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Supporting information:

1D-2D composite perovskite films with self-assembled chiral structure for non-reciprocal circularly polarized emission modulation

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Chemicals

Lead (II) bromide ($PbBr_2$, 99%), methylammonium bromide (MABr, 99%), dimethyl sulfoxide (DMSO, 99.8%), toluene (TOL, 99%) N,N-Dimethylformamide(DMF, 99.8%) *S*- and *R*-*α*-methylbenzenemethanamine (*S*- and *R*-MBA, 99%), hydrobromic acid (HBr, 40wt%, in H_2O), oleic acid (OA, 90%), oleylamine (OAM, 90%), 1-Octadecene (ODE, 90%) and chlorobenzene (CB, anhydrous, 99.8%) were purchased from Aladdin.

Synthesis of *S*-MBABr and *R*-MBABr

0.25 mL (2 mmoL) of organic amine (*S*-MBA or *R*-MBA) was added to a reaction bottle placed in an ice bath at 0°C. Next, 0.27 mL (2.4 mmoL) of HBr were added drop by drop to the organic amine, and the mixture was stirred magnetically for 4 hours to ensure complete reaction. After the reaction was completed, 20 mL ethanol was added, and a rotary evaporator was used to remove most of the solvent. The process was repeated for 3 times. The resulting crude solid product was recrystallized using isopropyl alcohol or n-hexane, washed with anhydrous ether and filtered to remove excess HBr. The purification step was repeated 2-3 times until the filtrate was colorless. Finally, the product was placed in a vacuum drying oven and dried at 50°C for 12 hours.

Synthesis of perovskite quantum dots

The perovskite quantum dots were synthesized by the ligand-assisted reprecipitation method. First, 5 mL of anhydrous TOL was measured and placed in a 25-ml three-necked flask and heated to 60°C by an oil bath. Then the precursor solution was prepared by weighing 0.16 mmol of MABr and 0.2 mmol of $PbBr_2$ in a vial, followed by the addition of 5 mL of anhydrous DMF, 50 μL of OAM, 0.5 mL of OA. The mixture was stirred at room temperature under ambient atmosphere until complete dissolution. Under vigorous stirring conditions in the three-necked flask, 250 μL of this precursor solution was rapidly injected into the flask using a 1 mL syringe, resulting in an immediate color change to yellow-green. After 5 minutes of stirring, the solution was transferred to centrifuge tubes and centrifuged at 7000 rpm for 5 minutes. The collected supernatant was thoroughly mixed with methyl acetate, followed by centrifugation at 12500 rpm for 5 minutes. The resulting solid precipitate was collected and dispersed in 200 μL of n-hexane. $PbCl_2$ (51 mg, 0.185 mmol) or PbI_2 (85 mg, 0.185 mmol) was added to a 100 mL three-necked round-bottom flask, followed by 1 mL of OA, 0.6 mL of OAM, and 5 mL of ODE. The solution was heated to 120°C under vacuum and stirred for 5 minutes until the $PbCl_2$ or PbI_2 salt was completely dissolved. $PbCl_2$ and PbI_2 precursor solution was cooled to room temperature, which was respectively added to the green $MAPbBr_3$ perovskite quantum dots solution drop by drop, adjusting the light to blue or red. The equivalent molecular formulas of different kinds of quantum dot were: blue, $MAPbBr_{1.2}Cl_{1.8}$; green, $MAPbBr_3$; red, $MAPbBr_{1.2}I_{1.8}$.

Preparation of 2D perovskite films

The 2D perovskite film precursor solutions were prepared by mixing $PbBr_2$, chiral ammonium bromide (*S*- or *R*-MBABr) in sulfoxide (DMSO) at a stoichiometric ratio of 1:2. The solution was stirred at 60 °C for 3 h, then cooled to room temperature and filtered through a 0.22 μm filter. Perovskite films were deposited on cleaned ITO glass substrates by spin-coating at 1000 rpm for 10 s and then 4500 rpm (or 3000 rpm, 1500 rpm) for 50 s. Chlorobenzene (CB) as antisolvent was added on the film after 20 s of spinning at 4500 rpm. Then the as fabricated films were annealed at 90 °C for 10 min. All the processes were carried out in a nitrogen-filled glove box.

