

A Survey of Toxic Gas Detection System Users in the Semiconductor Industry



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Introduction

A variety of toxic, corrosive, flammable, pyrophoric, and asphyxiant gases are used in semiconductor manufacturing. Continuous monitoring of such gases has increasingly become a requirement of local and state regulations which are typically based on the Uniform Building Code (Section 911 H-6 occupancy)¹ and Article 80 of the Uniform Fire Code². In addition, the Occupational Safety and Health Act requires each employer to render the workplace free from "recognized hazards causing or likely to cause death or serious physical harm to his employees"³. Concern for potential employee and community exposure to these gases has made gas detection systems (GDSs) an integral part of safety and health programs in the semiconductor industry. Evaluation of these systems without the benefit of hindsight is difficult since few comparative studies of commercial GDSs have been published (a search of the American Chemical Society *Chemical Abstracts - Annual Indexes* for the past five years revealed only two papers on this topic)^{4,5} and most semiconductor

companies do not conduct such studies in-house. The first part of this paper reviews several types of GDSs with respect to their principal of operation, sensitivity, selectivity, response time and cost. The GDS types discussed are those based on electrochemical sensors, semiconductor sensors, paper-tape detectors, flame-emission spectrometry (FES), Fourier-Transform Infrared Spectrometry (FTIR), and mass spectrometry (MS). The second part of the paper describes the results of a mail survey of Semiconductor Safety Association (SSA) members to assess GDS utilization and performance in the industry. Respondents provided information on GDS makes/models used, user satisfaction, gases used and monitored,

areas monitored, frequency of false alarms, alarm locations, frequency of calibration and maintenance, and other characteristics.

GDS Technology Overview

Table 1 lists a number of popular GDS models used in the semiconductor industry along with the process gases that they are capable of monitoring at or below the American Conference of Governmental Industrial Hygienists' Threshold Limit Value (ACGIH TLV), where applicable. GDSs employing electrochemical sensors, paper-tape sensors, infrared spectrometers, and mass spectrometers appear to have the

Table 1
Examples of Gases Monitored by Popular GDS Models

SENSOR TYPE	Formula	ACGIH TLV (ppm)	Gas Tech 2321/1620		IST AG80/80R		Sensidyne		MDA PSM 8/8E/XT		MDA 5710		TELOS 655		TELOS 650/550		TELOS ACM (FTIR)		Perkin-Elmer ICAMS		MDA System 16	
			a	b	a	b	a	a	d	e	f	c, e										
AMMONIA	NH ₃	25	X	X	X	X									X	X	X	X	X	X	X	X
ARSINE	AsH ₃	0.05	X		X	X							X	X	X	X	X	X	X	X	X	X
BORON TRICHLORIDE	BCl ₃	--	1	X	X	1						1	X	X	X	X	X	X	X	X	X	X
CHLORINE	Cl ₂	1	X		X	X						X								X	X	X
DIBORANE	B ₂ H ₆	0.1	X	1					X						X	X	X	X	X	X	X	X
DICHLOROSILANE	H ₂ SiCl ₂	--	1	X	X	1						1	X	X	X	X	X	X	X	X	X	X
HYDROGEN	H ₂	--	X	X	X						X											X
HYDROGEN CHLORIDE	HCl	5	X		X	X						X			X	X	X	X	X	X	X	X
HYDROGEN FLUORIDE	HF	3	X		X	X						X			X	X	X	X	X	X	X	X
HYDROGEN SULFIDE	H ₂ S	10	X	X	X	X								X	X	X	X	X	X	X	X	X
NITROGEN TRIFLUORIDE	NF ₃	10	X	X										X	X	X	X	X	X	X	X	2
ORGANIC VAPORS	--	--	3	X																X	X	X
OZONE	O ₃	0.1						X							X	X	X	X	X	X	X	X
PHOSPHINE	PH ₃	0.3	X		X	X								X	X	X	X	X	X	X	X	X
FREONS®	--	--	3	4																X	X	X
SILANE	SiH ₄	5	X	X	X	X								X	X	X	X	X	X	X	X	X

KEY:

- | | |
|--------------------------------|---|
| a. electrochemical | X -Gas is detected below TLV -if applicable (according to the manufacturer) |
| b. semiconductor | |
| c. paper tape | 1 -detected as HCl in the presence of moisture |
| d. flame emission spectrometry | 2 -with infrared sensor |
| e. infrared spectrometry | 3 -halogenated hydrocarbons detected as HF or HCl after pyrolysis on hot filament |
| f. mass spectrometry | 4 -Except for Freon 114 and Freon 116 |

capability for monitoring the widest range of process gases. GDSs using flame-emission spectrometry and semiconductor sensors are used for selected subsets of chemicals (but may be superior for a given application). Certain other GDSs (e.g. MDA 5710 and Telos 655) are designed to fill gaps in the monitoring capability of the vendor's primary system. The significant cost of GDSs has led to the development of multipoint systems which can sequentially sample 4-50 remote locations connected by tubing to a central analyzer. Instrument response times are generally on the order of seconds, but long lengths of tubing used to collect the samples can significantly increase the system response time. Additionally, some gases may react with the sampling-line material and be lost. Periodic challenge testing with known gas concentrations is essential to verify the integrity of such systems.

Electrochemical sensors

Electrochemical sensors are based on electrolytic cells (Figure 1). Typical operation involves diffusion of gas molecules through the permeable membrane, followed by adsorption and reaction at the surface of the electrode. The resultant increase in current, which is directly proportional to gas concentration, is measured with an ammeter. The membrane and constituents of the electrolyte are designed to give the sensor chemical selectivity for certain gases, but most sensors will have some cross-sensitivity to other gases. The importance of these depends on whether they are expected to be present at significant concentrations in the area being monitored. Sensitivities range from mid-ppb to low-ppm levels for semiconductor process gases. A study of H₂S electrochemical sensors reported a response time of 50 seconds at 50 ppm, and a recovery time of 5 minutes⁴. Both times varied with gas concentration. The study reported that reproducibility and stability were relatively good: over a 6-week period 8 electrochemical sensors initially calibrated at 40 ppm of H₂S maintained a mean value of 41 ± 6 ppm. Electrochemical sensors are not affected by changes in relative humidity, but are affected by changes in the ambient temperature. Costs vary from \$1500-3000/sensor for fairly simple models to \$20-30,000 for multipoint systems equipped with computers. Vendors include GasTech, Sensidyne, Telos,

and MDA Scientific. Routine maintenance, such as adding water to the electrolytic cell, can be performed by the user.

