MEASUREMENT OF DIELECTRIC PROPERITES OF MEDIUM USING WAVE TRANSMISSIBILLITY IN TERAHERTZ REGION

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An experimental method to measure frequency-dependent dielectric properties of thin medium was proposed. The reflected and transmitted terahertz (THz) waves were utilized to predict the properties of the medium. The propagated wave through the medium were analyzed as a pulse wave using Helmholtz equation with the dielectric properties. The boundary conditions of the medium were determined by continuity conditions between the medium. The wave transmissibility of the medium was predicted by the wave analysis. Experiments were performed to measure the wave transmissibility of the medium. The reflected waves on the surface of the medium were measured using pitch-catch transducers. The measured waves were used to obtain the transfer function. Wave speeds of reflected THz pulse were measured through the transfer function method. The numerical analysis to measure the dielectric properties were proposed using the wave analysis. The dielectric constants and loss factors were obtained through the proposed method.
Keywords: wave propagation, pulse wave, transfer function

1. Introduction

The wave in terahertz(THz) region remained unexplored area for many years due to the lack of practical sources and detectors. The pulsed wave in THz region are based on the generation and detection of an electromagnetic instantaneous fluctuation during a few picoseconds.[1] As opposed to continuous wave, the pulsed wave has broadband frequency characteristics and short emission time. The pulsed wave are ideal for spectroscopic applications and the study of ultrafast phenomena.[2] The wave has typically evolved from the photonics side by generating the electromagnetic transients with ultrafast femto-second.[3-4] The use of the pulsed THz waves on semiconductors allows measuring carrier lifetime and doping concentrations.[5] The application of THz waves on plasmas provides understanding about electron ionization and collision processes at the picosecond time scale.

In this study, the wave propagated with the dielectric medium was predicted to measure electromagnetic properties. The reflected wave by the medium was measured by pitch patch mode. The waves were settled to second reflected pulse wave except for the disturbance. The dielectric constant and attenuation values were obtained through numerical analysis in the frequency domain by transfer function method.

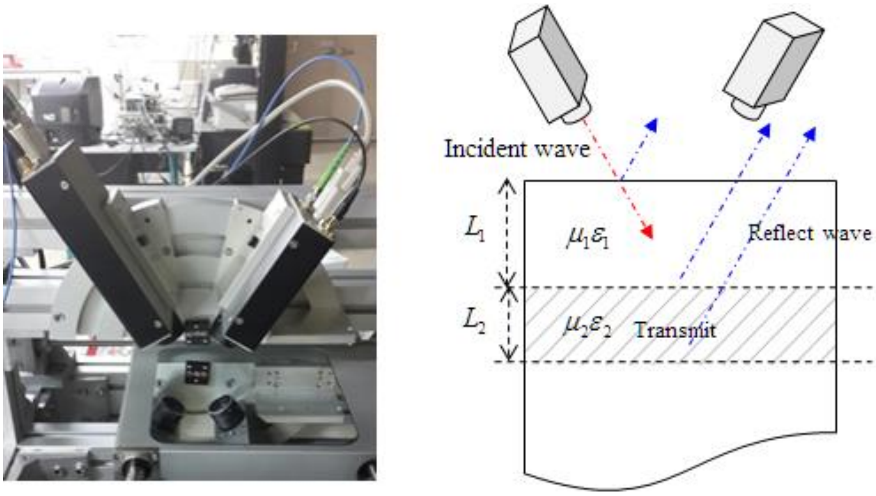

Figure 1: Experimental and analysis settings to measure THz wave with the dielectric medium.

2. The measuring method using wave transmissibility of the medium

2.1 Wave analysis with the thin dielectric medium

The interaction between wave and material was presented as the sum of material interactions with a series of monochromatic waves. Each monochromatic wave and its induced polarization was a simple harmonic oscillation. To describe the pitch catch mode, wave equation divided into two areas. $u_1(x)$ is the plane wave in air and $u_2(x)$ is the plane wave in dielectric material as shown in figure 1.

$$u_1(x) = Ae^{-ik_1x} + Be^{ik_1x} \qquad (1a\text{-}b)$$
$$u_2(x) = Ce^{-ik_2(x-L_1)} + De^{ik_2(x-L_1)}$$

Boundary conditions were determined by the following equations.

$$u_1(0) = U_0,\ u_1(L_1) = u_2(L_1),\ u_2(L_2) = 0,\ \frac{u_{1,r}(L_1)}{u_{1,i}(L_1)} = \frac{\cos\theta_2 - \cos\theta_1\varepsilon_0}{\cos\theta_2 + \cos\theta_1\varepsilon_0},\ \frac{u_{2,t}(L_1)}{u_{1,i}(L_1)} = \frac{2\cos\theta_2}{\cos\theta_2 + \cos\theta_1\varepsilon_0} \qquad (2a\text{-}e)$$

The transfer function between the incident and the reflected wave were determined by

$$\Lambda e^{i\phi} = \hat{u}_2(x_1)/U_0 \qquad (3)$$

The Newton–Raphson method was applied to derive to the complex wavenumber represented as[6]

$$\hat{k} = \sqrt{\mu\varepsilon}\omega + i2\pi\sqrt{\mu/\varepsilon}\gamma \qquad (4)$$

2.2 Measurements of the dielectric properties using the wave analysis

THz-TDS imaging system (FiCOTM, Zomega Terahertz Corp.) is composed of a femtosecond laser module. The THz-TDS module is composed of an emitter module, a receiver module, and optical installations including beams, lenses, and mirrors. The schematic diagram of the experimental setup for coherent detection of terahertz pulsed radiation is represented in Fig. 1. The THz imaging system used in this study has a frequency range of 0.1 THz - 3.0 THz, a frequency resolution of 11 GHz, and a time resolution of 20 fs.

Figure 2 shows the measured complex dielectric properties obtained from the proposed method. The properties in each frequency region were obtained by the numerical analysis. The measured properties with frequency that were averaged and compared. The properties were consistent with the existing values of the medium. The proposed method has the advantage that the dielectric constant and loss factor were derived at the same time.

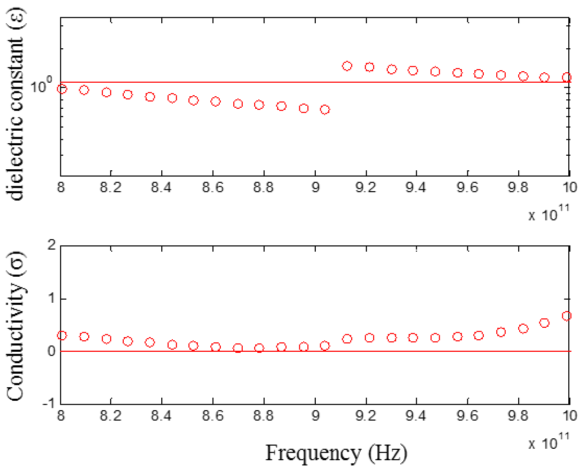

Figure 2: The measured dielectric properties of the medium using proposed method.

3. Conclusion

The method using the wave analysis in terahertz region was presented to identify the dielectric constant and attenuation of the medium. The experiments were performed to measure the wave transmitted and reflected the medium by pitch catch mode. The terahertz pulse waves were generated by a femtosecond laser module, and pulse waves were received until the second reflected pulse. The measured waves were analyzed using the wave approach. The dielectric properties were measured using the wave approach with the transfer function method.

4. Acknowledgements

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