Colloidosomes: A New Drug Delivery System

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Abstract:

The distinct structural and functional characteristics of colloidal particles, resulting in hollow colloidosomes called microcapsules, have attracted a lot of interest. This review highlights different techniques, including as microfluidics, self-assembly, and emulsion templating, to summarise current developments in the manufacturing of colloidosomes.

Colloidosomes' physicochemical characteristics, including permeability, stability, and surface modification, are examined in relation to possible uses in:

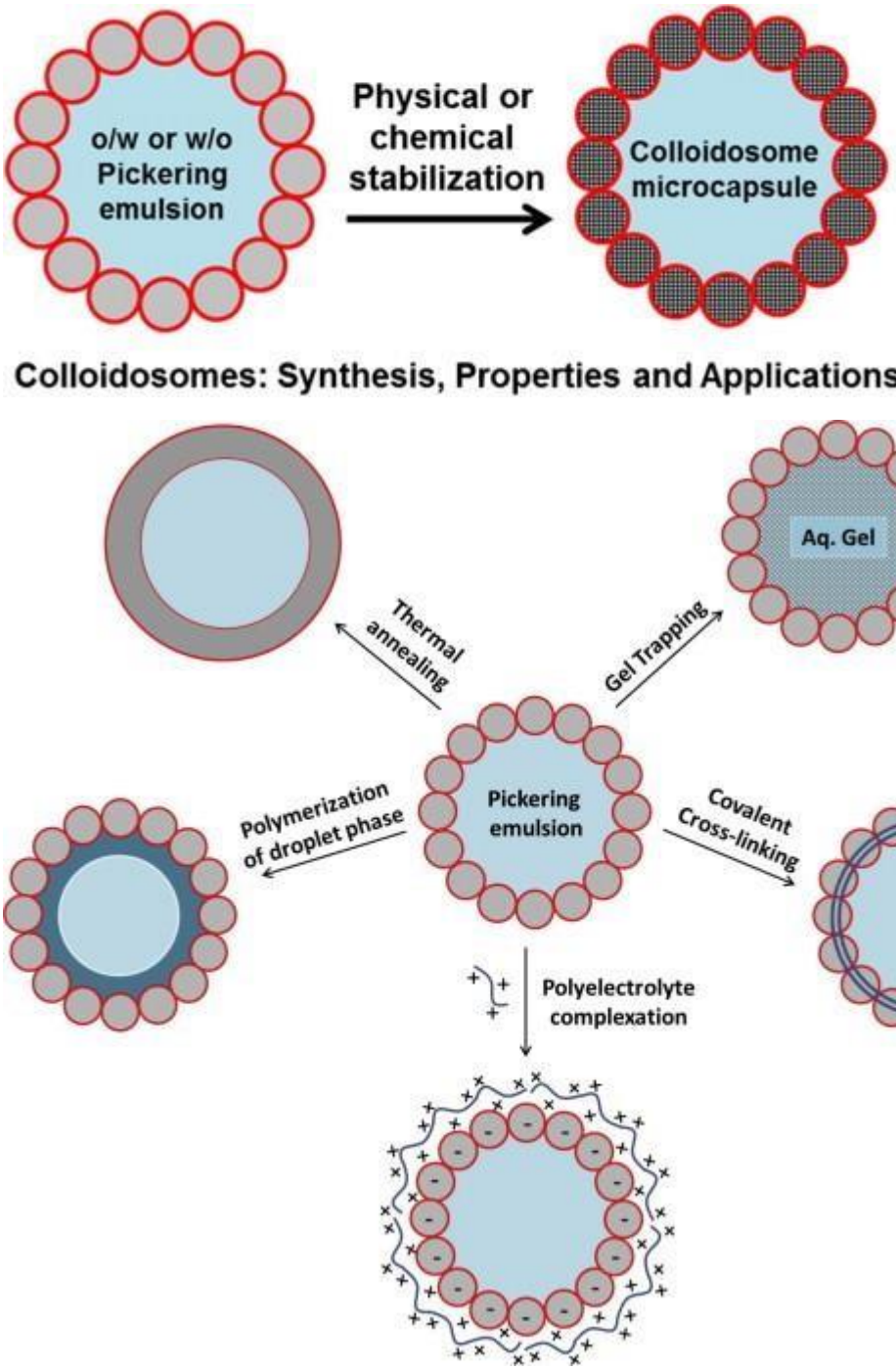
1. Regulated release techniques for medication administration and farming
2. Food components and minerals are encapsulated
3. Diagnostics and biosensing
4. Bio- and catalytic catalysis
5. Regenerative medicine and tissue engineering

Keywords: controlled release, biosensing, emulsion templating, microcapsules, selfassembly, and colloidosomes.

