Application Note: 50730

High-Speed, High-Sensitivity Detectors for Use in the Mid-Infrared Spectral Range

Key Words

- DLaTGS Detectors
- MCT Detectors
- Mid-IR Detectors
- Nicolet FT-IR

Overview

Most mid-infrared (mid-IR) analyses are performed with the standard deuterated L-alanine doped triglycine sulfate (DLaTGS) detector due to its ease of use, high sensitivity, and excel-lent linearity. When sample measurements must be made at high speed or when IR throughput is low, the highly sensitive mercury cadmium telluride (MCT) detector provides the ability to scan faster than an DLaTGS detector while maintaining a constant IR response. The response of the DLaTGS detector is reduced by half for every two-fold multiple of the scanning velocity. Scanning faster with an MCT detector reduces sampling time without affecting sensitivity.

Depending on the type of MCT detector chosen, 4 – 10 times higher sensitivity can be obtained as compared to an DLaTGS detector. The MCT-B (wide band MCT – 400 cm^{-1} cutoff) detector offers about four times higher sensitivity than the DLaTGS detector. The MCT-B detector is an excellent choice for slightly lower throughput measurements when sampling speed is important. The MCT-A detector (narrow band – 650 cm^{-1} cutoff) offers the highest mid-IR sensitivity and is ideal for low throughput analysis when high sampling rates are required. This higher sensitivity provides significantly greater IR response for small amounts of energy reaching the detector.

If an MCT-A detector is used to measure a high throughput sample (e.g., a polymer film), a 10% neutral density screen must be used to limit the energy reaching the detector. The neutral density screen will prevent detector saturation and the associated spectral anomalies.

In this note, the advantages of a high-speed, high-sensitivity detector for routine laboratory sampling needs will be illustrated in three examples.

Experimental

All measurements were made using a Thermo Scientific Nicolet™ x700 FT-IR spectrometer equipped with a KBr beamsplitter and DLaTGS, MCT-B, or MCT-A detectors. Collection parameters differ for the experiments and are noted with each spectral figure. The J-stop aperture of the Nicolet 6700 spectrometer used in this study was software controlled to optimize response for the different resolutions.

High-Resolution Gas Analysis

Figure 1 compares the results of MCT-A and DLaTGS detectors used to measure a 4-torr carbon monoxide gas sample in a 10-cm gas cell. A 10-minute collection time was used for both detectors. For the DLaTGS detector, 39 scans were collected at the optimum mirror velocity of 0.63 cm/sec. For the MCT-A detector, 150 scans were collected using a mirror velocity of 3.16 cm/sec without degrading the IR response.

The MCT-A spectrum shows a significantly better signal-to-noise ratio than the DLaTGS detector. The DLaTGS spectrum exhibits baseline noise which masks the absorbances above 2245 cm^{-1}. The MCT-A spectrum is virtually noise free and clearly shows five additional absorbance bands in the spectrum.

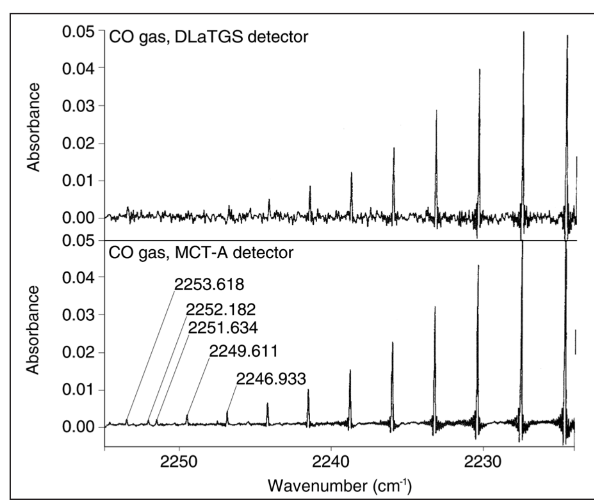

Figure 1: High-resolution gas analysis comparison of MCT-A to DLaTGS detectors

Rapid-Scan Analysis

Chemical changes on the millisecond time scale requires the use of rapid scanning. To obtain the needed time resolution, single pass interferograms were collected using rapid mirror scanning speeds.

