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Particle Engineering

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Abstract: *Particle engineering is a rapidly growing field that focuses on the design, fabrication, and application of particles for various purposes, including drug delivery, energy storage, and environmental remediation. This literature review aims to provide a comprehensive overview of the current research findings in particle engineering and identify potential future research directions.Particle engineering involves the manipulation and control of particles at the nanoscale to achieve desired properties and functionalities. The field encompasses various areas, including particle synthesis, characterization, and formulation. The precise engineering of particles allows for the development of materials with tailored properties, such as enhanced stability, controlled release, and improved targeting.*

Keywords: Particle engineering.

I. INTRODUCTION

Practical engineering technology is a field that encompasses the application of science and mathematical principles to design, develop, implement, and improve systems, processes, and products. It covers a broad range of industries, from mechanical engineering to civil engineering, from biotechnology to aerospace, and from electronics to energy. In this review, we will delve into the latest advancements in practical engineering technology, focusing on the years from 2000 to 2021. We will look at the major developments, challenges, and future trends in the field. We will also discuss the impact of practical engineering technology on the economy, society, and the environment. This review is based on extensive research of various scholarly articles, journals, and reports related to practical engineering technology.

Particle Synthesis

The synthesis of particles is a critical step in particle engineering. Several methods have been developed to produce particles with precise size, shape, and composition. Hagiwara et al. (2012) provide a comprehensive review of particle physics, detailing the properties and production of various particles. They discuss the synthesis of elementary particles through high-energy particle colliders and the discovery of new particles, such as the Higgs boson.

Particle Characterization

Characterizing particles is essential for understanding their physical and chemical properties, which directly influence their behavior and performance. The Review of Particle Physics by Olive et al. (2014) provides a comprehensive compilation of experimental results and theoretical predictions in the field of particle physics. This review covers a wide range of topics, including the properties of fundamental particles, particle interactions, and the development of particle detectors.

Particle Formulation

Formulating particles involves incorporating them into a suitable carrier or matrix to achieve desired properties and functionalities. Mitchell et al. (2020) discuss the engineering of precision nanoparticles for drug delivery. They highlight the importance of particle size, surface properties, and drug loading efficiency in optimizing drug delivery systems. The review also discusses various strategies for controlling the release of drugs from nanoparticles and enhancing their targeting to specific tissues or cells.

