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Efficient Optical Modulation of Terahertz Metamaterial Based on Charge Transfer at Organic/Inorganic Semiconductor Interface

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1. Introduction

Since Yen *et al*. experimentally demonstrated magnetic resonance using array of split-ring resonator (SRR) metamaterials (MMs) in terahertz (THz) frequency range [1], numerous studies have been carried out. To control MM response by optical means is one of the actively studied approaches for the realization of THz wave modulator. Recently, Yoo *et al*. reported that photo-induced modulation of THz transmission through Si were drastically enhanced by depositing thin layer of organic conjugated material, copper phthalocyanine (CuPc) [2]. Photo-induced metallization due to charge transfer from Si to CuPc plays crucial role. Here we demonstrate photo-induced effective modulation of resonant characteristics of SRR array fabricated on CuPc-coated Si [3]. Our findings may lead to the development of novel THz devices.

2. Experiment

We used 540μm thick, highly-resistive Si and CuPc without purification. Thin film of CuPc was deposited by thermal evaporation and then annealed at 250 ℃. Ag SRR array were fabricated on CuPc-coated Si substrate utilizing superfine ink-jet printer [4, 5] and then annealed at 240 ℃. Dimensions of each SRR meta-atom were as follows: period, side length, width, gap were 100, 60, 12, 6 μm, respectively, and the total area was 5 × 5 mm^2.

Optical characteristics were investigated using typical THz time-domain spectroscopy (THz-TDS). For optical modulation experiment, 532nm CW laser light was used. At this wavelength of light, free charge carriers can be excited only in Si.

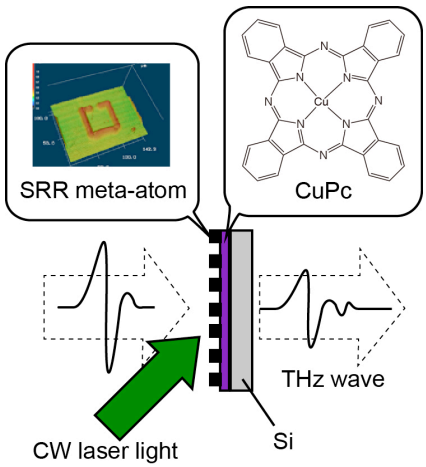

Fig. 1: Schematic representation of the THz modulation MM

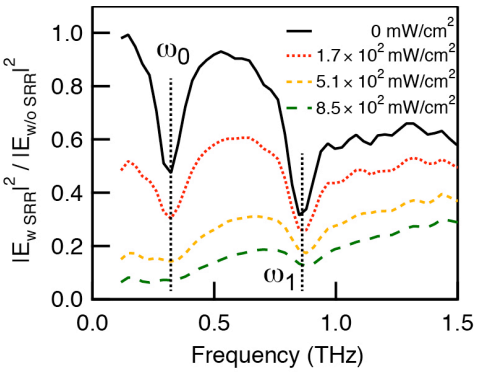

Fig. 2: Normalized THz transmission spectra through SRR array on CuPc-coated Si under different laser light irradiances.

3. Results and Discussions

Fig. 2 shows normalized THz transmission spectra through SRR array on CuPc-coated Si under different laser light irradiances. The sharp transmission dips can be recognized due to absorption induced by resonant interaction with SRRs. Upon increasing laser light intensity, transmission decreases in all frequencies of interest and almost no features can be recognized at higher laser light intensities. Photo-induced efficient metallization can occur at CuPc-coated Si, which is enough to short capacitive gap of SRR to erase resonant effect. This enables to fabricate THz devices that can be controlled via photo-irradiation with low powers.

4. Conclusions

We have demonstrated that SRR resonance can be efficiently modulated. Our findings may open the way to fabricate various types of novel MMs, which is currently under active study.

Acknowledgements

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