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Spectral Dependence on Sampling Frequency in Static Modulated Fourier Transform Infrared Spectrometer†

JU YONG CHO[1], HYUN KYU PARK[2], MIN SEOK JI[2] and WON KWEON JANG[1,*]

[1]Department of Electronic Engineering, Hanseo University, Seosan-si, Chungcheongnam-do 356-706, Republic of Korea
[2]Department of Avionics, Hanseo University, Seosan-si, Chungcheongnam-do 356-706, Republic of Korea

*Corresponding author: Fax: +82 41 6883448; Tel: +82 41 6601324; E-mail: jwk@hanseo.ac.kr

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The spectral dependence on the sampling frequency in the Fourier transform infrared spectrometer was discussed for the exact spectral information. To get the optimized sampling frequency without superfluous or insufficient data, two spectra of the solid sample in two different data spacing were compared in the three spectral ranges. The difference of spectral data of two different data spacing showed a decrease in the higher wavenumber region.

Keywords: Fourier transform, Sampling frequency, Spectrometer.

INTRODUCTION

The Fourier transform infrared spectrometer has many advantages of the wide and fast acquisition of the spectral information about the unknown species including remote sensing[1,2]. It has been used for remote sensing many toxic and noxious materials inaccessible. Many species have the intrinsic spectral characteristics mainly in the infrared region and the Fourier transform spectrometer can get the spectral data in the wide range rapidly. The data acquisition time depends on the data spacing and the number of scanning. In common cases, the spectral data acquisition is performed in the laboratory and there is not a strict time limitation. However, in the field application such as airborne and spaceborne inspection, the time for data acquisition can be the most decisive factor in the measuring system. The state of the target is also an important factor that effective to the accurate measurement[3,4]. The grating spectrometers can also do the remote sensing for the distant species, but most of all needs much longer time compared to that of the Fourier transform infrared spectrometer. Recently there have been many trials to realize the spaceborne spectrometer for monitoring earth environment. Some spectrometers loaded on the geostationary satellite are sending us the invaluable spectral information[5-9]. However, the conventional Fourier transform infrared spectrometers are all dynamic modulated types that need a minimal time for the moving optic to scan. The minimal time to scan is necessary to get the interferogram which has the spectral information. Though it is not a problem in the laboratory environment, it can produce an imprecise information when the state of the target is changing rapidly or the more resolved and accurate information is asked. Therefore, the sampling frequency is an important parameter for optimal data processing and the uniform sensitivity for the wavelength range is also effective. The material state of a gas phase sample can be changed timely according to the measuring environment such as the long scanning time and the higher number of scanning in the field application. Sometimes even the solid sample produces the incorrect spectral information with data spacing and wavelength region. Therefore the dependence on the sampling frequency in wide spectral ranges need to be reviewed.

In this study, we studied the dependence on the sampling frequency for the adequate data processing without any misinterpretation. Two data spacing for the polystyrene film were investigated in the infrared region. The absorption spectra in the different sampling frequencies were investigated in three spectral regions.

RESULTS AND DISCUSSION

Spectral change with sampling frequency

The absorption spectra of polystyrene with different data spacing of 15.43 and 1.93 cm^{-1} were measured with a conventional Fourier transformed spectrometer and denoted in Fig. 1. The solid line is for the 15.43 cm^{-1} and the dashed line is for the 1.93 cm^{-1}. As shown in Fig. 1, the discrepancies between

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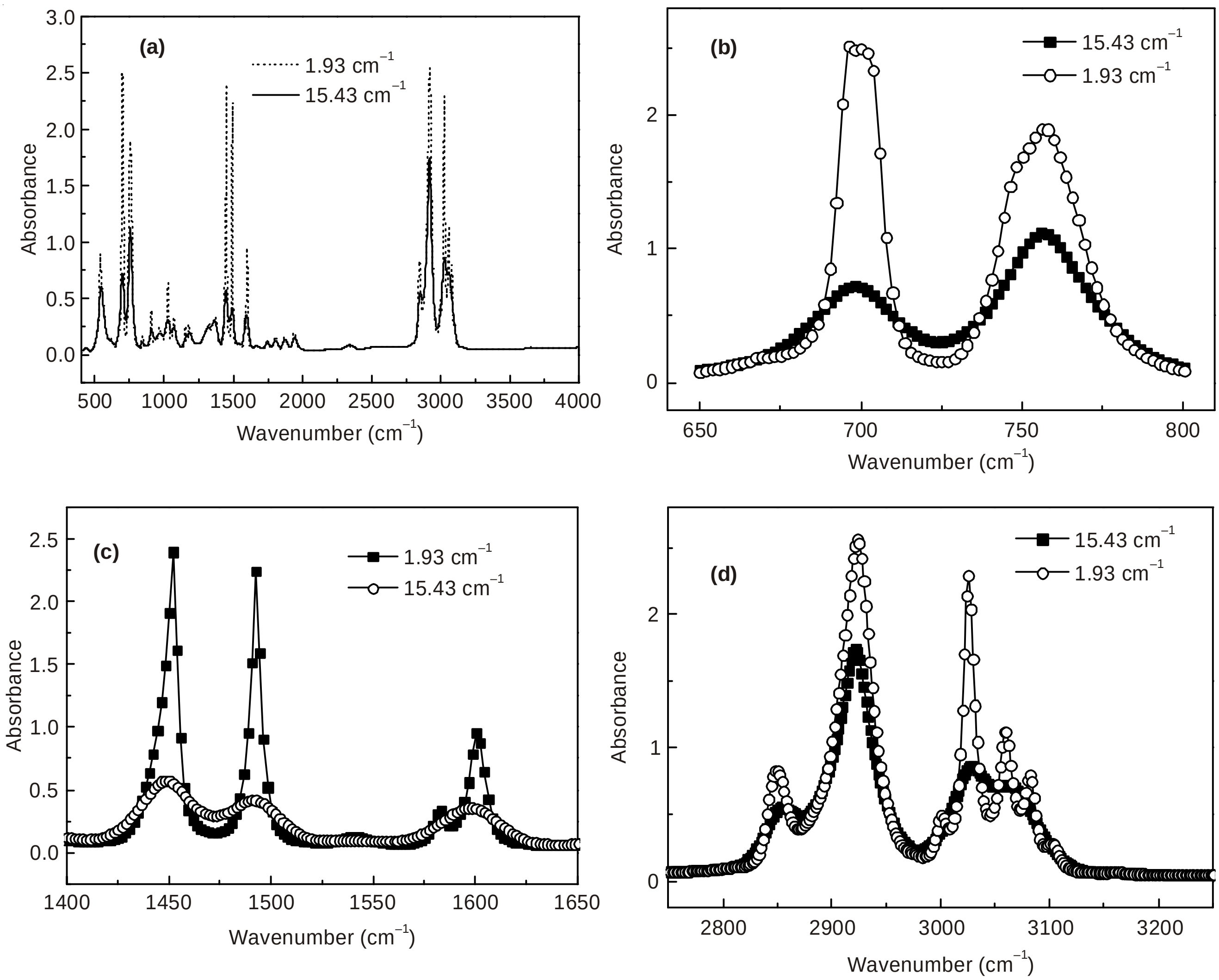