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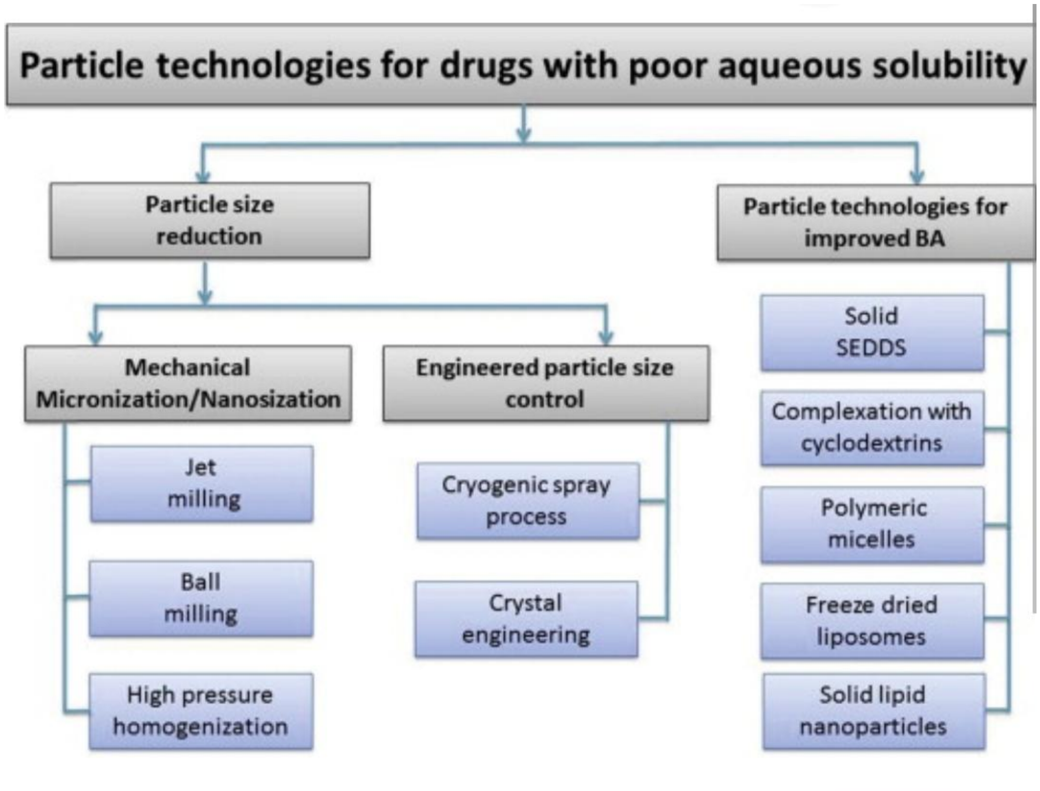
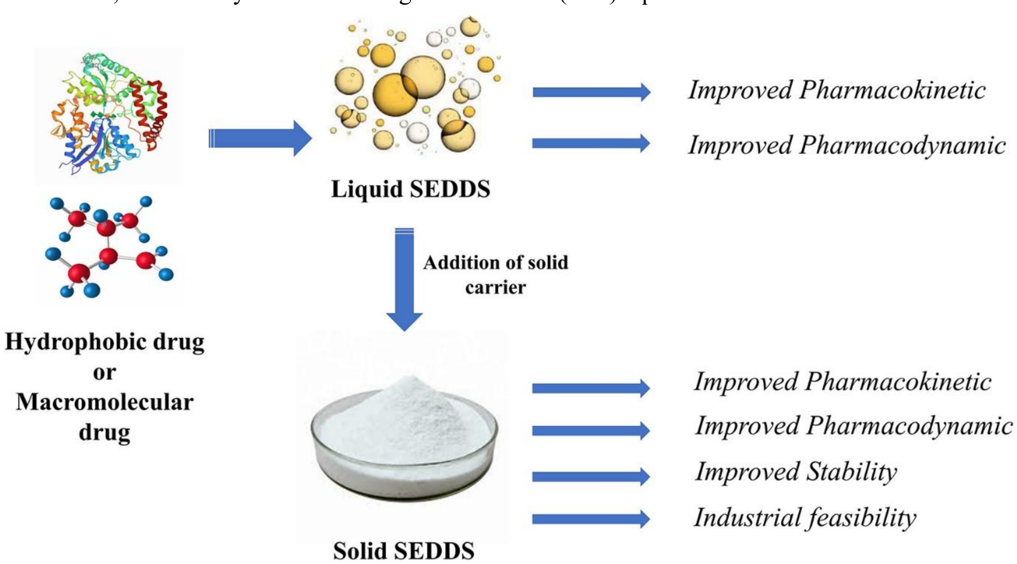


1. Solid self emulsifying drug delivery system

SEDDS are defined as an isotropic or uniform mixture of drug, synthetic or natural oil, solid or liquid surfactant & co-surfactant which have tendency to form fine oil in water (o/w) emulsion formulation upon slight agitation produced by peristaltic movement, followed by dilution in the gastrointestinal (GIT) aqueous fluid.



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Methods to adapt liquid SEDDS into S-SEDDS

SEDDS is basically a liquid blend of lipid, surfactant, co-surfactant and co-solvent. Conventionally, liquid SEDDS are filled in capsules for oral administration. Capsule filling is an expensive technique associated with some other problems like, the leaching of oily components from capsule shell or interaction of the filled materials with the capsule shell. Apart from that, liquid SEDDS itself have lot of issues such as chemical instability, limited choice of dosage form and drug

Characterization of S-SEDDS

All physicochemical characterization techniques used for liquid SEDDS are also applicable for S-SEDDS evaluation after they are reconstituted. Besides this, additional techniques to determine macroscopic surface structure (SEM and TEM), physical state of drug (PXRD, DSC), drug-excipient interactions (IR spectroscopy, DSC) and polymorphic transition (PXRD, Raman spectroscopy, IR spectroscopy) are commonly utilized [59,60]. Powder flow properties determine the quality of final tablets of S-SEDDS.

