Magnetic assembly of three-dimensional metamaterials

Takuo Tanaka[1, 2] and Kanna Aoki[1]

[1]RIKEN Metamaterials Laboratory, 2-1 Hirosawa, Wako, Saitama 351-0198 JAPAN

[2] Hokkaido University, Research Institute for Electronic Science

Metamaterial is an artificially designed material that consists of metal resonator array. Designing resonator array structure so that it is smaller than the wavelength of the light, metamaterials work as a homogeneous material whose electromagnetic properties inherited from its structure. By engineering such materials, we can design and control their magnetic permeability even in the optical frequency region in which all materials in nature lose magnetic response and their relative permeability is fixed at unity. Although application ideas for metamaterials have been proposed one after another, stagnant progress in producing metamaterials for profitable wavelengths is preventing them from expanding into commercial devices. Realization of three-dimensional metamaterials is even more difficult, thus there is still no demonstration of complete 3D metamaterials.

Metamaterial's controllability of magnetic permeability is originated from tiny resonators embedded in a medium. We have investigated the design principle of 3D metamaterials that works in the visible light region [1-3]. The shape of each resonator is metal ring with several cuts, which is termed as split ring resonator (SRR), and its feature size of each resonator is in the range of 1/4 ~ 1/10 of target wavelength. Numerous numbers of such resonators should be embedded in a medium to clearly develop the change in magnetic permeability. To meet these severe structural requirements, we devised a bottom-up approach with the aid of external magnetic field. When an external magnetic field is applied to a mixture of paramagnetic beads and gold microspheres dispersed in ferrofluid, paramagnetic beads instantly align their magnetic moment to the direction of the external magnetic field, and gold microspheres gather around an equator of paramagnetic beads to form a ring structure. This gold ring structure is identical to SRR. Using this self-organizing feature, we realize a three-dimensional metamaterial structure just by applying an external magnetic field. Moreover, the assembled ring structures are immediately disassembled, when an external magnetic field is eliminated. We can apply this feature for realizing an active metamaterial just by switching on/off an external magnetic field.

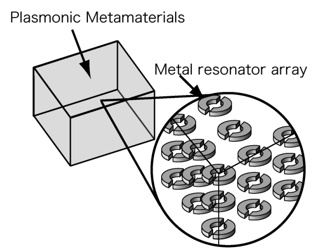

Fig. 1 Metamaterials.

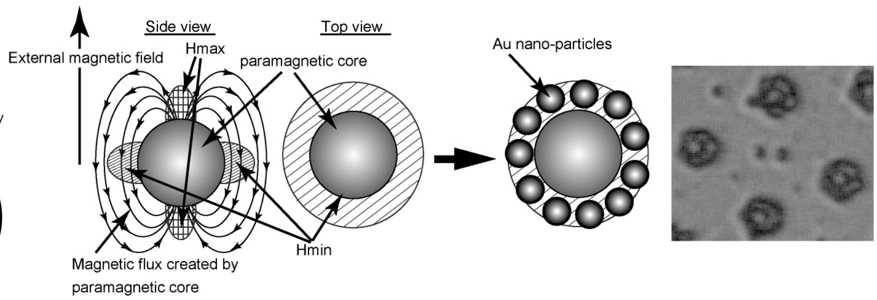

Fig. 2 Magnetic assembly of metamaterial structure.

References

[1] A. Ishikawa, T. Tanaka, and S. Kawata, Phys. Rev. Lett. **95**, 237401 (2005).
[2] A. Ishikawa and T. Tanaka, Opt. Commun. **258**, pp. 300-305 (2006).
[3] A. Ishikawa, T. Tanaka, and S. Kawata, J. Opt. Soc. Am. B **24**, 3, pp. 510-515 (2007).

Magnetic assembly of three-dimensional metamaterials

Presentation preference: I
(O for oral, P for poster, I if invited)

Section preference: 5
(choose from 1 to 7 or type in you suggested subject)

Corresponding author:

Takuo Tanaka

RIKEN Metamaterials Laboratory
2-1 Hirosawa, Wako, Saitama

351-0198

JAPAN

Phone: +81-48-467-9341
Fax: +81-48-467-9441
E-mail: t-tanaka@riken.jp