Introduction:

Colloidosomes are microcapsules whose shells are composed of colloidal particle.[1] Colloidosomes are made of colloidal particles, which are usually nano- to micrometer-sized, and are hollow, porous microcapsules[2] Because of their distinct structural and functional characteristics, which make them appropriate for a range of applications, these microcapsules have garnered a lot of interest [3] Other names for colloidalosomes include "hollow colloidal particles" and "colloidal capsules." [4] These superstructures have drawn a lot of interest recently due to their possible significance in the field of microencapsulation. Microencapsulation makes it possible to provide a variety of actives, including medications, insecticides, and scents, through the controlled release of active substances in a number of industrial sectors, including food, medicine, agrochemicals, cosmetics, and home and personal care goods.[5-9] We summarise the several methods used to create stable colloidosomes in this review, emphasising their applicability and future applications as microcapsules while also pointing out existing technical issues. In three articles published in

1996, Velev and colleagues revealed the first structures resembling colloidosomes. They used n-octanol droplets as templates for latex self-assembly. [10-12]



Properties Of Colloidosomes:

Physical Properties:

1. **Size:** Colloidosomes can range from nanometers to micrometers in size [13].
2. **Shape:** Colloidosomes can be spherical, ellipsoidal, or tubular [14].
3. **Porosity:** Colloidosomes have porous structures, allowing for controlled release and permeability [15].

4. **Surface Area:** Colloidosomes have high surface areas, enabling efficient interactions with surroundings [16]

Chemical Properties:

1. **Composition:** Colloidosomes can be composed of organic, inorganic, or hybrid materials [17].

2. **Surface Charge:** Colloidosomes can have positive, negative, or neutral surface charges [18].

3. **Hydrophobicity:** Colloidosomes can exhibit hydrophobic or hydrophilic properties [19].

4. **Stability:** Colloidosomes can be stabilized through cross-linking, coating, or other methods [20].

Mechanical Properties:

1. **Strength:** Colloidosomes can exhibit varying mechanical strengths, depending on composition and structure [21].

2. **Elasticity:** Colloidosomes can be elastic or rigid, influencing their deformation and rupture behavior [22].

3. **Permeability:** Colloidosomes' permeability can be tailored for controlled release applications [23].

Optical Properties:

1. **Transparency:** Colloidosomes can be transparent, translucent, or opaque [24].

2. **Reflectivity:** Colloidosomes can exhibit varying reflectivity, influencing their optical properties [25]. 3. **Fluorescence:** Colloidosomes can be designed to fluoresce for imaging and sensing applications [26]

Biological Properties:

1. **Biocompatibility**: Colloidosomes can be biocompatible, enabling biomedical applications [27]

2. **Cell Adhesion:** Colloidosomes can interact with cells, influencing cell adhesion and behavior [28]

3. **Toxicity:** Colloidosomes' toxicity can be tailored through material selection and surface modification

Method of preparation:

EMULSION BASED COLLOIDOSOMES: PREPARATION

Colloidosomes based on an oil-in-water emulsion

Water-in-oil emulsion is created by emulsifying aqueous solution in oil while colloidal particles are present. To lower the surface energy, particles are adhering to the droplets' surface. After that, the particles are sintered, Vander Waals forces are applied, or polycations are added to lock the particles together. These colloidal particles aid in the creation of an emulsion that is stabilised by water in oil.[29]

Based on an oil-in-water emulsion, colloidosomes:

Such an emulsion is created by emulsifying oil in an aqueous solution that contains particles and a surfactant.

The oil/water interface is stabilised by using this colloidal particle in the presence of a surfactant. By doing this, an electrostatic driving force is introduced to transport the colloidal particles to the interface of the emulsion. Next, a colloidalosomal dispersion based on an oilin-water emulsion is produced. To separate them from the supernatant, the collected colloidosomal dispersion was added to the non-aqueous phase (ethanol) and centrifuged. After obtaining the oil core colloidalosomes, they undergo an ethanol wash and are subsequently redispersed in water.

