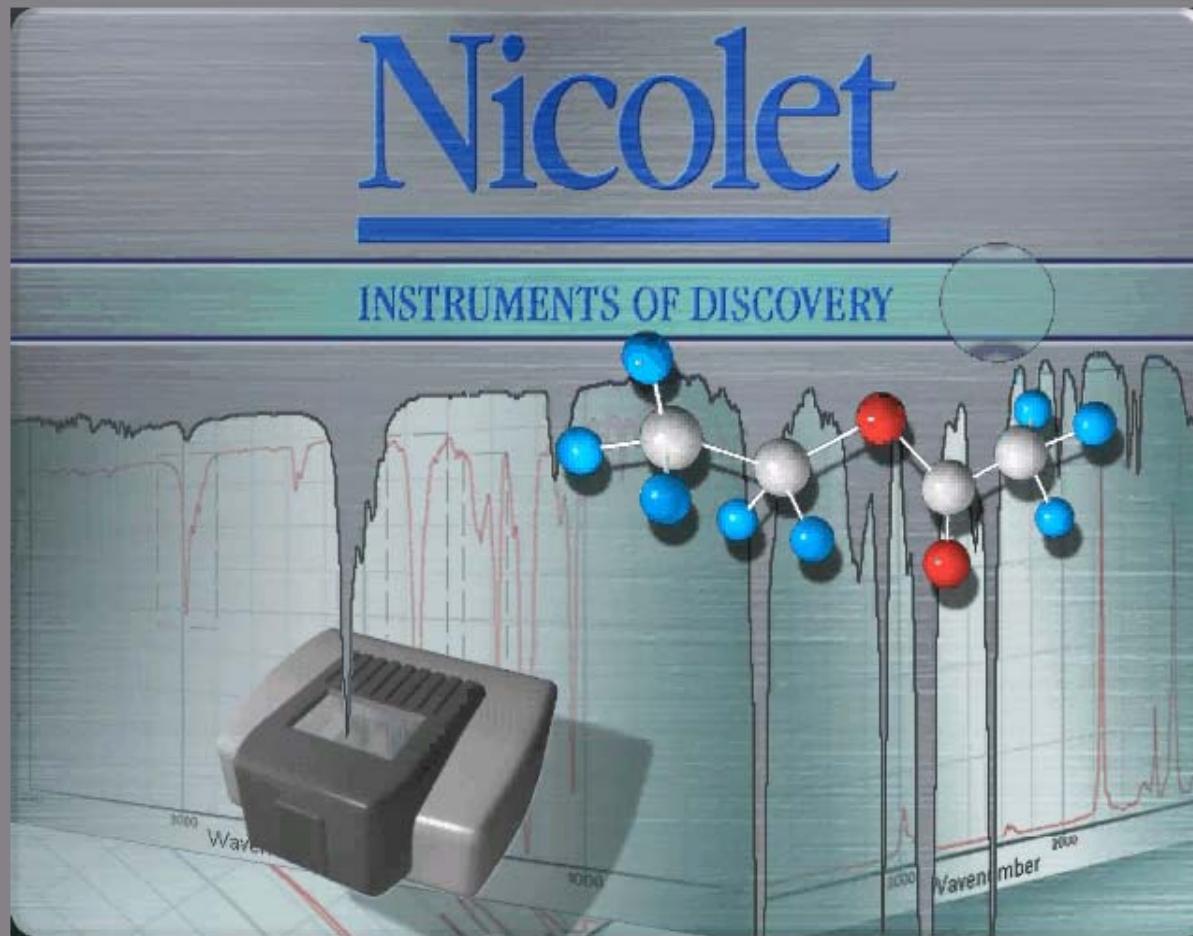




# FTIR as an analyze technique in Composite materials

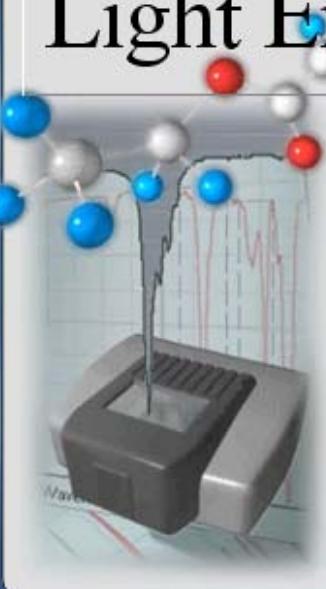


# FTIR as an analyze technique in Composite materials



**NICOLET**

# 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.

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## Light Energy

NICOLET

Infrared radiation is an important component of the sun's invisible energy. Infrared radiation lies just beyond what the human eye can see.

