Ammonia and NMP Monitoring in Cleanrooms Using Ion Mobility Spectroscopy

Abstract

The effect of ammonia (NH_3) and n-methyl pyrrolidinone (NMP) contamination on chemically amplified DV resists is well documented. While techniques such as gas chromatography and ion chromatography have been used to monitor for these compounds, they have certain drawbacks. The need for low ppb limits of detection requires pre-concentration of the sample over a period of time. These methods may also require laboratory analysis, unless automated, and require some expertise to operate. This paper describes the use of ion mobility spectroscopy (IMS) for monitoring these compounds in real time at low ppb levels. This method has been shown to be a low maintenance, continuous, reliable method for cleanroom monitoring. Theory of operation, hardware, and operating parameters are discussed.

Theory of Operation

IMS is basically an atmospheric pressure, time-of-flight technique. The heart of the IMS analyzer is the cell shown in Figure 1. Ambient air is drawn into the analyzer by way of an internal eductor or is delivered to the analyzer by way of a multi-point sampler. The air is drawn over a semi-permeable membrane which provides protection from dust and reduces potential interferences. The gas of interest permeates this membrane and is picked up on the other side by the carrier flow of externally supplied air or nitrogen. The carrier stream carries the sample to the ionization region of the cell which contains a small Ni63 radioactive source. In this region, the sample undergoes a series of ion-molecule reactions and becomes ionized. The ions are attracted towards the other end of the tube due to a high voltage electric field. They travel down the tube until they encounter the shutter grid, which is a series of interlaced wires that can either be electrically biased to stop the ions or allow them to pass. Periodically, the grid is pulsed to allow the ions to enter into the drift region where they separate based on size and shape. The ions are detected at the end of the tube by a collector plate, where their charge is converted into a current. This current produced a time based spectra, with a distinctive drift time for a specific compound. The on-board microprocessor identifies the compound by its drift time, and determines concentration by the peak height. Specificity of the technique is often enhanced by the addition of a dopant material to the carrier stream. The dopant affects the ionization processes, resulting in preferred ionization of the desired material while blocking potential interferences. This dopant is a proprietary material supplied by an internal permeation tube.