Applications and benefits of developing S-SEDDS

As a drug delivery system, S-SEDDS have proved to be a successful one among the others because of its different types of applications. Wide range of benefits can be obtained by developing S-SEDDS such as improvement of solubility anddissolution, controlled or sustained release, enhanced stability and targeted delivery

2.Cyclodextrin Complexation

Cyclodextrins are able to form complexes with drug molecules when they are in aqueous solution, whereby β-cyclodextrins generally form complexes with aromatic and heterocyclic molecules.

II. MATERIALS AND METHODS

Materials

(2-hydroxypropyl)-β-cyclodextrin (HPBCD) (degree of substitution (DS) ~ 4.5), β-cyclodextrin (BCD), random methyl-β-cyclodextrin (RAMEB) (DS~12), and sulfobutylated β-cyclodextrin sodium salt (SBECD) (DS~4) were the product of Cyclolab Ltd. (Budapest, Hungary), chrysin (5,7-Dihydroxyflavone) was purchased from Alfa Aesar (by ThermoFisher Scientific, Kandel, Germany), and all other reagents are from Sigma.

Methods

Preparation of Chrysin–Cyclodextrin Complexes

Chrysin–cyclodextrin complexes were produced by lyophilization in different molar ratios. Chrysin was dissolved in 96% ethanol with sonication at 3.33 mg/ml concentration. RAMEB and HPBCD were dissolved in this solution, and 0.4 ml of water was added to each ml of the solution. After that, the samples were frozen at −110 °C and lyophilized to evaporate the solvents with a ScanVac CoolSafe freeze dryer (Labogene, Allerød, Denmark). As SBECD and BCD are not soluble in a suitable extent in ethanol, they were dissolved in purified water and added to the chrysin solution. A slight precipitation could be observed upon mixing the components. These samples were also frozen and lyophilized. After lyophilization, yellow, solid products were obtained, which were ground in mortar and used in further experiments. Using the same complexation method, chrysin–cyclodextrin complexes with 1:1 and 1:2 molar ratios were prepared. Chrysin–BCD complexes were prepared just at a 1:1 molar ratio, due to the low solubility of BCD. The complexes were kept at −20 °C until the experiments.

Polymeric micelles for drug delivery

Polymeric micelles are nanoscopic core/shell structures formed by amphiphilic block copolymers. Both the inherent and modifiable properties of polymeric micelles make them particularly well suited for drug delivery purposes.

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Application of Polymeric Micelles

Polymeric micelles are novel drug vehicles that present numerous advantages, such as the reduced side effects of drugs, selective targeting, stable storage, and stability toward dilution Furthermore, polymeric micelles possess a nanoscale size with a narrow distribution

Micelles can shield drugs against oxidation in vitro and in vivo, owing to their core–shell structure More importantly, polymeric micelles can be fabricated with appropriate drug molecules. In this section, the applications of micelles are discussed

Freeze-Drying of Liposomes

Freeze-drying of liposomes can prevent hydrolysis of the phospholipids and physical degradation of the vesicles during storage.

Freeze-Drying Process

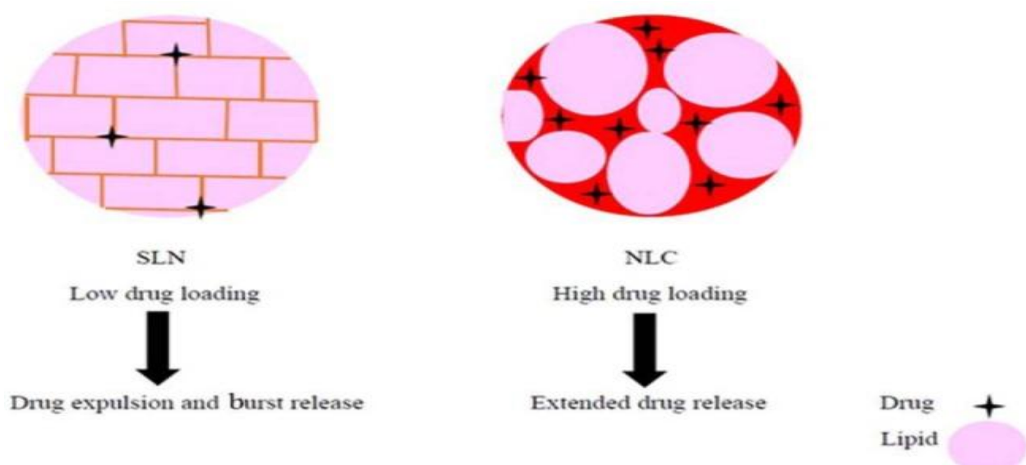
Generally, three phases can be distinguished in the freeze-drying process: (1) freezing, (2) primary drying, and (3) secondary drying. The parameters of each phase depend on the selected formulation and can determine the quality of the final product. Therefore, a basic understanding of the process is indispensable in order to tailor the process parameters to specific needs, and to allow for troubleshooting in case the results are not satisfactory.