Preparation of 1D perovskite films with wet treatment

The 2D perovskite prepared in the glove box in nitrogen atmosphere was moved to the temperature and humidity control box in the air environment, and the humidity was maintained at 60%. The product was left to stand for around 30 min until uniform and clear lines were formed on the surface of the film. It is then removed from the temperature and humidity control box for other tests.

Characterization

The UV-vis absorption spectra were recorded on a MAPADA UV-1800PC spectrophotometer. The PL spectra were achieved by a Horiba Fluorolog system (Horiba-F4600) with a Xe lamp as the excitation source. The X-Ray diffraction spectra were measured with the XRD Bruker D8 with Cu Kα (λ = 1.5406 Å) radiation source. Grazing incidence wide-angle X-ray scattering (GIWAXS) pattern were obtained by the beamline 1W1A of the Beijing Synchrotron Radiation Facility (BSRF) with a wavelength of 1.5400 Å and an exposure time of 10 s. The morphology of the perovskite films was characterized by a scanning electron microscopy (Apreo S LoVac) at 5 kV. The circular dichroism spectra were measured by a Jasco J-1700 CD spectrometer. The CPL spectra were measured on a circular polarization fluorescence spectrometer (Jasco CPL-200).

Figure S1 Surface texture of the W-*S*-MBA.

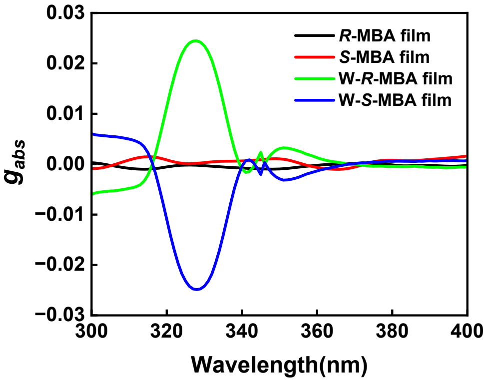

Figure S2 g_{abs} spectra of perovskite films.

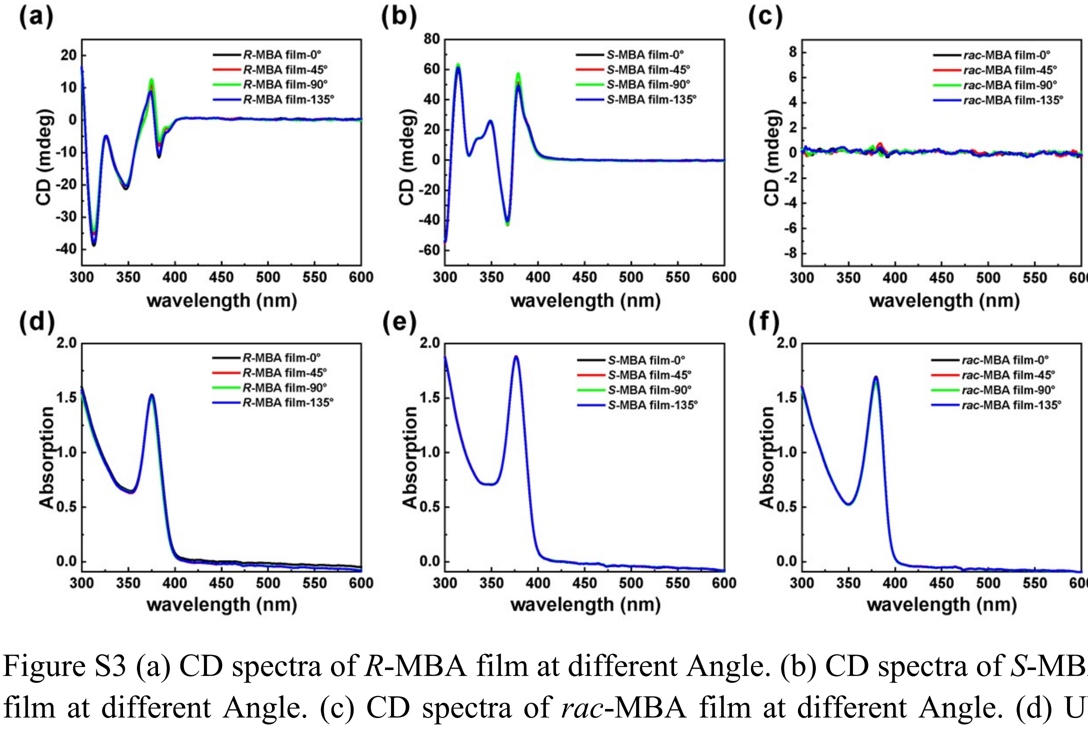

Figure S3 (a) CD spectra of *R*-MBA film at different Angle. (b) CD spectra of *S*-MBA film at different Angle. (c) CD spectra of *rac*-MBA film at different Angle. (d) UV absorption spectra of *R*-MBA film at different Angle. (e) UV absorption spectra of *S*-MBA film at different Angle. (f) UV absorption spectra of *rac*-MBA film at different Angle. The film was rotated on the axis of the optical path.