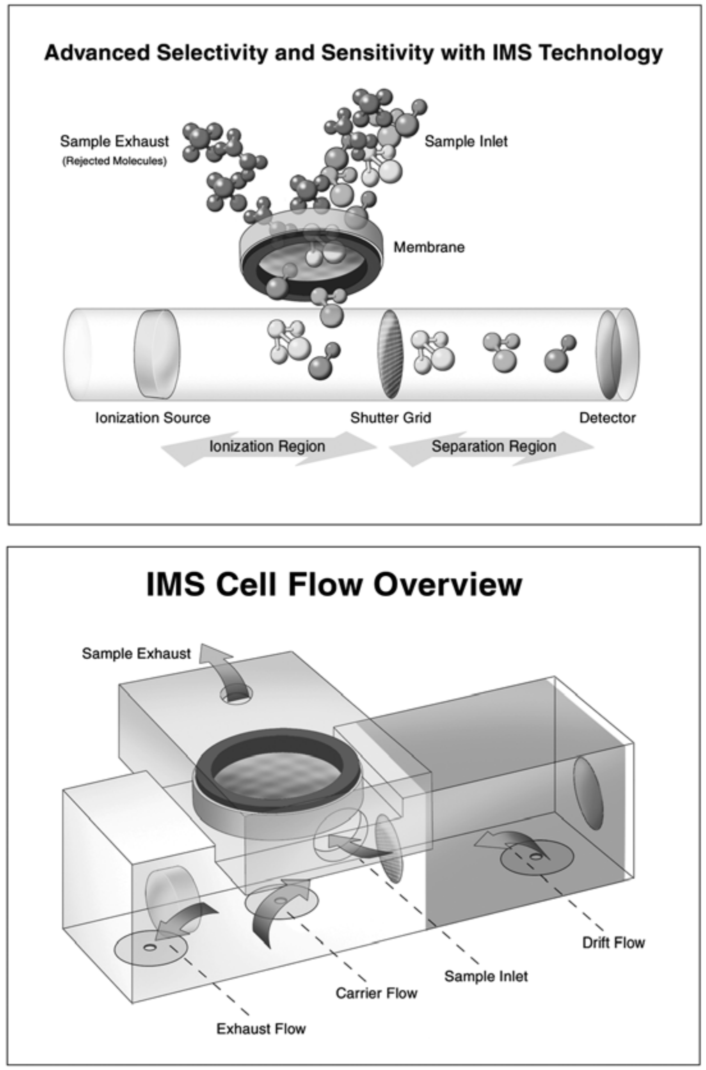

Figure 1. Schematic of an IMS Cell

Typical spectra for NH_3 and NMP are seen in Figures 2 and 3. As is typical in IMS, the dopant peak becomes smaller as the target compound peak becomes larger. This is due to charge exchange as charge is transferred from the dopant to the target compound.