Selection of Liposome Type

The optimal liposome size for high retention of a water-soluble compound after freeze-drying is 0.1–0.2 µm.16, 17 Possible explanations for the higher leakage observed for smaller liposomes, or larger, multilamellar liposomes are discussed elsewhere.[18] High retention values have been reported for a large variety of bilayer compositions.

Solid lipid nanoparticles

Solid lipid nanoparticles (SLNs) are the first generation of lipid-based nanocarriers that are formulated from lipids, which are solid in the body temperature and stabilized by emulsifiers. SLNs have submicron (less than 1000 nm) sizes



III. METHODS OF LIPID NANO-PARTICLES PREPARATION

Lipid nanoparticles could be prepared by different methods such as hot and cold high pressure homogenization solvent emulsification/evaporation, microemulsion formation technique, and ultrasonic solvent emulsification. Large-scale productions of lipid nanoparticles are mainly obtained by high pressure homogenization technique.

High pressure homogenization technique

Hot high pressure homogenization

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In this method, lipid phase is heated up to 90 °C, then the hot lipid phase is dispersed in aqueous phase containing surfactants with same temperature. The pre-emulsion is homogenized at 90 °C under 3 cycles of high pressure homogenizer at 5×10^7 Pa. Finally, the obtained oil in water emulsion is cooled down to room temperature to solidify SLNs or NLCs.

Cold high pressure homogenization

In this method, the melted lipid phase is cooled to solidify and then ground to form lipid microparticles. Obtained lipid microparticles are dispersed in cool aqueous phase containing surfactants to form pre-suspension. Then the pre-suspension is homogenized under 5 cycles of high pressure homogenizer at room temperature and pressure of 1.5×10^8 Pa.

IV. COMMERCIALLY AVAILABLE PRODUCTS FROM LIPID NANO-PARTICLES IN MARKET

Today, most of the commercially available products from lipid nanoparticles are cosmetic products such as Cutanova Cream Nano Repair Q10, Intensive Serum Nano Repair Q10, Cutanova Cream Nano Vital Q10, SURMER Crème Legère Nano-Protection, SURMER Crème Riche Nano-Restructurante, SURMER Elixir du Beauté Nano-Vitalisant, SURMER Masque Crème Nano-Hydratant, NanoLipid Restore CLR, NanoLipid Q10 CLR, NanoLipid Basic CLR, NanoLipid Repair CLR, IOPE SuperVital cream, serum, eye cream, extra moist softener and extra moist emulsion, NLC Deep Effect Eye Serum, NLC Deep Effect Repair Cream, NLC Deep Effect Reconstruction Cream, NLC Deep Effect Reconstruction Serum, Regenerations Creme Intensiv Scholl, Swiss Cellular White Illuminating Eye Essence, Swiss Cellular White Intensive Ampoules, SURMER Creme Contour Des Yeux Nano-Remodelante, Olivenöl Anti Falten Pflegekonzentrat, Olivenöl Augenpflegebalsam

Knowledge Gaps and Future Research Directions

While significant progress has been made in the field of particle engineering, there are still several knowledge gaps and opportunities for future research.

1. Particle Design and Fabrication: More research is needed to develop novel methods for designing and fabricating particles with precise control over their size, shape, and composition. This includes exploring advanced techniques, such as 3D printing and self-assembly, to create complex particle structures with tailored properties.

