# A Study on Development of EM Wave Absorber Using $TiO_2$ for Automotive Radar in Cars

Chang-Mook Choi[1] · Dong Il Kim[2]


## Abstract

In this paper, we designed and fabricated an electromagnetic(EM) wave absorber for automotive radar in cars using $TiO_2$ as a dielectric material and chlorinated polyethylene(CPE) as a binder. First of all, we confirmed that the optimum composition ratio of $TiO_2$ was about 70 wt.%. The complex relative permittivity of a sample containing $TiO_2$: CPE=70:30 wt.% was calculated from S-parameter. The EM wave absorption abilities were simulated for the EM wave absorbers of different thickness using the calculated relative permittivity, and the EM wave absorber was manufactured based on the simulated design. A comparison of simulated and measured results is in good agreement. Measurement shows that a 1.85 mm thick absorber has absorption ability higher than 20 dB in the frequency range of 76~77 GHz for automotive radars.


***Key words*** : Absorption Ability, CPE, EM Wave Absorber, Permittivity, $TiO_2$.

## I. Introduction

Automotive millimeter wave radars operating in the frequency range of 76~77 GHz[1] are used in such applications as forward looking to warn drivers of dangers. The wider use of automotive millimeter-wave radar will reduce serious traffic accidents that so frequently occur on limited-access highways in foggy or snowy conditions. But, radar systems create two major problems(false images and system-to-system interference)[2]. Because false echoes cause driving hazards, EM wave absorber should be used to cover the guard rails on both sides of the road or the inner walls of tunnels for preventing false echoes of the radar.

In general, EM wave absorbers can be broadly divided into two types from the viewpoint of material. One is wave absorber using dielectric material and the other is magnetic wave absorber using ferrite material[3].

In this paper, we designed and fabricated an EM wave absorber using $TiO_2$ as a dielectric material with CPE, and the complex relative permittivity($\varepsilon_r=\varepsilon_r'-j\varepsilon_r''$) was calculated from S-parameters. The EM wave absorption abilities are simulated for the EM wave absorbers of different thickness, and the EM wave absorber was manufactured based on the simulated design. The simulated and measured results agree very well. As a result, we developed a sheet-type absorber using $TiO_2$ for eliminating false image and system-to-system interference in automotive millimeter wave radars.

## II. Theory of EM Wave Absorber

For an EM wave absorber made of a conductor-backed single layer as shown in Fig. 1, return loss($RL$) can be obtained from an equivalent circuit as follows[4],[5]:

$$RL=-20\log_{10}\left|\frac{z-1}{z+1}\right| \quad [\mathrm{dB}] \tag{1}$$

Here, $z$ is the normalized input impedance.

If an EM wave absorber is installed in a rectangular waveguide as shown in Fig. 2 and $TE_{10}$ mode is the only propagating mode in waveguide region[6], the normalized input impedance is expressed as [7]

$$z=\mu_r\sqrt{\frac{1-(\lambda/2a)^2}{\varepsilon_r\mu_r-(\lambda/2a)^2}}\cdot \tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_r\mu_r-(\lambda/2a)^2}\,d\right) \tag{2}$$

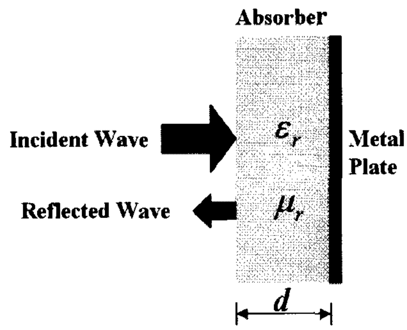


Fig. 1. EM wave absorber made of a conductor-backed single layer.