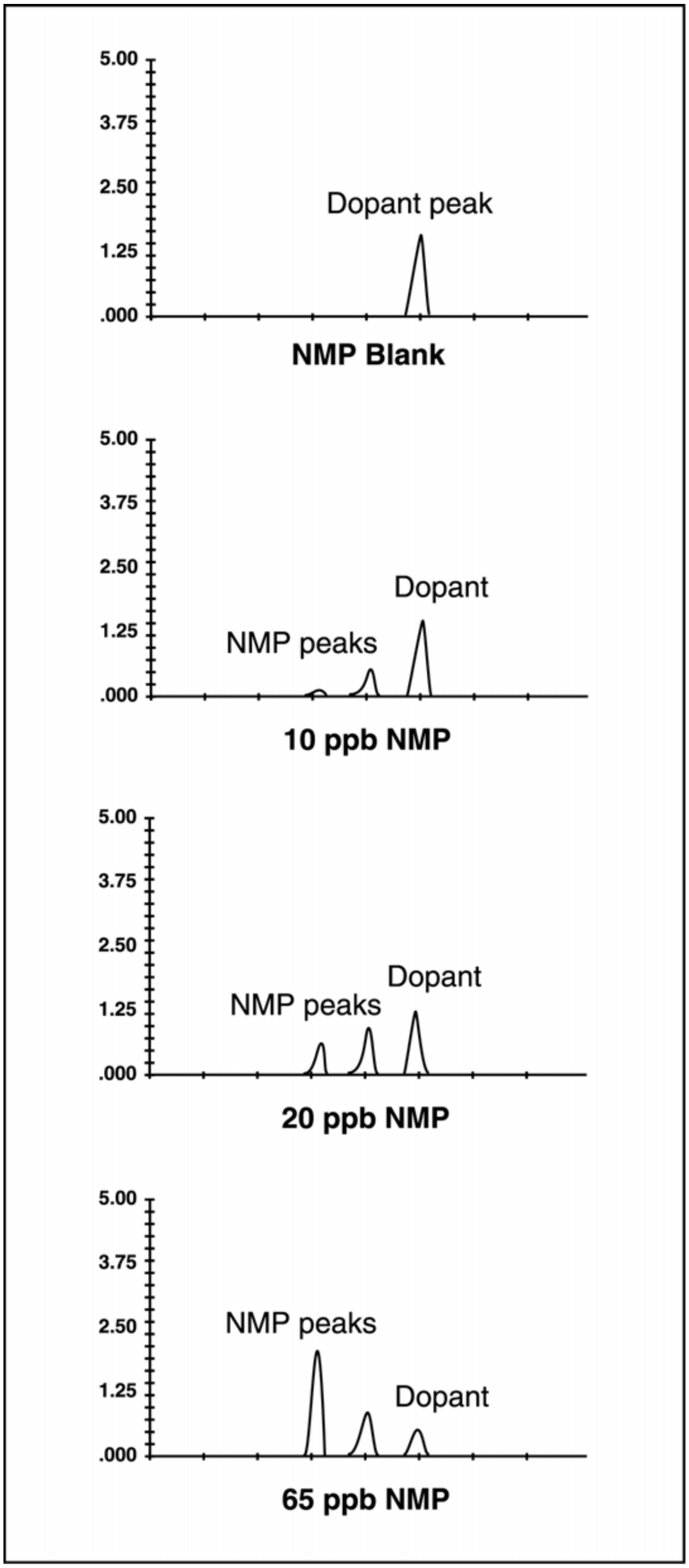

Figure 2. NMP Spectra

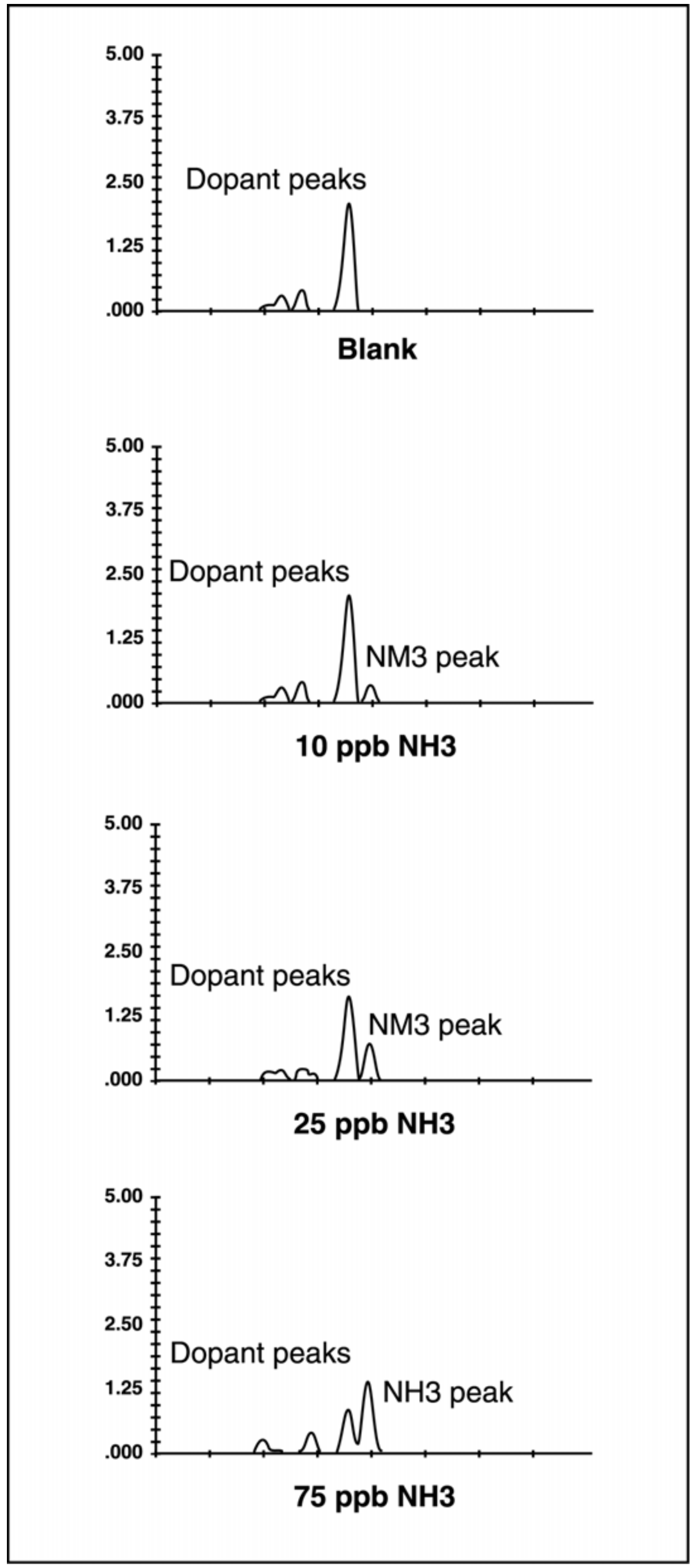

Figure 3. NH_3 Spectra

Hardware

Having been developed for heavy industrial use, all analyzers are enclosed in NEMA-4X enclosures, which are corrosion resistant and waterproof. The NH_3 analyzer is housed in a dual enclosure, with the electronics on the right side and the temperature controlled pneumatics on the left. Because of space requirements in the fab and because the NMP analyzer does not require rigid temperature control, the NMP analyzer is most often supplied in a smaller, single enclosure unit.