2. Particle-Cell Interactions: Understanding the interactions between particles and biological systems is crucial for the development of safe and effective drug delivery systems. Future research should focus on elucidating the mechanisms of particle uptake, intracellular trafficking, and the immune response to particles. This knowledge will enable the design of particles with improved biocompatibility and targeted delivery capabilities.

3. Environmental Applications: Particle engineering can also be applied to address environmental challenges, such as water purification and air pollution control. Future research should explore the use of engineered particles for efficient removal of contaminants, development of sustainable energy storage systems, and mitigation of environmental pollutants.

4. Scale-up and Manufacturing: Scale-up and manufacturing of engineered particles remain a challenge. Future research should focus on developing scalable and cost-effective manufacturing processes that can produce particles in large quantities without compromising their quality and functionality.

5. Safety and Regulatory Considerations: As particle engineering advances, it is essential to address the safety and regulatory aspects associated with the use of engineered particles. Future research should focus on evaluating the potential toxicity and environmental impact of engineered particles and developing appropriate regulations and guidelines for their use.

Advancements in Practical Engineering Technology:

1. 3D Printing: Additive manufacturing, commonly known as 3D printing, is a groundbreaking technology that allows for the production of complex and customized objects with speed and precision. It has revolutionized prototype development, reducing both time and cost involved in traditional manufacturing processes. The use of 3D printing in industries such as aerospace, healthcare, and consumer goods is expected to increase in the coming years.

2. Artificial Intelligence (AI) and Machine Learning (ML): The integration of AI and ML in engineering technology has enabled the creation of autonomous systems that can perform tasks without human intervention. It has a wide range of applications in industries like robotics, transportation, and energy, where it is used to increase efficiency, reduce costs, and improve safety.

3. Internet of Things (IoT): In simple terms, IoT refers to the interconnectivity of devices over the internet. This technology has been widely adopted in various industries, allowing for real-time data collection, analysis, and monitoring of systems. In engineering, IoT is used to improve maintenance processes, optimize energy usage, and enable remote monitoring and control of systems.

4. Augmented and Virtual Reality: These technologies have transformed the way engineers design and build products. Augmented reality (AR) combines virtual objects with the real world, enhancing the visualization and communication of designs. Virtual reality (VR) creates a simulated environment, allowing engineers to virtually test and validate designs before they are built physically. These technologies have proven to be valuable tools for design optimization, collaboration, and training purposes.

5. Renewable Energy: With the growing concern for environmental sustainability, there has been a significant focus on renewable energy sources such as solar, wind, and hydropower. Engineers have played a pivotal role in developing technologies for harnessing and utilizing these renewable sources efficiently and cost-effectively. Advancements in energy storage systems and microgrid technology have also enabled the integration of renewable energy systems into the existing power grids.

Challenges in Practical Engineering Technology

Despite the numerous advancements in practical engineering technology, there are several challenges that engineers face. One of the biggest challenges is the need for continuous innovation to keep up with the fast-paced changes in technology. With new technologies emerging every day, engineers must continuously upgrade their skills and knowledge to remain relevant and competitive in the job market.

Another challenge is the ethical considerations surrounding the use of technology. The use of automation and AI-powered systems in industries has raised concerns about job displacement and the potential misuse of these systems. Engineers must ensure that their innovations do not have negative impacts on society and that they are used ethically and responsibly.

Impact on society:

Practical engineering technology has had a profound impact on society, transforming the way we live, work, and interact with our environment. For instance, advancements in transportation technology have made travel faster, safer, and more convenient. In healthcare, technology has allowed for the development of sophisticated medical devices, diagnostic tools, and treatment methods, improving the quality of life for patients. Furthermore, the adoption of sustainable engineering practices has helped reduce the impact of human activities on the environment.

V. CONCLUSION

In conclusion, practical engineering technology continues to advance at an unprecedented pace, shaping the world around us. With the integration of emerging technologies, engineers are developing innovative and sustainable solutions for a variety of industries. As we move towards a more interconnected and technology-driven future, the role of practical engineering technology will become even more crucial in solving complex real-world problems.

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