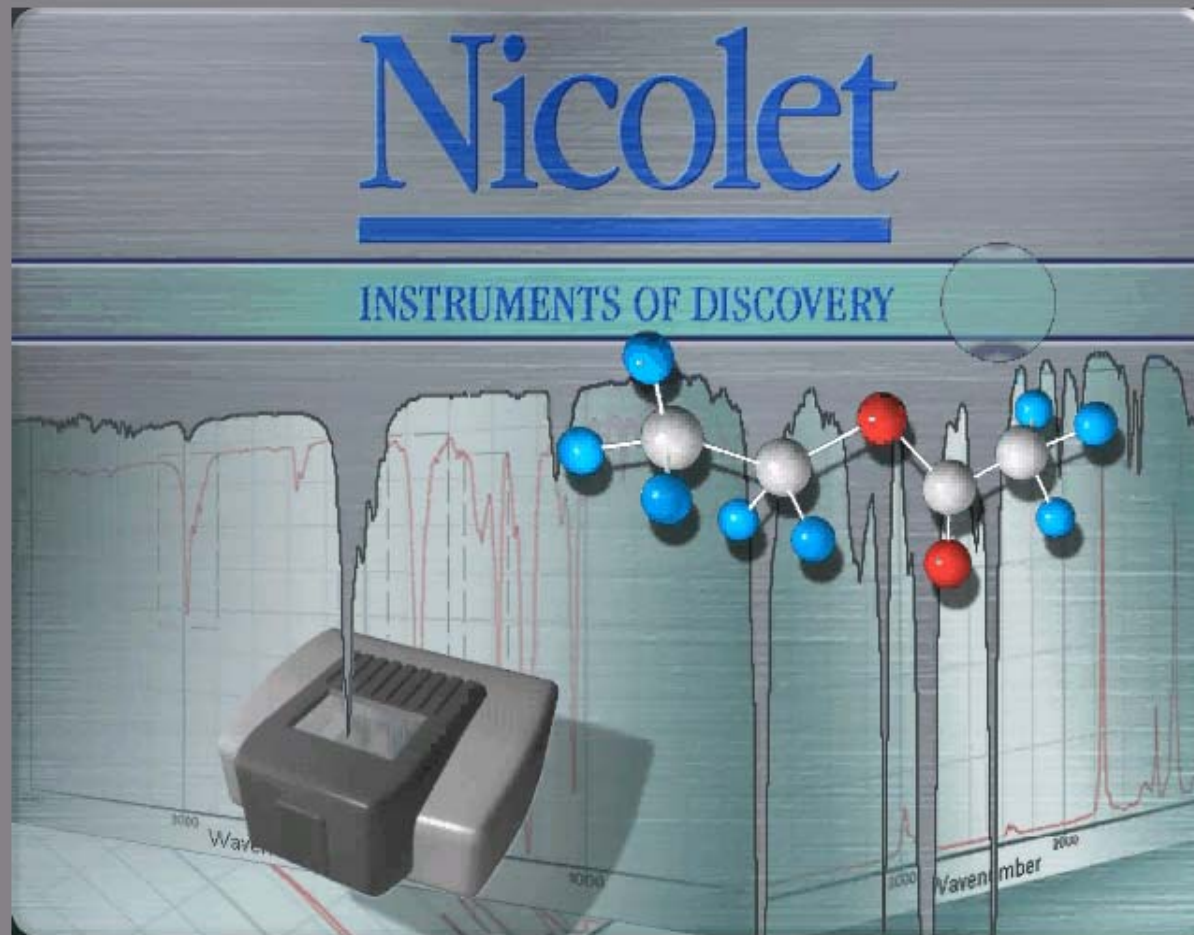




FTIR as an analyze technique in Composite materials



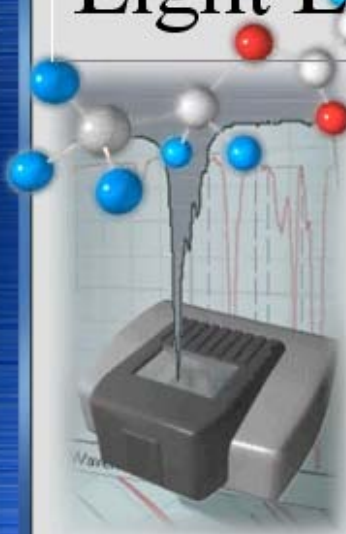
FTIR as an analyze technique in Composite materials





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Light Energy



The first portion of this tutorial introduces the electromagnetic spectrum and demonstrates the components of an electromagnetic ray. It also shows how electromagnetic rays, such as visible and infrared rays, can be measured.

