

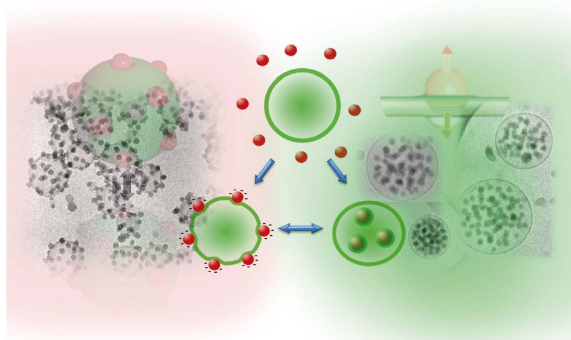


Raphael Michel (Autor)

Liposomes in Contact and Interacting with Silica Nanoparticles: From Decorated Vesicles to Internalized Particles.

Raphaël Michel

Liposomes in Contact and Interacting with Silica Nanoparticles:
From Decorated Vesicles to Internalized Particles



Cuvillier Verlag Göttingen
Internationaler wissenschaftlicher Fachverlag

<https://cuvillier.de/de/shop/publications/6552>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen, Germany

Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>



Table of Content

Table of Content	20
1 Introduction	1
1.1 Context and Motivation.....	1
1.2 Silica Nanoparticles.....	2
1.3 Liposomes: Definition and Properties.....	2
1.4 Interaction in Mixed Systems Liposome/Nanoparticle.....	4
1.4.1 Role of the Lipid Bilayer Phase Behavior.....	4
1.4.2 Nature of the Interaction between Liposome and Nanoparticles.....	6
1.4.2.1 Van der Waals Interaction.....	6
1.4.2.2 Electrostatic Interaction.....	7
1.4.2.3 Hydration Forces.....	8
1.4.2.4 Hydrophobic Interaction.....	9
1.4.3 Resulting Structures.....	10
1.4.3.1 Supported Lipid Bilayer (SLB) Formation and Particle Internalization..	10
1.4.3.2 Decorated Vesicles.....	15
1.5 Aim and Outline.....	16
1.6 References.....	18
2 Methods	26
2.1 Characterization Techniques.....	27
2.1.1 Visual Inspection.....	27
2.1.2 Zeta Potential Measurements.....	27
2.1.2.1 Theoretical Aspects.....	27
2.1.2.2 Measurement.....	28
2.1.3 Dynamic and Static Light Scattering (DLS & SLS).....	29
2.1.3.1 Measurement and Instrument Description.....	29
2.1.3.2 Static Light Scattering.....	32
2.1.3.3 Cumulant Analysis of the DLS Data.....	32
2.1.4 Small Angle Scattering.....	33
2.1.4.1 Theoretical Background.....	33
2.1.4.2 Differences between SAXS and SANS.....	37
2.1.4.3 Small Angle Neutron Scattering (SANS).....	38
2.1.4.4 Small Angle X-ray Scattering (SAXS).....	42
2.1.4.5 Model free Analysis of the Small Angle Scattering Data.....	43
2.1.4.5.1 Behavior at the Limit q Tending to Zero - Guinier Approximation....	43
2.1.4.5.2 Behavior in the Large q Limit - Porod Law.....	43
2.1.4.5.3 Scattering Invariant.....	44
2.1.4.5.4 Kratky-Porod Plot.....	44
2.1.4.6 Model Analysis of the Small-Angle Scattering Data.....	45
2.1.4.6.1 Form Factors.....	46
2.1.4.6.2 Log-Normal Size Distribution.....	47
2.1.5 Fluorescence.....	48
2.1.5.1 Fluorescence Spectroscopy.....	48
2.1.5.2 Fluorescence Correlation Spectroscopy (FCS).....	48
2.1.6 Cryogenic Electron Microscopy (cryo-TEM).....	51
2.1.6.1 Principle.....	51



