

Series in BioEngineering

The Series in Bioengineering serves as an information source for a professional audience in science and technology as well as for advanced students. It covers all applications of the physical sciences and technology to medicine and the life sciences. Its scope ranges from bioengineering, biomedical and clinical engineering to biophysics, biomechanics, biomaterials, and bioinformatics.

More information about this series at <http://www.springer.com/series/10358>

Manoranjan Arakha · Suman Jha

Interfacial Phenomena on Biological Membranes



Springer

Manoranjan Arakha
National Institute of Technology Rourkela
Rourkela, Odisha
India

Suman Jha
National Institute of Technology Rourkela
Rourkela, Odisha
India

ISSN 2196-8861
Series in BioEngineering
ISBN 978-3-319-73325-8
<https://doi.org/10.1007/978-3-319-73326-5>

ISSN 2196-887X (electronic)
ISBN 978-3-319-73326-5 (eBook)

Library of Congress Control Number: 2017963270

© Springer International Publishing AG 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

1	Nanoparticle	1
1.1	Synthesis of Nanoparticles	2
1.2	Different Kinds of Nanoparticles	4
1.2.1	Zinc Oxide Nanoparticle (ZnONP)	5
1.2.2	Iron Oxide Nanoparticle (IONP)	5
1.2.3	Silver Nanoparticle (AgNP)	5
1.2.4	Liposome	6
1.2.5	Albumin-Functionalized NPs	6
1.2.6	Polymeric NPs	7
1.2.7	Quantum Dot	7
1.3	Physicochemical Properties of Nanoparticles	8
1.3.1	Shape, Size, and Curvature	8
1.3.2	Surface Concentration	9
1.3.3	Surface Functionality	10
1.3.4	Surface Potential	11
1.4	Physicochemical Properties of Biological Membranes and Biomacromolecules	11
1.4.1	Cell Membrane	11
1.4.2	Bacterial Cell Wall	12
1.4.3	Eukaryotic Cell Membrane	13
1.4.4	Nucleic Acid Biomacromolecules	14
1.4.5	Protein Biomacromolecules	15
1.5	Nanoparticle Interfacial Interaction with Biological Membranes and Biomacromolecules	18
1.5.1	Nanoparticle–Biological Membrane Interaction	19
1.5.2	Cellular Internalization of Nanoparticles	20
1.5.3	Nanoparticle–Nucleic Acid Interaction	20
1.5.4	Nanoparticle–Protein Interaction	21

1.6 Applications of Nanoparticle–Biomolecular Interactions in Biological Sciences	23
1.6.1 Nanoparticles as Novel Antibiotics	23
1.6.2 Nanoparticle-Mediated Approach for Cancer Diagnosis and Therapy	24
1.6.3 Nanoparticle Acting as a Protein Folding Chaperone	25
1.6.4 Detection of Protein Aggregation Using Nanoparticles	27
1.6.5 Advantages of Nanoparticles-Based Therapeutics Over Conventional Therapies for Amyloidoses	28
References	29
2 Synthesis and Characterization of Nanoparticles	37
2.1 Synthesis of Zinc Oxide Nanoparticle and Its Surface Modification	37
2.1.1 Introduction	37
2.1.2 Materials and Methods	37
2.1.3 Results and Discussion	38
2.1.4 Surface Modification of ZnONP	42
2.2 Synthesis and Surface Modification of Iron Oxide Nanoparticle	45
2.2.1 Introduction	45
2.2.2 Materials and Methods	45
2.2.3 Results and Discussion	47
2.3 Synthesis of Silver Nanoparticle Using Bacteria from Coal Mine—A Green Synthesis Approach	49
2.3.1 Introduction	49
2.3.2 Materials and Methods	50
2.3.3 Results and Discussion	52
References	57
3 Effect of Interfacial Potential on Antimicrobial Propensity of ZnONPs	61
3.1 Introduction	61
3.2 Materials Methods	62
3.2.1 ZnONP-Bacteria Interfacial Potential Measurement	62
3.2.2 Bacterial Cell Viability in Presence of ZnONPs	62
3.2.3 ROS Detection	63
3.2.4 Bacterial Morphology on ZnONP Treatment	63
3.3 Results and Discussion	64
3.3.1 ZnONP-Bacteria Interfacial Potential	64
3.3.2 Surface Potential Neutralization of <i>B. Subtilis</i> and <i>E. Coli</i> by ZnONPs	68