Visible radiation

Infrared radiation

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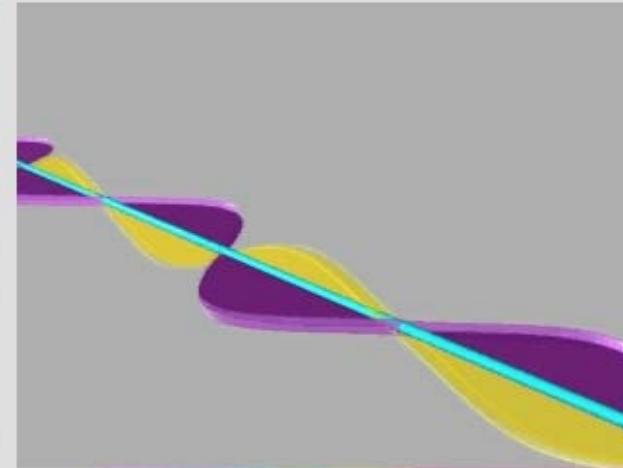
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## Light Energy

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

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## Light Energy

NICOLET

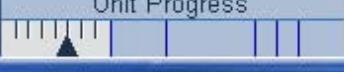


X-Rays   Far Ultra violet   Ultra violet   **Visible**   Near Infra red   Mid Infra red   Far Infra red   Micro waves   Radio Waves

**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.

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## Light Energy

NICOLET

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

Wavelength .001 cm

Wavenumber 1000 cm<sup>-1</sup>

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<sup>-1</sup>. In spectroscopy, it is more convenient to report infrared radiation in wavenumbers rather than wavelengths because wavenumbers are proportional to energy.

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**Wavelength Scale**

25 nm	~ Size of a flu virus	1 $\mu$ m	~ Diameter of a smoke particle	25 $\mu$ m	~ Width of a human hair	1 mm	~ Thickness of a dime	2.5 cm	~ 1 inch	30 cm	~ 1 foot	.9 m	~ 1 yard
-------	-----------------------	-----------	--------------------------------	------------	-------------------------	------	-----------------------	--------	----------	-------	----------	------	----------

Because of the large difference in wavelengths present across the electromagnetic spectrum, we used a logarithmic scale to calculate the relative wavelengths displayed in this tutorial. Each time you see the displayed wave double in size, it represents a 100 fold increase in wavelength.

All forms of electromagnetic energy move equally through air and space and travel at the same speed, regardless of their wavelength. This is known as the speed of light (186,000 miles per second or 300,000 kilometers per second). At this speed, a beam of light can circle the earth nearly eight times per second.

The frequency of an electromagnetic ray refers to the number of waves that pass a fixed point in a unit of time and is often expressed in hertz (cycles per second). Because all electromagnetic rays move at a constant speed, their frequency and wavelength are directly linked; the smaller the wavelength of a ray, the higher is the ray's frequency value.

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**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.

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## A Simple Spectrometer

NIQOLET

Source

SUN

Sample

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.

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## 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

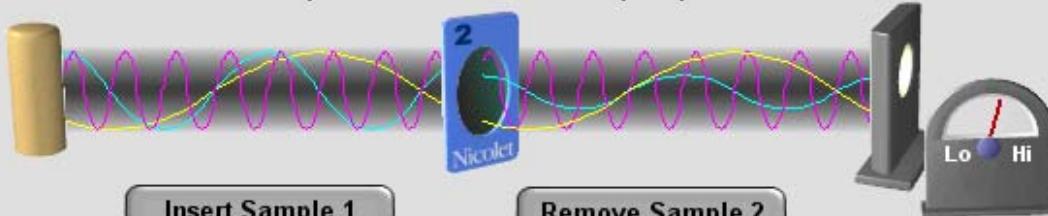
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## A Simple Spectrometer

NICOLET

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



Insert Sample 1      Remove 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.

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## A Simple Spectrometer

NICOLET

The diagram illustrates a simple spectrometer. On the left, two wavy lines represent infrared spectra: a red line with higher frequency and intensity, and an orange line with lower frequency and intensity. On the right, a molecular model shows a blue sphere connected by a rod to a green sphere, representing atoms in a molecule. The blue sphere is moving, illustrating molecular vibration.

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.