Semiconductor Sensors

Metal-oxide-semiconductor sensors, also known as "solid-state" gas sensors,

are built by depositing thin metal-oxide films (e.g., ZnO, SnO) on silicon using the same basic processes as those used to manufacture computer chips (Figure 2). Adsorption of the sample gas on the surface of the metal oxide, followed by catalytic oxidation, results in a change in its electrical resistance as a logarithmic

Figure 1
Enlarged Cross-sectional View of an Electrochemical Sensor.
 Adapted from Kaminski [4]

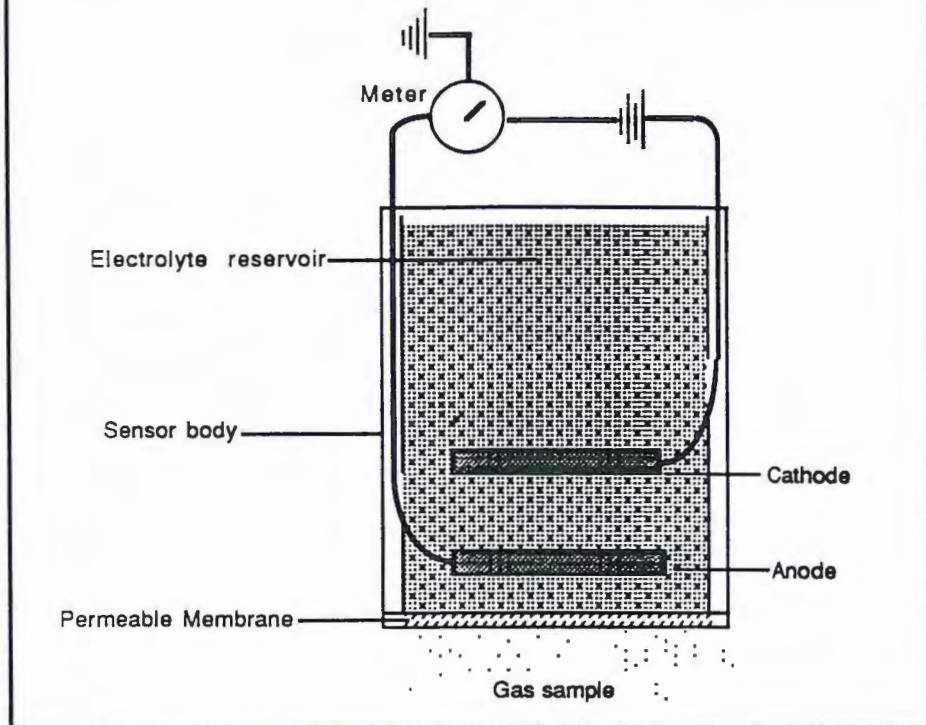
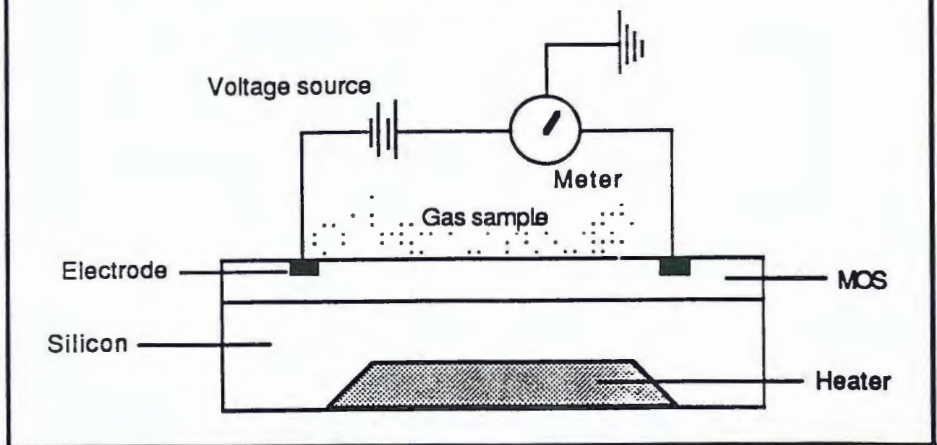


Figure 2
Cross-sectional and Enlarged View of Metallic Oxide Semiconductor (MOS) Sensor in a Silicon Wafer.
 Adapted from Rogers [6]



function of the gas concentration¹³. The surface of the device is heated to a constant temperature in the 150-300° C range to speed the rate of reaction and minimize the effects of ambient temperature changes. Semiconductor sensors are not highly selective, responding to a range of oxidizable chemicals. Sensitivity varies from ppm to percent levels depending on the gas analyzed: for hydrides (except SiH₄) sensitivity is not adequate for TLV-level monitoring. In a study of H₂S semiconductor sensors from five manufacturers, average response times ranged from 10-152 seconds over all measured concentrations⁹. Several of the sensors tested were affected significantly by changes in relative humidity. Another study found that H₂S semiconductor sensors from 6 manufacturers exposed to 40 ppm for 6 weeks held calibration to ± 1 ppm⁴. The devices are relatively inexpensive, \$500-1500/unit, and require little maintenance. Vendors include IST and Matheson.