Unit Progress

Home Exit Back Next



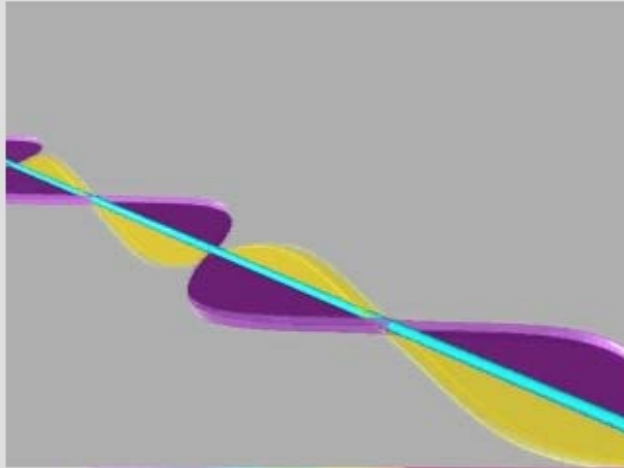
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Light Energy

NICOLET



Both visible and infrared radiation are forms of electromagnetic energy. Electromagnetic rays consist of electric and magnetic fields that vibrate at right angles to each other.

Electromagnetic ray



Unit Progress

Home Exit Back Next



Light Energy

NICOLET

X-Rays

Far Ultra violet

Ultra violet

Visible

Near Infra red

Mid Infra red

Far Infra red

Micro waves

Radio Waves

Infrared Radiation

Infrared radiation is absorbed by organic and other molecules, causing them to vibrate. Radiation from the sun is weak in the infrared range and much of the energy is absorbed by the earth's upper atmosphere. A strong infrared source, such as an ordinary fire, makes your skin feel hot when you get too close. The infrared rays cause the molecules in your skin to vibrate. The vibrating molecules create friction, which you feel as heat.

Visible and infrared radiation make up a small portion of the electromagnetic spectrum, which is the continuous range of light energy. All forms of electromagnetic radiation have similar characteristics; they pass straight through some substances, they are reflected by others and they are absorbed by the rest.

Home

Exit

Unit Progress

Back

Next

FTIR as an analyze technique in Composite materials



Light Energy

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X-Rays Far Ultra violet Ultra violet Visible Near Infra red Mid Infra red Far Infra red Micro waves Radio Waves

