

SPECTRA OF THE MONTH

EXPANDING INTO THE MIR: MEASURING PLASTIC
REFLECTANCE WITH AVANTES AND NLIR

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INTRO

BACKGROUND OF APPLICATION

Avantes has long been known for our capabilities in UV, VIS, and NIR measurement. These wavelength regions are used for many measurement techniques, such as reflectance, absorbance, and irradiance, which are applicable for a number of applications. One area where we have been limited in the past is in measurements that require analysis of the mid-infrared, or MIR, region, which extends beyond the NIR range. This limitation was primarily due to the high costs detectors needed to read signal in this wavelength range. But now, with technology developed by our sister company NLIR, reading data in this region with our instruments is possible, thanks to their SPEKTRUM wavelength converter. This device utilizes an internal laser to convert signal in the MIR region down to the NIR region, which can be read with our CMOS-based spectrometers. The result is a much lower cost solution for MIR applications, such as grain or soil analysis, remote sensing, and material characterization. To demonstrate this expanded capability, we performed measurements of several plastics utilizing NLIR's wavelength converter along with one of our spectrometers.

This experiment aimed to measure the reflectance of multiple plastic samples in the mid-infrared spectral region. Measurements were taken in AvaSoft and converted using a third-party software to properly demonstrate spectra in the MIR. The plastic samples used for this experiment (Figure 1) consisted of ABS and Delrin in black and white colors, specifically chosen to express how spectral measurements in the MIR can be used to characterize the composition of a material and are less affected by the color of the sample compared to measurements in the visible range.



FIGURE #1 Plastic samples used for this experiment, including black ABS (top-left), black Delrin (top-right), white ABS (bottom-left), and white Delrin (bottom-right).

DESCRIPTION OF SPECTROSCOPY SETUP

The experimental setup (Figure 2) centered around the compact AvaSpec-NXS4096CL, or Nexos, spectrometer. Built using Avantes' semi-automated manufacturing process for improved consistency and reproducibility, the Nexos features a CMOS linear array detector, ultra-low stray light, and flexible communication options. For this experiment, the spectrometer was configured with a 682–886 nm range to support MIR wavelength conversion, along with a 50-micron slit to balance throughput and resolution.

The two NLIR components utilized for this setup were the TOUCH and the SPEKTRUM. The TOUCH is NLIR's measurement interface that integrates a silicon carbide MIR light source such that a sample can be easily placed onto a measurement area for reflection values to be read out via a fiber optic connection. It is designed to work with varying sample shapes while also minimizing background noise, and even includes a cover that has a built-in gold reference tile (Figure 2). The SPEKTRUM is NLIR's wavelength conversion module. This instrument converts incoming signal in the range of 1.9-5.3 μm to a range of 682-886nm, enabling the use of Si and GaAs detectors. This conversion is driven by an internal high-power, continuous-wave 1064nm laser inside a lithium niobate crystal. This conversion is done in real-time, with no time lag or scanning elements. These aspects make this tool a perfect pairing with our AvaSpec spectrometers to measure data in the mid-infrared that was previously unattainable for our instruments.

Other accessories used for this experiment included a 200-micron core fiber optic cables, specifically constructed with an indium fluoride core for MIR light transmission, and a 50-micron core fiber optic cable with FCPC connections to connect the NLIR SPEKTRUM to our Nexos spectrometer.



FIGURE #2 Experimental setup for plastic measurements. The spectrometer was connected to the NLIR SPEKTRUM via fiber optic cable, while the SPEKTRUM connected to the TOUCH measurement device. Samples were measured by placing them directly on the TOUCH surface, which includes an integrated gold reference tile for convenient referencing.

DESCRIPTION OF METHODOLOGY

The plastic samples used for this experiment were provided to us by a customer for a previous application. The sample set had dozens of plastic samples, but only four were chosen specifically to demonstrate that in the MIR region, a more significant distinction in reflection is seen between material composition as opposed to color, as would be seen in the visible and NIR regions. Besides selecting the most ideal samples for this measurement, no other sample preparation was done. To perform the measurements, first a dark and reference measurement were taken, with the cover placed on the NLIR TOUCH. Samples were then simply placed on the measurement area with the cover removed.

For data analysis, we used the Reflectance mode in AvaSoft, our exclusive custom software package. This mode is designed for reflection applications, where the reference measurement will report 100% and the dark measurement will report 0%. In this experiment, the embedded gold reference tile of the NLIR TOUCH was used as the reference, and a measurement of the tile with the light source disengaged was used as the dark. We used an integration time of 800ms, which can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum. We set averaging to 5, meaning 5 measurements were averaged together for each reported spectra to provide more consistent spectral results. Because AvaSoft reports these measurements in the NIR region, an additional step was needed to convert the data back to the actual MIR region that is being measured. This was done by saving the AvaSoft measurements to ASCII files, creating a conversion script in MATLAB, and plotting the converted data set. This process is very simple and can even be done in real time with a few adjustments to the script.

