worker safety since the part cleaned is inside a glove box rather than an unprotected environment.

The amount of pellets or shaved dry ice in the air stream does not seem to influence the degree of material removal. The pressure delivering the dry ice, however, has the most impact. Lowering the feed pressure reduces the ice consumption and the cost of operation.

**SEMATECH Technology Transfer**
**2706 Montopolis Drive**
**Austin, TX  78741**

**http://www.sematech.org**