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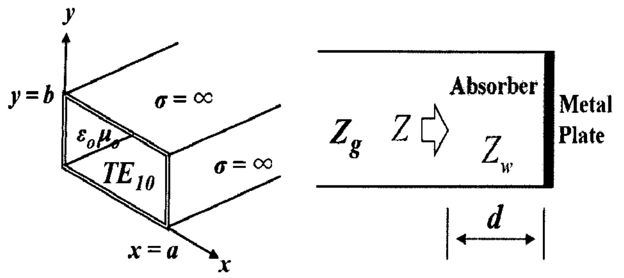



(a) Rectangular waveguide (b) Absorber in rectangular waveguide

Fig. 2. Absorber in rectangular waveguide.

where $\lambda$ is the wavelength, $d$ is the thickness of the sample, a is the x-direction length of the rectangular waveguide, $\mu_r$ is the complex relative permeability, and $\varepsilon_r$ is the complex relative permittivity. The reflectionless condition for normal incidence of an electromagnetic wave is given by

$$\mu_r\sqrt{\frac{1-(\lambda/2a)^2}{\varepsilon_r\mu_r-(\lambda/2a)^2}}\cdot \tanh\left(j\frac{2\pi}{\lambda}\sqrt{\varepsilon_r\mu_r-(\lambda/2a)^2}\,d\right)=1 \qquad (3)$$

Hence, if equation (3) is solved, the relationship between the material properties(complex relative permittivity and permeability) and the sample thickness can be obtained.

## Ⅲ. Preparation and Measurement of Samples

### 3-1 Sample for Measurement

We fabricated some samples of different composition ratio of $TiO_2$ and CPE. $TiO_2$ was mixed with CPE as a binder, and sheet-type absorbers were fabricated by using an open roller. The surface temperature of the open roller was kept uniform during sample preparation because the surface temperature affects the EM wave properties of sheet type absorbers[8]. The manufacturing process of absorber is shown in Fig. 3.

The dimensions of the samples for measurement of the complex relative permittivity and absorption ability were 2.54×1.27×1.5 mm and 2.54×1.27×3 mm.

### 3-2 Measurement Method

For the reflection measurements in this research, measurement equipments including an ANRITSU ME 78080A broadband vector network analyzer, a rectangular waveguide, a sample jig, and a short plane are used. The measurement system is shown in Fig. 4. Fig. 5 presents a photo of the absorber, the jig, and the sample. The reflection coefficient of the sample can be obtained from

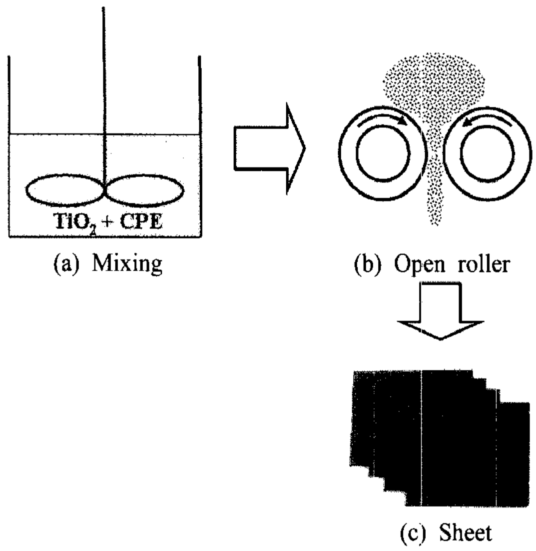



Fig. 3. Manufacturing process of absorber.

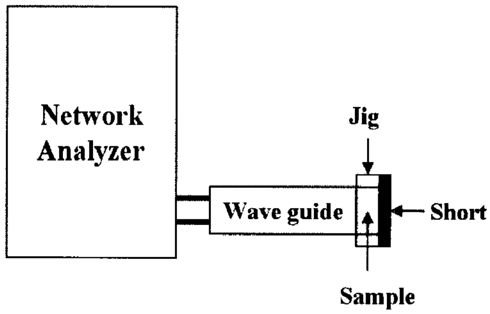



Fig. 4. Measurement system.