TEST DATA AND RESULTS

Displayed below are the spectral measurements of the plastic samples, reported in reflectance in the NIR range visible in AvaSoft:

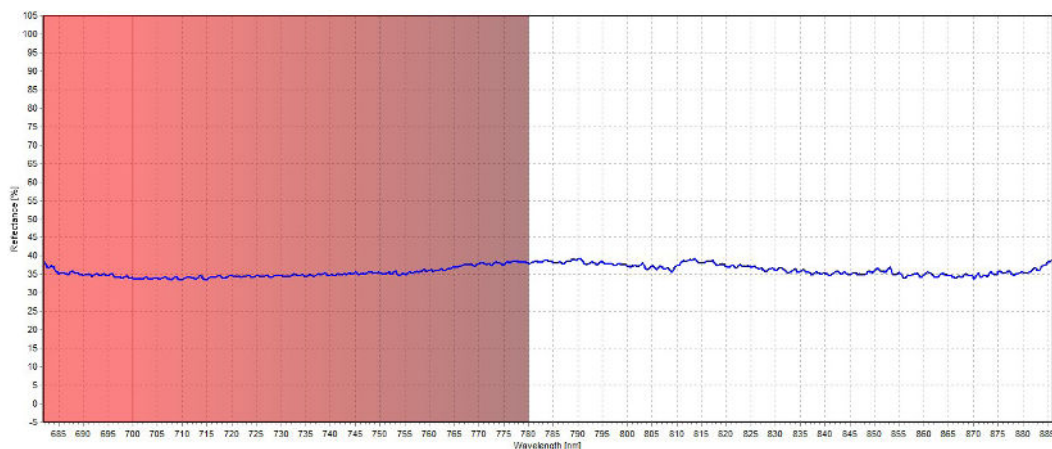


FIGURE #3: Reflectance spectrum of black ABS in AvaSoft..

TEST DATA AND RESULTS

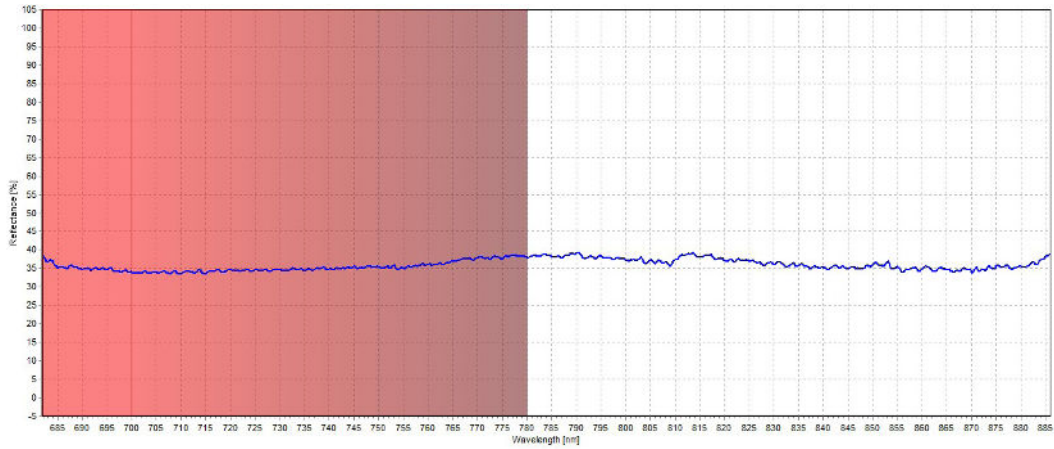


FIGURE #3: Reflectance spectrum of black ABS in AvaSoft..

