Biocompatible Nanoparticles

Encapsulines as Versatile Natural Enzyme Cages

Technology

Biocompatible nanoparticles are increasingly important in targeted drug delivery, diagnostics, biotechnological processes, and consumer products. Encapsulins, a novel class of natural protein cages, offer a modular platform for packaging, protecting, and controllably releasing biologically active molecules, with advantages in biocompatibility, productivity, and scalability over conventional systems.

The invention uses encapsulins as self-organizing protein cages with tunable internal diameter and defined packing properties as a versatile platform. The core is targeted loading, stabilization, and functional modification of these cages, together with their integration into therapeutic and diagnostic applications as well as bulk industrial or household materials. The technical innovation is the rational control of assembly, cargo selectivity, and surface functionalization, enabling precise control over biological activity.

The invention specifically employs Type I encapsulins from Mycobacterium smegmatis and other bacteria, which form self-assembling 60-mer cages with controllable inner diameter and pore size, as nanoreactors. The key design is two-part: (1) enzymes are engineered as linked pairs (tandem enzymes) tagged with an encapsulin localization sequence (ELS) that directs them into the cage during self-assembly, and (2) the cage is optimized by pore engineering to improve molecular flux and by surface decoration with targeting ligands for cell-specific delivery. This architecture achieves very high internal enzyme concentrations (>2 mM) while maintaining full catalytic activity in the confined space.

Key applications include: (i) therapeutic use as a targeted drug delivery system with improved bioavailability, reduced side effects, and potential for combination therapeutics (proteins, small molecules, nucleic acids); (ii) diagnostics and bioanalytics as highly sensitive detection systems with increased signal strength and multiplexing capability for point-of-care and laboratory assays; and (iii) industrial biotechnology or consumer products, where enzyme compartmentalization enables enhanced catalysis, higher process productivity, and protection from inhibitors.

The encapsulin enzyme platform addresses three main market segments: targeted cancer therapeutics (≈USD 20–25+ billion, particularly HER2-positive cancers and enzyme–prodrug strategies), industrial biocatalysis and enzyme stabilization (≈USD 0.7–1.2 billion), and diagnostic applications including companion diagnostics and protein-nanoparticle drug delivery systems (≈USD 10–15+ billion). Its competitive advantage is genetically programmable, scalable manufacturing and a multifunctional design that combines cargo protection, targeting, and controlled release.

The inventors are open to co-development of this promising early stage invention.

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Innovation

- **Novel encapsulation technology:** Nature-based, biocompatible cage structures with variable size and chemical activatability for diverse cargo.
- **Precise Assembly Control:** Rational design and optimization of self-organization enable reproducible large-scale manufacturing.
- **Multi-Functional Surface Modification:** Targeted attachment of ligands (e.g., targeting peptides, detection markers) for functionalization without compromising core function.
- **Broad Cargo Compatibility:** Successful packaging of proteins, enzymes, nucleic acids, and small molecules in a single system.

Applications

- **Oncology & Rare Diseases:** Personalized therapeutics and combination treatments with improved tolerability through targeted drug delivery.
- **Infectious Diseases:** Vaccines and therapeutic proteins with enhanced immunogenicity and protection against enzymatic degradation.
- **Diagnostics & Companion Diagnostics:** Highly sensitive and multiplex-capable biomarker assays for prognosis, monitoring, and therapy guidance.
- **Enzymes & Biocatalysis:** Optimized bioprocesses in pharma, chemistry, food industry and household detergents through compartmentalization and substrate concentration.
- **Regenerative Medicine:** Controlled release of growth factors and differentiation signals for tissue engineering and wound healing.

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