Paper-tape Detection Systems

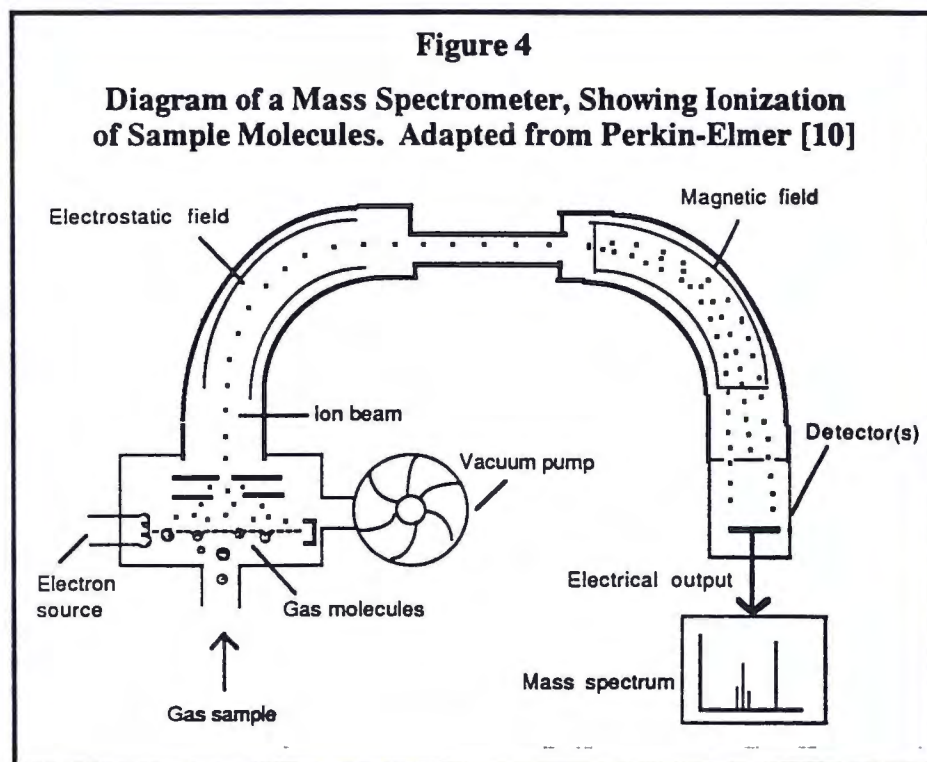
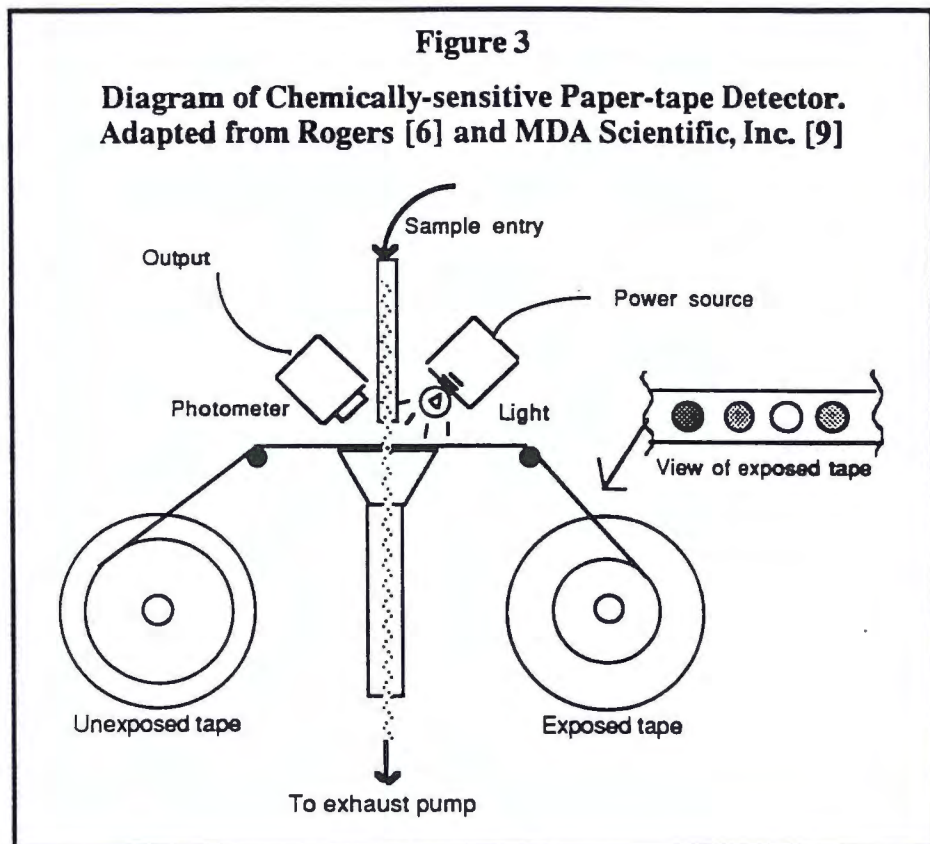
In paper-tape detectors, sample gases react with a chemically-impregnated tape to produce a colored stain. The intensity of the stain, which is proportional to the gas concentration, is measured with a photometer by the reduction in light reflectance from an LED source (Figure 3). Paper-tape detectors can provide good selectivity by using the appropriate chemical reagent in the tape. Accuracy and reproducibility of results are dependent on the quality control of the paper-tape manufacturing process, as well as instrument optics and electronics. Sensitivity is in the low-ppb range for hydride gases, and varies with the gas analyzed to the ppm range. Instrument response times vary from 5-60 seconds, depending on the gas and the monitoring level required. The cost for paper-tape systems with electronic output ranges from \$8,000 (single point) to \$30,000 (multipoint). Paper tape is continuously used during monitoring and can cost \$150-200/month for multipoint systems. The primary vendor is MDA Scientific. Routine maintenance, such as changing tapes, can be performed by the user.

Mass Spectrometry

A mass spectrometer (MS) determines the chemical composition of a gas by identifying the *fingerprint* of its molecular fragments. A small amount

of sample gas at very low pressure is ionized by an electron beam (or other means). These ions are then accelerated, exposed to electric and magnetic forces that separate the ions according to their mass/charge ratio (m/z), and focused on an ion detector (Figure

4). The result is a mass spectrum that uniquely identifies any given compound. A computer library of mass spectra is used for comparison and confirmation of the identity of the sample. Computer storage of data allows future reanalyses. Mass spectrometry is highly specific and



has a broad dynamic range (ppb to percent). The output of the MS is directly proportional to the concentration of the sample gas. Mixtures of certain known compounds can be quantitatively analyzed using the unique mass peaks associated with each component of the mixture. A disadvantage of the direct-inlet MS is that background gases and vapors can interfere with the detection of hydrides at low-ppm to ppb concentrations. For example, O₂ and N₂ can interfere with the detection of B₂H₆ and PH₃, and aromatic hydrocarbons can interfere with the detection of the AsH₃^{15,16}. The instrument response time depends on the number and types of compounds selected for analysis, but is generally from 10-15 seconds per sample. The cost of an MS system is approximately \$180,000. A multipoint system with up to 50 sampling points is available from Perkin-Elmer. Vendor service may be required for maintenance and calibration.

