Uncovering the Origin of Chirality from Plasmonic Nanoparticle/Cellulose Nanocrystal Composite Films

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Introduction

Chirality, a widely existing phenomenon in nature, is used to describe any object that cannot be superimposed on its mirror image. In the case of plasmonic chirality, various plasmonic NPs were incorporated into the CNC films to produce plasmonic chirality, and a specific CD line shape was observed. Significant dip were observed in the CD spectra of composite films.

However, the mechanism of forming these specific CD line shapes and the intrinsic relationship between the CD line shapes and plasmonic–photonic systems remains unclear.

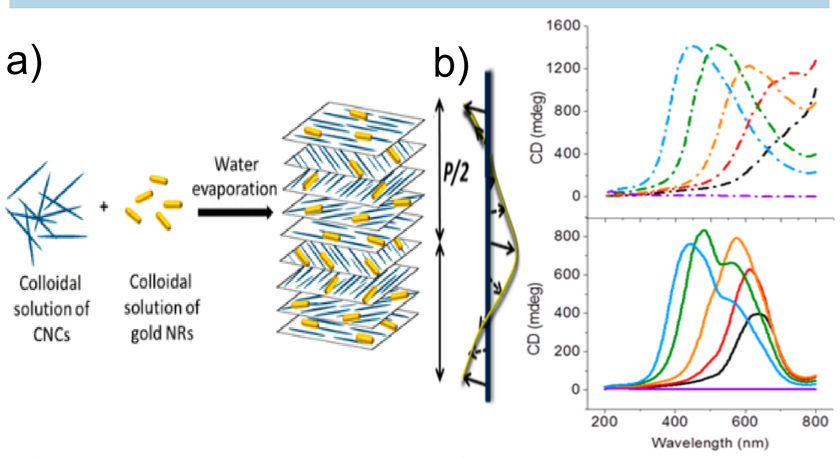


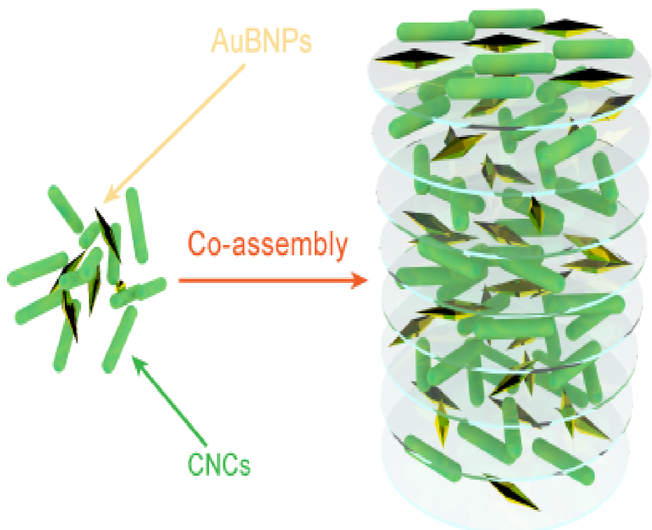
Fig.a CNC/Nanoparticles composite film.

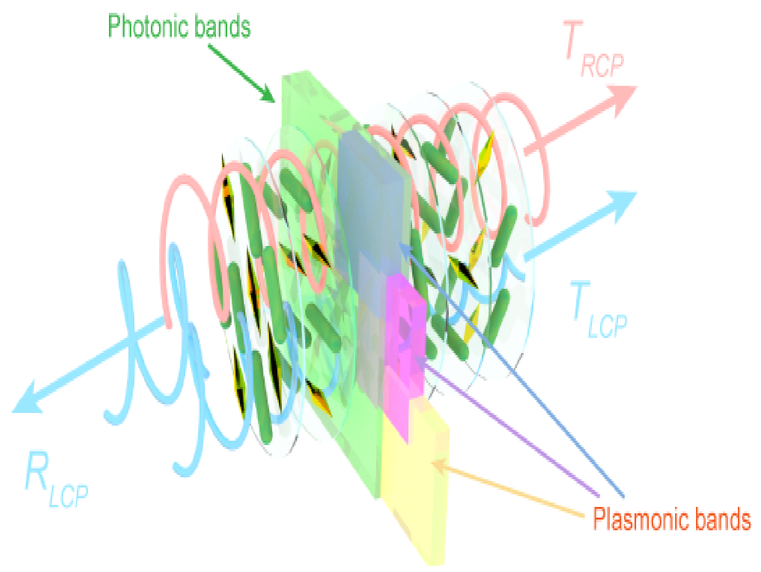
Fig.b CD signals of pure/composited film with different helical pitchs

Motivations

We notice that SP-CD (surface-plasmon mediated CD) signals was always existed in PBGs (photonic band gaps). So our objective was clear :

- Figure out the relationship between plasmonic-photonic coupling and SP-CD.
- Provide a numerical method for solving multiple scattering problems of coupled systems.





Methods

To numerically analyze the unique chiral responses, we further developed a noval transfer-matrix method to study complex collective plasmonic scattering by chiral arrangement in the cholesteric structure of CNCs.

