Optical Switching in Near Infra-Red Metamaterial with Nematic Liquid Crystal Structure

Boyoung Kang[1], J. H. Woo[1], E. Choi[1], E.S. Kim[1], J. Kim[1], Tae-Jong Hwang[2], Young-Soon Park[2], D.H. Kim[2], and J. W. Wu[1],*
1. Department of Physics, Ewha Womans University, Seoul, KOREA
2. Department of Physics, Yeungnam University, Gyeongsan, KOREA
**E-mail:jwwu@ewha.ac.kr*

Functional metamaterials have attracted research interests, where metamaterial resonances are controlled and tuned by a variety of external means[1]. Particularly, various schemes have been proposed in tera Hz spectral regime, for example, varying the incident polarization direction or temperature to control the coherent coupling[2,3]. The importance of near-infrared (NIR) metamaterial is emerging owing to its telecommunication application by development of nano fabrication technique. Here, we examine an optical switching of metamaterial resonance in a metamaterial-liquid crystal cell structure in the NIR spectral regime.
We designed a metamaterial possessing the polarization-dependent transmission characteristic, which is composed with a planar array of double-split ring resonators (DSRRs). The schematic diagram of metamaterial design and measured FE-SEM image are shown in Fig. 1 (a) and (b), respectively. The DSRRs, of which outer diameter is 220 nm and the lattice constant is 250 nm, are patterned on 35 nm–thick gold film by e-beam lithography method and lift-off process. Once obtained the pattern, a thermal annealing process is followed in order to stabilize the thin gold layer. The metamaterial accommodates two distinct resonances along the two eigen-mode excitation axes depending on incident polarization angle in the near infrared regime.

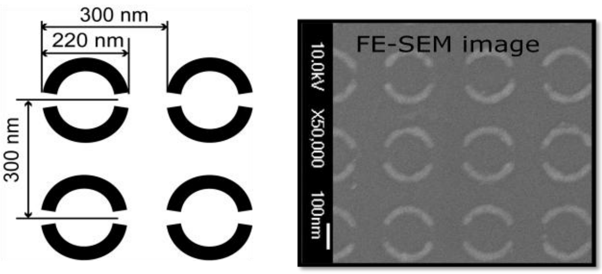

Fig. 1 (a) A schematic diagram of nano sized double-split ring resonator,
(b) A FE-SEM image of metameterial.

In this study, we employed an azo-twisted nematic (TN) liquid crystal cell as an optical control part. The azo molecule in liquid crystal undergoes photo-isomerization process by absorbing UV light, which change the phase of liquid crystal[4]. Upon UV irradiation, the TN alignment cell rotating incident polarization state was changed to isotropic state not rotating incident polarization. To hybridize the polarization dependent meramaterial and optical polarization-controllable device makes optical switching of meta resonance possible. A twisted nematic liquid crystal cell having the planar metamaterial in the alignment layer is filled with azo-nematic liquid crystal. Before UV irradiation, the polarization direction of the incident light gets rotated by 90 degree to excite the high frequency (long wavelength) resonance at 1650 nm. Upon UV irradiation, a photo-isomerization process takes place in the twisted-nematic alignment destroying the twist of nematics, which results in an optically isotropic liquid crystal cell. Hence, the polarization direction of the incident light does not undergo a rotation, subsequently exciting the low frequency (short wavelength) resonance at 1170 nm. In Fig.2, as UV irradiation time is increasing, the light transmission of high frequency resonance is switched-off while the light transmission of low frequency resonance is switched-on. This switching behavior occurring in a single device is all-optical and reversible process. The switching speed depends on intensity of UV light. A single structure switching the meta resonance in NIR spectral regime has potential applications in the photonic switching in optical fiber telecommunications[5].

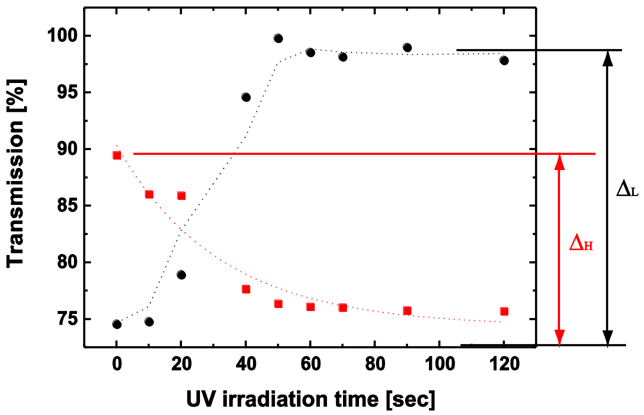

Fig. 2 Switching behavior at high- and low frequency resonance by increasing the UV irradiation time.

References

1. Nikolay I. Zheludev, Science **328**, 582 (2010).

2. Boyoung Kang, E. Y. Choi, Hyun-Hee Lee, E. S. Kim, J. H. Woo, J. Kim, Tae Y. Hong, Jae H. Kim, and J. W. Wu, Opt. Express **18**, 11552 (2010).

3. J.H.Woo, E. S. Kim, E. Choi, Boyoung Kang, Hyun-Hee Lee, J. Kim, Y. U. Lee,Tae Y. Hong, Jae H. Kim, and J.W.Wu, Opt. Express **19**, 4384 (2011).

4. Boyoung Kang, Hyunhee Choi, Mi-Yun Jeong, and J. W. Wu, J. Opt. Soc. Am. B **27**, 204 (2010).

5. Boyoung Kang, J.H.Woo, E. Choi, Hyun-Hee Lee, E.S. Kim, J.Kim, Tae-Jong Hwang, Young-Soon Park, D.H. Kim, and J. W.Wu, Opt. Express **18**, 16493 (2010).