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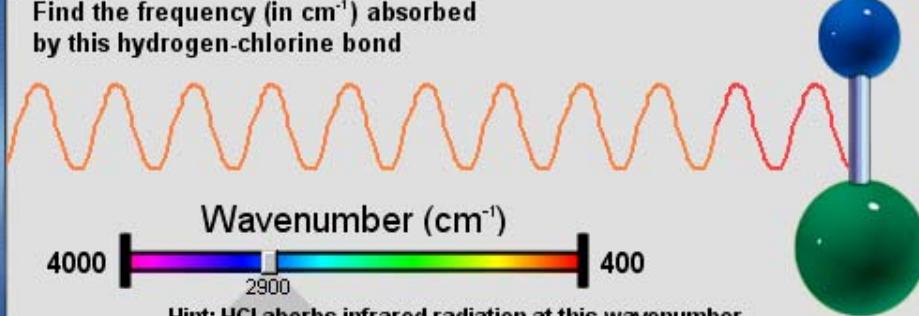
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## A Simple Spectrometer

NICOLET

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



Wavenumber ( $\text{cm}^{-1}$ )

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.

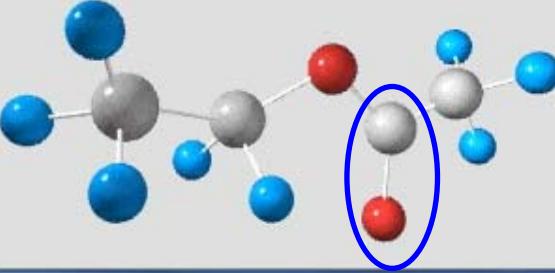
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## A Simple Spectrometer

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.

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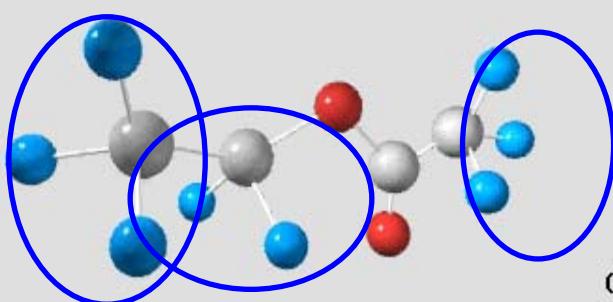
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## A Simple Spectrometer

NIKOLET

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  $\text{CH}_2$  and  $\text{CH}_3$  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.

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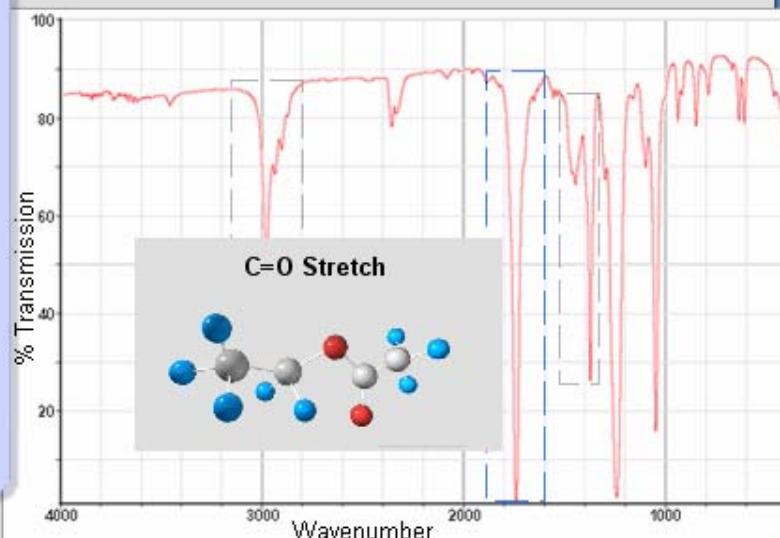


# A Simple Spectrometer

NICOLET

### Transmission spectrum of ethyl acetate

Click a peak to see how these vibrations are recorded in the infrared spectrum of ethyl acetate.



