

A NEW METHOD FOR ALCOHOL CONTENT DETERMINATION OF FUEL OILS BY TERAHERTZ SPECTROSCOPY

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Abstract — In this study, we developed a simple method for alcohol content analysis in fuel oils by Time-Domain Terahertz (THz) Spectroscopy. Frequency dependent absorption coefficients, refractive indices, and dielectric constants were calculated from the measurements of pure fuel oils and their mixtures with ethanol. Ethanol mixtures of gasoline were modeled successfully with a simple model in which the mixture behavior was described with a basic contribution approach of pure liquids. The results suggest that there is no strong interaction between the ethanol and the molecules in the gasoline. We concluded that this new approach offers a simple and useful method to determine the concentration of ethanol in gasoline currently with a 3% (by volume) maximum absolute error. With improvements, this error would be reduced to below 1%.

I. INTRODUCTION AND BACKGROUND

THz Time-Domain Spectroscopy (THz-TDS) is a non-contact technique to probe static properties of sample. It allows coherent measurement of THz pulse in time domain. Therefore, by a single measurement, absorption coefficient and refractive index of a sample can be directly determined. THz waves are able to penetrate a wide variety of materials. Since THz waves are low-energetic, they can be used to probe combustible compounds without any danger of combustion. Yet, there are few THz spectroscopy studies on fuel oils.^{1,2} The ethanol content in gasoline is regulated in many countries; therefore, a safe and reliable technique is required for the determination of the alcohol content in fuel oils. In this study, we developed a new and a simple method based on THz spectroscopy to detect ethanol amount in gasoline.

II. RESULTS

Fuel oil samples (diesel and gasoline) were probed by THz waves and their optical properties were determined. Differences in both frequency dependent refractive index and absorption coefficient are caused by the variation in compositions of the ingredients in gasoline and diesel. It was shown that qualitative analysis of fuel oils could be done by comparing optical parameters obtained by THz-TDS technique. Pure ethanol, gasoline and their mixtures were measured by THz-TDS. Optical parameters were presented such as absorption coefficient, refractive index and real part of permittivity. Ethanol has higher refractive index and absorption coefficient than that of gasoline. Therefore, addition of ethanol to the mixture causes an increase in both refractive

index and absorption coefficient. Optical parameters of ethanol and gasoline found in this study are in good agreement with the literature values.^{2,3}

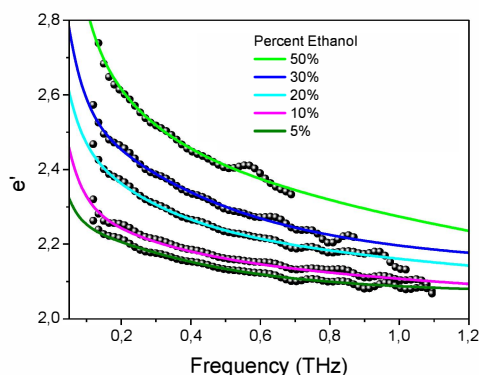


Figure 1. The Debye relaxation model (solid line) along with the real part of permittivity data (circles) derived from the experimental measurements for the mixtures of ethanol and gasoline.

Debye model is a useful theoretical modeling used to investigate dielectric relaxation parameters of pure compounds in both THz and microwave spectral region.^{3,4} By using Debye model, we calculated the dielectric relaxation parameters of pure liquids; ethanol and gasoline. Then, we constructed a simple method derived from Debye model considering basic contribution approach. We simultaneously fitted the both real part (Figure 1) and imaginary part of permittivity data determined experimentally. The maximum absolute error of ethanol percentage in gasoline based on our approach is ca. 3%. However, the average of absolute errors of all liquid mixtures is about 1%. In gasoline-ethanol mixtures, it may be possible to conduct a more precise measurement by minimizing systematic and measurement errors.

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