

Electronic Supplemental information

Integrating photon up- and down-conversion to produce efficient light-harvesting materials for enhancing natural photosynthesis

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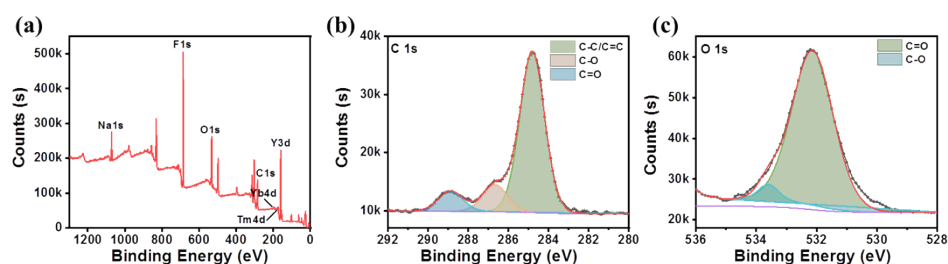


Fig. S1 X-ray photoelectron spectra of UCNPs@PAA. (a) Survey spectrum; (b) High-resolution C 1 s spectrum; (c) High-resolution O 1 s spectrum.

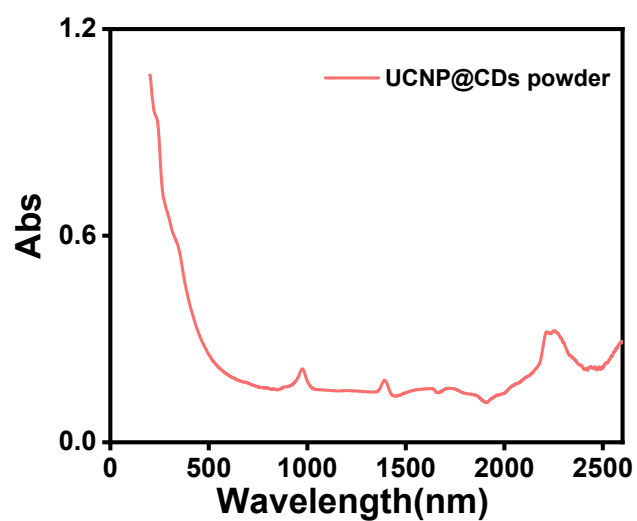


Fig. S2 Absorbance of UCNP@CDs powder.

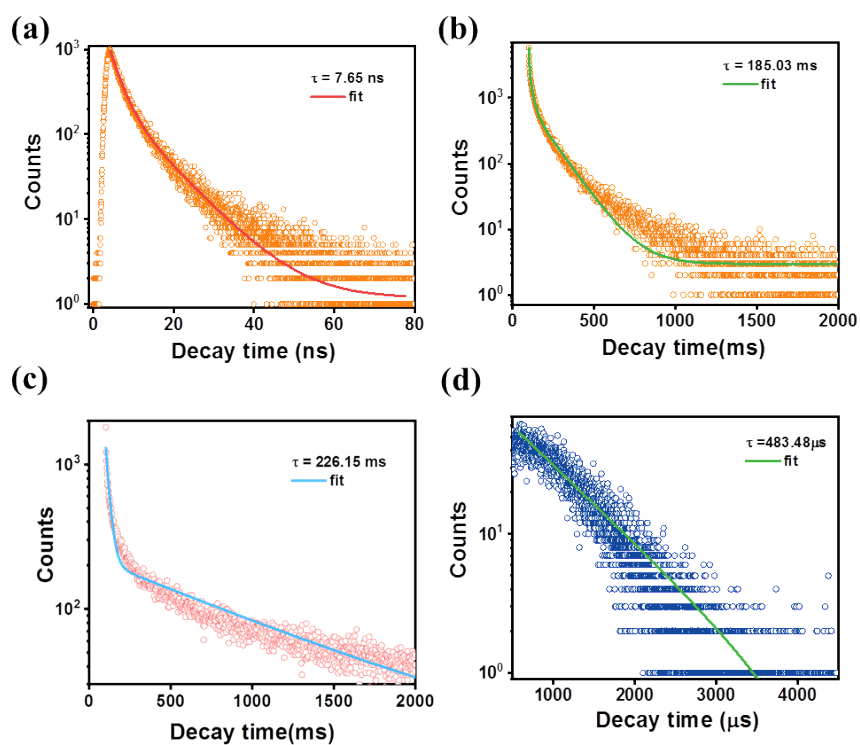


Fig. S3 Decay curves of 3.2% UCNP@CDs/CMC film. (a) Fluorescence decay curves ($\lambda_{ex} = 365 \text{ nm}$); (b) Phosphorescence decay curves in air atmosphere ($\lambda_{ex} = 365 \text{ nm}$); (c) Phosphorescence decay curves in nitrogen atmosphere ($\lambda_{ex} = 365 \text{ nm}$); (d)

Upconversion luminescence decay curves ($\lambda_{\text{ex}} = 976 \text{ nm}$, monitored at 470 nm).