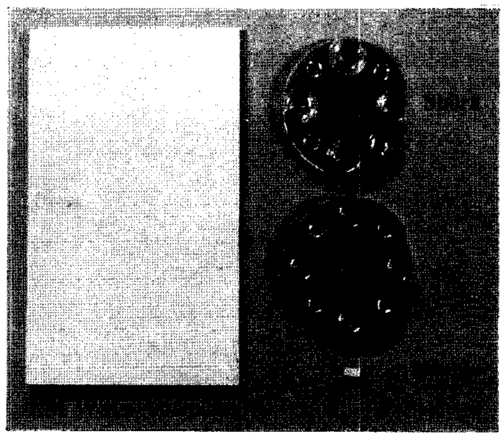
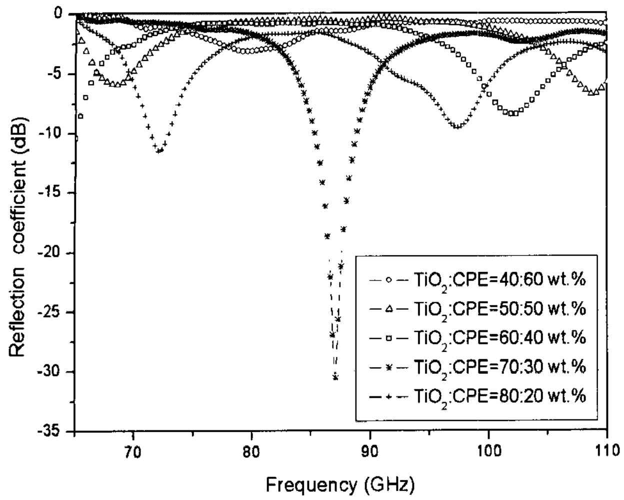


Fig. 5. A photo of absorber, test jig, and sample.

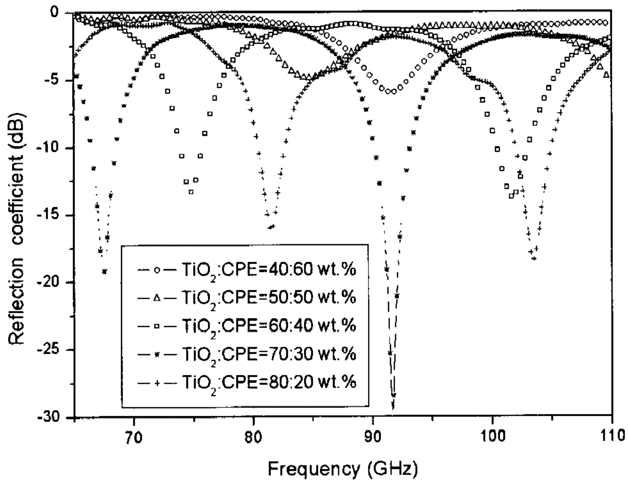
$S_{11}$ after a self calibration.

## Ⅳ. Results and Discussion

Fig. 6 shows the dependence of the measured reflection coefficient on the composition ratio as a function of frequency. Absorption abilities of samples containing $TiO_2$ 70 wt.% with thickness of 1.5 mm and 2.0 mm




(a) Thickness: 1.5 mm




(b) Thickness: 2.0 mm

Fig. 6. Reflection coefficients of samples of different composition ratios of $TiO_2$ and CPE.

have maximum values at 87 GHz and 92 GHz, respectively. As a result, we confirmed that the optimum composition ratio of $TiO_2$ is about 70 wt.%. A SEM micrograph of a sample containing $TiO_2$ 70 wt.% is shown in Fig. 7. It shows that all $TiO_2$ particles were well mixed with the binder and that no air holes were present.

Therefore, we carried out the EM wave absorber design with a sample containing $TiO_2$ 70 wt.%. Because the relative permeability is $\mu_r$=1 in absorber sample without magnetic material, the relative permittivity is only calculated from S-parameter of the sample using 1-port method($\ell-2\ell$ method)[9]. Fig. 8 shows plots of the measured complex relative permittivity at different frequencies.