3.3.3 Enhanced ROS Production in Presence of ZnONP-Bacteria Interface	69
3.3.4 Surface Morphology of Bacteria upon ZnONP Treatment	70
3.4 Discussion	70
3.5 Conclusion	76
References	76
4 Effect of Surface Functionality on Antimicrobial Propensity of Iron Oxide Nanoparticles	79
4.1 Introduction	79
4.2 Materials and Methods	80
4.2.1 Growth Kinetic Analysis	80
4.2.2 CFU Measurement	80
4.2.3 ROS Detection	81
4.2.4 LIVE/DEAD BacLight Fluorescence Microscopy Assay	81
4.3 Results and Discussion	82
4.3.1 Effect of the Interfaces upon Bacterial Cell Viability	82
4.4 Discussion	84
4.5 Conclusion	88
References	89
5 Effect of ZnONP Surface Defects on Cytotoxic and Antimicrobial Propensities	91
5.1 Introduction	91
5.2 Materials and Methods	92
5.2.1 Cell Culture and ZnONP Stock Solution Preparation	92
5.2.2 Cytotoxicity of ZnONPs	92
5.2.3 ZnONP-Induced ROS Generation	93
5.2.4 Comet Assay	93
5.2.5 Cell Cycle Analysis	93
5.2.6 ZnONP-Induced Autophagy	94
5.2.7 ZnONP-Induced Apoptosis	94
5.2.8 Morphological Changes	95
5.3 Results and Discussion	95
5.3.1 Cytotoxic Propensity of ZnONPs	95
5.3.2 Effect of ZnONP Treatment on the Cell Cycle	99
5.3.3 Induction of Autophagy upon ZnONPs Treatment	100
5.3.4 ZnONPs Treatment Causes Apoptotic Cell Death	102
5.3.5 HT1080 Morphology upon ZnONPs Treatment	103
5.3.6 Antimicrobial Propensity of ZnONPs	106
5.3.7 Conclusion	108
References	109

6 Effect of Interfacial Assembly of Antimicrobial Peptide on Conformational and Functional Dynamics of the Peptide	111
6.1 Introduction	111
6.2 Materials and Methods	112
6.2.1 Preparation of AgNP–nisin Conjugates	112
6.2.2 Biophysical Characterization of AgNP–nisin Conjugates	113
6.2.3 Antimicrobial Activity of AgNP–nisin Conjugates	114
6.2.4 Interfacial and Intracellular ROS Detection	114
6.2.5 Membrane Destabilization and Internalization of AgNP–nisin Conjugates	115
6.3 Results and Discussion	115
6.3.1 Interfacial Assembly of Nisin at AgNP Interface	115
6.3.2 The Interfacial Assembly Enhances the Antimicrobial Propensity of Nisin	122
6.3.3 Oxidative Stress Mediated Antimicrobial Activity of AgNP–nisin Conjugates	125
6.3.4 Membrane Destabilization by AgNP–nisin Conjugates . .	126
6.3.5 Proposed Mechanism of the Assembled Nisin Antimicrobial Activity	129
6.3.6 Conclusion	133
References	133
7 Effect of Globular Protein Interfacial Assembly on Conformational Dynamics of the Protein	137
7.1 Introduction	137
7.2 Materials and Methods	138
7.2.1 Preparation of ZnONP Solution	138
7.2.2 Preparation of Lysozyme–ZnONP Conjugates	138
7.2.3 Circular Dichroism (CD) Spectropolarimetry	138
7.2.4 Intrinsic Tryptophan Fluorescence Spectroscopy	139
7.2.5 ANS Fluorescence Studies of Lysozyme	139
7.2.6 Lysozyme Tryptophan Fluorescence Quenching Study Using Acrylamide	139
7.2.7 Thioflavin T Assay of Lysozyme Fibrillation Kinetics . .	139
7.2.8 Transmission Electron Microscopy Study	140
7.2.9 Circular Dichroism (CD) Spectropolarimetry	140
7.3 Results and Discussion	140
7.3.1 Interfacial Assembly of Lysozyme at ZnONP Interface .	140
7.3.2 Antamyloidosis Propensity of ZnONP Interface	147
7.4 Conclusion	150
References	151