Advantages of MCT-B Detectors in FTIR Microscopy

Introduction

Mercury cadmium telluride ($Hg_{1-x}Cd_xTe$) is a semiconductor alloy commonly used in infrared photoconductive detectors. These detectors are often referred to as MCT detectors. In an MCT detector, incident light is absorbed, which results in electrons being promoted from a valance band to a conduction band; this causes a change in the bias current in the detector. The resultant electrical signal is proportional to the intensity of the light absorbed. Varying the composition of the MCT alloy allows for alterations to the band gap and changes the usable spectral range, but there is often a trade-off between spectral range and sensitivity. For example, the detector known as an MCT-B detector has a lower spectral cutoff (example: 450 cm^{-1} versus 650 cm^{-1}), that is, it has an extended spectral range compared to an MCT-A detector, but at the expense of responsivity and detectivity (approximately 4x smaller). The actual values depend on the exact composition of the MCT element. The lower performance, however, can often be compensated by increasing collection time.

While an MCT-A detector with a spectral rage of 4000–650 cm^{-1} suffices for the majority of FTIR microscopy applications, there are use cases where critical features appear in the extended portion of the spectral range. For example, molecules with heavier atoms, such as metal oxides and minerals, have characteristic vibrations at lower frequencies. Even for materials that have peaks at higher frequencies, the lower-frequency peaks can be essential for the analysis.

In this tech note, the utility of the MCT-B detector is illustrated with two examples. The first example involves the FTIR microscopy analysis of patinas forming on the surface of a penny, to determine and differentiate the forms of copper oxides. The second example deals with the analysis of a white pigment in a polymer sample. These examples demonstrate the benefits of user swappable MCT detectors offered by the Thermo Scientific™ Nicolet™ RaptIR+™ FTIR Microscope.

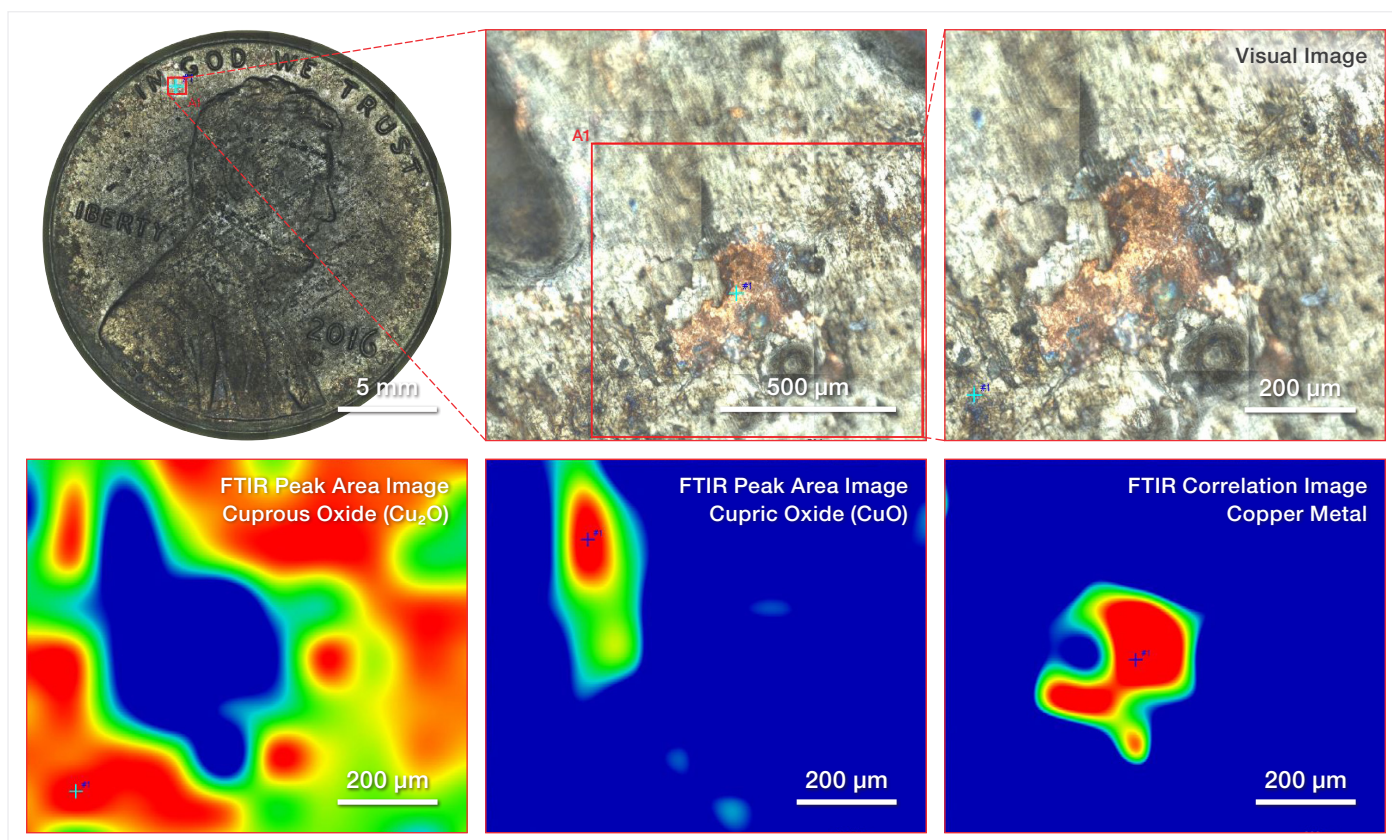Thermo Scientific Nicolet RaptIR+ FTIR Microscope shown with swappable detectors.