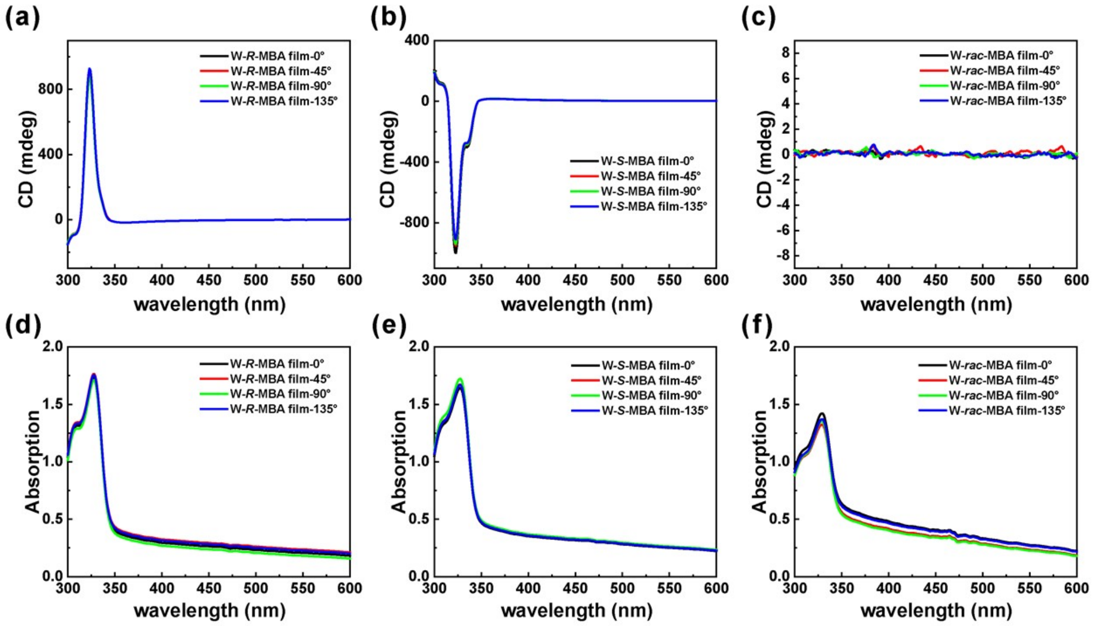

Figure S4 (a) CD spectra of W-*R*-MBA film at different Angle. (b) CD spectra of W-*S*-MBA film at different Angle. (c) CD spectra of W-*rac*-MBA film at different Angle. (d) UV absorption spectra of W-*R*-MBA film at different Angle. (e) UV absorption spectra of W-*S*-MBA film at different Angle. (f) UV absorption spectra of W-*rac*-MBA film at different Angle.

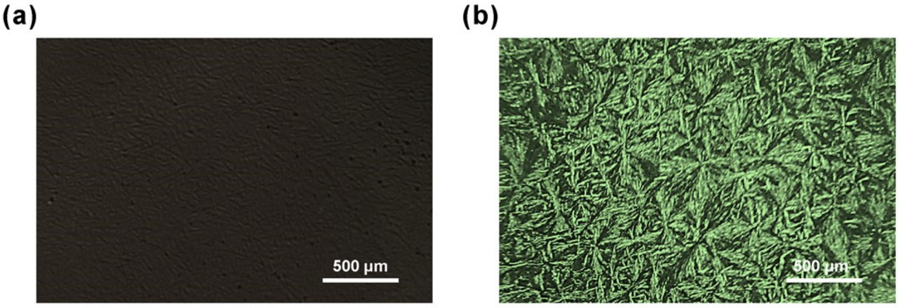

Figure S5 (a) Cross polarized optical microscopy image of *R*-MBA film. (b) Cross polarized optical microscopy image of W-*R*-MBA film.

