



Analysis of Nitrous Oxide Survey Data

**International SEMATECH Manufacturing Initiative
Technology Transfer #09065015A-TR**

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Abstract: This report from the ESHT001 project presents the results of a survey on the use of nitrous oxide in semiconductor manufacturing by International SEMATECH Manufacturing Initiative (ISMI) and Semiconductor Industry Association (SIA) members. The data were gathered to develop a response to the U.S. Environmental Protection Agency (EPA) proposed mandatory greenhouse gas (GHG) reporting rule. Results of other surveys in this series are in Technology Transfers #09065012A-TR and #09065014A-TR.

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1 EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) proposed Mandatory Reporting of Greenhouse Gases rule was published in the Federal Register on April 10, 2009, beginning the 60-day comment period. The preamble explains the EPA's basis for the proposed rule. Subpart I outlines specific requirements for semiconductor manufacturing facilities. The proposed rule requires electronics manufacturing facilities to report "nitrous oxide emissions from chemical vapor deposition" (April 10, 2009 FR, p. 16648). It further requires facilities to report annual nitrous oxide (N₂O) consumption as emissions (April 10, 2009 FR, p. 16649). The International SEMATECH Manufacturing Initiative (ISMI) Environment, Safety, and Health Technology Center conducted a survey of ISMI and Semiconductor Industry Association (SIA) members to identify the semiconductor manufacturing processes that use N₂O and the utilization efficiency (UE) for those processes.

2 SURVEY QUESTIONS

The survey asked for the following information:

- Do you manufacture or operate chemical vapor deposition (CVD) process equipment that uses N₂O? If so, what is the name of the process?
- What is the wafer diameter for this equipment (in mm)?
- What is the general name for the process?
- Have you characterized the N₂O emissions from the process?
- What methodology was used to characterize the N₂O emissions and process byproducts?
- Please provide the percentages (of total) that each methodology was used to characterize process emissions and byproducts.
- What was the measured N₂O utilization efficiency? (please provide answer as w/w% with indicator of accuracy of measurement (+/-))

3 SURVEY RESULTS

Seventeen companies submitted 37 responses (34 U.S., 3 overseas).

3.1 Processes that Use N₂O

The survey identified N₂O use in the following semiconductor manufacturing processes:

- Chemical vapor deposition (nitride, polysilicon glass, oxide, etc.)
- Diffusion (oxidation, nitridation, etc.)
- Rapid thermal processing
- Chamber seasoning

3.2 Emissions Characterization

Respondents reported using N₂O in 150 mm, 200 mm, and 300 mm process tool sets; however, no emissions characterization data were available for 150 mm processes and only one data set was provided for 200 mm processes. Only two of the responding companies have N₂O emissions characterization data. Characterization data were collected using either the 2001 or the 2006 *ISMI Equipment Environmental Characterization Guideline*. Both guidelines describe the protocol for quantitative measurements of tool emissions using quadrupole mass spectrometry or fourier transform infrared mass spectrometry. Two other companies estimated utilization efficiency using a stoichiometric and material balance approach. One company estimated N₂O UE after abatement and assumed a 99% destruction or removal efficiency (DRE) in the abatement device.

3.3 Utilization Efficiency

Eleven respondents reported the N₂O utilization efficiencies shown in Table 1. Responses 1 through 8 are measured data while 9 through 11 are estimated. The measured utilization efficiencies range from 1–20% for a 200 mm process (response 7) to a high of 83.5% for a 300 mm process. The average measured UE is 40%. Results 1–6 and 8 were from 300 mm tool sets. For responses 7 and 8, the mid-point of the range was used to calculate the overall average. The large difference between responses 7 and 8 is attributed to the method by which N₂O is supplied to certain 200 mm tools compared to 300 mm tools. If only the 300 mm results are considered, the average UE is 43%.

Table 1 N₂O Utilization Efficiency

Utilization			
Fab	Efficiency (%)	Accuracy (± %)	Comments
1	18	10	*
2	18	N/A	*
3	13.95	3.26	*
4	33.1	0.39	* deposition
4	54.1	1.37	* seasoning
5	83.5	4.92	*
6	64.7	0.73	* deposition
6	34.6	0.11	* seasoning
7	1 to 20	N/A	200 mm tools
8	50–80	N/A	*
9	44	N/A	estimated
10	99	N/A	estimated after abatement with burners
11	100	N/A	estimated

* process in 300 mm tool

4 CONCLUSIONS

N₂O is used in a variety of semiconductor processes in both older and newer generation tool sets. Survey respondents provided little emissions characterization data for older generation tools; the majority of data is for 300 mm tools. The survey did not attempt to determine the quantity of N₂O used in the various processes but instead focused on collecting UE data. The measured UE of N₂O varies widely from a low of 1–20% in characterized 200 mm processes to a high of 83.5% for a 300 mm process. The average of all measured UE is ~40%. If only 300 mm results are considered, the average measured UE is 43%.

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