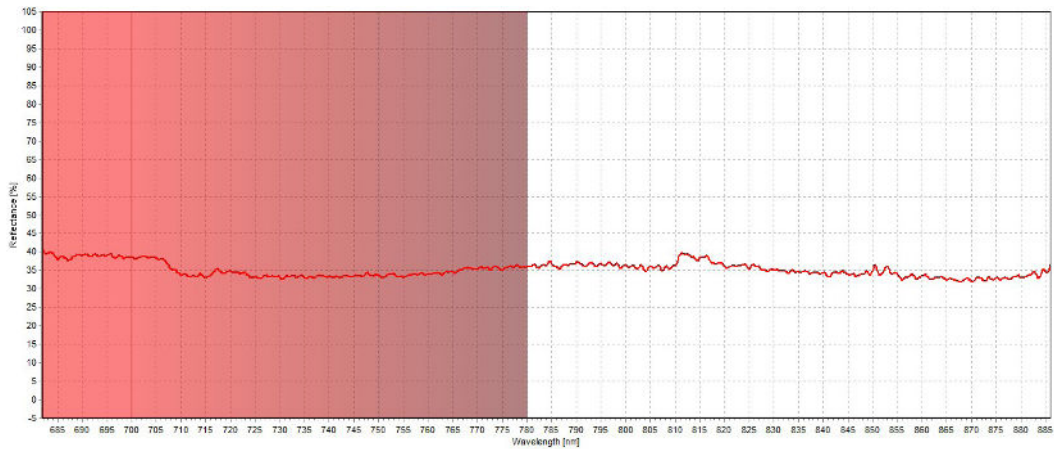


FIGURE #4: Reflectance spectrum of white ABS in AvaSoft

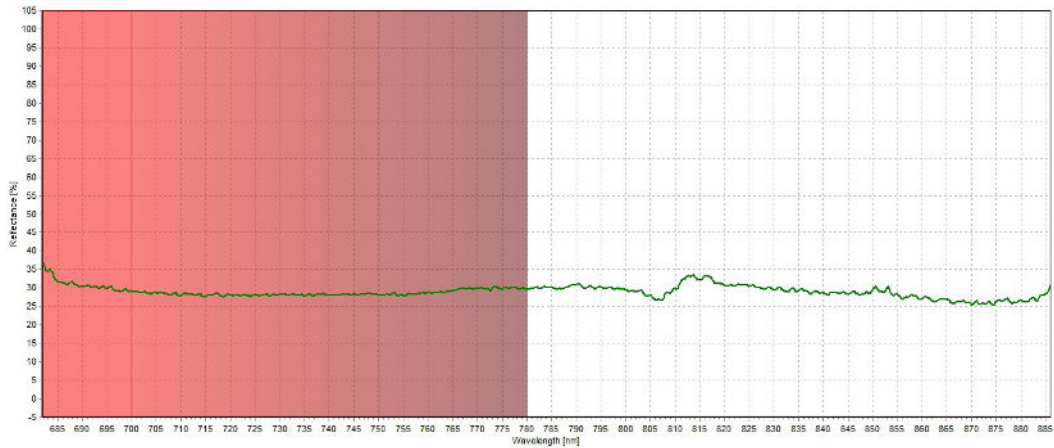


FIGURE #5: Reflectance spectrum of black Delrin in AvaSoft.

TEST DATA AND RESULTS

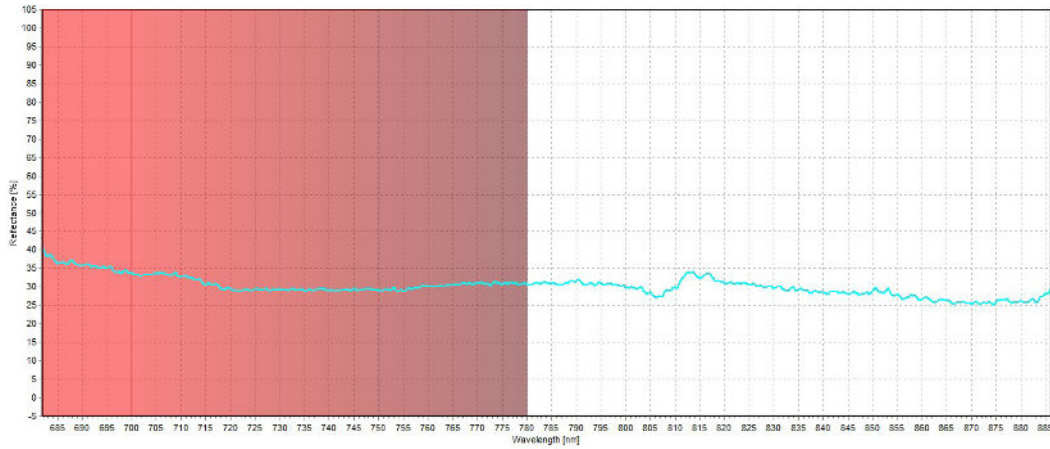


FIGURE #6: Reflectance spectrum of white Delrin in AvaSoft.