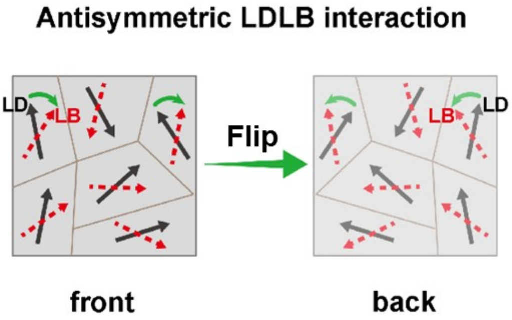

Figure S6 Schematic diagram of the LDLB interaction.

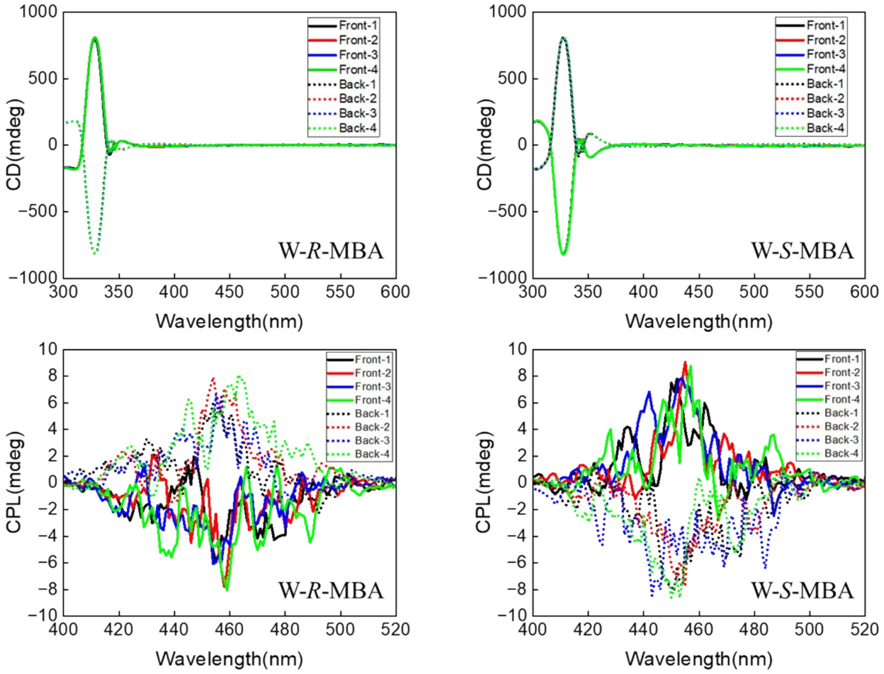

Figure S7. CD and CPL spectra from different positions of W-*R*-MBA and W-*S*-MBA films.