Wavelength .001 cm

Wavenumber 1000 cm-1

Mid Infrared

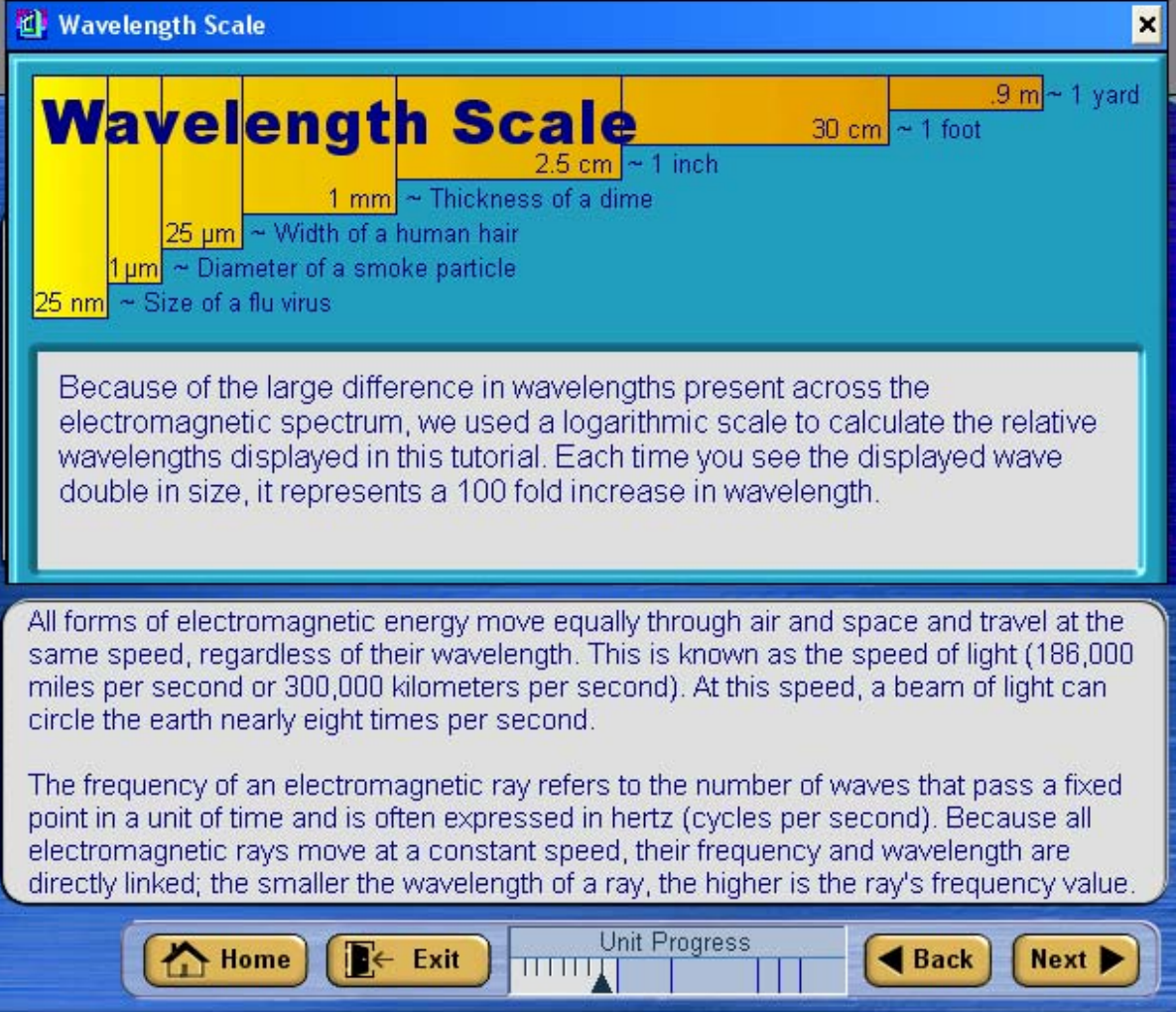
Scale

Each ray of electromagnetic energy has a unique wavelength. Wavelength is the length of a single wave from crest to crest, expressed in centimeters or meters. The shorter the wavelength of a ray, the more energy it contains.

We can also measure a ray by finding its wavenumber. This is the number of waves that fit in a centimeter. Wavenumber is the inverse of wavelength and is expressed in cm^{-1} . In spectroscopy, it is more convenient to report infrared radiation in wavenumbers rather than wavelength because wavenumbers are proportional to energy.

Home Exit Unit Progress Back Next

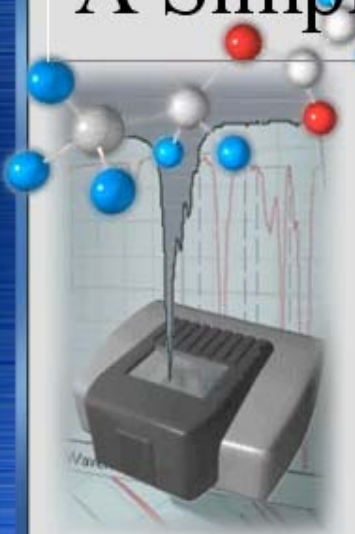
FTIR as an analyze technique in Composite materials





NICOLET

A Simple Spectrometer



The next section explores the basic concepts of a simple spectrometer and shows how they can be applied to infrared spectroscopy.

Unit Progress

Home Exit Back Next



A Simple Spectrometer

NICOLET

Source

Sample

Detector

Try these colored eyeglasses to see their effects

- Blue
- Rose
- Clear

When you expose a material to visible radiation (white light), some of the light may be absorbed by the material and the rest passes through unchanged. If you look through a colored lens, for example, the color you see is the transmitted frequencies of light mixed together.

Colorless lenses transmit all of the light so your eyes can detect the full range of colors.

Unit Progress

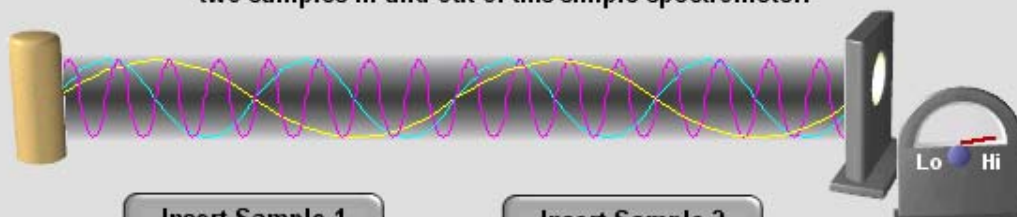
Home Exit Back Next



A Simple Spectrometer

NICOLET

Watch what happens to the detector as you move the two samples in and out of this simple spectrometer.



Insert Sample 1 Insert Sample 2

Expose the material to infrared radiation and the same thing may happen. Some of the infrared energy may be absorbed and the rest will be transmitted.

If you place a detector that is sensitive to infrared radiation in the path of the transmitted beam, you can determine how the beam was changed. This is the basic principle of an infrared spectrometer.

Unit Progress

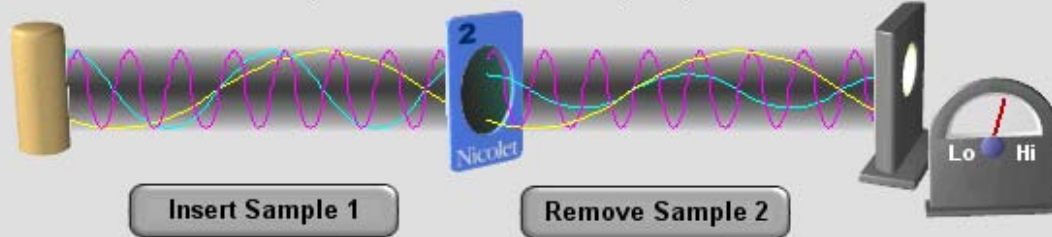
Home Exit Back Next



A Simple Spectrometer

NICOLET

Watch what happens to the detector as you move the two samples in and out of this simple spectrometer.