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Figure 1. Visible and FTIR Images of the penny in this study. The chemical images show the spatial distribution of cuprous oxide (Cu_2O), cupric oxide (CuO), and copper metal. The red areas indicate the presence of the material and the blue area the absence of the material. Note that for Cu_2O and CuO, chemical images are created using the peak areas of their characteristic peaks. The correlation image for copper metal is created using the copper response (essentially, the flat line seen in figure 2) as the reference.

Results

Patinas forming on copper surfaces are caused by corrosion of the copper metal surface when it interacts with substances in the environment (oxygen, carbon dioxide, water, salts, etc.). This can result in the formation of copper oxides, hydroxides, carbonates, chlorides, nitrates, and/or sulfates depending upon what the copper metal is exposed to. This variability has ramifications in terms of studying corrosion mechanisms as well as the study of historical copper artifacts and artworks. Figure 1 shows areas of a penny where two types of copper oxides, cupric oxide (CuO) and cuprous oxide (Cu_2O), are present. Copper metal has no discernible FTIR spectral features (see Figure 2). The spectra from the cuprous oxide (Cu_2O) and cupric oxide (CuO) are shown in Figure 2. In this case all the spectral features occur in the extended region offered by an MCT-B detector (below 650 cm^{-1}). The analysis of these copper oxides would not be possible with an MCT-A detector.
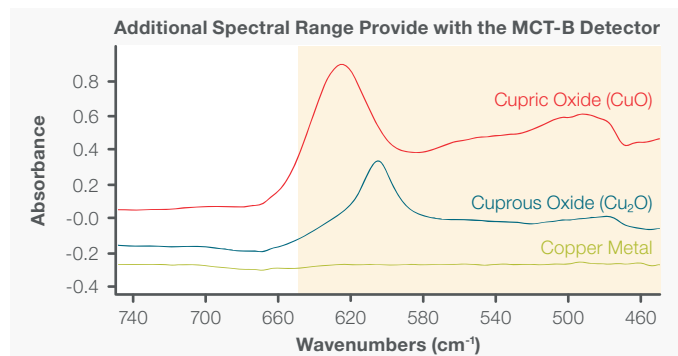

Figure 2. Representative spectra from the penny corresponding to cupric oxide (CuO), cuprous oxide (Cu_2O). The spectrum without any spectral features is attributed to bare copper metal. All the peaks for the oxides are found below 650 cm^{-1}, in the additional spectral range afforded by the MCT-B detector (highlighted in yellow).

Titanium dioxide (TiO_2) is a commonly used white pigment that can be found in paints, polymers and even pharmaceuticals. Figure 3 shows a cross-section of a polymer: Layer A is polyethylene (PE) whereas layer B consists of a mixture of PE and TiO_2, as can be seen in their respective FTIR spectra in Figure 4. Using an MCT-A detector with a cutoff at 650 cm^{-1}, the partial TiO_2 peak appears as a shoulder at the edge of the spectral range. When an MCT-B detector with a cutoff at 450 cm^{-1} is used, the full TiO_2 peak is observed. This difference in spectral appearance has direct implications on the ensuing correlation images. Using an MCT-A detector, the resulting correlation image overestimates the similarity between Layer A and Layer B, as evidenced by the red and yellow colors visible in the Figure 4 images shown for Layer A, because only a small portion of TiO_2 spectrum is captured. When the full TiO_2 spectrum using an MCT-B detector is included in the correlation image, the compositional difference between Layer A and Layer B is abundantly evident. In this case, although it is possible to observe the difference in the layers using an MCT-A detector, using an MCT-B detector provides more striking contrast between the layers; hence, less ambiguous differentiation.