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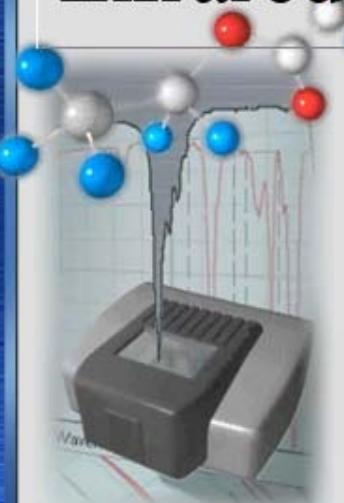
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**NICOLET**

## 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.

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## Infrared Spectrometers

NICOLET

The diagram illustrates the components of an FTIR spectrometer. On the left, the 'Optical Bench' is shown with various optical elements: a light source, mirrors, lenses, and a sample compartment containing a gold-colored cylindrical sample. A red line traces the light path from the source through the bench to a detector. To the right, a computer system is shown, consisting of a monitor displaying an 'Interferogram' (a wavy line) and a base unit. The monitor also displays a spectrum with multiple peaks, labeled '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.

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## Infrared Spectrometers

NICOLET



**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.

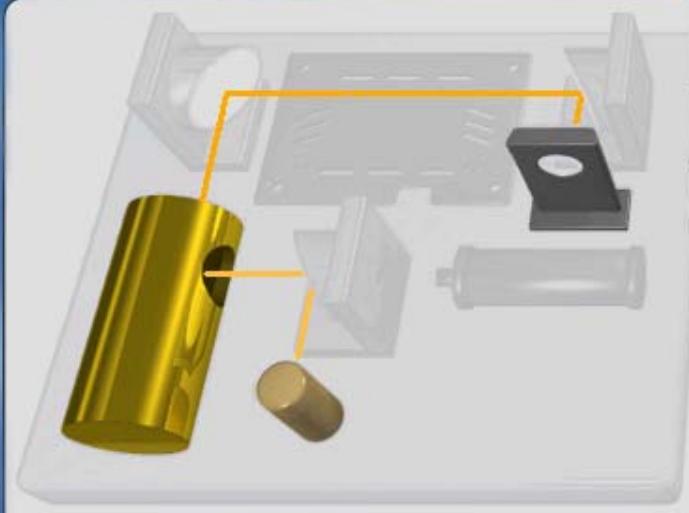
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## Infrared Spectrometers

NICOLET



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](#)

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## Infrared Spectrometers

NICOLET

Sample Interferogram

Sample Interferogram

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

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

Hide Sample

Hide Background

Mirror Position

5

0

-5

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**

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

**Background Single Beam**

4000 Wavenumbers 400

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**

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## Infrared Spectrometers

NICOLET

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

Sample Interferogram

Fourier Transform Calculations

Sample Single Beam

Wavenumbers

Sample Energy Curve

The Single-beam Spectrum

Wavenumbers

4000 3000 2000 1000 400

Hide Sample

Hide Background

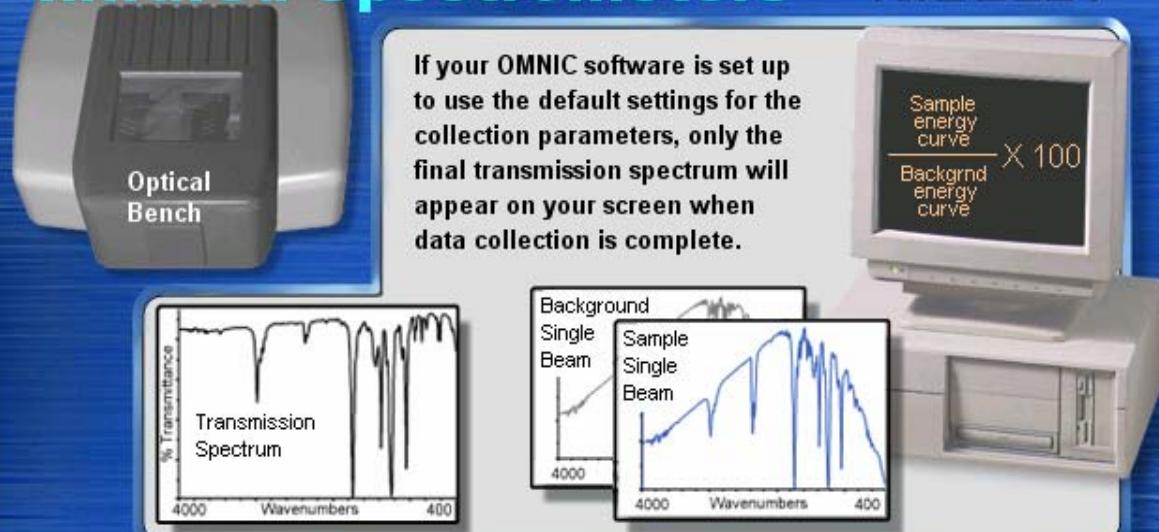
The computer reads the interferogram, which shows the total amount of infrared radiation that reached the detector at each

MECHATRON



## Infrared Spectrometers

NICOLET



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.