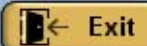


Expose the material to infrared radiation and the same thing may happen. Some of the infrared energy may be absorbed and the rest will be transmitted.

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Home

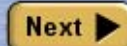


Exit

Unit Progress



Back

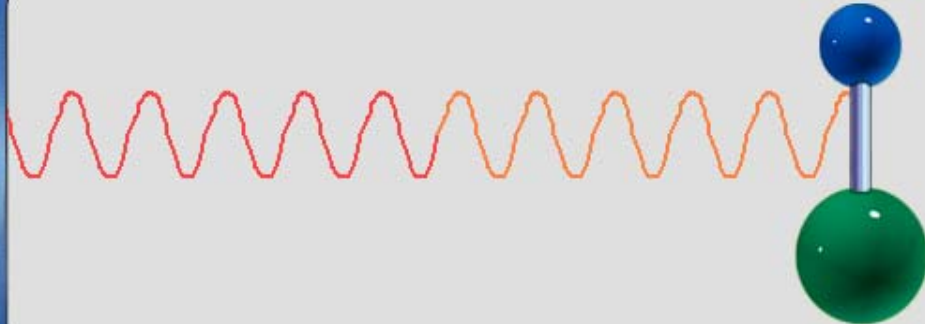


Next



A Simple Spectrometer

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Molecules that make up a material are composed of atoms bound together. The atoms in a molecule are always moving, or "vibrating." The intensities of the vibrations increase when infrared radiation is absorbed.

Unit Progress

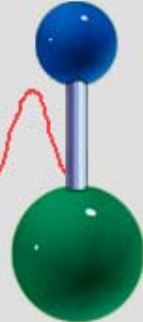
Home Exit Back Next



A Simple Spectrometer

NICOLET

Find the frequency (in cm^{-1}) absorbed by this hydrogen-chlorine bond



Wavenumber (cm^{-1})

4000 2900 400

Hint: HCl absorbs infrared radiation at this wavenumber.

Each chemical bond requires a precise amount of energy to make it vibrate. This energy can be absorbed only in a single exchange.

Each frequency of infrared radiation provides energy in a precise amount. Radiation is absorbed by a molecule only if the frequency of the radiation provides energy in the precise amount required by one of the bonds in the molecule.

Unit Progress

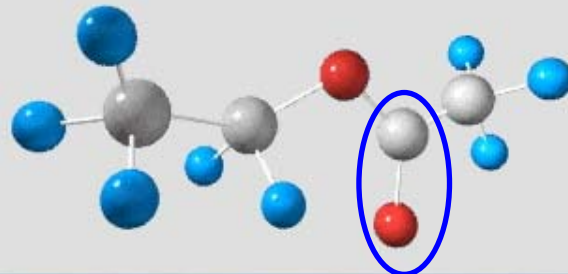
Home Exit Back Next



A Simple Spectrometer

NICOLET

Ethyl acetate molecule

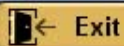


C=O stretch

Depending on the number of ways it can move (bend, stretch, etc.), each kind of bond may absorb infrared radiation at one or more specific frequencies. The double bond between carbon and oxygen (C=O), for example, absorbs energy near 1750 wavenumbers, causing a characteristic stretching vibration.

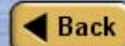
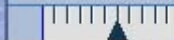


Home

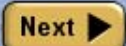


Exit

Unit Progress



Back



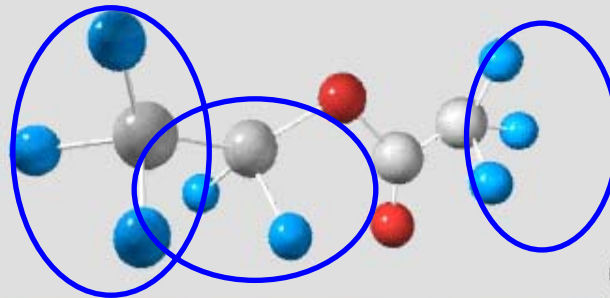
Next



A Simple Spectrometer

NICOLET

Ethyl acetate molecule



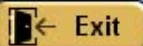
C-H stretch

Groups of atoms and their associated bonds, known as chemical functional groups, may also absorb energy and produce characteristic vibrations within a molecule. For example, the carbon-hydrogen bonds in the CH_2 and CH_3 functional groups move several different ways.

The stretching motions you see here occur when the molecule absorbs radiation in the range between 3000 and 2850 wavenumbers.