Emulsion-based water-oil-water colloidalosomes:

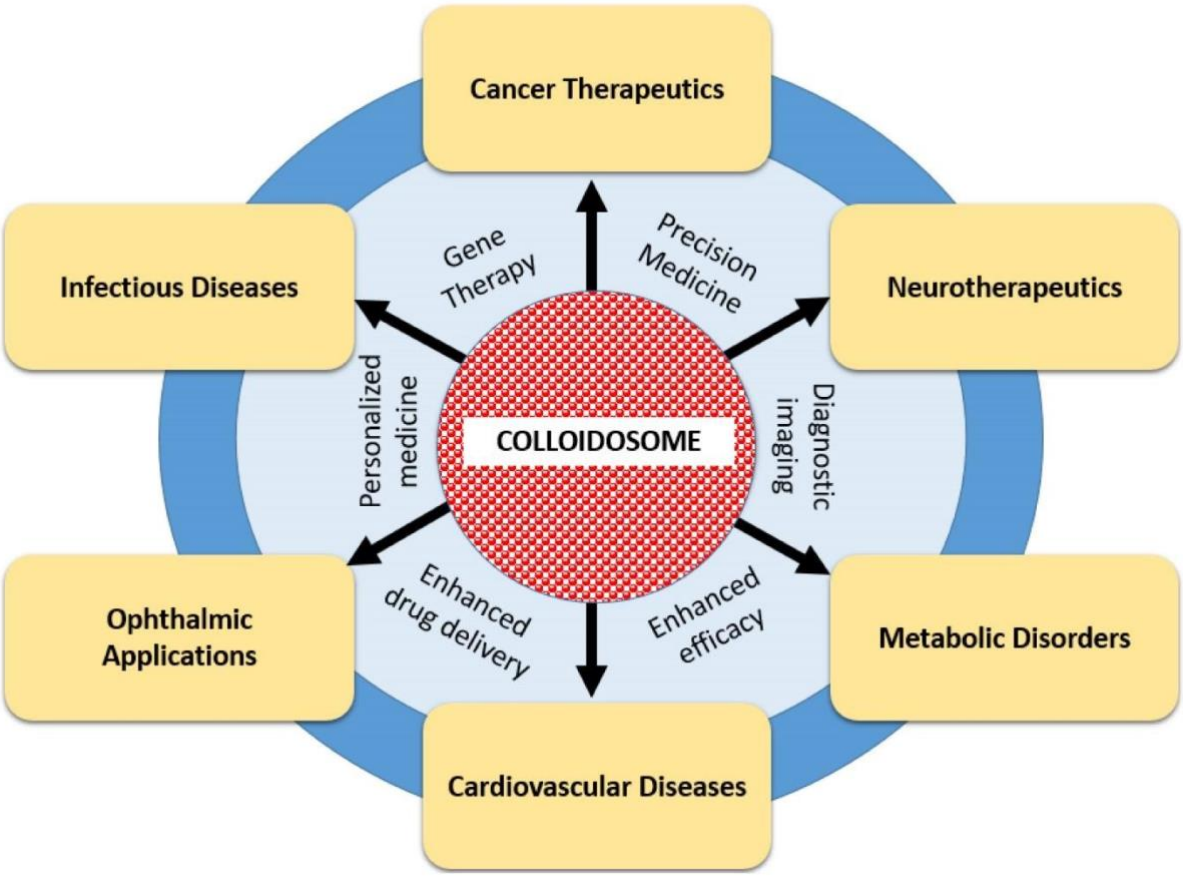
In the oil phase, a pendant drop of a latex particle aqueous suspension forms. A monolayer of closely spaced particles adsorbed on the drop surface byParticle suspension is repeatedly infused into and removed from the capillary during the oil phase. Ultimately, the densely coated adsorbed particle-ladenpendant water drop in oil is transferred through a particle-free planar oil-water interface to form a massive pendant colloidosome. This is made up of a spherical water/oil/water film supported by latex particles that may bridge both surfaces.Thirteen W/O/W double emulsions are used as templates to create nanoparticle colloidosomes with selective permeability are generated by using water-in-oil-in-water (W/O/W) double emulsions as templates.[30]

Factors Affecting Colloidal Formation:

Several factors that might be expected to affect the formation of stable colloidosomes.

