Fabrication of a terahertz wave absorber based on dielectric spheres

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***Abstract*—A terahertz wave absorber composed of dielectric spheres is proposed. The proposed absorber offers advantages compared to other metamaterial-based absorbers owing to low-cost and flexibility of fabrication that strongly relaxes the constraints for the optical domain. The dielectric spheres composed of titanium oxide (TiO_2) are aligned with a hexagonal lattice on an aluminum substrate. The absorption over 90% is obtained at the frequencies of the Mie resonances of the spheres. Furthermore, as results from simulation, the performances of metamaterial based absorber are kept over a wide range of incident angles.**

I. Introduction

In recent years, electromagnetic wave absorber by using metal resonator array has been proposed[1,2]. A dual-layer of 2 dimensional metamaterials, i.e. metasurfaces, is one of the representative examples. By adjusting the phase of the reflection from each layer so that the reflected waves interfere destructively, the electromagnetic waves are absorbed into the metal resonators and dielectric interlayer. Because of the large phase shift due to the resonance of the metasurfaces, the planar absorber thinner than the operating wavelength can be designed. The dielectric spheres that exhibit Mie resonances can be used as the resonators constituting the metamaterials[3]. The metamaterials composed of the dielectric spheres offers advantages due to mass-productivity and flexibility of the configuration. In this work, the possibility to fabricate electromagnetic wave absorber with the dielectric sphere arrays is demonstrated.

II. Samples

The microspheres made of TiO_2 were aligned with a hexagonal lattice on an aluminum tape. Figure 1(a) and (b) shows schematic and microscope image of the sample, respectively. The spheres were fixed with the glue on the aluminum surface. The average diameter of the TiO_2 spheres was 53.3 μm and the period was 68.4 μm. Because the permittivity of the TiO_2 is larger than $100+i1$ in the terahertz region, the resonant wavelength is larger than the diameter of the spheres.

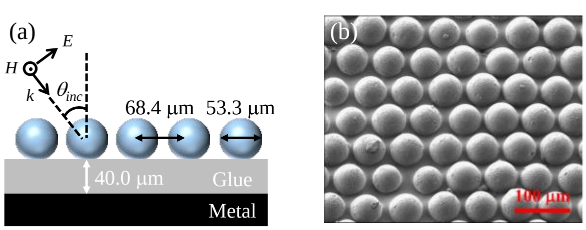

Fig. 1 schematic (a) and SEM image (b) of fabricated absorber

III. Results and Discussion

The reflection spectra of the sample were measured by using a terahertz time domain spectroscopy (THz-TDS) system in order to characterize the absorption of the sample. The reflection coefficients were obtained by normalizing the reflected waves from the sample with those from a silver mirror. In addition, numerical calculation based on Finite Element Method (FEM) was performed. In our simulation, the dispersion of the permittivities of the TiO_2 microspheres[4] and glue layer were defined. Although we could not measure the dielectric constant of glue layer of metal tape directly, we used the frequency dispersion of typical acrylic tape which was measured by the THz-TDS. For example, the values of the permittivity $\varepsilon \sim 2.15 + i\,0.17$ at 0.54 THz and $\varepsilon \sim 2.09 + i\,0.28$ at 0.73 THz, respectively were measured and considered in our numerical model. Figure 2 shows the absorption spectrum in the frequency range from 0.2 to 0.9 THz. The absorption spectrum is calculated as $A = 1 - R - T$, where R is the energy reflection coefficient and T is the energy transmission coefficient. Here, T is zero because the aluminum film was used as the substrates. The absorption peaks were observed at 0.54 THz and 0.73 THz with absorption coefficient 82% and 96%, respectively. The numerical calculation agrees well with the experimental results as seen in Fig 2. Figure 3 shows spatial distribution of the resonant magnetic field of the metamaterial absorber illuminated by a plane wave. The two absorption peaks are originated from the first and second order Mie resonances of the spheres.

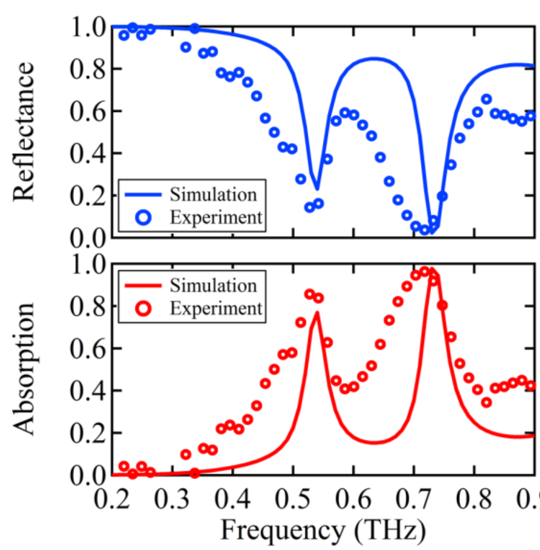

Fig. 2 Simulated (solid curve) and measured (symbols) reflection an absorption spectra.

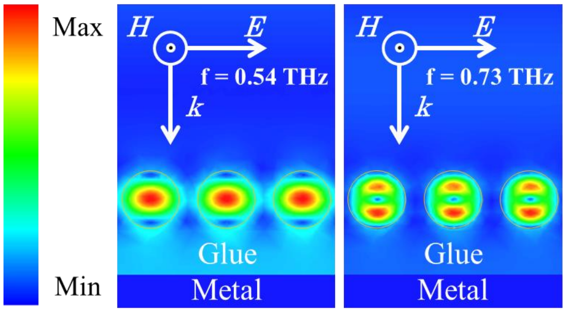

Fig. 3 Magnetic field distribution at the resonant frequencies.

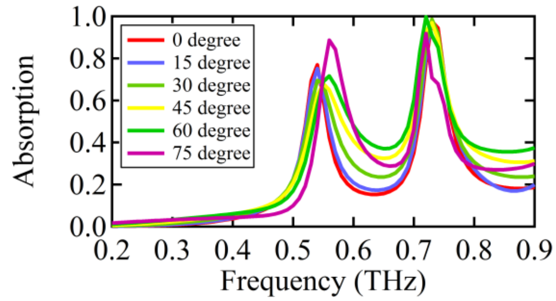

Fig. 4 Absorption spectra of the metamaterial based absorber caluculated for different incident angles from 0 to 75 degrees.

In Fig. 5, the absorption spectra were calculated for the incident angles (θ_{inc}) from 0 to 75 degrees with 15 degrees incremental steps in the case of *p*-polarization. The two large absorption peaks are still observed for the large incident angle as seen in Fig. 5. Although the amplitude of the absorption peaks around the first and second Mie resonance decrease or increase slightly and small resonant frequency shift are occurred by changing θ_{inc}, the absorption spectra are not dramatically affected by the incident angle.

IV. SUMMARY

The simple and flexible fabrication process of the absorber for the terahertz waves has been proposed. The absorber was composed of the dielectric spheres and the metal substrate. The proposed absorber can be fabricated even on the curved surfaces. The absorber was demonstrated by using TiO_2 microspheres and the absorption higher than 90 % was observed. The absorption is caused by the Mie resonances in the spheres. The numerical results demonstrate that the metamaterial-based absorber operates quite well over a wide range of incident angles.

V. ACKNOWLEDGEMENT

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