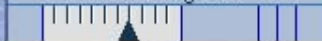


Home

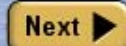


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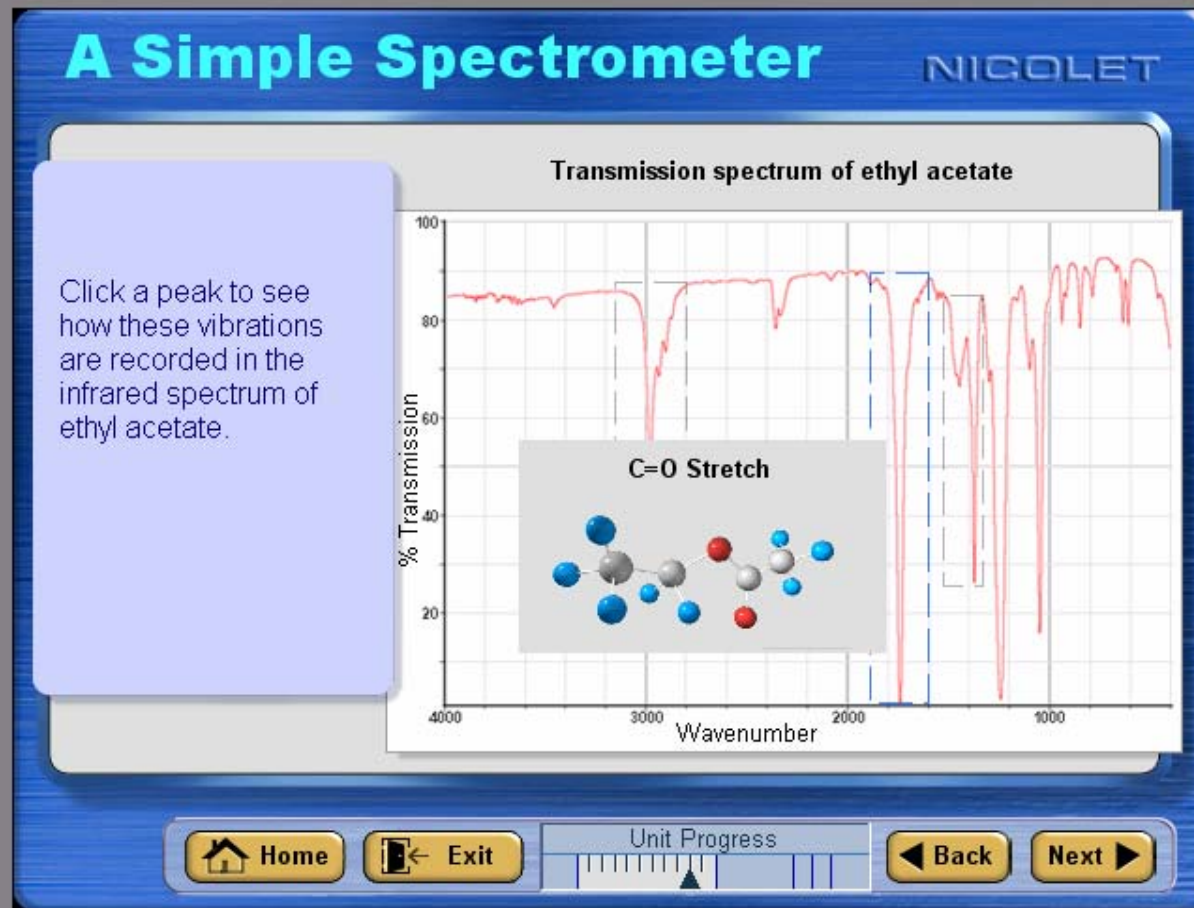
Unit Progress



Back




Next





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Infrared Spectrometers



Section three takes you on a tour through a typical FT-IR spectrometer and demonstrates how the components work together to produce a spectrum.

Unit Progress

Home Exit Back Next



Infrared Spectrometers

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Optical Bench

Interferogram

Computer

An FT-IR spectrometer operates under the same principle as the simple spectrometer you saw earlier in this tutorial. Its mechanisms are housed in two basic components: an optical bench and a computer.

Unit Progress


Home Exit Back Next



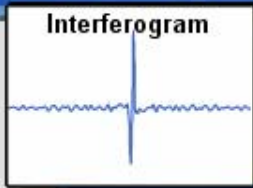
Infrared Spectrometers

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Optical Bench



Interferogram



The optical bench measures the intensity of a specially encoded infrared beam after it has been passed through a sample. The resulting signal, called an "interferogram," contains information about all frequencies present in the beam.

