Engineering Protein-Based Colloids

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Protein-based colloids provide a uniquely programmable platform for materials design. Because proteins are genetically encodable, their interactions, stability, and function can be rationally engineered, enabling applications across optics, health technologies, and environmental sensing. Within this landscape, fluorescent proteins (FPs) have emerged as powerful genetically defined optical modules that rapidly expanded from biological labels and sensors into synthetic materials. However, their broader materials use is often limited by fragility under non-native conditions. To address this challenge, a genetically encoded macro-oligomerization strategy was developed to strengthen FP–FP interactions through electrostatic control, yielding assemblies that remain stable for months in organic solvents and other harsh environments and can be embedded into non-aqueous polymer matrices. In parallel, computational protein engineering enabled the creation of highly supercharged FP variants that preserve photoluminescence and thermal stability while supporting controlled self-assembly with partner proteins in solid materials. Living biomaterials were also explored through the engineering and downsizing of bacterial spheroplasts, improving their interfacing with synthetic polymers and enabling more controlled interactions between living compartments and man-made matrices. More recently, the controlled production of cell-sized microbeads has enabled the encapsulation of bacteria, generating modular living–synthetic units whose composition and responsiveness can be tuned. Together, these advances illustrate how proteins can serve not only as structural building blocks of materials but also as functional components for applications in areas such as food technology and security.

Keywords:
Protein engineering; Protein-based colloids; Fluorescent proteins; Living biomaterials

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