Background Single Beam

Sample Single Beam

Transmission Spectrum

4000 Wavenumbers 400

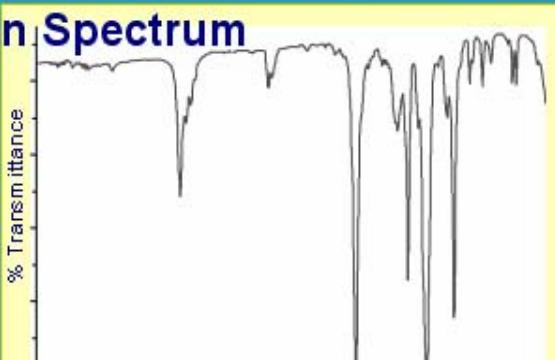
Sample energy curve  
Background energy curve X 100

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.

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

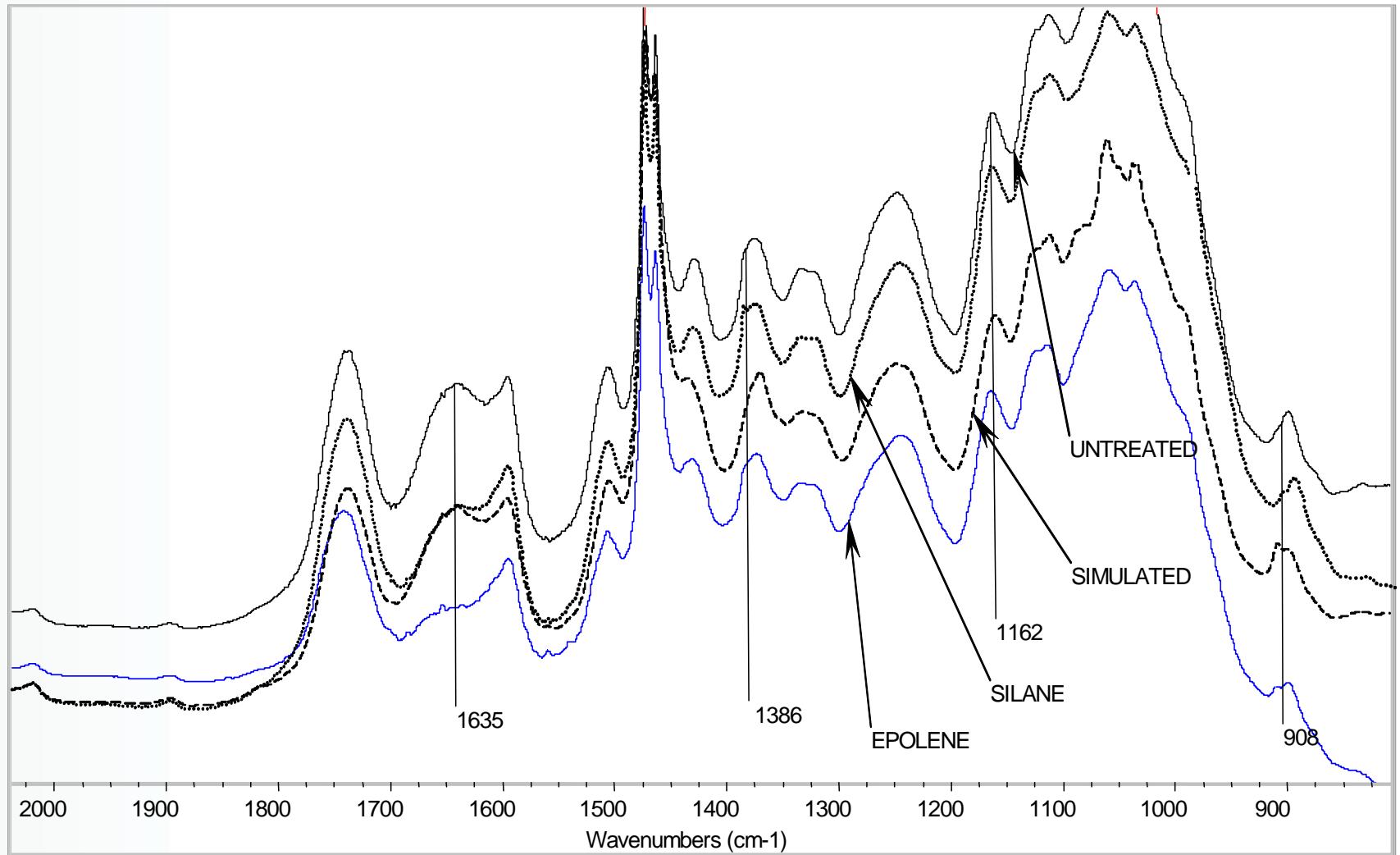