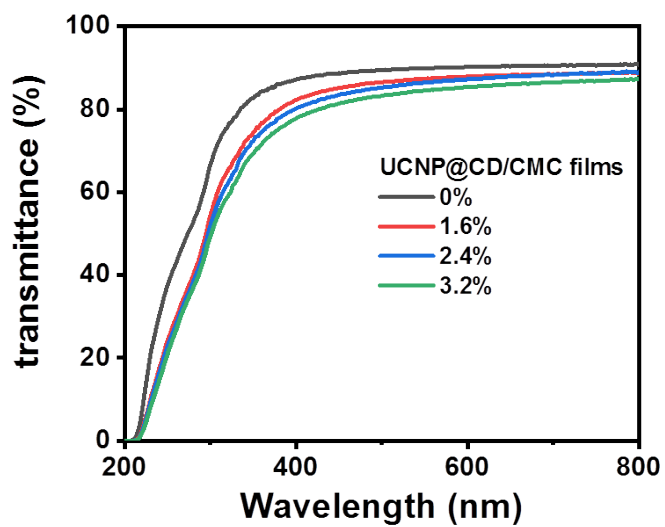


Fig. S4 Transmittance of different UCNP@CDs/CMC films.

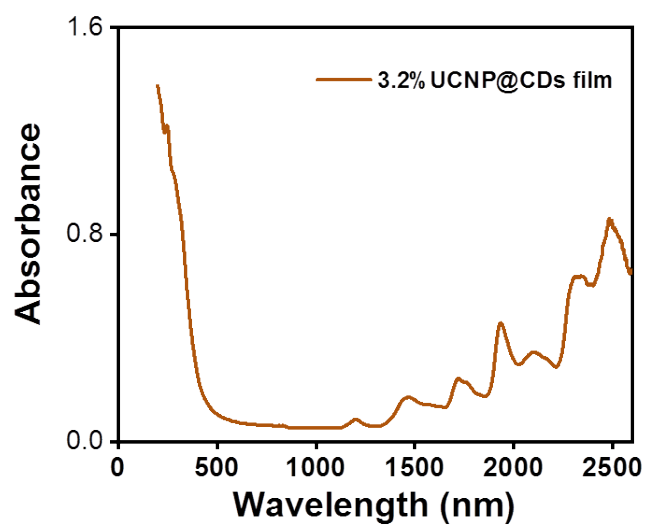


Fig. S5 Absorbance of 3.2% UCNP@CDs/CMC film

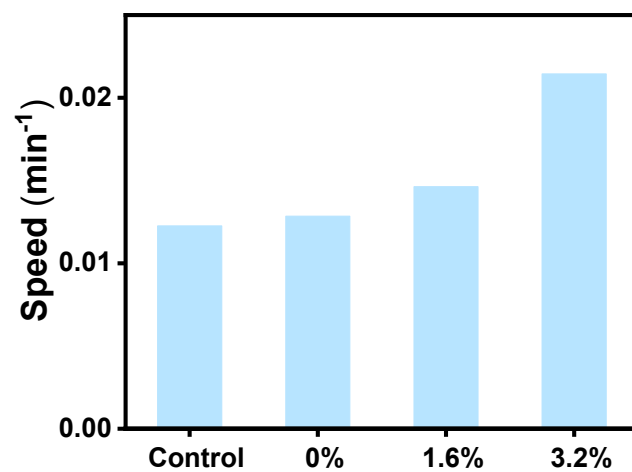


Fig. S6 Reduction speed of DCPIP by chloroplasts under different light-harvesting films

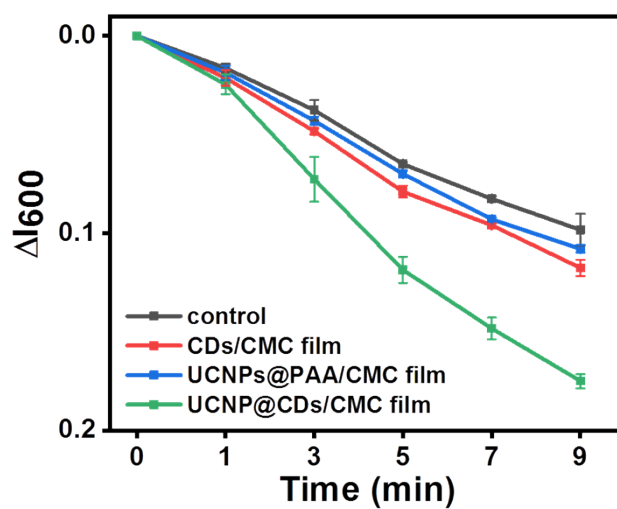


Fig. S7 Reduction of DCPIP by chloroplasts under different light-harvesting films (light intensity = 10 mW cm⁻²).