Particle size:

System consisting of a mixture of small and large spherical colloidal particles with opposite electrical charges. Small particles will be attracted to the surface of large particle due to electrostatic attraction. When concentration of small particles is insufficient to saturate the surface of one large particle, which tends to occur “bridging flocculation’’. When concentration small particles exceeds some critical volume, that may generate a sufficiently high depletion attraction between the colloidosomes to promote their flocculation. .**Critical Saturation Concentration:** Simple geometric consideration can be used to calculate the volume fraction of small mono disperses and in compressible particles required to saturate the surface of a single layer of particles. [31]



Application of colloidosomes:

The biomedical, pharmaceutical, and cosmetic industries have found endless uses for liposomes as encapsulating agents. These industries are particularly interested in liposome encapsulation and controlled release in the areas of drug delivery, cosmetic delivery, food delivery, LCD display devices, polymer blends, paints, catalytic material, and even living cells. The colloidal particles, or functional biopolymers, can additionally work as a targeting agent, guiding the colloidalosomes to the intended site via the action of the functional biopolymer. As a result, the generated colloidosomes can offer an integrated mechanism for the colloidosomes' targeted distribution, which also enhances the material's biocompatibility and controlled release.

1)Expanded gel is used to create colidosomes. By allowing the medication to be released by particle and entraining it in the particle core

2)Colloidosomes as a vehicle for the transport of drugs and proteins

3)Colloidosomes during the immobilisation of

4)enzymessing colidosomes to transport drugs or proteins

5)Colloidosomes for regulated and extended medication release

6)Colloidosomes to improve the solubility of drugs

7)Colloidosomes for modified biodistribution and pharmacokinetics
8)Using colosomes in tumour treatment
9)Colloidosomes in the treatment of infections, fungal diseases, and viruses
10)Colloidosomes in dermatology and cosmetics
11)Drug administration through ocular colloidalosomes
12)Delivering Colloidosomes to the Brain
13)Using colloidalosomes to transport DNA
In the immobilisation of enzymes, colidosome[32]

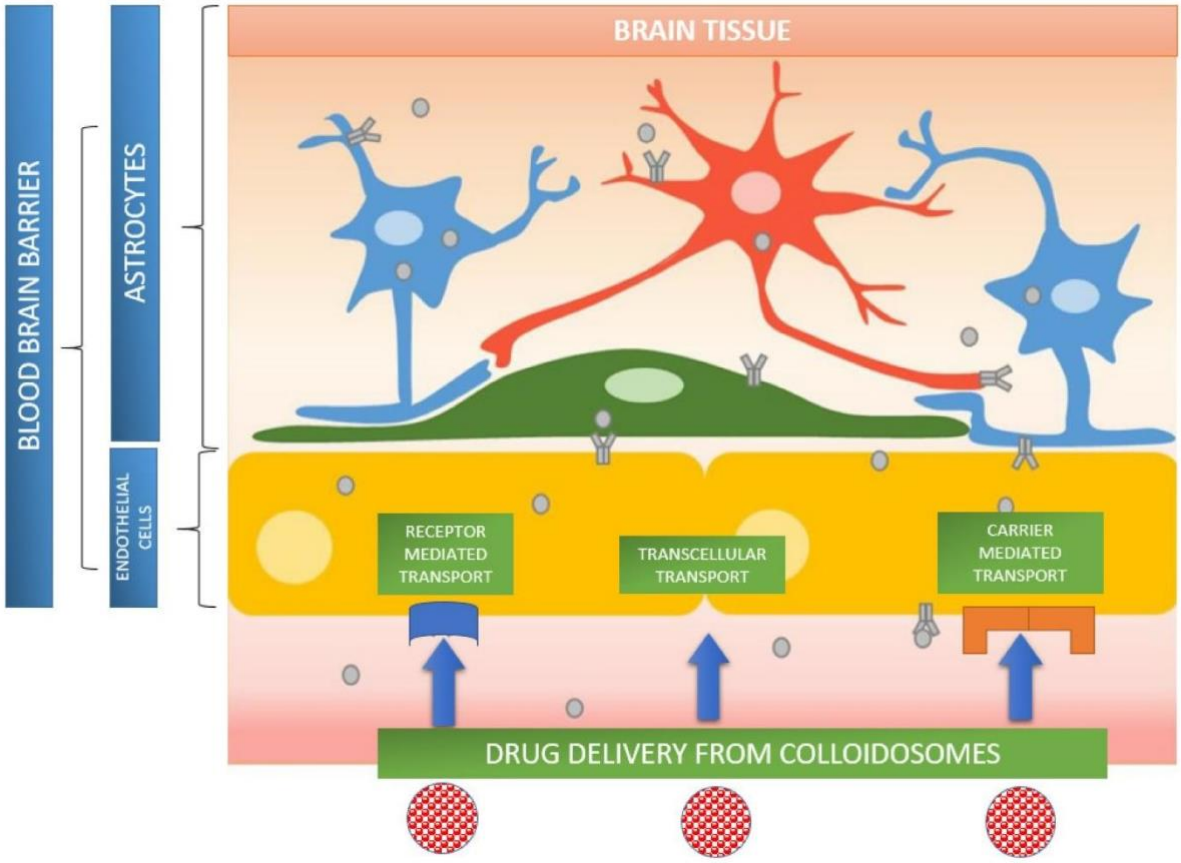
POTENTIAL BENEFITS OF COLLOIDOSOMES SIZE – Allows flexibility in applications and choice of encapsulated materials