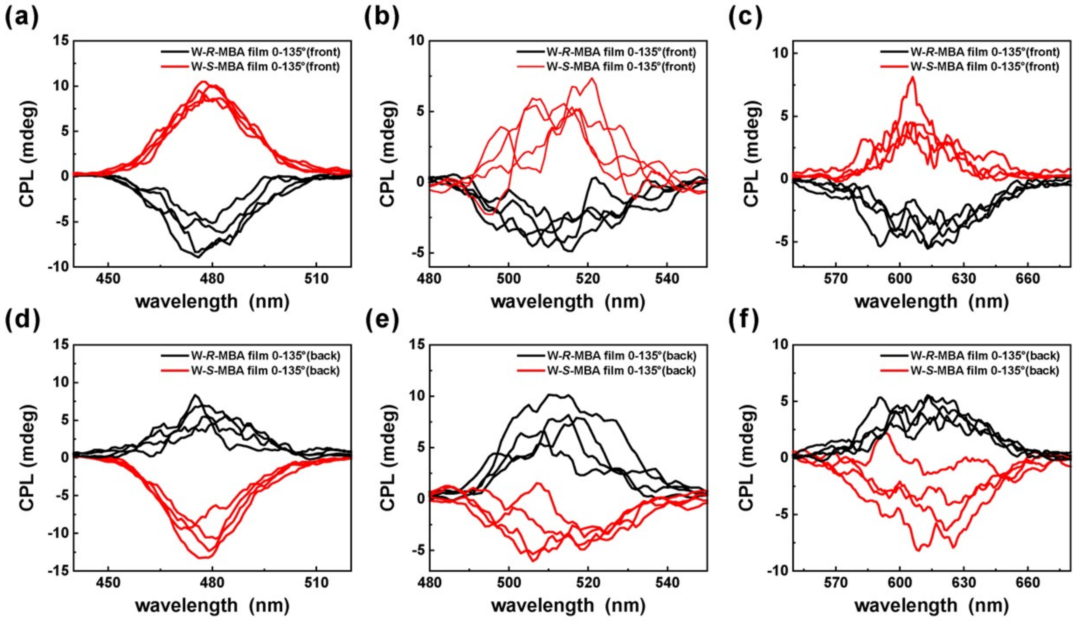

Figure S8 (a-c) CPL spectra of W-*R*-/*S*-MBA film (front) at different Angle with different QDs (475 nm, 512 nm, 608 nm) as light source. (d-f) CPL spectra of W- *R*-/*S*-MBA film (back) at different Angle with different QDs (475 nm, 512 nm, 608 nm) as light source.

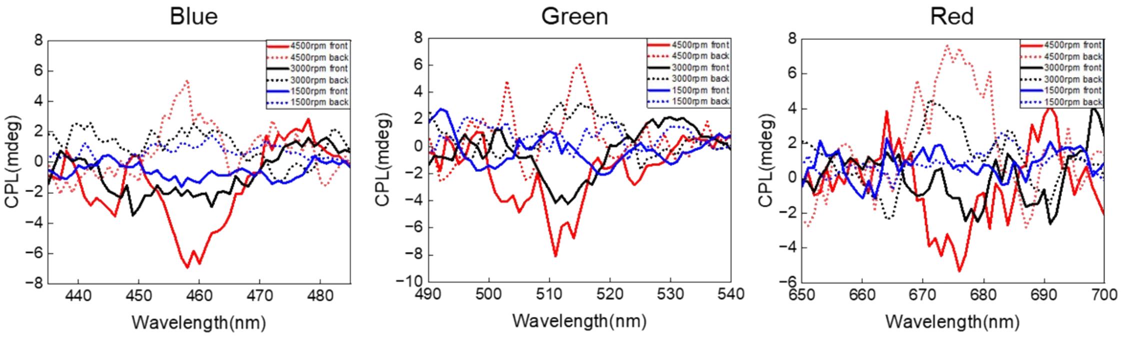

Figure S9. CPL spectra of W-*R*-MBA film with different thickness from the front and the back. The film thicknesses at 4500 rpm, 3000 rpm, and 1500 rpm were approximately 600 nm, 1 μm, and 2 μm, respectively.

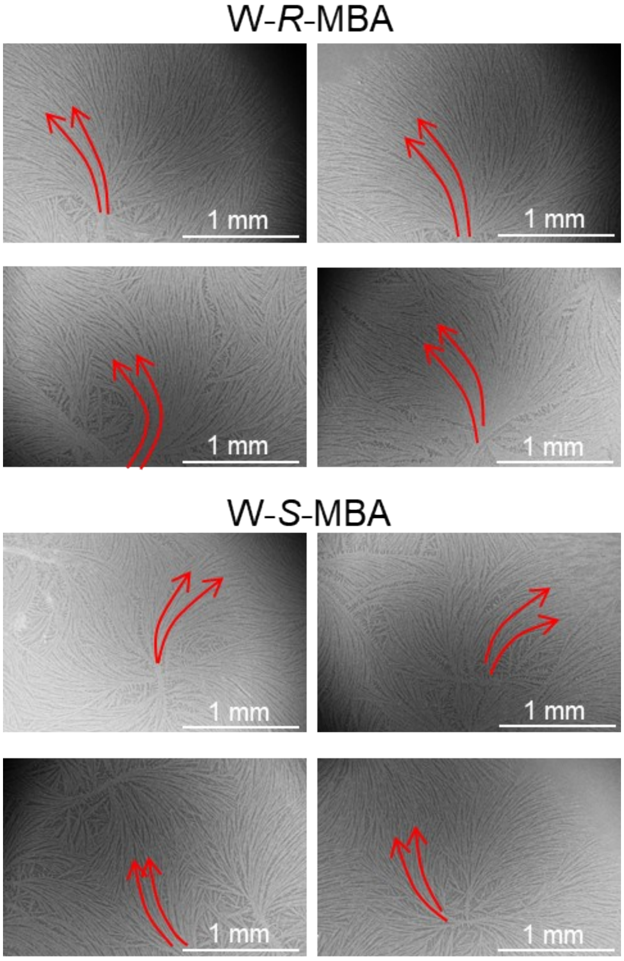

Figure S10 Large-field SEM images at different locations of W-*R*-MBA and W-*S*-MBA.