Figure 2 compares MCT-B and DLaTGS detector signal-to-noise ratios for a rapid-scan data collection at 20 scans/second. The wide spectral range MCT-B detector was chosen for this experiment because of the open-beam, high-throughput measurement. Both spectra are the result of a single-scan sample ratioed to a 256-scan background. These 16 cm^{-1} resolution spectra were collected using identical parameters with a moving mirror velocity of 5.06 cm/sec. At this high sampling rate, the signal strength measured by the DLaTGS detector is about one tenth the signal of the MCT-B detector.

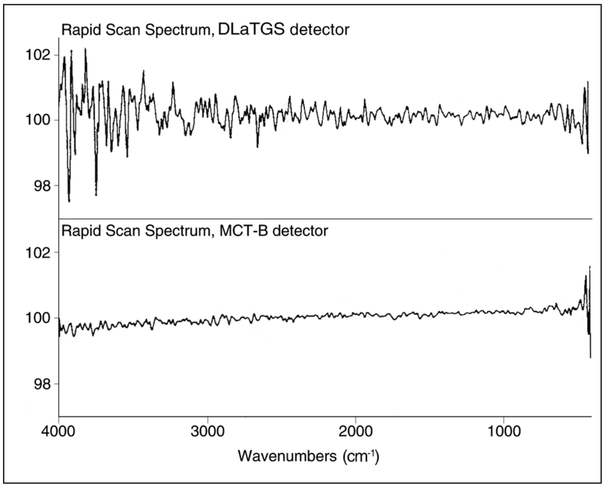

Figure 2: Rapid-scan data comparison of MCT-B to DLaTGS detectors

The resulting signal-to-noise ratio is better in the MCT-B spectrum and confirms the performance advantage of the MCT-B detector over the DLaTGS for rapid-scan measurements. Under these same conditions, the MCT-A detector has a slightly higher sensitivity and lower signal-to-noise than the MCT-B, but at the cost of a narrower spectral range.

Grazing-Angle Analysis

The analysis of thin films of organic materials on reflective substrates is generally measured by grazing angle specular reflectance. The IR throughput of a grazing angle accessory is typically less than 10% due to vignetting at the high angle of incidence. An IR polarizer is generally used in conjunction with the accessory to enhance the signal from the oriented chemical species. The polarizer further reduces the throughput of IR by at least 50%. The resulting throughput of the grazing angle accessory is typically less than 5% of the open beam energy.

In Figure 3, the grazing angle spectrum of a 40-angstrom thick lubricant on a rigid memory disk is shown. The intensity of the broadband absorbance at 1260 cm^{-1} is used to measure the thickness of the fluorinated lubricant and, therefore, the quality of the disk.

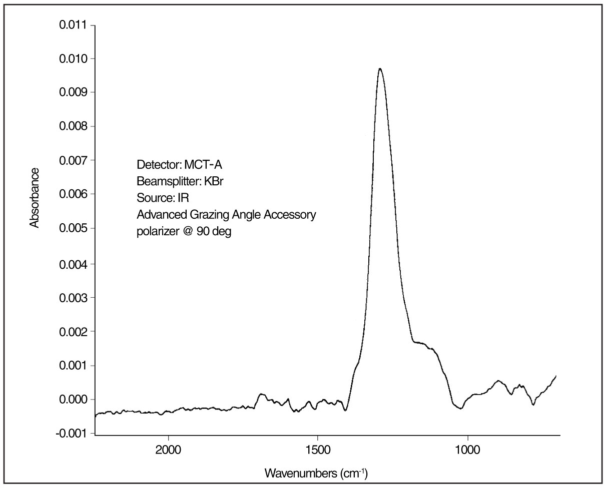

Figure 3: Grazing-angle spectrum of a 40-angstrom thick lubricant

This spectrum was measured with the high-sensitivity MCT-A detector. The data collection parameters were 256 scans (less than 2 minutes) at an 8 cm^{-1} resolution using a scanning velocity of 3.16 cm/sec. The combination of low signal (the film is quite thin) with the restricted IR throughput requires that the MCT be used for this measurement.

Conclusions

For IR applications with low throughput measurements, high-speed sampling, or high-spectral resolution measurements, an MCT detector will significantly improve sensitivity and reduce sampling time.

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