Flame Emission Spectrometry

In flame-emission spectrometry (FES), also known as flame photometry, the sample is drawn into a continuous H₂/air flame. The gas molecules are raised to excited states in the flame and upon returning to the ground state emit light at characteristic wavelengths. The emitted radiation is passed through optical filters or a monochromator to isolate the wavelengths desired for analysis. A photomultiplier tube (PMT) measures the intensity of the radiation, which is proportional to the concentration of the gas (Figure 5). Selectivity is obtained by measurement of radiation emitted at wavelengths selected for the compound of interest. In one commercial system positive responses are confirmed by activating chemical scrubbers designed to remove the target compound. Depending on the result of this test, either the compound or *unknown* is reported. The FES system is sensitive to low-ppb concentrations of hydride gases, such as arsine, phosphine and diborane, but does not detect chlorine, hydrogen chloride, hydrogen fluoride, or hydrocarbons. The response time for each sample is about 8 seconds. A multipoint FES system is available from Telos for approximately \$40,000. Routine maintenance, such as cleaning the flame compartment window, can be performed by the user.

Infrared Spectrometry

Infrared (IR) spectrometry is based on the principle that chemical bonds in functional groups of molecules absorb radiation at characteristic wavelengths. IR spectrometers contain an IR light source, a sample cell, and a detector that measures absorbance. Compounds in a sample can be identified by examining specific wavelengths in the IR spectrum. The Fourier Transform Infrared Spectrometer (FTIR) is the most promising type of IR instrument for monitoring semiconductor process gases, having excellent selectivity for most gases and vapors, and sensitivity to low-ppm or mid-ppb levels¹⁷. Radiation from an IR source is passed through an optical system (Michelson interferometer) to generate a frequency spectrum by light interference. The frequency spectrum, or interferogram, is then converted into a conventional broad-band wavelength spectrum by a computer program using the mathematical procedure known as Fourier transform (Figure 6). The FTIR can store spectral data on the computer for future reanalyses. Response time depends on the target compound, but will generally be about 45 seconds/sample. Diatomic nonpolar molecules such as Cl₂ and F₂ are non-detectable, as they do not absorb IR

radiation. In one study comparing an FTIR instrument to the MDA 7100 paper-tape system, the FTIR was found to be more accurate in detecting arsine, diborane and phosphine at levels of 0.2 ppm or greater (approximate FTIR detection limit)⁸. However, the MDA system was considerably more sensitive, being capable of detecting these gases below 0.01 ppm. FTIR instrument costs range from \$20,000-150,000. Currently, Telos is the primary vendor for semiconductor applications. Maintenance and instrument recalibration require vendor service.

Summary

Although all of the major process gases used in semiconductor manufacturing can be detected with commercially available GDSs, selection of a GDS for a specific site requires careful consideration of the monitoring goals and potential hazards. Often the use of more than one type of GDS is necessary to meet the monitoring needs at a semiconductor facility. The characteristics of GDSs employing electrochemical sensors, semiconductor sensors, paper-tape detectors, flame-emission spectrometry, infrared spectrometry, and mass spectrometry were discussed. GDSs using MS and FTIR have recently shown promise for monitoring a wide range of

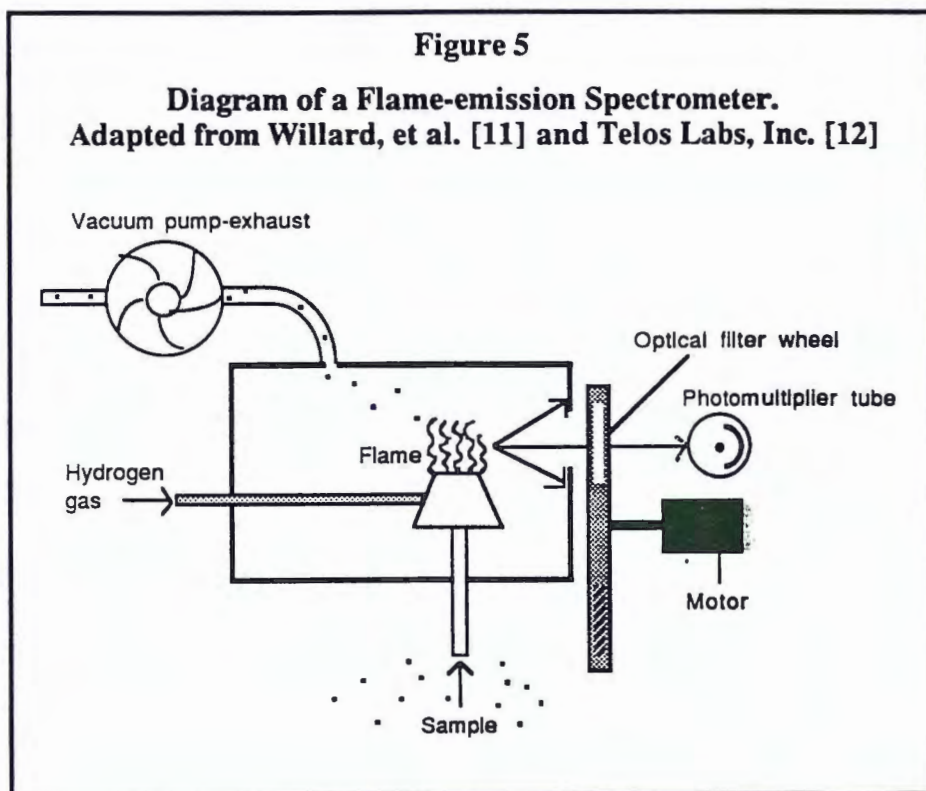
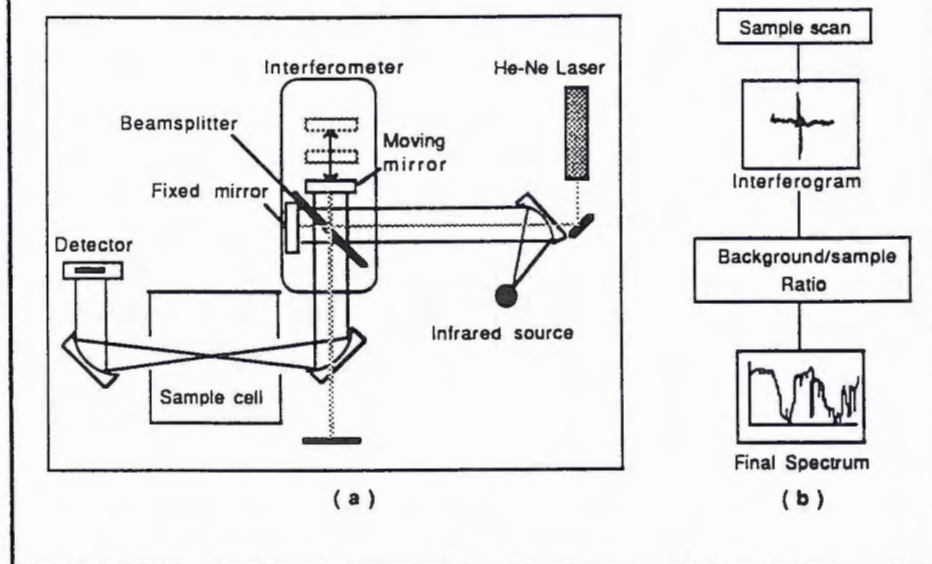


Figure 6

The FTIR Instrument. (a) Optional Diagram.

