Optical Activities of Nanoscale Planar Spiral Nanotrenches in Titanium Films

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Considerable recent interest has been inspired by the giant optical activities of planar metallic chiral nanostructures which promise practical applications such as miniaturized optical devices for polarization conversion and wavelength filtering. In this paper, we present our experimental and numerical studies of optical transmission through spiral nanotrenches in Ti films. Titanium films of 100nm in thickness were deposited on fused quartz substrates using e-beam evaporation, and then nanotrenches of Archimedean spirals were milled in these Ti films using focused Ga ion beam at ion beam energy of 30keV and a beam current of 50pA. Two different types of Archimedean spiral nano-trenches were engraved in the Ti films: one with 7 periods and the other with only one period with different radial periods (310 nm and 370 nm).

To measure the optical transmission through these nanotrenches, a collimated circularly polarized white light beam is shined perpendicularly on the sample, and the transmitted light is collected with a 40× objective and coupled to an imaging spectrograph. Transmission optical microscopic pictures of 7-period spiral nanotrenches show that the transmission for left-handed and right-handed circularly polarized (LCP and RCP) illumination match with each other, namely, no optical activities (Fig. 2a-b). The transmission peaks at the surface plasmon resonance wavelength (500 nm for structures with 370 nm radial period, Fig. 3a). In contrast, up to 5 percent difference can be observed in transmission spectra for LCP and RCP light for the single one-period spiral nanotrenches (Fig. 2c-d, 3b), indicating a giant optical activity for only 100 nm thick film. Interestingly, the optical activities can be boosted for the 1-period spiral trenches by arranging them into a periodic array of square lattice, and the transmission spectra difference between LCP light and RCP light can reach 20 percent, with peak wavelengths right at the array period.

To gain insights on the underlying physical mechanisms, numerical simulations based on finite time domain method are performed. The transmission spectra from our simulation agree qualitatively with the experimentally measured spectra (Fig. 3c-d). Furthermore, additional calculations of local field distributions near the metal-air interface suggest that two basic conditions should be satisfied to generate optical acvitities: (1) the near field distribution should be enantiomerically sensitive, or the near field distribution should be different for LCP and RCP incident light; (2) the near field should be scattered anisotropically. For 7-period spiral nanotrenches, the second condition is not satisfied. More detailed discussions will be presented at the conference.

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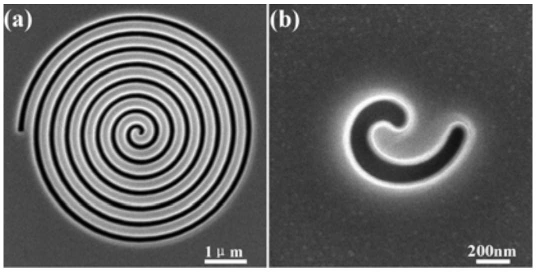

Fig. 1. (a) An SEM image of the 7 period spiral nanotrenches with 370nm radial period and 120nm trench width; (b) An SEM image of the 1 period spiral nanotrench with 370nm radial period and 120nm trench width.

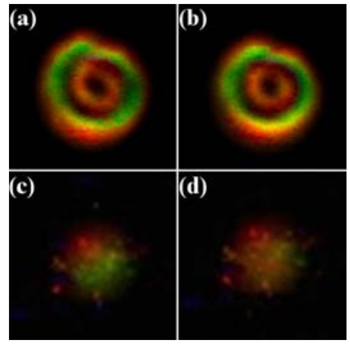

Fig. 2. Optical images of the transmitted light through spiral nanotrenches under left-handed circularly polarized (LCP) and right-handed circularly polarized (RCP) illumination. (a) LCP for 7 period spiral nanotrench; (b) RCP for 7 period spiral nanotrench; (c)LCP for the 1 period spiral nanotrench; (d) RCP for the 1 period spiral nanotrench.

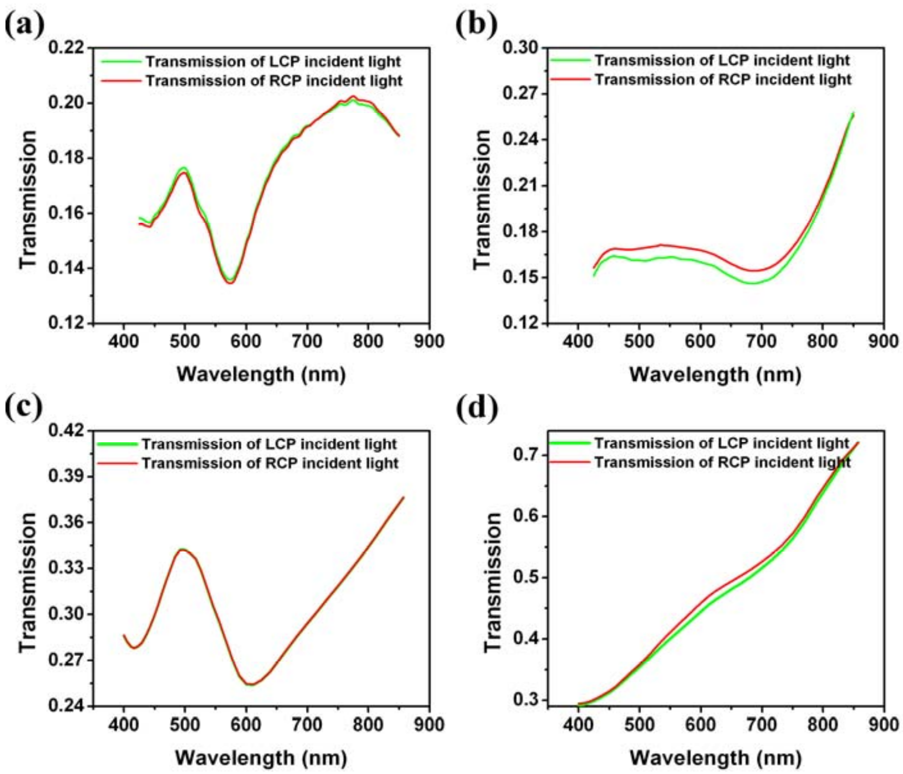

Fig. 3. Measured and simulated transmission spectra of the 7-period spiral nanotrenches with 370nm radial period and 120nm trench width (a, c) and for the 1-period spiral nanotrenches with 370nm radial period and 120nm trench width (b, d).