Summary

An MCT-B detector provides additional spectral range at low frequencies compared to an MCT-A detector. This additional spectral range can be critical for FTIR microscopy analyses of metal oxides, among other applications. The Thermo Scientific Nicolet RaptIR+ FTIR Microscope allows the user to readily swap between an MCT-A detector and an MCT-B detector when the situation requires it.
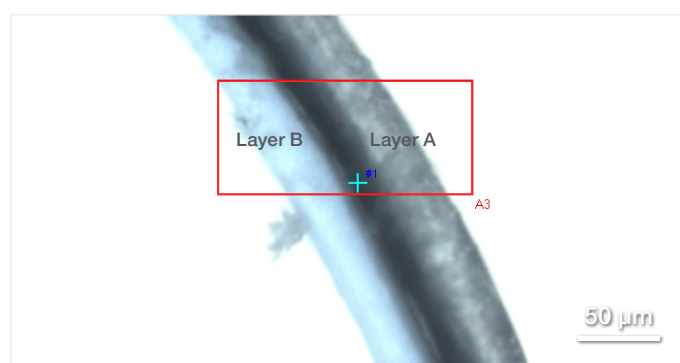
Figure 3. Visual Image of a cross-section of a layered polymer composite using the 15X objective of the Nicolet RaptIR+. The two outer layers are both polyethylene, but Layer B also has titanium dioxide in it.
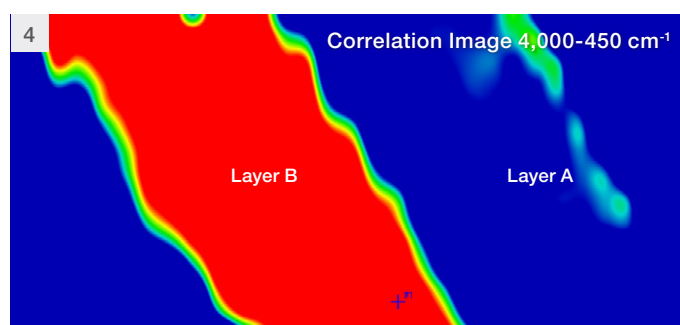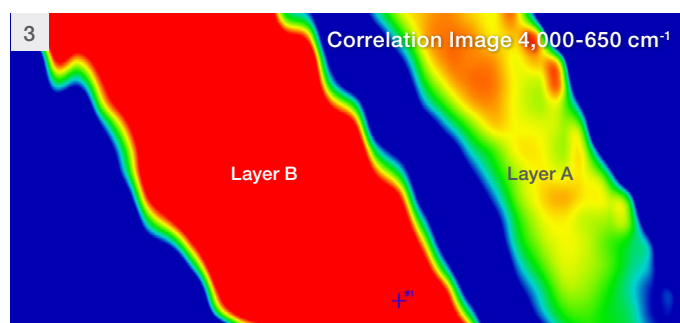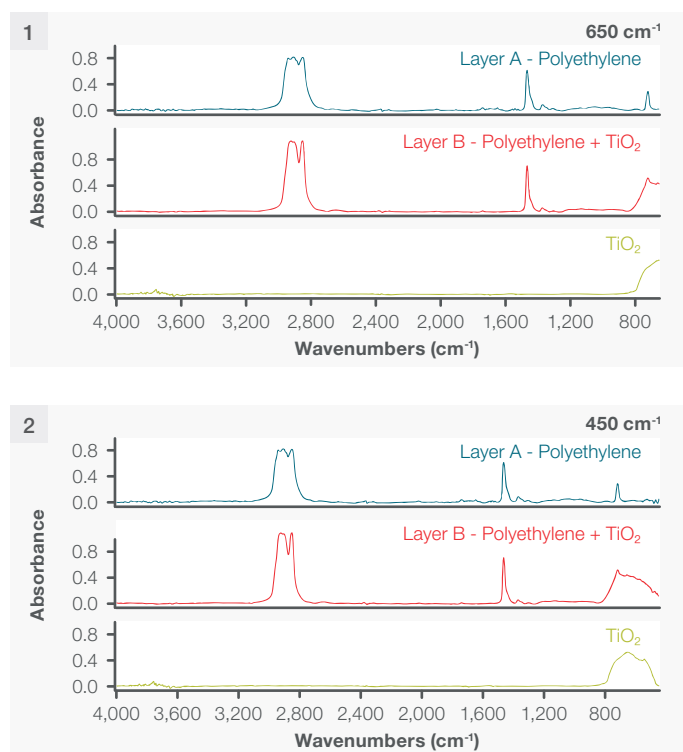

Figure 4. (1) Representative spectra from Layer A, Layer B, and TiO_2 with the spectral cutoff at 650 cm^{-1}; (2) representative spectra from Layer A, Layer B, and TiO_2 with the spectral range extended to 450 cm^{-1}; (3) the correlation image based on a spectrum from Layer B with the cutoff at 650 cm^{-1} (MCT-A); (4) the correlation image based on a spectrum from Layer B with the cutoff at 450 cm^{-1} (MCT-B).

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