Manipulation of circular polarization in a three-dimensional chiral photonic crystal

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Optical activity, which consists of optical rotation and circular dichroism in the basis of the circular polarization, can occur when light passes through a structure without mirror and spatial inversion symmetry, such as helices or chiral molecules. Artificial optically active photonic media are effective tools for manipulating the polarization of photons, which could be useful in several applications including spin-photon interfaces in quantum information processing [1]. Quasi-two-dimensional chiral systems made from metals, dielectrics, or semiconductors exhibit starkly modified electric fields at the material interface, and show large degrees of optical rotation [2]. Three-dimensional (3D) helical structures are expected to further enhance the optical activity, although their fabrication at the optical wavelength scale is still challenging, especially for semiconductor materials. So far, such 3D helical structures have been realized using, for instance, a liquid crystal [3], a polymer [4], and a metamaterial [5] and studied only in terms of the circular dichroism.

In this study, we demonstrate for the first time a GaAs-based 3D chiral photonic crystal based on a rotationally-stacked woodpile structure, and successfully manipulate the circular polarization using both kinds of optical activity. The structure of the sample belonging to a spatial group with 4_1 screw operation was fabricated by a micro-manipulation technique [6] (see Fig.1).

We characterized both the optical rotation and the circular dichroism by measuring the polarization of laser light transmitted along the helical axis. Figure 2 shows the wavelength dependences of polarization rotation angles and of ellipticities for linearly polarized light after transmission. Both sets of experimental data show good agreement with finite-difference time-domain calculation results, and suggest large optical activity in our structure. Further experiments on input azimuth angular dependences of the polarization rotation angle resulted in sinusoidal oscillations of output polarization rotation angle, together with some offset. This offset reaches -45° at 1300nm, demonstrating a large genuine optical rotation angle [2]. A reciprocal optical activity was confirmed in the same structure by illuminating the laser light from the backside, further validating the manifestation of the large optical activity.

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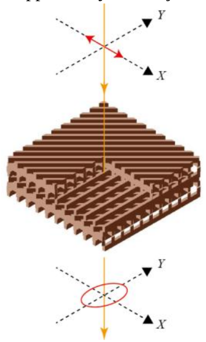

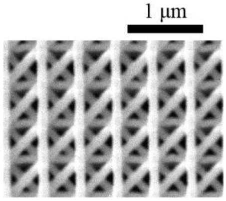

Fig.1: Schematic (left) and scanning electron micro-graph (right) image of the 3D chiral photonic crystal structure.

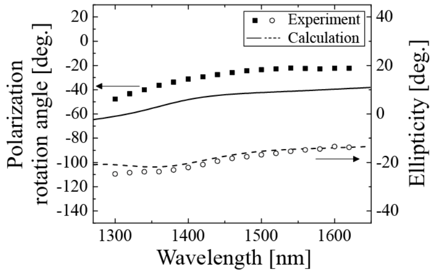

Fig.2: Wavelength dependence of optical activity in the structure shown in Fig.1.