PERMEABILITY -Allows selective and aimed release

MECHANICAL STRENGTH –Allows yield stress to be adjusted to withstand varying of mechanical loads and to enable release by defined shear rates

COMPATIBILITY-Allows encapsulation of fragile and sensitive ingredients such as biomolecities and cells.[33]

Nanoparticle Colloidosomes
Water-in-Oil-inWater (W/O/W) double emulsions serve as templates for the creation of these colloidosomes. Hydrophobic nanoparticles in oil self-assemble at surfaces to create a colloidal shell.[34,35] After removing the oil phase, nanoparticle colloidosomes of varying permeability and size are formed.
Layer-by-layer colloidosomes (LbL): This process includes layering polyelectrolytes onto a template (e.g., biocrystals, nanoparticles) and then removing the template to create hollow polymer capsules[36,37] The LbL technique allows for the encapsulation of enzymes and other active substances.
Nature-of-colloids-based approaches customise colloidosome composition, size, and morphology by leveraging colloidal material qualities and interactions with core materials.



Formulation of colloidosomes:

1.Emulsification-

Emulsification is a process of mixing two or more immiscible liquids to create a stable emulsion. In colloidosome formulation, emulsification involves mixing a colloidal suspension with an oil phase to create droplets.

Steps:

1. Preparation of colloidal suspension

2. Mixing with oil phase

3. Homogenization using sonication or high-shear mixing

4. Stabilization using surfactants or polymers **Advantages:**

1. Simple and scalable

2. High encapsulation efficiency

3. Controlled release kinetics **Disadvantages:**

1. Limited control over particle size

2. Potential for emulsion instability

2. Solvent Evaporation-

Solvent evaporation involves evaporating a solvent from a colloidal suspension to form colloidosomes.

Steps:

1. Preparation of colloidal suspension

2. Addition of solvent (e.g., ethanol, acetone)

3. Evaporation of solvent using heat, vacuum, or airflow

4. Collection of colloidosomes **Advantages:**

1. Simple and cost-effective

2. High yield

3. Controlled particle size **Disadvantages:**

1. Limited control over shell thickness

2. Potential for particle aggregation

3. **Microfluidics**

Microfluidics involves using microfluidic devices to control droplet formation and size.

Steps:

1. Preparation of colloidal suspension

2. Injection into microfluidic device

3. Droplet formation using flow-focusing or T-junction

4. Collection of colloidosomes **Advantages:**

1. High precision control over particle size

2. Uniform particle distribution

3. Controlled release kinetics **Disadvantages:**

1. Complex device design and operation

2. Limited scalability

4. Coacervation

Coacervation involves phase separation of polymers to form colloidosomes.

