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FROM DYNAMIC STRUCTURES TO FUNCTIONAL MATERIALS

Multicomponent Supramolecular Polymers for the Design of Fully Synthetic Antitumor Vaccines

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Synthetic vaccines commonly rely on the conjugation of antigens to immunogenic carrier proteins of biological origin to enhance immunogenicity. Although these bioconjugate vaccines have proven highly effective, their biological complexity introduces challenges related to batch-to-batch variability, limited structural characterization, and inconsistent antigen loading. Such heterogeneity can compromise manufacturing reproducibility and ultimately affect vaccine efficacy, underscoring the need for alternative platforms that enable precise molecular control while maintaining robust immune activation.

Supramolecular polymers have emerged as a versatile class of materials that combine structural order with dynamic, reversible intermolecular interactions. Their modular design enables the construction of adaptive assemblies that mimic key features of biological systems, including responsiveness to external stimuli and environmental adaptability. Among these, peptide-based supramolecular materials are particularly attractive for biomedical applications owing to their intrinsic biocompatibility, synthetic accessibility, and the broad range of physicochemical properties afforded by amino acid building blocks. These characteristics provide unique opportunities to engineer well-defined, multifunctional nanostructures with precisely controlled composition.

The modularity of supramolecular polymers makes them especially well suited for vaccine design, where the controlled presentation of multiple functional components—including antigens, targeting ligands, and immunostimulatory molecules—is essential for eliciting effective immune responses. A universal supramolecular polymer platform capable of incorporating these functionalities through simple co-assembly combines the immunological advantages of protein conjugate vaccines with the synthetic precision, compositional control, and stability of small-molecule-based systems. This approach provides a versatile strategy for the multivalent presentation of tumor-associated antigens and facilitate the development of next-generation antitumor vaccines.