Resonant frequency shift of complementary split ring resonator in terahertz region

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1. Introduction

The goal of our research is to convert the frequency of terahertz waves, and for this purpose, we explore resonant frequency shifts of split ring resonators (SRRs) in this study. SRRs have some resonances corresponding to its geometrical parameters [1]. We attempt to shift the resonant frequency of the SRR with the change of resonant modes by external effects. For our purpose, SRRs are needed to have high quality factor and wideband shift of the resonant frequency. In this study, we investigate the transmission spectra change of the complementary SRRs on thin Si substrate.

2. Simulation model

We simulated transmission spectra of complementary SRR models. The software, which we used in our study, is COMSOL Mutiphysics®, which uses the finite element method. Our SRR consists of Au and Si, whose dielectric constant ε_{Si} is set to be 11.7. The thickness of Au and Si are 500 nm and 5000 nm, respectively. The structure of the complementary SRR is shown in Fig. 1. The gold, white and gray sections indicate Au, air and Si, respectively. The direction of an incident electromagnetic wave ***E*** is normal to the surface of the SRR, and the polarization of the incident THz waves is depicted in Fig 1. The mode of resonance changes by varying the conductivity of the Si. To evaluate how large the width of resonant frequency shift, we defined figure of merit (FOM) as follows;

$$\mathrm{FOM} = \frac{\Delta f}{\mathrm{FWHM1}}, \qquad \mathrm{FOM'} = \frac{\Delta f}{\mathrm{FWHM2}}.$$

Here, Δf means the width of the resonant frequency shift, and FWHM1, FWHM2 are full width of half maxima of resonant peaks for high conductivity σ_h and low conductivity σ_l of Si.

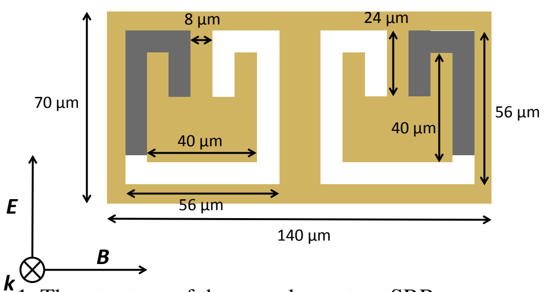

Fig. 1. The structure of the complementary SRR

3. Result and discussion

The transmission spectra of our SRR structures are shown in Fig. 2. The spectrum of the complementary SRR (C-SRR) for σ_l = 1 S/m is shown by solid line, and the C-SRR for σ_h = 30542 S/m (at 1 THz) is represented as dotted line. We observe that the resonant frequency shift from 0.48 THz to 0.95 THz with changing from σ_l to σ_h. The second peak is also observed for σ_l around 1.0 THz that is attributed to the second order mode of the SRR. FOM and FOM' are 3.43 and 6.23, respectively. We also simulated reflection spectra of positive SRR models, and both FOM and FOM' of the C-SRR are much better than those of positive SRRs. We will explain the detail of mechanism about the C-SRR at our presentation.

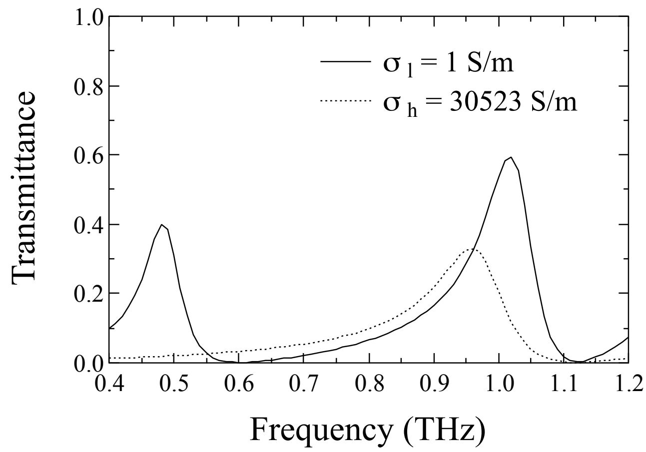

Fig. 2. Transmittance spectra of complementary SRR

References

[1] W. J. Padilla. *et al*., Phys. Rev. Lett. **96**, 107401 (2006).