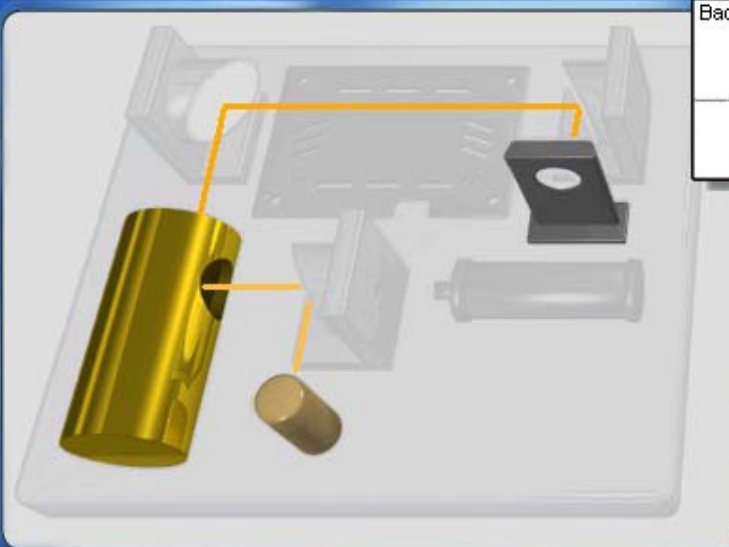
Unit Progress

Home Exit Back Next




Infrared Spectrometers

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Background Interferogram



An interferogram is generated by recording the amount of radiation reaching the detector over time. We call this the "background interferogram" because it shows the energy passing through the components of the optical bench.

More

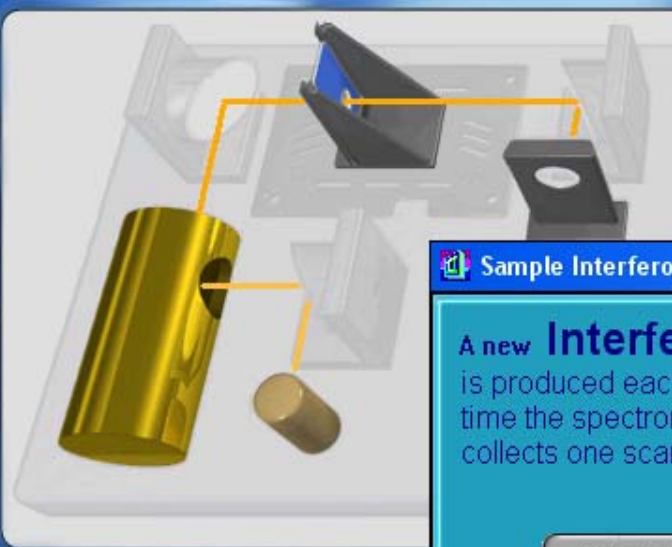
Home Exit Unit Progress Back Next



FTIR as an analyze technique in Composite materials

Infrared Spectrometers

NICOLET



Sample Interferogram

A new **Interferogram** is produced each time the spectrometer collects one scan.

When a sample absorbs some radiation, the intensity of the radiation is reduced. This reduces the interference pattern of the infrared radiation reaching the detector.

Hide Sample

Hide Background

— Mirror Position →

Volts

Data Points

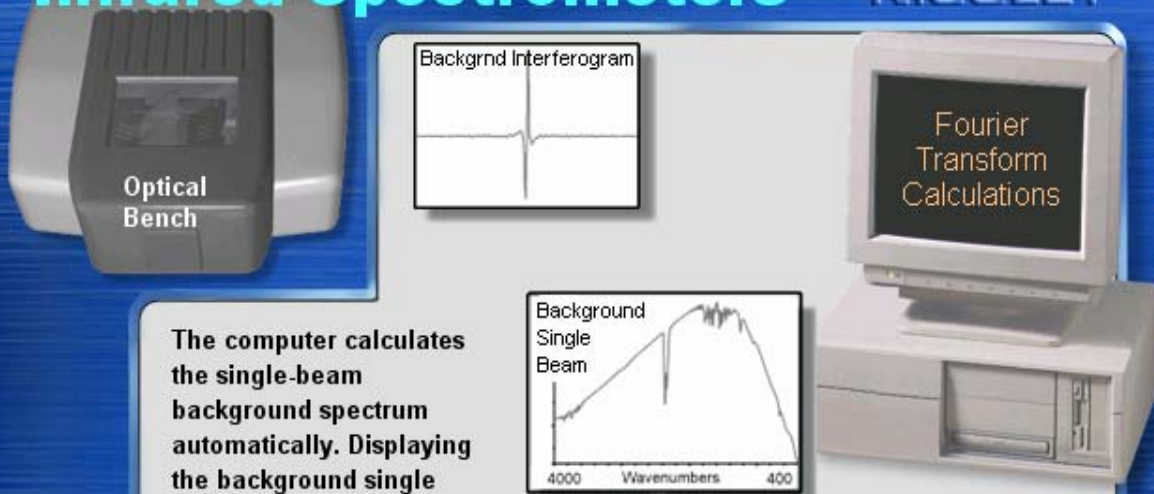
The interferogram records the total intensity of infrared radiation reaching the detector at each position of the moving mirror. The intensity of the radiation detected at a given mirror position along the X-axis is indicated by the height of the curve at that point.

A new interferogram is produced each time the moving mirror travels the length of its track (completes one scan). If you collect more than one scan, the computer adds the individual



Infrared Spectrometers

NICOLET



Optical Bench

Background Interferogram

Fourier Transform Calculations

Background Single Beam

4000 Wavenumbers 400

The computer calculates the single-beam background spectrum automatically. Displaying the background single beam is optional.

