Electronic Supplementary Material (ESI) for Nanoscale.

Broadband Circular Polarizers constructed by Helix-like Chiral Metamaterials

Ruonan Ji,[a,b,c], Shao-Wei Wang,[a,b,†] Xingxing Liu,[a,b,c] Xiaoshuang Chen [a,b] and Wei Lu [a,b]

[a] National Laboratory for Infrared Physics, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai 200083, China.

[b] Shanghai engineering research center of energy-saving coatings, Shanghai 200083, China.

[c] University of Chinese Academy of Sciences, Beijing 100049, China.

[†]Corresponding author: wangshw@mail.sitp.ac.cn

Supplementary Information

The hybridization model for chiral plasmonic arc pairs is shown in Fig. S1(a), LCP incident light first impinges on the upper arcs, then rotates counter-clockwise and anti-aligns with the lower arc. Therefore, due to the symmetry of the structure, LCP excites a bonding mode with same current directions of the two layers. Similarly, RCP rotates clockwise and excites an anti-bonding mode with a higher energy level.

The surface currents induced by the corresponding polarized incident waves at resonant wavelengths marked in Fig. 3(a) of the bi-layer helix-like metamaterials is shown in Fig.S1(b). At λ_{RH1}=1.94μm, the directions of induced surface currents are different at the upper part and lower part, and the current node occurs in the middle of the structure, which is quite similar with the anti-bonding mode in twisted arcs. And at λ_{LH2}=3.59μm, the directions of induced surface current are all same in the whole structure, corresponding to the bonding mode in the twisted arcs. While for the other two resonant dips at λ_{LH1}=1.73μm and λ_{RH2}=3.91μm, the resonant modes are more complex and with more than one current nodes.

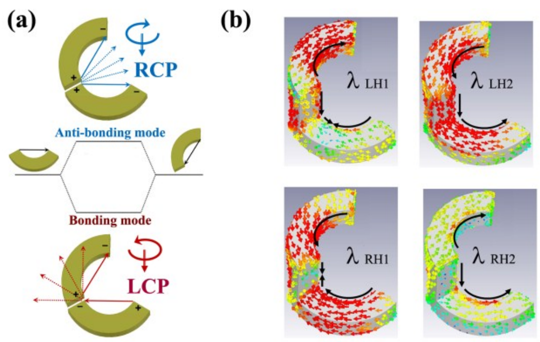

Fig. S1 (a) Hybridization model for chiral plasmonic arcs pairs. (b) Induced Surface currents at resonant wavelengths marked in Fig. 3(a) of a bi-layer helix-like metamaterial. The geometric parameters as follows, *t*=200 nm, *r*=500nm, *w*=200 nm, *d*=280 nm, *ϑ*=120°, *β*=20° and *p*=1200 nm.

Fig. S2 illustrates the influence of with and without substrate and spacers. In Fig.S2 (a), calcium fluoride (CaF_2) is used as the material of substrate (half-space geometry) and spacers. The permittivity index of calcium fluoride is given by Li etc[1]. After the dielectric spacers and substrate are added, the operation band obviously shifts to longer wavelength with a broader bandwidth. While as the former optimal match is destroyed as the effective refractive index changes, the bianisotropic optical response slightly reduces. The transmittance of LCP is increased while the transmittance of RCP is reduced slightly.

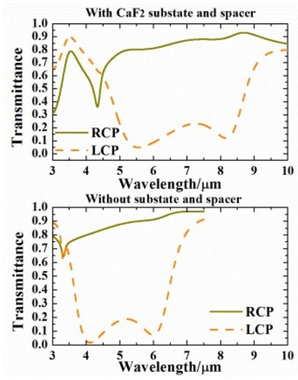

Fig. S2 Transmittance curves of proposed four-layered helix-like metamaterial with calcium fluoride substrate and spacers(a) and without substrate and spacers(b). The geometric parameters are as Fig. S1.

The simulation results for transmittance curves of calcium fluoride substrate with different thicknesses are presented in Fig. S3. The results are obtained with commercial coating design software (CODE). As shown in Fig. S3, with the thickness increase of calcium fluoride, the transmittance curves are quite similar, except for the number increase of interference peaks.

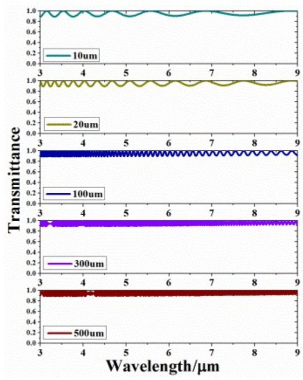

Fig. S3 Transmittance curves of calcium fluoride substrate with different thickness.

Then, the transmittance and extinction ratio curves of proposed metamaterial with different substrate thicknesses are studied. As presented in Fig. S4, when the thickness of substrate is 0.2μm, no interference peaks are observed in the transmittance curves as the thickness of substrate is much smaller than the incident wavelength. The number of interference peaks is increased and the transmittance values fluctuate around the no interference case when the thickness of substrate increases. Similar phenomena are observed in the curves of extinction ratio. The thickness of substrate doesn't influence the overall performance of the device. There exists only a slightly fluctuation of extinction ratio at some certain wavelengths resulted from the interference.

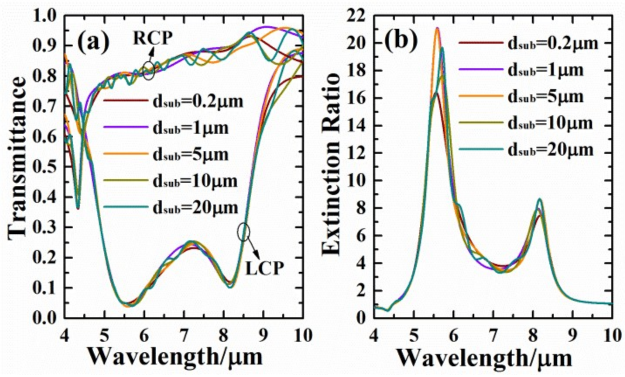

Fig. S4 Transmittance and extinction ratio curves of proposed metamaterial with different thicknesses of substrate. Calcium fluoride is used as the material of substrate and spacers, and the thickness of the substrate is d_{sub}=20μm. Structure parameters are as follows, *t*=140 nm, *r*=450nm, *w*=120 nm, *d*=460 nm, *ϑ*=120°, *β*=20° and *p*=1200 nm.

References

1. H. H. Li, *Journal of Physical & Chemical Reference Data*, 1980, **9**, 161-289.