論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Study on Chitosan Nanoparticle-Based Structures for Acoustic Cavitation Enhancement
著者(和文)	XIEXue
Author(English)	Xue Xie
出典(和文)	学位:博士(工学), 学位授与機関:東京科学大学, 報告番号:甲第353号, 授与年月日:2025年3月26日, 学位の種別:課程博士, 審査員:北本 仁孝,曽根 正人,和田 裕之,林 智広,中村 健太郎
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Institute of Science Tokyo, Report number:甲第353号, Conferred date:2025/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	材料 ライフエンジニアリング	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
学生氏名： Student's Name	XIE Xue		審査員主査： Chief Examiner	Prof. Kitamoto	

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

Ultrasound has extensive applications in medicine fields and industrial reactions. A key mechanism behind these applications is acoustic cavitation, where the formation, growth, and collapse of microbubbles induce intense local physical and chemical effects. In this study, a novel composite structure using chitosan nanoparticles as a stabilizing shell for gas cores has been developed. This structure not only introduces a higher number of cavitation nuclei through the surface hydrophobicity of chitosan chains but also promotes acoustic microstreaming, which accelerates rectified diffusion around the gas cores. The resulting enhancement in cavitation holds promise for improved therapeutic and industrial outcomes.

The composite is synthesized via an emulsion process that combines an aqueous suspension of chitosan nanoparticles with anionic surfactants such as sodium dodecyl sulfate (SDS). By emulsifying these components, air cores become encapsulated by a layer of chitosan nanoparticles, forming a stable microbubble-like structure. Key synthesis parameters—including the amount and concentration of crosslinkers, shaking speed and time, and the volume ratio between the chitosan nanoparticle suspension and SDS solution—play crucial roles in determining the final characteristics of the composite. By adjusting the crosslinker concentration, nanoparticle diameters can be varied from approximately 20 nm to several hundred nanometers. Moreover, loading model drugs—such as proteins—into these nanoparticles not only alters their size but has also demonstrated a loading efficiency exceeding 90%. This high efficiency is critical for therapeutic applications, ensuring that even if the composite shell is disrupted by ultrasonic irradiation, the encapsulated drug retains its bioactivity and can be effectively delivered. To prepare CNP-shelled composites, longer shaking times and higher volume ratios between the CNP suspension and SDS solution are preferable. Extended shaking durations provide sufficient energy for the migration and deposition of CNPs at the gas-core interface, ensuring a stable and complete shell structure.

The potential of these composites in enhancing acoustic cavitation has been rigorously evaluated using iodide dosimetry and terephthalic acid (TA) dosimetry during ultrasonic irradiation at a frequency of 20 kHz. The SDS benchmark showed a 1.12-fold improvement over ultrasonically treated sodium iodide solution decomposition. The use of composites enhanced hydroxyl radical generation by 1.73- to 1.98-fold, surpassing SDS by 54% to 77%, suggesting enhanced acoustic cavitation. Moreover, the study highlights the complex interplay between various experimental parameters and their impact on the fluorescence intensity of TA solutions. Increasing the quantity of SDS or reducing the amount of chitosan nanoparticles in the composites, as well as increasing the concentration of the composite, consistently led to a decrease in fluorescence intensity. Through analysis, linear and logarithmic fitting models were employed to understand these relationships, with logarithmic models demonstrating a higher accuracy as indicated by superior R-squared values. The investigation also underscored the significance of considering residual SDS, acetic acid presence, and experimental consistency in influencing the results. Ultimately, recent results provided valuable insights into predicting fluorescence intensity through composite formulations. Composite has a recognized boosting influence on ultrasonic acoustic cavitation known from iodide dosimetry, and the trend of the calculated results agrees with the experimental data from TA dosimetry.

Despite these promising developments, several challenges remain. The synthesis process, while straightforward, requires further optimization to ensure consistent and reproducible results. Critical factors such as bubble size, shell thickness, and specific ultrasound parameters must be systematically studied to maximize the efficiency of drug or gene delivery. Addressing these issues is essential for the transition from laboratory studies to clinical or industrial applications.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).
注意：論文要旨は、東京科学大学リサーチリポジトリ(T2R2)にてインターネット公表されますので、公表可能な範囲の内容で作成してください。
Attention: Thesis Summary will be published on Science Tokyo Research Repository Website (T2R2).