The computer decodes the interferogram data to obtain an energy curve. The energy curve shows the intensity of the radiation reaching the detector at each frequency.

The background energy curve (it's also called a 'background single-beam') establishes the energy distribution of the beam before it reaches the sample.

[More](#)

[Home](#) [Exit](#) [Back](#) [Next](#)

Unit Progress



FTIR as an analyze technique in Composite materials

Infrared Spectrometers

NICOLET

Optical Bench

Sample Interferogram

Fourier Transform Calculations

The computer calculates the single-beam sample spectrum automatically. Displaying the sample single beam is optional.

Sample Single Beam

4000 Wavenumbers 400

Sample Energy Curve

The Single-beam Spectrum is derived from the interferograms using Fourier transform.

Hide Sample

Hide Background

4000 Wavenumbers 400

The computer reads the interferogram, which shows the total amount of infrared radiation that reached the detector at each

MECHATRON



FTIR as an analyze technique in Composite materials

Infrared Spectrometers

Optical Bench

If your OMNIC software is set up to use the default settings for the collection parameters, only the final transmission spectrum will appear on your screen when data collection is complete.

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Sample energy curve
Backgrnd energy curve
 $\times 100$

Transmission Spectrum

Background Single Beam

Sample Single Beam

4000 Wavenumbers 400

4000 Wavenumbers 400

The computer divides the sample single beam by the background single beam. The result is a transmission spectrum, which shows the change in intensity at each frequency that is due solely to absorptions by the sample.

Transmission Spectrum

The **Transmission Spectrum** is calculated by dividing the single beams.