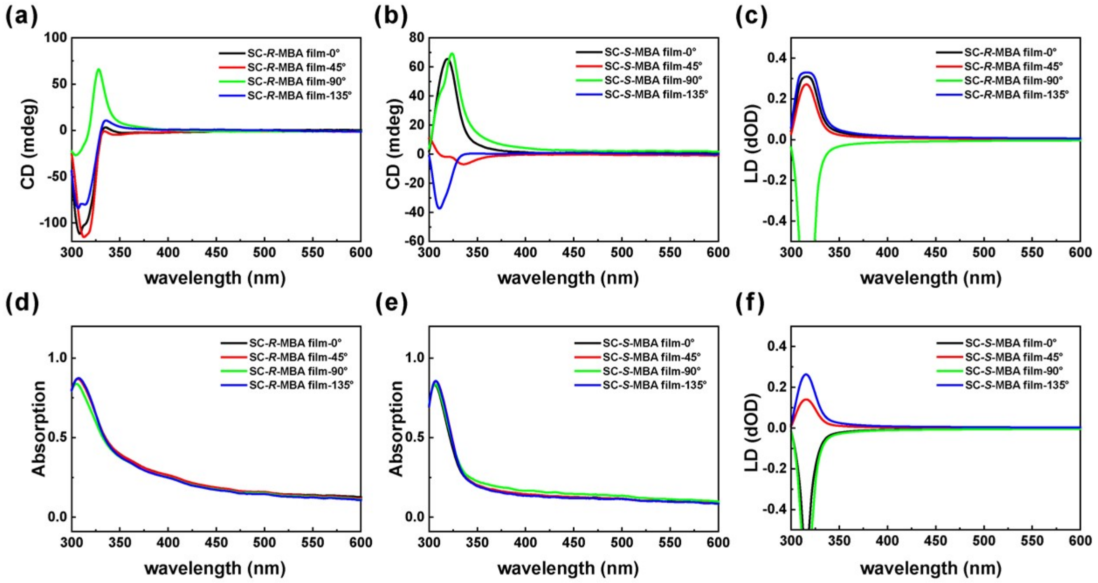

Figure S11 (a) CD spectra of SC-*R*-MBA film at different Angle. (b) CD spectra of SC-*S*-MBA film at different Angle. (c) LD spectra of SC-*R*-MBA film at different Angle. (d) UV absorption spectra of SC-*R*-MBA film at different Angle. (e) UV absorption spectra of SC-*S*-MBA film at different Angle. (f) LD absorption spectra of SC-*S*-MBA film at different Angle.

