High-Sensitivity, Fast-Response Monitoring of PFC and Abatement Tool Emissions By FTIR Spectroscopy

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Abstract

FTIR Spectroscopy is normally applied for gas analysis within a lab environment; but with the correct components, it can provide a rugged solution, capable of on-site operation and high performance and fast quantitative analysis of PFCs in the low ppb concentration range.

Introduction

Semiconductor fab plants are faced with monitoring and reducing their PFC emissions to meet SEMI Environmental, Health and Safety (EHS) requirements. In some cases these unsafe emissions are continuous, while in other cases they are intermittent or random.

In all cases it has become necessary to have high-sensitivity online gas analyzers installed with real-time readouts, at the in-plant waste abatement tool and/or at the plant discharge towers.

FTIR Spectroscopy can detect all infrared-active molecules simultaneously and accurately. A rugged gas analyzer based on FTIR spectroscopy offers superior construction for industrial settings via a rugged FTIR spectrometer mounted on a shock/vibration suspension system. It consists of a stainless steel long path gas cell with protected gold-coated SS mirrors capable of withstanding corrosive environments, and specialty software producing state of the art gas analysis and system hardware management.

FTIR Spectrometer

The selected spectrometer is an ABB Bomem WorkIR™ spectrometer, an industrial unit that requires minimum maintenance and can withstand moderate levels of noise and vibration. The spectrometer is equipped with a DTGS detector because of its linearity and capability to run at standard room temperature. Its high sensitivity limit compares favorably with other more sensitive LN_2-cooled detectors due to its ability to respond linearly at much higher light intensities.

Gas Cell

A CIC Photonics 4Runner™ gas cell is used due to its long pathlength (6.5-m pathlength) and high energy throughput (>40%). This gas cell provides low ppb detection limits with a DTGS detector. Its long pathlength and high transmission translates into high SNR. Due to the nature of the vapors and gases being contained in the gas stream before and after the abatement tool, the gas cell is heated to prevent vapor condensation and corrosive attack. The preferred materials for the construction of the gas cell are nickel-plated 316 stainless steel and protected gold-coated stainless steel mirrors.

Specialty Software

The software package is the CIC Photonics SPGAS™ software which provides a sophisticated chemometric package and includes total and automated operational management of hardware components (spectrometer, temperature controller, sensors, valves, and gauges), data archiving capabilities, operator alerts and warnings, and several communication options including DeviceNet and Ethernet/IP. The protocols are used to distribute the data, in real time, to EHS authorities off the plant floor via Internet or Intranet thereby ensuring the proper functionality of the abatement tool.

The chemometric package is a weighted multiband, multicomponent CLS quantification methodology, the latest based upon chemometrics originated at Sandia National Laboratories. This method ensures the discrimination of molecules with like elements, structures, and spectral absorptions.

Table 1 shows LODs that can be achieve with the system.

Table 1 Gas Analyzer LOD

Gas	LOD
H_2O	50ppb
HF	50ppb
CO_2	5ppb
CO	40ppb
NO	100ppb
SO_2	10ppb
SiF_4	<30ppb
SiH_4	<30ppb
NO_2	7ppb
NF_3	<50ppb
NH_3	10ppb

Application

The system is connected both before and after the abatement tool to monitor the performance of the tool. *Figure 1* shows the system interconnection. Due to the high concentration of the analytes before the abatement system, a 5-cm gas cell is used in front of the abatement tool and the 6.5-m gas cell is used after the abatement tool.

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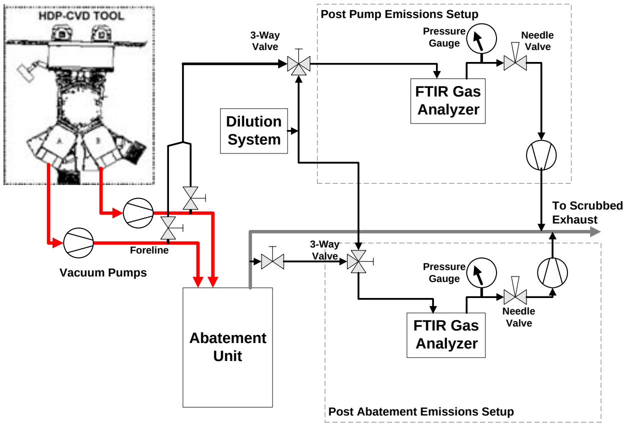

