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Supporting Online Material for

Gold Helix Photonic Metamaterial as Broadband Circular Polarizer

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Numerical methods:

The numerical calculations shown in this Report have been performed using a commercially available finite-integration technique (FIT) software package (CST Microwave Studio). Several examples have also been checked using a finite-difference time-domain program (Lumerical Solutions Inc.). For the calculations using the Drude free-electron model for the dielectric function of gold, we have taken the plasma frequency $\omega_{pl} = 1.37 \times 10^{16}$ s^{-1} and the collision frequency $\omega_{col} = 1.2 \times 10^{14}$ s^{-1}. The refractive index of the glass substrate is $n = 1.5$, the thin ITO film is neglected. The actual calculations are performed using the two orthogonal linear polarizations of light. It is then straightforward to translate these results into the transmittance for circular polarization of the incident light.

Experimental methods:

The polymer templates are made via standard direct laser writing (DLW) (Nanoscribe GmbH) into a positive-tone resist (AZ 9260 from MicroChemicals GmbH). For the gold electroplating we use a sulfite-based gold electrolyte containing sodium disulfitoaurate(I) ($Na_3[Au(SO_3)_2]$) as gold species, sodium sulfite (Na_2SO_3) and ethylenediamine ($C_2H_4(NH_2)_2$) for stabilization, and ethylenediaminetetraacetic acid disodium salt dihydrate Na_2EDTA ($C_{10}H_{16}N_2Na_2O_8 \times 2H_2O$). The pH value is 8.5. The cathode is the thin indium-tin oxide (ITO) layer described above, with a sheet resistance of 500 Ω. The anode is a platinized titanium mesh. During growth, the temperature of the electrolyte is actively stabilized to 57°C using a thermometer coupled to a hot plate. For the structures shown in Fig. 3, we have used a constant electrical current of 0.6 µA (corresponding to a current density of 3 mA/cm^2), leading to a total growth time of about 11 minutes. Finally, to remove the polymer, the composite samples are exposed to air plasma for 14 hours (PlasmaPrep5 by Gala Instrumente GmbH).

For the optical experiments, we have used a commercial Fourier-transform microscope spectrometer (Bruker Tensor 27 with Bruker Hyperion 1000). A home-made compact holder encompasses a linear CaF_2 "High Extinction Ratio" holographic polarizer and a super-achromatic quarter-wave plate that can be rotated from the outside of the microscope. This custom-made MgF_2 based quarter-wave plate (Bernhard Halle Nachfl.) has a phase error below only ± 14% in the entire spectral range from 2.5 to 7.0 µm wavelength of light. This modification allows for conveniently adjusting left and right-handed circular

polarization of the incident light. Furthermore, we have modified the reflective ×36 Cassegrain optics with NA = 0.5 by introducing a small diaphragm such that the full opening angle of the light incident onto the sample is reduced to about 5 degrees. By tilting the sample we achieve actual normal incidence of light onto the sample. Normalization of all transmittance spectra shown is with respect to the transmittance of the glass substrate and the ITO layer.