Giant microwave and optical gyrotropy in bilayered chiral metamaterials

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Abstract: We report on a novel type of artificial material, which exhibits a very strong gyrotropy in the microwave and optical part of the spectrum, the bilayered chiral metamaterial. The specific rotary power of the optical metamaterial exceeds 600°/mm.

The recent explosive increase in interest in gyrotropic media is driven by an opportunity for the development of negative index metamaterials, where simultaneous electric and magnetic responses of gyrotropic structures are required to achieve negative refraction. However, naturally available gyrotropic materials showing negative refraction are not yet identified. Sculptured thin films (in the form of helical pillars) have been discussed as possible candidates for achieving strong artificial gyrotropy in the optical part of the spectrum. However, from the metamaterial perspective it would be very desirable if gyrotropy could be achieved by planar patterning with the use of well-established planar nano-technologies, thus making fabrication of optically active nano-structures a practical proposition. Recently it has been shown that electromagnetic-field coupling between two identical mutually twisted *planar* metal patterns creates a true 3D-chiral structure, which displays an exceptionally strong gyrotropic response in the microwave part of the spectrum [1, 2].

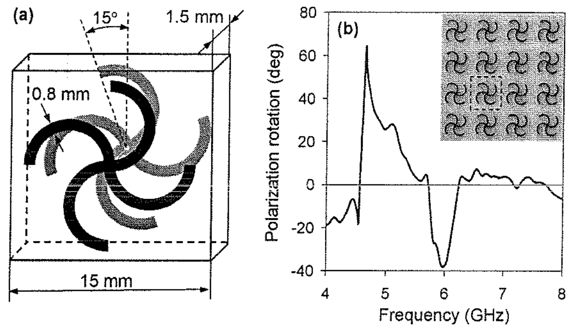

Fig. 1. (a) Helicoidal bilayered structures formed by two mutually twisted planar metal rosettes separated by a dielectric slab. (b) Frequency dispersion of polarization plane rotation exhibited by the bilayered chiral metamaterial. Inset shows a fragment of the actual metamaterial, which is made of copper rosettes etched on a standard PC-board. The dashed box indicates the elementary translation cell.

In this paper we report on bilayered chiral metamaterials designed to operate in the microwave and optical part of the spectrum correspondingly. Those are very promising metamaterials, which exhibit a very strong polarization rotation at the designed frequencies. The microwave planar metamaterial is based on the bilayered chiral rosette structure (see Fig. 1a). The bilayered chiral structures were arranged on a square grid, as shown in the inset to Fig. 1b, with a cell size of 15 mm, which ensures no diffraction at frequencies below 20 GHz. Fig. 1b shows spectral dependence of polarization plane rotation exhibited by the metamaterial in the 4-8 GHz range. In this frequency range the gyrotropy of the chiral metamaterial is resonant and exceptionally strong. Remarkably, the structure, which has thickness of only 1/30 of the wavelength, exhibits polarization plane rotation of more than 40°.

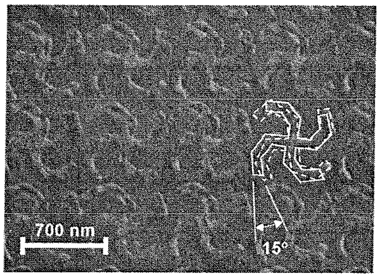

Fig. 2. An SEM micrograph of the bilayered chiral nano-structure

The optical bilayered chiral metamaterial was designed as a scaled-down version of the microwave structure with 700x700 nm^2 unit cell (see Fig. 2). It was fabricated on a thick silica substrate using electron beam lithography and consists of two 50 nm thick Al films, which are structured on a nanometer scale and separated by 50 nm thick dielectric layer. The results of our preliminary measurements in the region of low transmission losses, namely at 660 nm, indicate that the polarization rotation in the zero diffraction order approaches 0.1°, which corresponds to optical rotary power exceeding 600°/mm. More importantly, the nano-structure is expected to rotate even stronger close to the resonant wavelength, where transmission losses are still tolerable. More experiments are underway to verify this prediction.

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[2] A. V. Rogacheva, V. A. Fedotov, A. S. Schwanecke and N. I. Zheludev, Phys. Rev. Lett., in press (2006); arXiv:physics/0604105