Displayed below are the converted measurements using the SPEKTRUM Wavelength Converter:

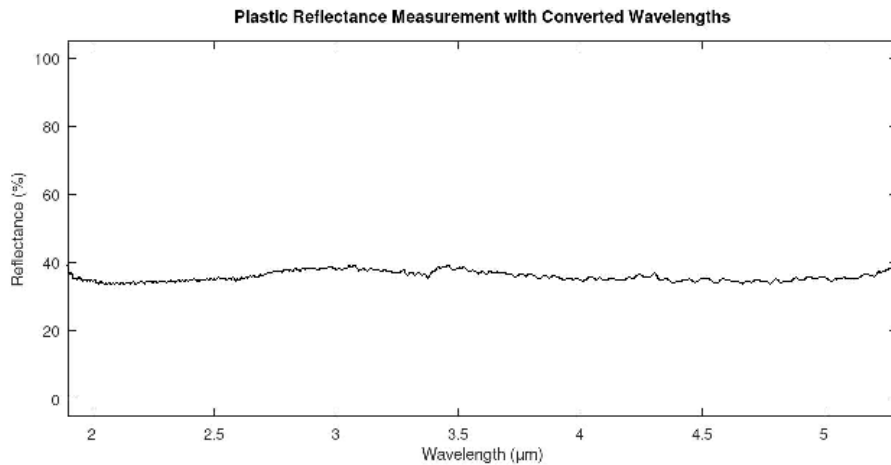


FIGURE #7: Reflectance spectrum of black ABS, converted back to MIR region.

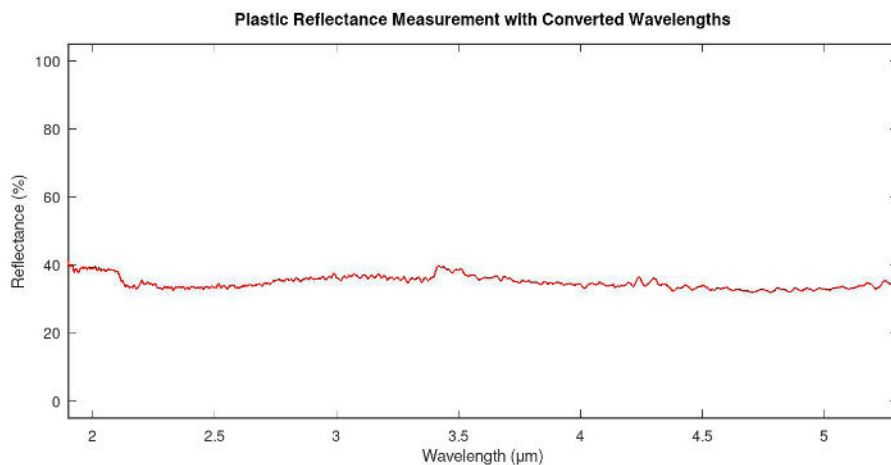


FIGURE #8: Reflectance spectrum of white ABS, converted back to MIR region.

TEST DATA AND RESULTS

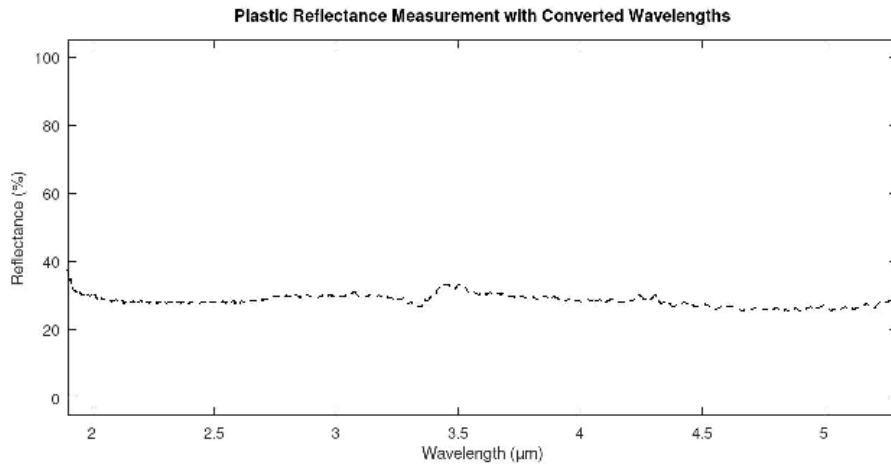


FIGURE #9: Reflectance spectrum of black Delrin, converted back to MIR region.

