Supplemental Document

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Tunable strong circular dichroism at large-angle oblique incidence via plasmonic bound states in the continuum: supplement

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Supplementary Note 1: Fabrication Procedure of the Metasurface

The designed metasurface can be fabricated using established nanofabrication techniques, particularly as the fabrication of metal-insulator-metal (MIM) structures has been demonstrated in previous studies [S1]. As shown in Fig. S1, the procedure begins with depositing a silver (Ag) base layer onto a quartz substrate via electron beam deposition (EBD), followed by depositing a silica (SiO_2) spacer layer using inductively coupled plasma chemical vapor deposition (ICP-CVD). A photoresist film is then spin-coated onto the spacer layer, patterned with periodic nanostructures through electron beam lithography (EBL) and development. Finally, Ag and SiO_2 are sequentially deposited via EBD and ICP-CVD respectively, after which the residual photoresist is removed by lift-off using an organic solvent (e.g., acetone), resulting in the completed MIM array.

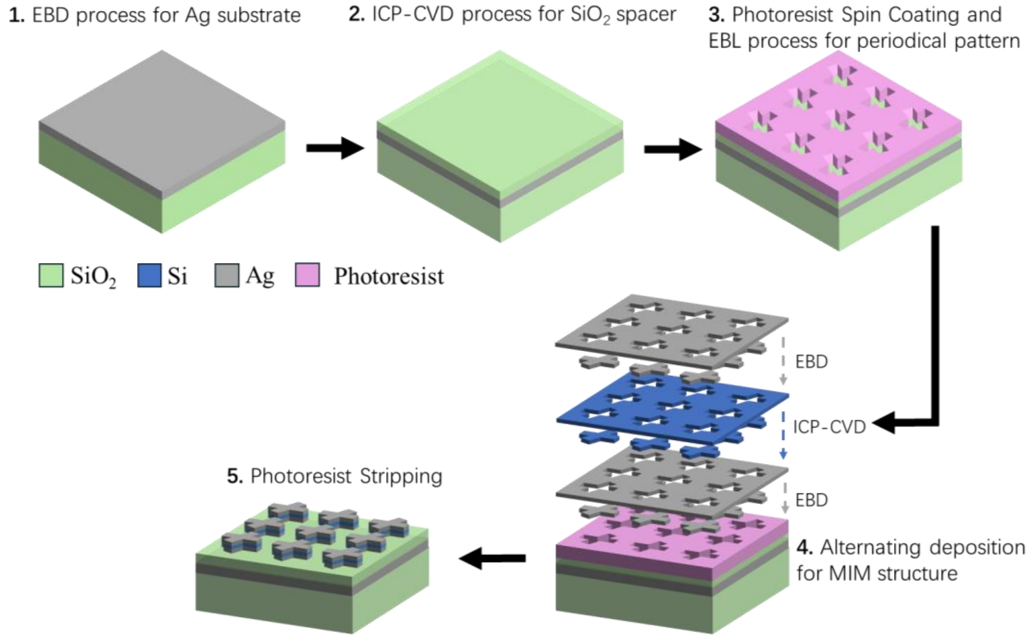

Fig. S1. Fabrication process flow of the designed metasurface. Step 1: Deposit a 100 nm-thick Ag base layer on a SiO_2 substrate via EBD; Step 2: Grow a SiO_2 spacer layer on the Ag base using ICP-CVD; Step 3: Spin-coat a photoresist layer on the spacer. Then, pattern periodic unit cells in the photoresist via EBL and development; Step 4: Alternately deposit Ag (by EBD) and Si (by ICP-CVD) to form MIM nanostructures; Step 5: Remove residual photoresist using organic solvents (e.g., acetone).

Supplementary Note 2: Influence Caused by Fabrication Deviations

The most common issue encountered when fabricating MIM structures using multiple deposition steps is that the upper layer dimensions become slightly smaller than the lower layer dimensions. Therefore, in our simulations, we investigated the impact of such pyramid-like structural deformation on the designed metasurface. As shown in Figure S2(a), when the deformation is mild, the top-layer dimensions reduced by 10% relative to the bottom layer., i.e., $L_t = 0.9L$ and $W_t = 0.9W$. As illustrated in Figure S2(b), the resonant wavelength undergoes a blue shift when structural deformation occurs compared to the ideal case. Concurrently, the resonance amplitude exhibits attenuation, with the reflection minimum (R_{rr}) increasing from ~0 to ~0.23. Such changes weaken the circular dichroism (CD) generated by the resonance. Figure S2(c) presents CD results for varying cross-arm angles α. It demonstrates that even under deformation, the optimal angle for achieving strong CD remains near α = 70˚. This analysis indicates that the designed metasurface exhibits a certain degree of sensitivity to pyramid-like fabrication deformations, necessitating control of dimensional deviations within 10%.

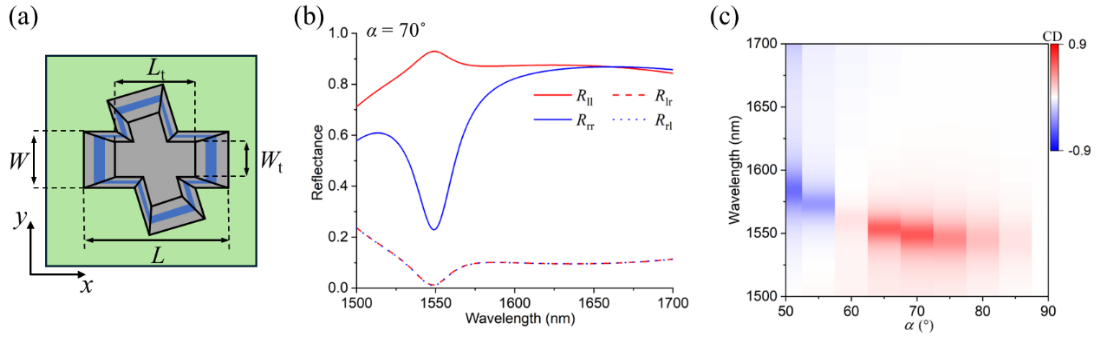

Fig. S2. Simulation results of metasurface deformation effects. (a) Schematic of pyramid-type structural deformation. (b) Simulated reflection spectra at 10% deformation with an incident angle of 75˚. (c) CD spectra versus cross-arm angle α at 10% deformation.

References

S1. A. Das, C. Mao2, S. Cho, K. Kim, and W. Park, "Over 1000-fold enhancement of upconversion luminescence using water-dispersible metal-insulator-metal nanostructures." Nat. Commun. **9**, 4828 (2018).