(b) Flow Chart of Instrument Output.

Adapted from Willard, et al. [11]



process chemicals. Both of these systems have the potential for identifying not only pure process chemicals, but also mixtures of compounds found in process emissions.

GDS User Survey

Questionnaires were sent to 200 safety and health professionals at semiconductor manufacturing and research facilities, selected from approximately 700 members listed in the 1988 Semiconductor Safety Association directory. The survey form consisted of multiple-choice and fill-in-the-blank questions. Name, company, and mailing address were optional (only one anonymous response was received). Respondents were asked to fill out a form for each GDS make/model used at their facility (excluding portable monitors). Sixty-two survey forms were received from 34 individuals, a 17% response rate to the mailing. Respondents represented 29 semiconductor manufacturers and research laboratories, including 2 overseas facilities. With the exception of GDS make/model number, no attempt was made to clarify or obtain missing answers for survey questions, thus results for specific questions may not add up to the total number of respondents ($n = 34$) or GDSs ($n = 62$). Results are presented as percent of total respon-

dents or GDSs unless otherwise noted. The percentages may not add up to 100% due to rounding, or because multiple answers were allowed for certain questions. Questions on GDS utilization were grouped by respondent, while for questions on GDS characteristics each survey form was considered independently.

Respondents were safety engineers (41%), industrial hygienists (21%), managers (15%), other engineers (15%), equipment technicians (6%), and other personnel (3%). The respondents represented facilities with 500+ employees (69%), 50-500 employees (28%), and < 50 employees (3%). U.S. Department of Commerce data (1984) shows a different distribution (64% < 50 employees) in the industry, but is skewed by the inclusion of sales offices. Respondents at 32% of facilities indicated that their GDSs were tested in-house prior to purchase, while 15% did not know (presumably because of GDS purchase was prior to their employment). This suggests that the majority of buyers in the industry are dependent on word-of-mouth or the vendors for comparative information.

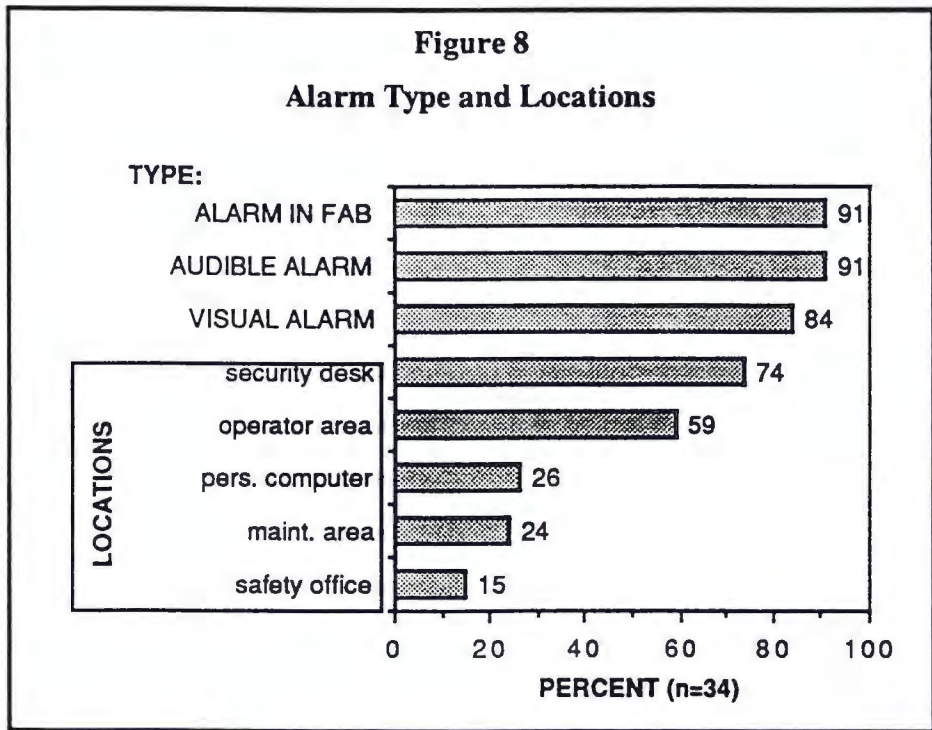
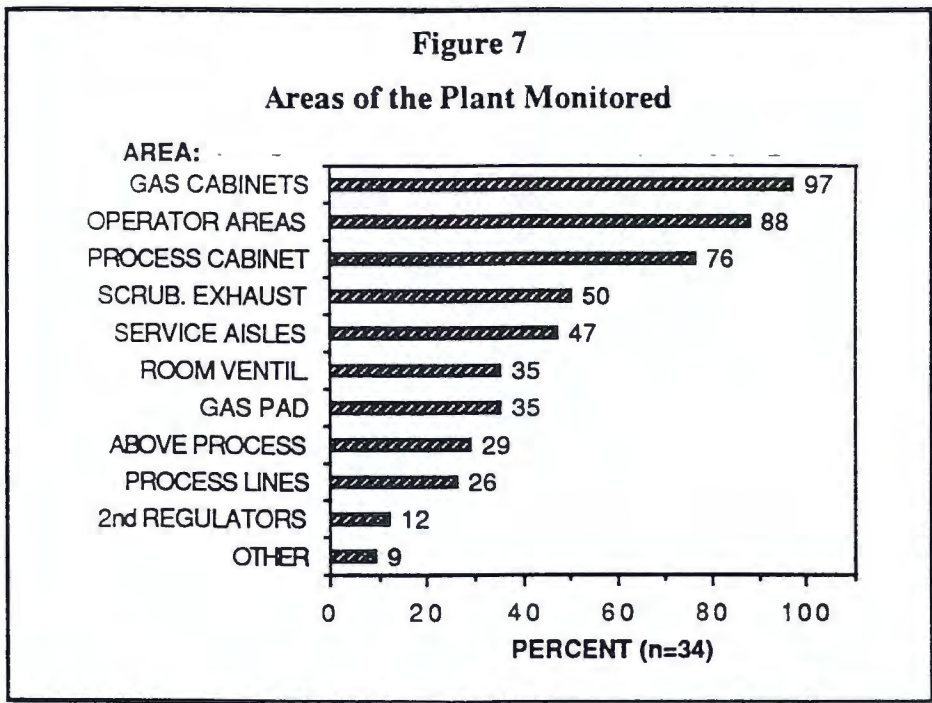
GDS Utilization