$\frac{\text{Sample Single Beam}}{\text{Background Single Beam}} \times 100\% =$

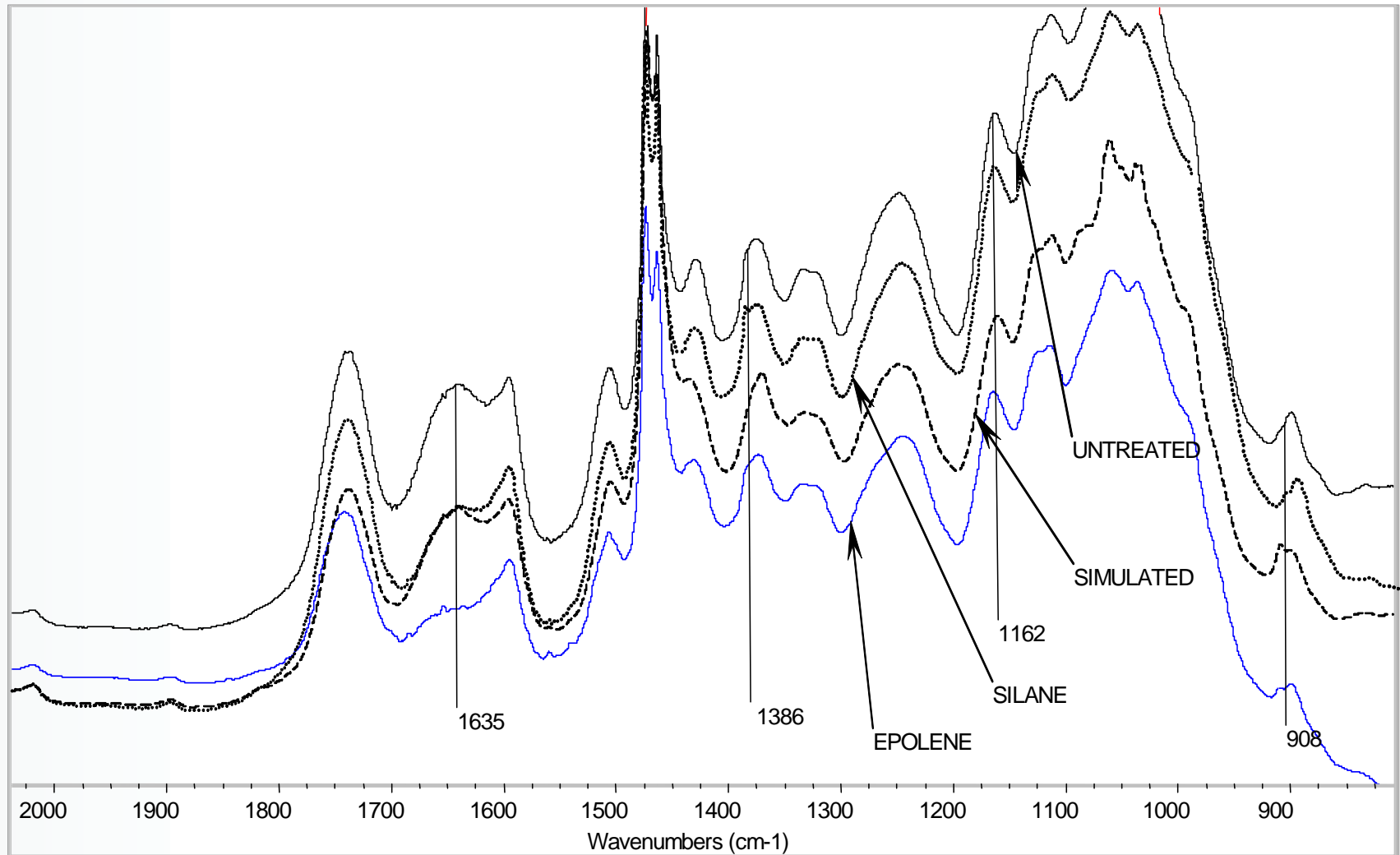
% Transmittance

More

Next



HDPE/wood spectra





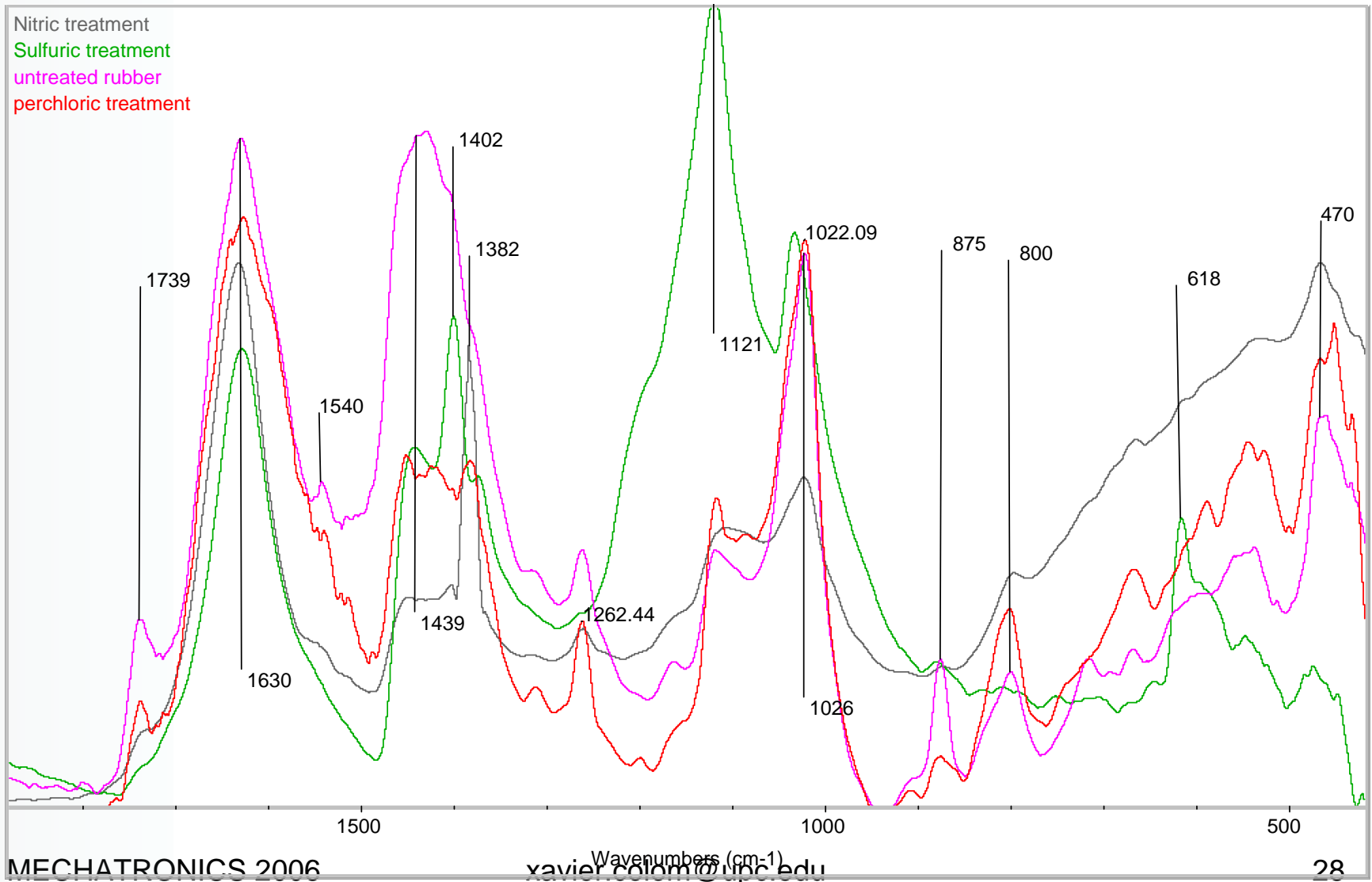
FTIR as an analyze technique in Composite materials

NBR/glass fiber composite



FTIR as an analyze technique in Composite materials

HDPE/tyre composite





FTIR as an analyze technique in Composite materials

Epoxy/CF composite



FTIR as an analyze technique in Composite materials



FTIR as an analyze technique in Composite materials



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