Steps:

1. Preparation of polymer solution

2. Addition of colloidal particles

3. Phase separation using temperature, pH, or solvent

4. Collection of colloidosomes **Advantages:**

1. High encapsulation efficiency

2. Controlled release kinetics 3. Biodegradable and biocompatible **Disadvantages:**

1. Limited control over particle size

2. Potential for particle aggregation[38]

Colloidosome as drug delivery system:

1. Lipid-based Colloidosomes

Composition: Lipids (e.g., phospholipids, cholesterol) Characteristics:

- Formed through self-assembly of lipids

- Typically 100-500 nm in size

- Can encapsulate hydrophilic and hydrophobic drugs Applications:

- Cancer therapy (e.g., Doxil)

- Gene delivery

- Vaccine delivery - Anti-inflammatory therapy Examples:

- Liposomal doxorubicin (Doxil)

- Liposomal amphotericin B (AmBisome)

- Liposomal cyclosporine (Sandimmune)

2. Polymer-based Colloidosomes

Composition: Synthetic polymers (e.g., PLGA, PEG) Characteristics:

- Formed through solvent evaporation or emulsion methods

- Can be tailored for specific drug release profiles - Can encapsulate hydrophilic and hydrophobic drugs Applications:

- Cancer therapy (e.g., paclitaxel)

- Protein delivery

- Tissue engineering

- Wound healing Examples:

- PLGA-based colloidosomes for paclitaxel delivery

- PEG-based colloidosomes for siRNA delivery

- Poly(lactic acid) (PLA) colloidosomes for vaccine delivery[39,40]

3. Protein-based Colloidosomes Composition:

Proteins (e.g., albumin, gelatin)

Characteristics:

- Formed through coacervation or gelation methods
- Biodegradable and biocompatible
- Can encapsulate hydrophilic and hydrophobic drugs Applications:
- Cancer therapy (e.g., doxorubicin)
- Vaccine delivery
- Tissue engineering
- Wound healing Examples:
- Albumin-based colloidosomes for doxorubicin delivery
- Gelatin-based colloidosomes for growth factor delivery
- Collagen-based colloidosomes for tissue engineering

4. Metal-Organic Framework (MOF) Colloidosomes

Composition: Metal ions and organic linkers Characteristics:

- Highly porous and tunable structure
- High surface area and drug loading capacity - Can encapsulate hydrophilic and hydrophobic drugs Applications:
- Cancer therapy (e.g., cisplatin)
- Gas delivery
- Imaging
- Biomedical diagnostics Examples:
- MOF-based colloidosomes for cisplatin delivery
- MOF-based colloidosomes for oxygen delivery
- Zirconium-based MOF colloidosomes for imaging

Hybrid Colloidosomes

Composition: Combination of two or more materials (e.g., lipid-polymer, protein-polymer)

Characteristics:

- Combines benefits of individual materials
- Tailorable properties and functionality

- Can encapsulate hydrophilic and hydrophobic drugs Applications:

- Cancer therapy

- Tissue engineering

- Vaccine delivery

- Wound healing Examples:

- Lipid-polymer hybrid colloidosomes for doxorubicin delivery - Protein-polymer hybrid colloidosomes for growth factor delivery[41,42]

Stability and Storage:
Long-term stability and storage of colloidosomes are crucial for successful commercialisation and clinical translation. Colloidosomes can degrade, aggregate, or leak enclosed cargo over time, reducing their effectiveness and shelf life.[43] Researchers are studying ways to improve the stability of colloidosomes, including optimising the shell composition, adding stabilising agents or excipients, and testing different storage conditions (e.g., lyophilization and cryopreservation).[44,45] Developing sophisticated characteriszation methodologies and faster stability testing can help understand degradation mechanisms and discover potential stabilisation approaches.

Conclusion:

Mixing coarse and fine emulsions with oppositely charged droplets creates colloidosomes with big droplets surrounded by a layer of microscopic droplets. Colloidal particles selfassemble onto emulsion droplet interfaces to form capsules. Once the particles have formed elastic shells, the emulsion droplets are moved to a new continuous phase fluid that is identical to the one inside them. Colloidosomes are hollow, elastic shells with precise control over their permeability and elasticity. It is used in a variety of consumer products, including beverages, food, medications, flavours, fragrances, and cosmetics. It may be feasible to limit their susceptibility to gravitational separation, manage their stability to environmental pressures, build novel controlled or triggered release systems, compartmentalise active agents, and control specific chemical reactions. Using diverse colloidal particles gives for greater versatility. Various release mechanisms are possible, including controlling permeability for slow, sustained release or rupture stress for shear-induced breakdown. This versatility opens up possibilities for various applications.

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