Respondents reported that the most commonly monitored areas were: gas cabinets (97%), operator areas (88%),

process cabinets (76%), and scrubber exhaust (50%). Other areas were each monitored by < 50% of respondents (Figure 7). The prevalence of scrubber-exhaust monitoring may be due to recent changes in Article 80 (monitoring of emissions) and the emission reporting requirements of EPA SARA Title III. Such emission monitoring is likely to increase as the impact of these changes is felt. Fewer facilities monitored the gas pad itself (35%), presumably because nearly all monitor the gas cabinets where a leak could be detected first. Most sites were equipped with audible alarms in the fab (91%), with nearly as many having additional visual alarms (84%) (Figure 8), which is consistent with Article 80 requirements. The most common locations for GDS alarm notification panels were the security desk (74%) and operator area (59%) (Figure 8), probably because these areas are most likely to be manned at all times. Interestingly, 26% use personal computers for alarm notification. Since safety and health personnel are often away from their desks, it makes sense that only 15% used the safety office for alarm notification. Respondents indicated the use and monitoring status at their facilities of common process gases and vapors listed in Table 1. As Figure 9 indicates, all of the gases listed were used by 55% or more of facilities, except nitrogen trifluoride, ozone, and hydrogen sulfide. All users of arsine, and all but one user of phosphine, monitor these gases with a GDS, which is expected due to their high toxicity. The level of monitoring among users of other hazardous gases was less: diborane (81%), silane (57%), chlorine (62%), hydrogen chloride (55%), and others (< 50%). The reason for lower monitoring levels for these gases is probably because of their lower perceived hazards, since the technology to monitor them is readily available.

GDS Characteristics

The most frequently reported GDS sensor types were paper-tape (44%), flame-emission (23%), and electrochemical (16%). Less common sensor types were semiconductor (8.1%), infrared (3.2%), photoionization (3.2%), and catalytic filament (non-specific sensors for flammable gases) (3.2%). No respondents reported using a mass spectrometer-based GDS. The GDS models most often reported were the MDA PSM 8 series (27%) and the TELOS 550-650 series (23%), with



other makes/models (including other MDA and Telos models) each comprising 6% or less of the sample (Figure 10). Grouping by GDS model was originally planned, but rejected because insufficient (<5) responses were available for most models. Responses were instead grouped by sensor type: electrochemical, paper-tape, flame-emission, and "other". The group designated "other" was composed of semiconductor, in-

frared, photoionization, and catalytic-filament sensors.

Five questions were asked for which respondents were expected to estimate answers, so categorical choices covering ranges of values were given on the survey form. The questions, and most frequency chosen responses were: frequency of calibration -- 2-5 times/year (37%); frequency of maintenance -- 2-5 times/year (46%) (Figure 11); frequen-

