17a-P14-2

ナノ金属構造およびフォトニック結晶共振器間の相互作用の検討

Investigation of electromagnetic interactions in two-dimensional metallic array nanostructures and photonic crystal nanocavity composite system

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[Introduction] We have studied dielectric-metal hybrid systems consisting of a photonic crystal nanocavity (PCC) and metallic meta-atoms, where both electric and magnetic components of light can be controlled in sub-wavelength range. Recently, we succeeded in emitting circularly polarized light from the combined structure of PCC, a metal split ring resonator (SRR) and bar resonator (BAR)[1]. To expand and deepen such technique, interaction between the elements including those between metallic meta-atoms should be investigated. In this report, we investigate the shift of resonant wavelength of two-dimensional SRR arrays when the spacing is changed. Also, we investigate the shift of resonant wavelength of a combined structure of SRR + PCC when the relative position is changed.

[Structure and Results] Figure 1 (a) shows a schematic model of array structure. The outer shape of each SRR is square, ℓ =210nm on a side. The size is designed to show a magnetic dipole resonance at 1550 nm for the case of isolated ones. The metal is gold and SRRs are placed on top of SiO_2. When we decreased the lattice constants from the almost isolated case of $a_x=a_y$=1000nm to 400nm and calculated the transmission of the light incident from the vertical direction, the blue shift of resonant wavelength is observed (Fig. 1b). We also decreased a_y and a_x independently down to 400nm (shown in Fig. 1 (c) and (d), respectively). It is seen in Fig. 1 (c) that the resonant wavelengths also blue-shift for the case that a_y is decreased. In contrast, the resonant wavelengths red-shift when a_x is decreased. These results indicate that the phase of coupling constants are opposite for the vertical coupling and horizontal couplings. These characteristics can be explained by the model that neighboring SRRs couple each other not only by the interaction between magnetic dipoles formed in the center of the ring but also by the interaction between the electric dipole formed in the gap (similar model is reported in Ref. 2). As schematically shown in Fig. 1 (e), all SRRs are excited in the same phase when a plane wave is incident vertically. In this case, interactions between electric dipoles of neighboring SRR have apparent difference in x and y directions, where they attract each other (bonding) in x direction while they repel (anti-bonding) each other in y directions. Because magnetic dipole interaction between neighboring SRRs indicates repulsion in both x and y direction, we consider the calculated difference between Fig. 1 (c) and (d) is due to the electric dipole interaction. We also investigated the case of the coupling between SRR and PCC (Fig. 2). It is shown that the resonant wavelengths blue shift as the coupling increases by changing the SRR position from H_z node to antinode. We believe this characteristic can be explained by taking into account both magnetic and electric dipole interactions. Details will be presented at conference. **[References]** [1] 李他、秋季応物 13a-PA5-1 (2012). [2] I. Sersic et al., PRL 103, 213902 (2009).

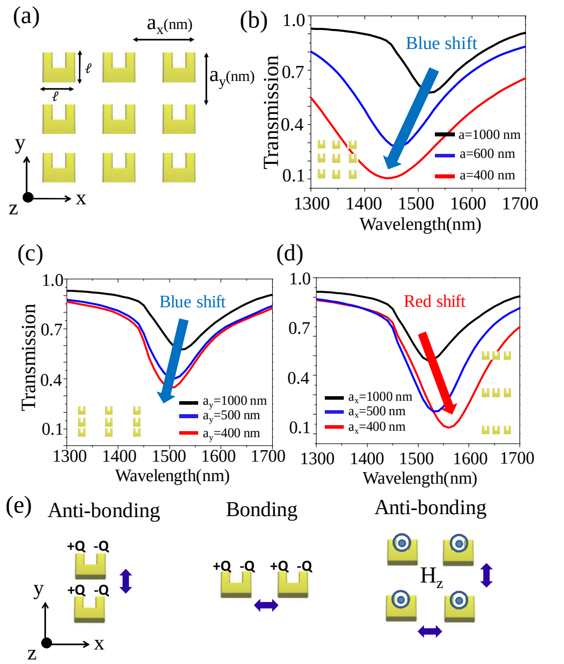

Fig. 1 Simulation results and model of coupling: (a) SRR array structure, (b) transmission spectra for decreasing both lattice constant ($a_x=a_y$) (c) spectra for decreasing vertical lattice constant (a_y), (d) spectra for decreasing lateral lattice constant(a_x), (e) model of coupling between SRRs.

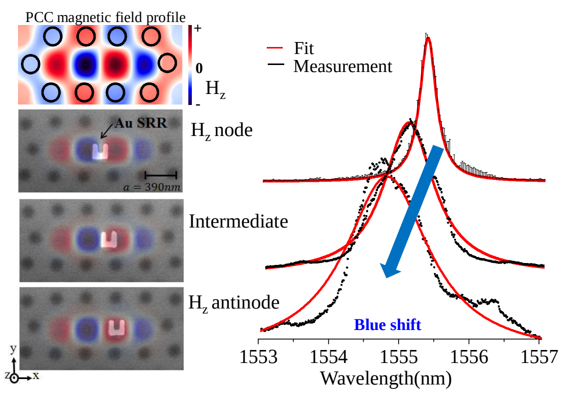

Fig. 2. Experimental results: PCC+SRR drop spectra for different SRR locations.