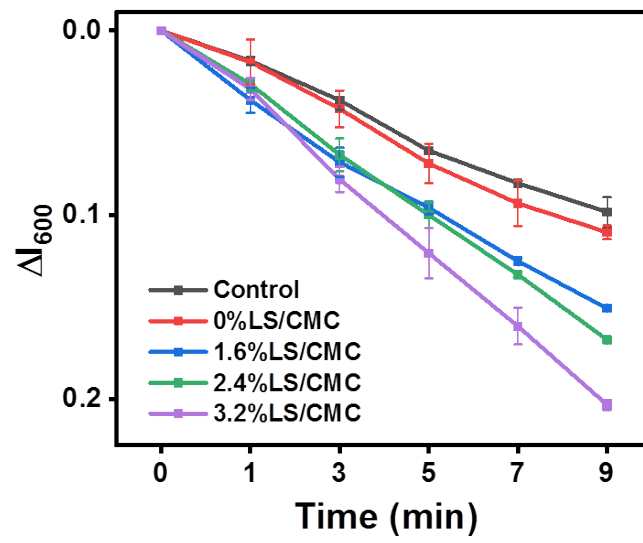


Fig. S8 Reduction of DCPIP by chloroplasts under different LS/CMC light-harvesting films (light intensity = 10 mW cm^{-2})

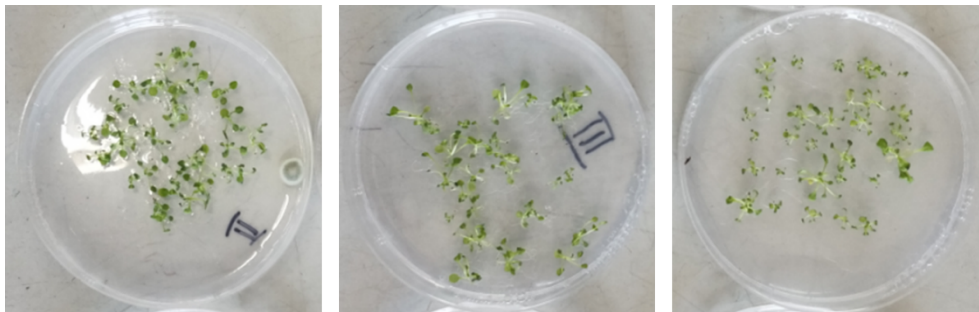


Fig. S9 Images of 2-week-old *Arabidopsis thaliana*.

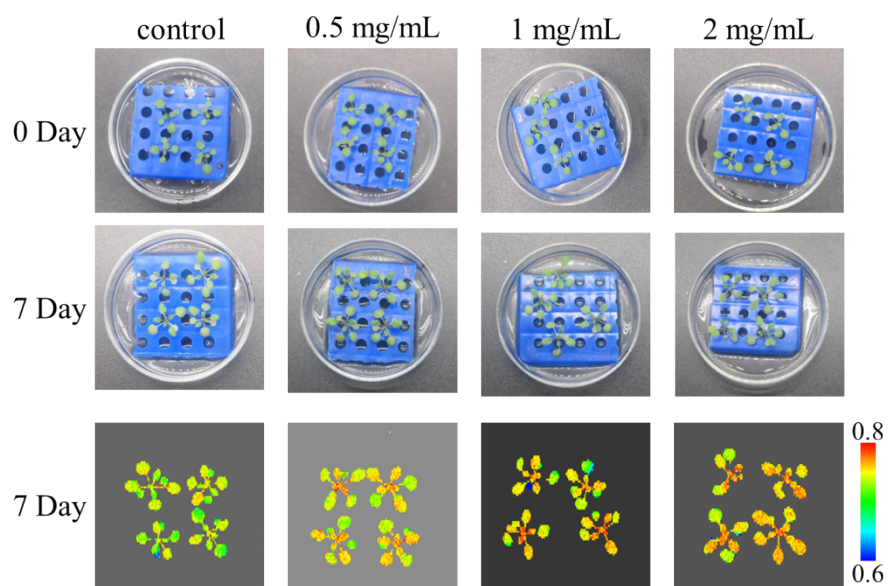


Fig. S10 Photographs and Chlorophyll fluorescence images of *Arabidopsis thaliana* incubated in different concentration UCNP@CDs aqueous solution for 0 and 7 days.