Tunable and Sustainable UV-Protection: A Chromoprotein-Based Approach to Sensing and Shielding

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Ultraviolet light (UV) tracking and shielding are critical for safeguarding food, pharmaceuticals, and electronics. Nature has addressed this issue by using proteins as dynamic UV shields. For example, the dorsal skin of marine vertebrates exhibits dynamic patterns of protein expression that change with UV exposure. In contrast, current man-made indicators and filters rely on synthetic dyes and inorganic compounds with a poor environmental footprint, limited tunability, and restricted suitability for integration into sustainable materials. Chromoproteins (CPs) offer a sustainable alternative since they can be produced cost-effectively via microbial biofermentation and tuned through genetic engineering.
Here, we exploit controlled Fluorescence Resonance Energy Transfer (FRET) between two CPs as the basis for a ratiometric UV sensor. A significant challenge of traditional FRET constructs is that they rely on large, fused protein tandems that display low solubility and expression yield, hindering their scalability and integration into materials. We avoid this limitation by developing a pipeline for the high-yield production of stable, non-fused CP heterodimers. By modifying monomeric proteins like mGreenLantern and mKillerOrange, we promote dimerization through rational protein design and targeted mutagenesis. Computational prediction and optimization identify key amino acid substitutions that favour intermolecular binding at defined interfaces, achieving FRET proximity without the steric burden of fusions. Engineered CP pairs are cloned into co-expression plasmids for microbial hosts, enabling robust production and purification. The resulting dimers function as sensitive, ratiometric UV sensors whose fluorescence ratio reports the cumulative light-exposure history, enabling sustainable UV tracking and shielding in next-generation packaging and protective coatings.

Keywords:
Chromoproteins, FRET, protein engineering, heterodimerization, biosensors, sustainable materials

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