All analyzers are supplied with a digital display for the concentration. Remote indication is given by a 4-10 mA loop, two user-set alarm contract closures, and a fault alarm. Should the on-board diagnostics detect a problem, the fault relay closes and a fault code is displayed on the front display. Although the analyzers are factory calibrated, field calibration is easily performed. External permeation generators can be used, or the analyzer can be fitted with an optional internal calibration generator. This internal calibrator eliminates the need for extra hardware and greatly increases the ease of use.

Most systems are also supplied with a multi-point sampler. This device allows the use of one set of analyzers to be used to monitor four to sixteen separate points. The multipoint sampler also increases the utility of the system by providing an RS-232 and parallel printer port for periodic concentration reporting.

Utilities and Maintenance

The analyzers require 115 VAC and dry (-40°C dewpoint or better) air or nitrogen and 20-120 psi. A CE certified, 230 VAC unit is also available.

Maintenance requirements are low. The membrane and NMP dopant must be replaced on a yearly basis and a radioactive wipe test must be performed every six months.

Performance

Both analyzers have a limit of detection of <1 ppb. Response and cleardown is rapid with a >95% of the full response being achieved in less than four minutes. Typical response and cleardown characteristics are seen in Figure 4.

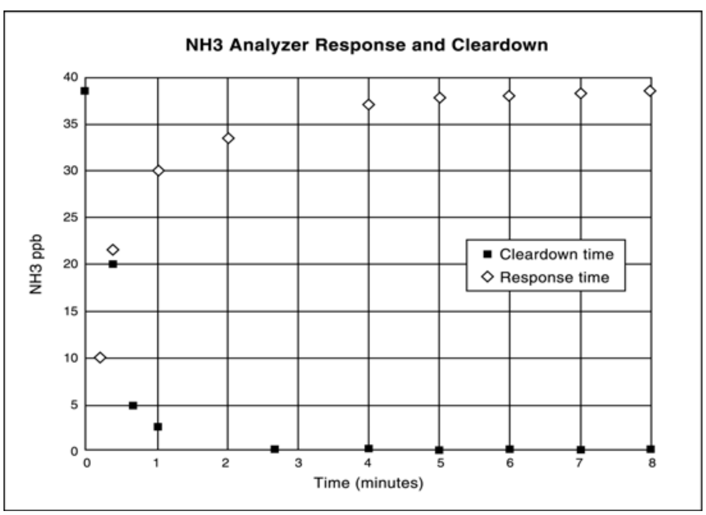

Figure 4. NH_3 Analyzer Response and Cleardown

Security and Interferences

The NMP analyzer has been tested in the presence of a wide variety of common cleanroom chemicals without interference to concentrations normally found.

The NH_3 analyzer does exhibit some suppression due to ppm levels of oxygenated solvents. However, the effect is minor in concentrations normally found in cleanrooms.

NMP has also been shown to have a slight suppressant effect on the ammonia reading.

Other Compounds Monitored by IMS

Other compounds that may affect chip processing, as well as health and safety, can be monitored by IMS. These compounds include hydrogen fluoride, hydrogen chloride, chlorine, hydrogen peroxide, hydrogen bromide, chloride, bromine, etc. Specificity for these compounds is achieved by selection of appropriate dopants, membranes, and specific drift times.

Conclusion

IMS has been successfully used to monitor for ppb levels of various contaminants in the cleanroom. It has proven to be a reliable, low-maintenance, real-time alternative to previously used techniques.

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