Transfer Matrix of composite system

$$Q = D_N^{-1} D_{N-1} P_{N-1} T \dots D_{n+1}^{-1} D_n P_n T \dots D_1^{-1} D_0 P_0 T$$

P → Propagation matrix in chiral background.

T → Effective transfer matrix of nanoparticle with specific orientation.

D → Boundary Matrix.

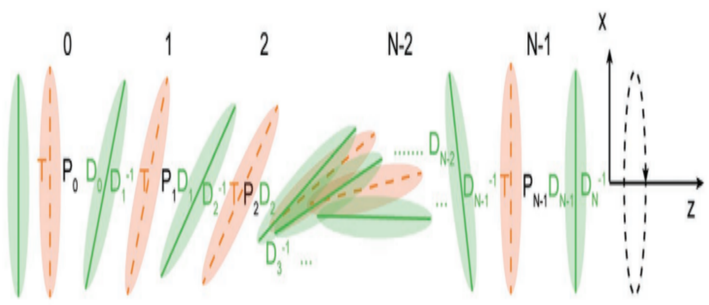


Fig.c Schematic of a left-handed chiral composited structure consisting of N layers of plasmonic materials embedded chiral photonic crystals.

Results

We successfully captured the characteristic SP-CD signal into/out of PBGs on both simulations, experiments and calculations.

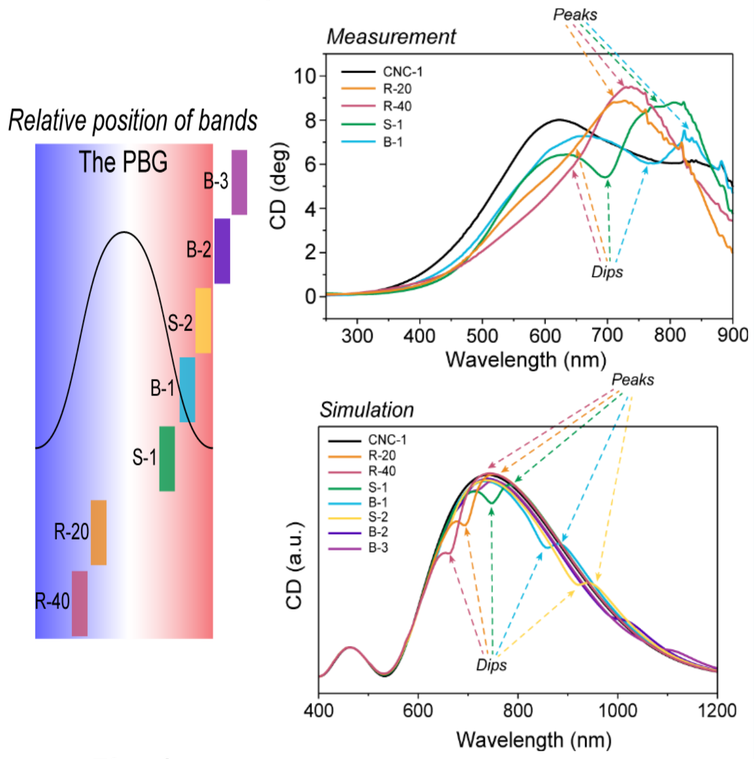


Fig.d SP-CD signals by Sim.& Exp.

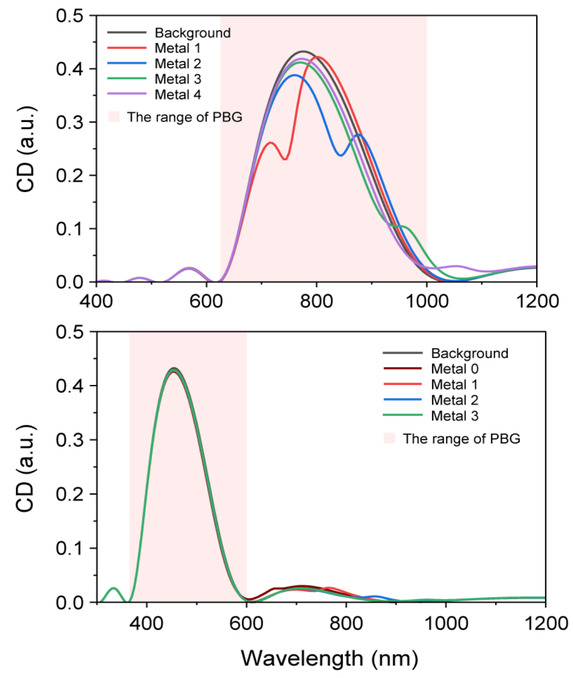


Fig.e SP-CD signals into/out of PBGs, calculated by transfer matrix method

Conclusions

This study successfully addresses the problem of how to explain the generation of characteristic SP-CD signals :

- This plasmonic chirality, determined by the coupling states, is proven to originate from a multiple scattering combination of plasmonic NPs under a chiral excitation field.
- A novel transfer-matrix method was established to perform numerical analysis of this complex multiple scattering efficiently.

(S.X. Zhao [†], H. Zhu[†] , J.C. Lu, L.C. Zhao, L. Zhou & L.M. Gao **Adv. Funct. Mater. 32, 2201927 (2022)**)

References

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