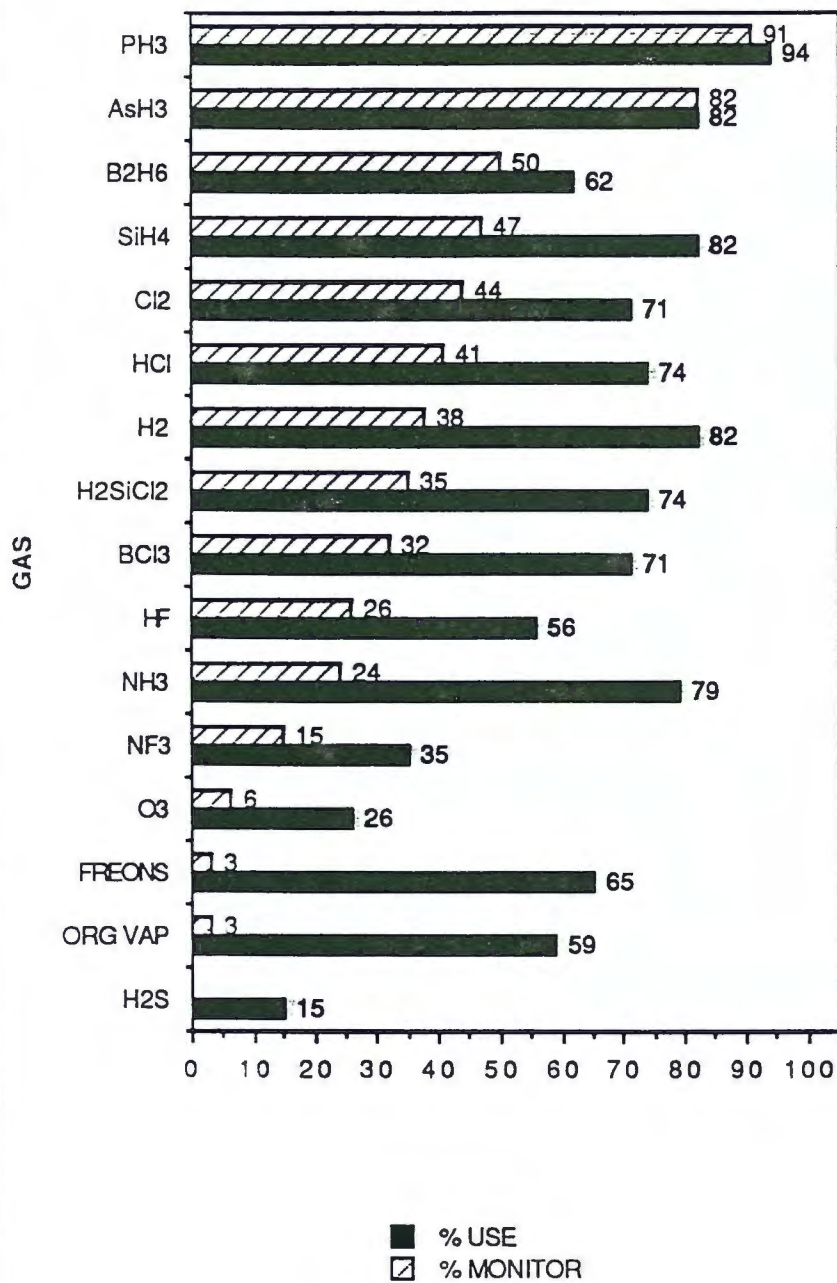
aluminum • cadmium • gallium • indium • mercury
tellurium • zinc • arsine • diborane • phosphine • am
glycol
(MEK)
boron
trichloride
(HCl)
(NO)
(PO)
silic
tung
a • (AsH₃) • arsine • TITLE 80 • diborane • (PH₃) • ph
butyl phosphine • (TMT) • tetramethyl tin • pentabor
EPA • "cellosolve"
FIRE CODES • ame
mine • ethyl acetate
formaldehyde • freon
methyl ethyl ketone
trichloride • (BF₃) • b
m • dichlorobenzene
chloride • (HF) • hy
dioxide • (NO) • nitro
rus oxychloride • (Si
ride • (SF₆) • sulfur
ride • (TBA) • tertiary
• diborane • dichlor
• (TBP) • tertiary
m • cadmium
ane • acetone
tetrachloride • b
formamide • ethan
ethylene glycol • fo
alcohol • (MEK) • met
(BCl₃) • boron trichl
trichloride • chloroform • d
(HCl) • hydrogen cl
(NO₂) • nitrogen d
(POCl₃) • phosphor
• ACIDS • (SF₆) • s
hexafluoride • (TBA)
arsine • (B₂H₆) • dil
(PH₃) • phosphine
• SOLVENTS • cadmi
zinc • pentaborane
carbon tetrachloride • emyl benzene • (HMDG) • hex
methyl formamide • ethanolamine • ethyl acetate • eth
diamine • ARE YOU COVERED ON THESE • freons • (H
methyl alcohol • (MEK) • methyl ethyl ketone • phenol
acid vapors • (BCl₃) • boron trichloride • (BF₃) • bor
carbon tetrachloride • chloroform • dichlorobenzene • f
bromide • (HCl) • hydrogen chloride • (HF) • hydrogen
chloride • (NO₂) • nitrogen dioxide • (NO) • nitrogen oxid
trifluoride • (C₂H₆) • ethane • (C₂H₄) • ethylene
ride • ethan
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ide
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• (A
scl
stramethyl tin • aluminum • cadmi
• zinc • pentaborane • acetone • (n
• (CCL₄) • carbon tetrachloride • ethyl benzene • (HMD
ne • dimethyl formamide • ethanolamine • ethyl acetat
ethyl
alcoh
yle
• (H
Br
F₃)
trachl
mercury • tellurium • zinc • pentaborane • acetone • f
• SAFETY • CONFIDENCE • PEACE OF MIND •
hexamethyldiazane • tungsten hexafluoride • zinc

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Figure 9
Overall Gas Use and Monitoring



cy of false alarms -- 0-5 times/year (74%) (Figure 12); percent of time GDS is running properly -- 96-100% (54%) (Figure 13); and response time of the GDS to a gas leak -- 1-3 minutes (48%) (Figure 14). It can be seen that GDS operation was not trouble-free: 49% reported a maintenance frequency of > 5 times/year and 63% reported a calibration frequency of > 5 times/year (Figure 11); nearly 20% reported that their GDS

was properly operating < 90% of the time (Figure 13); and 27% reported > 5 false alarms/year (which corresponds to about 20 systems) (Figure 12). In answering the question on GDS response time to a gas leak, respondents may have relied either on personal experience or information provided by vendors. Additionally, respondents with multipoint systems may or may not have included the time it takes to draw

the sample through various lengths of tubing. To test for differences between sensor types for the categorical questions, observed frequency tables of the sensor types vs. answer categories were prepared (Figure 15). Differences were observed for percent of time GDS is running properly, and frequency of calibration, but were not statistically significant (chi-square) because the sample size was too small. No statistically significant differences were observed between sensor types for frequency of false alarms, frequency of maintenance, and response time in minutes. It is interesting to note that users of paper-tape systems appear to calibrate their GDSs more frequently than users of other sensor types (possibly due to the ease of this activity). This may be the reason why it also appeared that paper-tape system users reported their systems were running properly more often than users of other sensor types.

Ten statements requiring subjective evaluation of GDS performance were included in the survey to which responses could be one of 5 choices: strongly agree, agree, unsure, disagree, and strongly disagree. Numerical results were obtained by converting the categories to integers: 1 (strongly disagree) to 5 (strongly agree). The mean responses for each question by sensor type are presented in Table 2. Paper-tape sensors received the most favorable rating overall. The analysis of variance (ANOVA) showed a significant difference ($p < 0.05$) between sensor types for statements 3, 6, 9 and 10 (i.e., variation between one or more sensor types was greater than variation within types). Tests for statistically significant differences (Scheffe F-test, $p < 0.05$) between pairs of means for the sensor groups were performed for these statements. For statement 10 (routine maintenance is easy to perform), paper-tape was rated higher than the electrochemical and flame-emission groups. For statement 9 (good service is provided by the GDS vendor), paper-tape was rated higher than the group designated "other." For statement 6 (calibration of the GDS is not difficult), paper-tape and "other" were rated higher than the flame-emission and electrochemical groups. For statement 3 (if a leak occurred the GDS would detect it), no significant difference between sensor group pairs was found.