Fig. 1. Absorption spectra of polystyrene with different data spacings of 15.43 and 1.93 cm^{-1} in three wavelength regions

two data spacings of 15.43 and 1.93 cm^{-1} in three spectral ranges showed differences in their peak heights. The discrepancies of two different data spacings in lower wavenumber are larger than in higher wavenumber. The sharpness of absorption peaks also highly depends on the resolution as shown in Fig. 1(c) and 1(d).

Happ-Genzel apodization function and Mertz phase correction were used to process the collected data through Fourier transform. As shown in Fig. 1, the sampling frequency is a decisive factor of describing the absorption spectrum of the sample. Though the higher sampling frequency unambiguously assures the true spectral behaviour of the specimen, there is a limitation because of the capacity of data processing.

To compare the spectral data in different sampling frequencies of 15.43 and 1.93 cm^{-1} in three wavelength regions, the absorbance values normalized as following[10]:

$$\frac{F'(\bar{\nu})}{F(\bar{\nu})}=\frac{\int_{\bar{\nu}_1}^{\bar{\nu}_2} f'(\bar{\nu})d\nu}{\int f(\bar{\nu})d\nu}$$

where, $F'(\bar{\nu})$ is the integrated absorbance of the interested wavenumber range from $\bar{\nu}_1$ to $\bar{\nu}_2$ and $F(\bar{\nu})$ is the integrated absorbance of the overall wavenumber range from $\bar{\nu}_1$ to $\bar{\nu}_2$. $f'(\bar{\nu})$ is the absorption spectrum of the interested range and $f'(\bar{\nu})$ is the overall absorption spectrum.

Table-1 denotes the values of normalization in two different data spacing. As shown in Fig. 1, there were notable discrepancies in the absorption spectra of two different data spacing of 15.43 and 1.93 cm^{-1}. The difference between two data spacing decreased with increasing wavenumber. In the 650 to 800 cm^{-1} region, the discrepancy showed the largest discrepancy of 28.1 % compared to that of 2,750 to 3,250 cm^{-1}. This may come from the sensitivity of detector and the data processing of the interferogram. The signal to noise ratio can be affected by the detector noise and other source noises. The Fourier transform spectrometer has the advantages over the grating spectrometer in two fundamental of the multiplex (Fellgett) and the throughput (Jacquinot). The first benefit of multiplex comes from the measuring the spectral information about all wavelengths simultaneously and the second one comes from the maximum optical throughput. The signal to noise ratio, resolution, the number of scanning and scanning time are related with the trading rules. Moreover, the apodization function, phase correction, scanning mirror velocity and other source noise must be considered with the mechanical stability.

TABLE-1
COMPARISON OF THE NORMALIZED ABSORPTION OF TWO DIFFERENT DATA SPACING IN THREE SPECTRAL BANDS

Bandwidth (cm^{-1})	$\frac{F'(\bar{\nu})}{F(\bar{\nu})}$		Difference between 15.43 and 1.93 cm^{-1} (%)
	15.43 cm^{-1}	1.93 cm^{-1}	
650-800	0.1271	0.1628	28.1
1,400-1,650	0.0968	0.1129	16.6
2,750-3,250	0.3424	0.3437	0.4

In this study, we present the spectral change of two different data spacing in three infrared spectral ranges and found a trend that the discrepancy decreased with increasing wavenumber. Though this is an experimental phenomena in restricted solid sample of polystyrene and experimental conditions, the sampling frequency should be controlled with the measuring method and data processing.

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