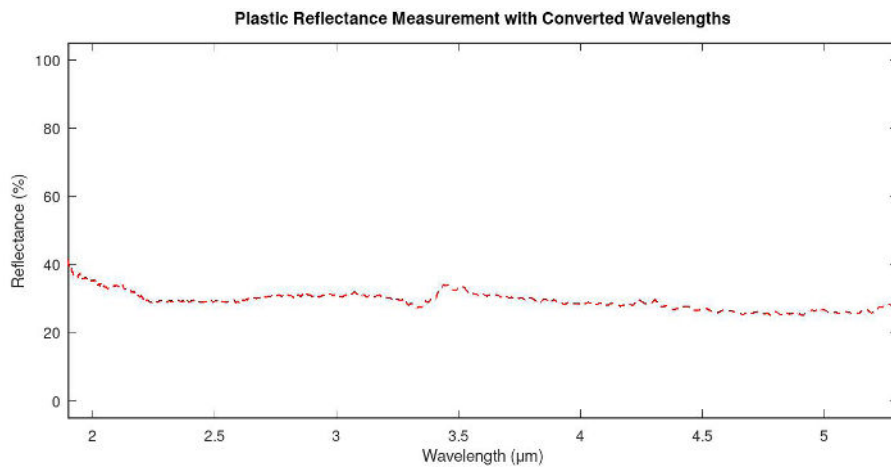


FIGURE #10: Reflectance spectrum of white ABS in AvaSoft

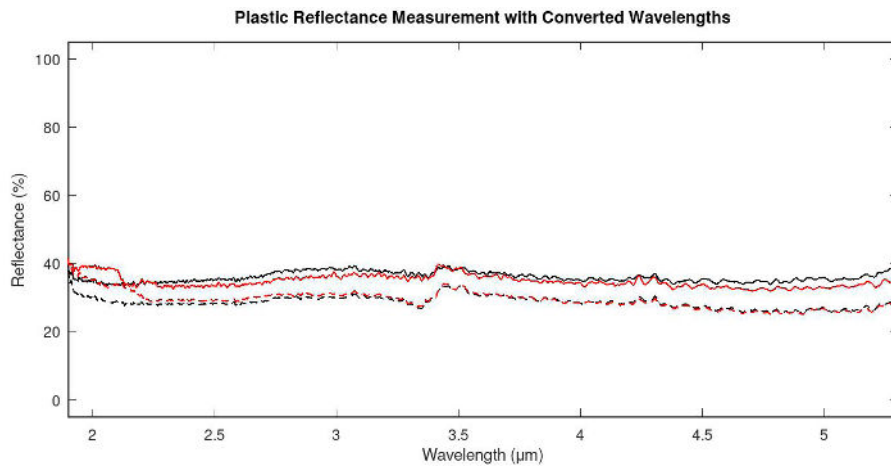


FIGURE #11: Reflectance spectra of black ABS (solid black), white ABS (solid red), black Delrin (dashed black), and white Delrin (dashed red), shown together for comparison.

ANALYSIS

Since the plastic measurements in AvaSoft are not converted, they can be somewhat disregarded for analysis, though they are included to demonstrate how the raw data appears before conversion (Figures 3-6). The converted spectra, however, shows that all four plastic measurements have two reflectance peaks around $3.5\mu\text{m}$ and two reflectance peaks around $4.3\mu\text{m}$. These peaks in the MIR are all indicative of plastic, which verifies that the measurement in the mid-infrared and conversion down to the NIR are both accurate.

Further analysis of the data can be done regarding the overall reflectance values for the plastic samples. Both black and white ABS show reflectance between 35-40%, while Delrin shows reflectance closer to 30% across the spectral range. Despite the very different colors of the black and white samples for each plastic, little difference is seen for the samples in terms of color, but rather the difference is seen in terms of composition. This is critical in determining what plastic a material is made of, which is critical for many applications, such as recycling. It is worth noting that both white plastic samples also showed a bump in reflectance in the lower end of the spectral range, around $1.9\text{-}2.1\mu\text{m}$. While the exact cause of this isn't certain, it could be that the white samples simply reflected a bit more light in the form of heat in this region, whereas the black plastic samples may have just absorbed this light.

CONCLUSION

In conclusion, the present experiment highlights the use of our spectrometers combined with instruments from NLIR to measure spectra in the MIR region, a feat previously unattainable by just our devices. Plastic samples were compared to show that in the MIR region, primary spectral differences described compositional differences rather than ones associated with color as would be the case in the visible region. The AvaSpec-NXS4096CL is an ideal instrument for a broad range of applications and industries, including reflectance measurements. We are confident that this experiment is just the first of many that can showcase our collaborative options with our sister company NLIR, and how utilizing instruments from both teams can provide a whole new frontier of measurement capabilities. Please contact Avantes for more information on the configuration that is best suited for your data collection.

CONTACT

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