Figure 13

Percent of Time Running Properly (n = 57)

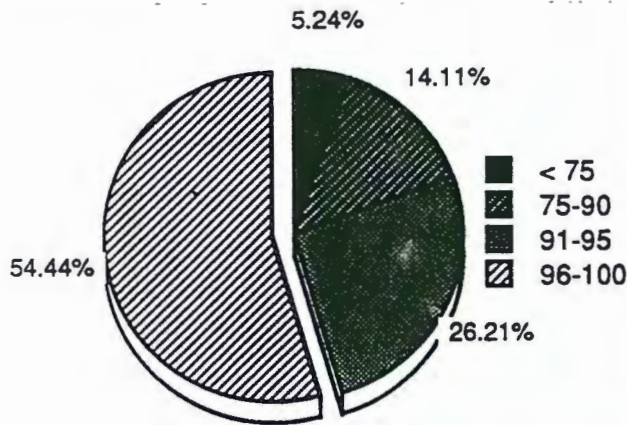


Figure 14

Response Time in Minutes (n = 58)

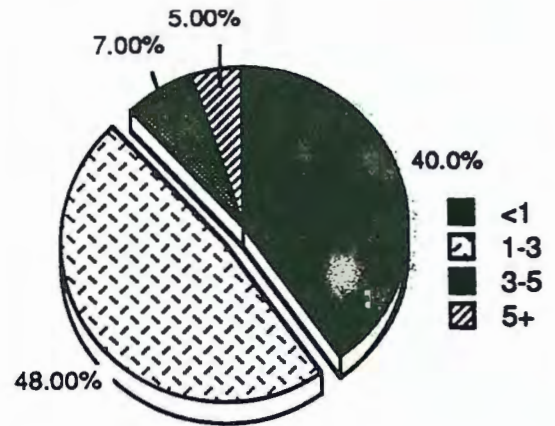


Figure 15

Observed Frequency Tables for Sensor Types v. Answer Categories

Freq. of calibration-# of times/year:

	A 0-1	B 2-5	C 6-11	D 12-24	E 24+	Totals:
ELECTROCHE...	1	5	2	0	0	8
PAPER TAPE	1	4	8	8	10	27
FLAME EMS...	0	8	5	1	0	14
OTHER	1	5	0	4	1	11
Totals:	3	22	13	11	11	60

Percent of time GDS is running properly:

	A <75	B 75-90	C 91-95	D 96-100	Totals:
ELECTROCHE...	0	0	4	1	5
PAPER TAPE	2	1	5	19	27
FLAME EMS...	0	4	3	7	14
OTHER	1	3	3	4	11
Totals:	3	8	15	31	57

Freq. of maintenance-# of times/year:

	A 0-1	B 2-5	C 6-11	D 12-24	E 24+	Totals:
ELECTROCHE...	1	5	2	1	0	9
PAPER TAPE	2	7	8	8	8	27
FLAME EMS...	0	10	4	0	0	14
OTHER	0	6	3	1	1	11
Totals:	3	28	15	8	7	61

Freq. of false alarms-# of times/year:

	A 0-5	B 6-11	C 12-24	D 24+	Totals:
ELECTROCHE...	4	2	0	0	6
PAPER TAPE	21	3	1	2	27
FLAME EMS...	8	2	0	0	10
OTHER	7	3	0	1	11
Totals:	40	10	1	3	54

Response time in minutes:

	A <1	B 1-3	C 3-5	D 5+	Totals:
ELECTROCHE...	4	5	0	0	9
PAPER TAPE	8	18	2	1	28
FLAME EMS...	6	7	1	0	14
OTHER	5	1	1	2	9
Totals:	23	28	4	3	58

Table 2 - Evaluation of GDS Performance by Sensor Type

Survey Statement:	SENSOR TYPE				OVERALL	ANOVA F-test
	ELECTRO-CHEMICAL	PAPER TAPE	FLAME EMISS SPECTR.	OTHER		
	mean(s.d.)					
1. The GDS performs as advertised	3.3 (0.7)	4.1 (0.7)	3.9 (0.7)	3.6 (1.0)	3.9 (0.8)	p = 0.083
2. The overall reliability of the system is high	3.4 (0.7)	4.0 (0.9)	3.8 (0.7)	3.3 (1.1)	3.7 (0.9)	p = 0.11
3. If a gas leak occurred the GDS would detect it	3.5 (0.7)	4.1 (0.6)	4.1 (0.5)	4.0 (0.6)	4.0 (0.6)	p = 0.038
4. Actual gas leaks are detected by the GDS	4.0 (0.0)	4.1 (0.5)	3.8 (0.8)	3.8 (0.8)	4.0 (0.6)	p = 0.45
5. False alarms occur too frequently	2.4 (0.9)	2.3 (1.2)	2.4 (1.2)	2.9 (1.1)	2.5 (1.1)	p = 0.53
6. Calibration of the GDS is not difficult	2.8 (1.1)	4.2 (0.5)	2.8 (1.3)	3.9 (0.7)	3.6 (1.1)	p = 0.001
7. The selectivity of the GDS is adequate	3.7 (0.9)	4.0 (0.6)	3.4 (1.1)	3.3 (1.3)	3.7 (0.9)	p = 0.096
8. The sensitivity of the GDS is adequate	3.4 (0.7)	4.0 (0.9)	4.1 (0.5)	3.6 (0.9)	3.9 (0.8)	p = 0.14
9. Good service is provided by the GDS vendor	3.3 (0.7)	4.1 (0.7)	3.7 (1.0)	3.1 (0.9)	3.7 (0.9)	p = 0.0061
10. Routine maintenance is easy to perform	3.1 (0.8)	4.3 (0.5)	2.9 (1.1)	3.5 (1.0)	3.7 (1.0)	p = 0.0001
number of responses =	10	27	14	11	62	

Key: 1 = Strongly Disagree 3 = Unsure 5 = Strongly Agree
 2 = Disagree 4 = Agree

Summary

A survey of users in the semiconductor industry provided information on GDS utilization and performance for monitoring process gases. The majority (67%) of systems reported were based on either paper-tape detectors or flame-emission spectrometry. Arsine, phosphine, and diborane were the gases most often monitored by users. Nearly all GDSs were used with audible and visual alarms in the fab. The majority of respondents monitored operator areas, gas cabinets, process cabinets, and scrubber exhaust, while less than 50% monitored other plant areas. Most respondents (74%) estimated that false alarms occurred 0-5 times/year. No significant differences between sensor types were found for frequency of false alarms, or ability to detect a gas leak. However, significant differences between sensor types were observed for subjective performance characteristics, with paper-tape detectors receiving the highest rating overall. Due to the potential for selection bias and the fact that the response to the mailed survey was fairly low (17%), results cannot be considered conclusive. The data collected may be useful for designing future studies and assisting other users in GDS selection, evaluation, and implementation.

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