Absorption abilities of the EM wave absorbers are simulated using the measured complex relative permittivity by changing the thickness without changing the composition. The simulated and measured results with the thickness of 1.85 mm have absorption ability higher

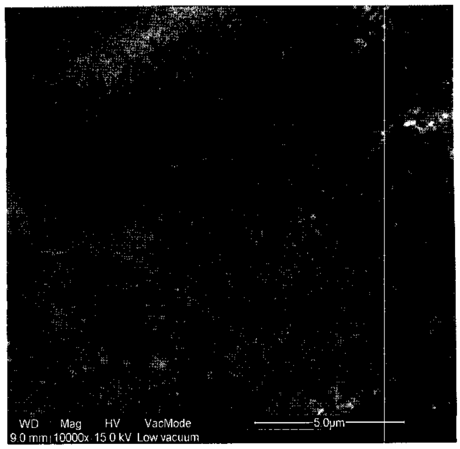



Fig. 7. SEM micrograph of a sample containing $TiO_2$:CPE =70:30 wt.%.

than 20 dB in the frequency range of 76~77 GHz as shown in Fig. 9. Simulated and measured results agree very well.

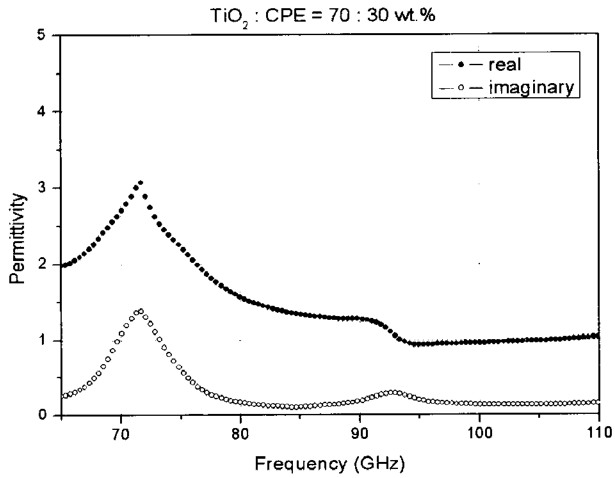



Fig. 8. The measured complex relative permittivity($TiO_2$: CPE=70:30 wt.%).

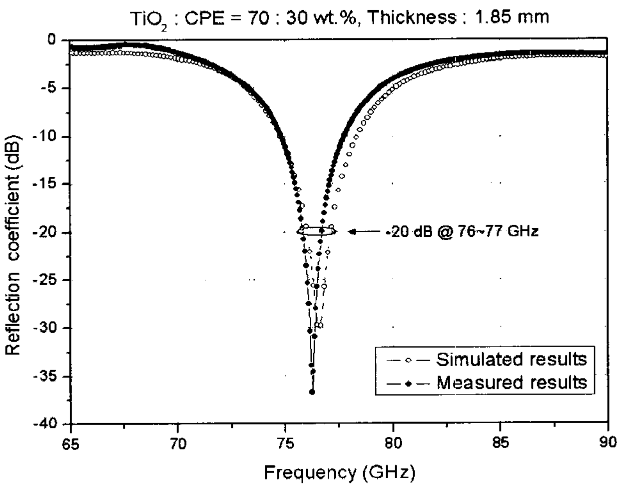



Fig. 9. Comparisons of simulated and measured results.

## V. Conclusion

The problems with false images and system-to-system interference can be eliminated through the use of EM wave absorber. Therefore, we designed and fabricated an EM wave absorber for automotive radars in car using $TiO_2$ as a dielectric material and CPE as a binder. First of all, we confirmed that the optimum composition ratio of $TiO_2$ was about 70 wt.%. The complex relative permittivity of a sample containing $TiO_2$:CPE=70:30 wt.% was calculated from S-parameters. The EM wave absorption abilities were simulated for the EM wave absorber of different thickness using the calculated relative permittivity, and an EM wave absorber was manufactured based on the simulated design. A comparison of simulated and measured results is in good agreement. Measurement shows that a 1.85 mm thick absorber has absorption ability higher than 20 dB in the frequency range of 76~77 GHz for automotive radars.

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