Figure 1 System interconnection with abatement unit

Figure 2 shows the high intensity spectra of SiF_4, NF_3 and HF present in the system before it enters the abatement unit, while *Figure 3* show the intensity of the SiH_4, SiF_4, NF_3 and HF during the entire *HDPCVD process.*

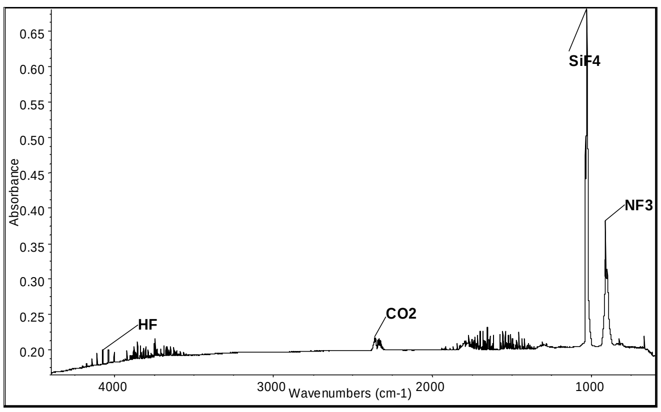

Figure 2 FTIR Spectra for Clean Process (Before Abatement Unit – 5-cm Gas Cell)

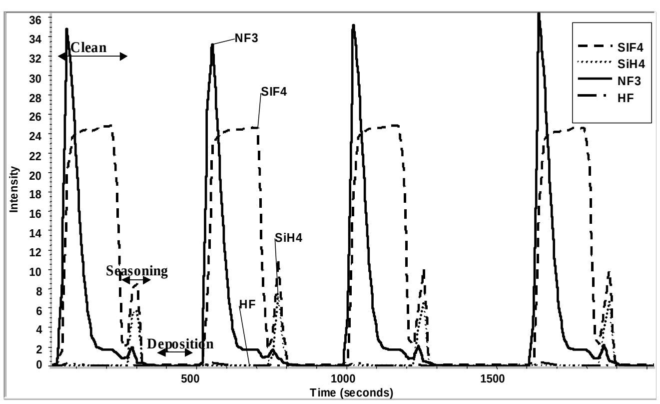

Figure 3 FTIR Intensities HDPCVD Process (Post Pump Data – 5-cm Gas Cell)

Finally, *Figure 4* shows that the abatement unit is performing within specs since the spectra do not show visible evidence of SiH_4, SiF_4, NF_3 or HF.

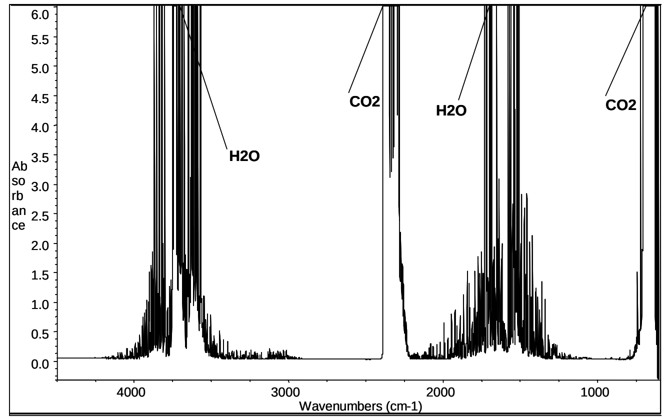

Figure 4 FTIR Spectra Post Abatement Unit (6.5-m Gas Cell)

Conclusions

FTIR spectroscopy is a viable technique for monitoring PFC and abatement tools emissions, which, by offering high sensitivity, is able to meet today's and future EHS PFC limit of detection requirements. FTIR spectroscopy is capable of detecting all IR active gas species; but those few that are not IR-active, like oxygen or nitrogen, can be detected with other techniques like QMS or GC, either of which can be incorporated to work in conjunction with FTIR.

Acknowledgments

Abatement data compliments of Applied Materials

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