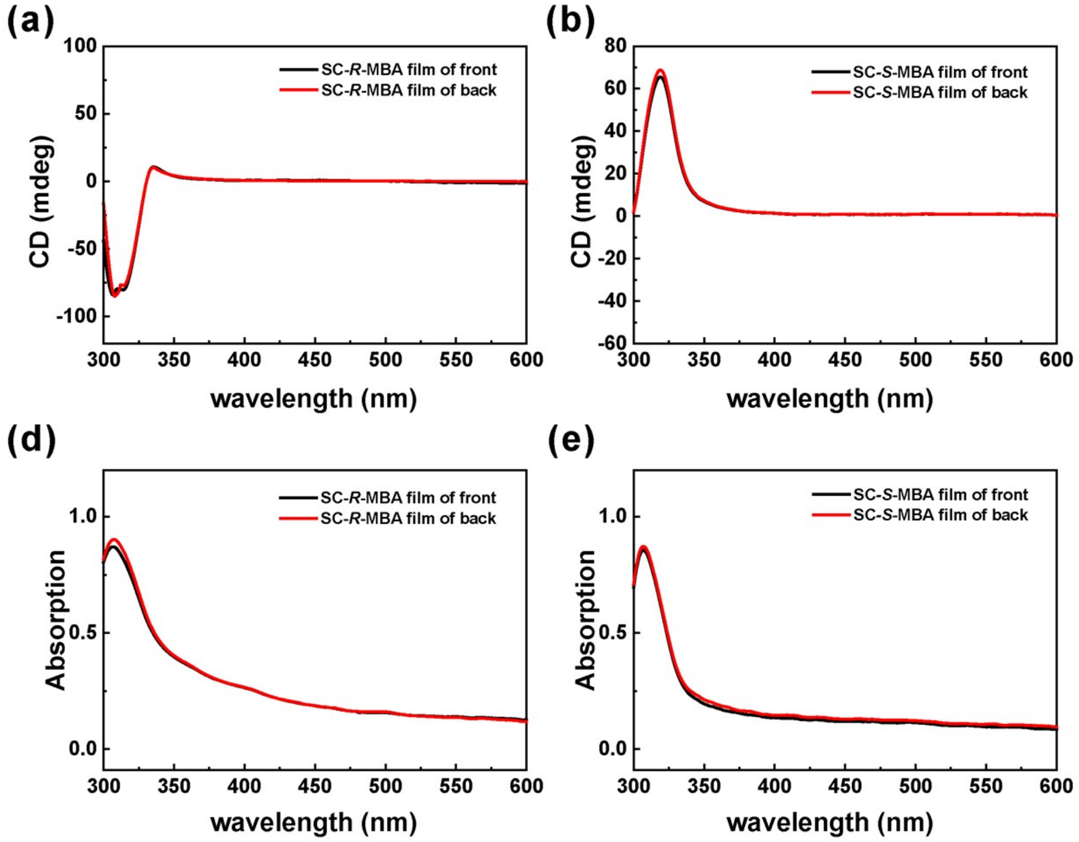

Figure S12 (a) CD spectra of SC-*R*-MBA film of front and back. (b) CD spectra of SC-*S*-MBA film of front and back. (c) UV absorption spectra of SC-*R*-MBA film of front and back. (e) UV absorption spectra of SC-*S*-MBA film of front and back.

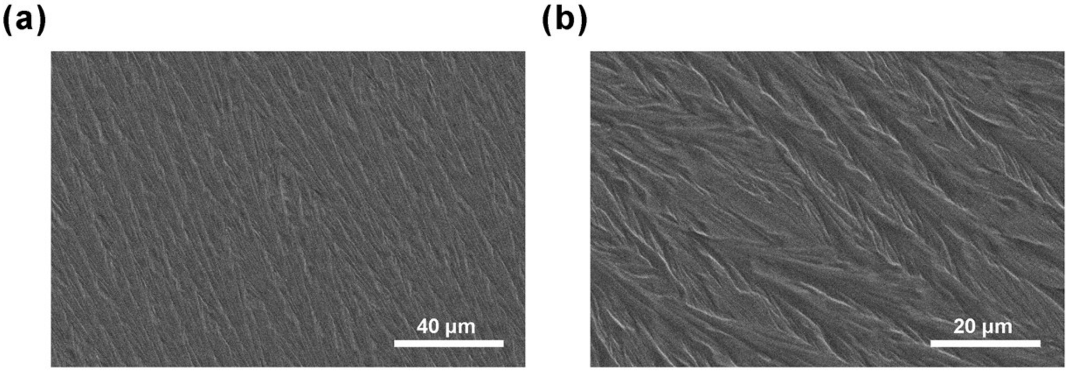

Figure S13 (a) SEM of SC-*R*-MBA film. (b) SEM of SC-*S*-MBA film.

Table S1 g_{lum} values of the CPL.

Wavelength (nm)	Direction	W-*R*-MBA	W-*S*-MBA
475 ($MAPbBr_{1.2}Cl_{1.8}$)	Front	-0.0024	0.0032
475 ($MAPbBr_{1.2}Cl_{1.8}$)	Back	0.0016	-0.0035
512 ($MAPbBr_3$)	Front	-0.00085	0.0012
512 ($MAPbBr_3$)	Back	0.0023	-0.00079
608 ($MAPbBr_{1.2}I_{1.8}$)	Front	-0.0011	0.00099
608 ($MAPbBr_{1.2}I_{1.8}$)	Back	0.0011	-0.0019

Table S2 g_{abs} values of W-*R*-MBA and W-*S*-MBA at different wavelength.

Wavelength (nm)	Direction	W-*R*-MBA	W-*S*-MBA
327	Front	0.024	-0.025
327	Back	-0.025	0.025
475	Front	0.00025	-0.00029
475	Back	-0.00022	0.00024
512	Front	0.00040	-0.00045
512	Back	-0.00050	0.00037
608	Front	0.00043	-0.00027
608	Back	-0.00036	0.00031