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### HDPE/wood spectra



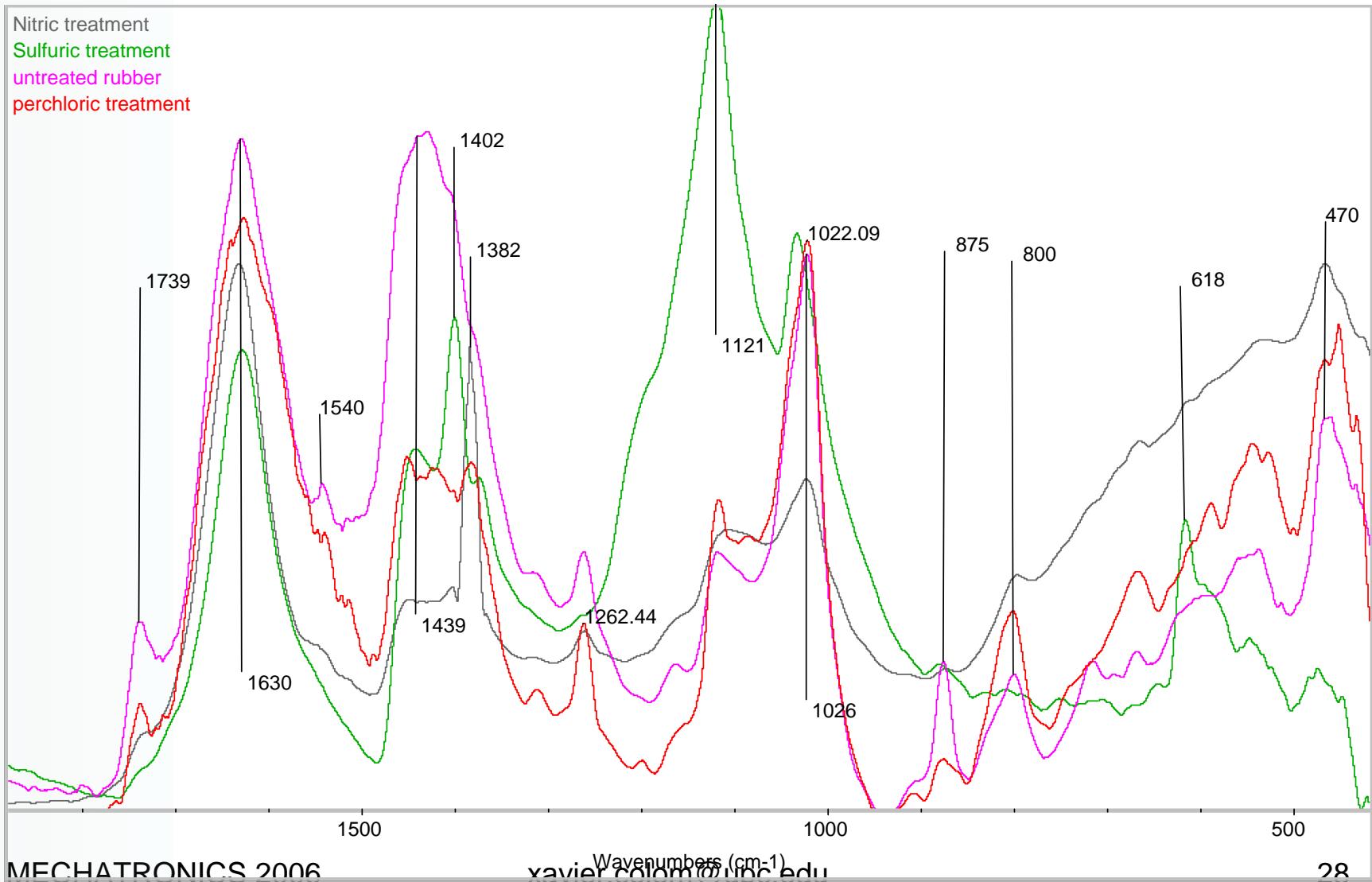


### NBR/glass fiber composite



# 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



## FTIR as an analyze technique in Composite materials



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