2.1.6.2	Background of Electron Microscopy.....	52
2.1.6.2.1	Electron-Specimen Interactions	52
2.1.6.2.2	Instrumental Aspects	53
2.1.6.2.3	Sample Preparation for Cryo-TEM.....	55
2.1.6.3	Operating Methods	56
2.1.7	Differential Scanning Calorimetry.....	57
2.1.7.1	Principle.....	57
2.1.7.2	Operating Methods	58
2.2	Materials and Sample Preparation	58
2.2.1	Silica Nanoparticles	58
2.2.1.1	Bare Silica Nanoparticles	58
2.2.1.2	Functionalized Silica Nanoparticles	59
2.2.2	Liposome.....	60
2.2.2.1	Liposomes Composed of One Type of Lipid (DPPC and DOPC)	60
2.2.2.2	Liposomes Composed of a Mixture of Lipids (DPPC/DMPA and DMPC/DMPA)	62
2.2.3	Sample Preparation	64
2.3	References.....	64

3 Control of Stability and Structure of Gel-phase Liposomes by Means of Nanoparticles.....69

3.1	Introduction.....	69
3.2	Concentration Ratio and Surface Coverage Calculation	70
3.2.1	Concentration Ratio	71
3.2.2	Maximum Surface Coverage	72
3.3	Results.....	74
3.3.1	Stability.....	74
3.3.1.1	Visual Inspection	74
3.3.1.2	Dynamic and Static Light Scattering (DLS & SLS).....	76
3.3.1.3	Differential Scanning Calorimetry	79
3.3.1.4	ζ -Potential.....	83
3.3.2	Structure.....	85
3.3.2.1	ζ -Potential.....	85
3.3.2.2	Cryo-TEM	87
3.3.2.3	Small Angle Neutron Scattering (SANS).....	90
3.3.3	Influence of pH and Ionic Strength.....	93
3.3.3.1	Stability Behavior - Experimental Results	93
3.3.3.2	Stability Behavior - DLVO Theory	95
3.3.4	Influence of the Vesicle Surface Charges	99
3.3.4.1	Visual Inspection	100
3.3.4.2	Dynamic and Static Light Scattering (DLS & SLS).....	101
3.3.4.3	Differential Scanning Calorimetry	103
3.3.4.4	Small Angle Neutron Scattering (SANS).....	107
3.3.4.5	DLVO Theory - Total Interaction Energy Calculation	109
3.3.5	Influence of the Nanoparticle Surface Charges	111
3.3.5.1	Stability.....	112
3.3.5.2	Structure.....	115
3.4	Discussion	117
3.5	Conclusion	122
3.6	References.....	123



4	Internalization of Silica Nanoparticles within Fluid Liposomes	127
4.1	Introduction	127
4.2	Concentration Ratio and Surface Coverage Calculation	128
4.2.1	Bilayer Volume ratio (β)	129
4.3	Results	132
4.3.1	Stability.....	132
4.3.1.1	Visual Inspection.....	132
4.3.1.2	Dynamic Light Scattering (DLS)	134
4.3.1.3	Static Light Scattering (SLS)	137
4.3.2	Structure	139
4.3.2.1	Cryogenic Transmission Electron Microscopy (Cryo-TEM)	139
4.3.2.2	Small Angle Neutron Scattering (SANS)	144
4.3.2.3	Fluorescence Correlation Spectroscopy (FCS)	148
4.3.3	Influence of pH and Ionic Strength	151
4.3.3.1	Visual Inspection.....	151
4.3.3.2	Dynamic and Static Light Scattering	153
4.3.4	Influence of Vesicle Size.....	155
4.3.4.1	Sample Preparation and Calculation of the Concentration Ratio.....	155
4.3.4.2	Visual Inspection.....	156
4.3.4.3	Dynamic and Static Light Scattering	156
4.4	Discussion	159
4.5	Conclusion.....	164
4.6	References	165
5	Summary and Outlook	169
5.1	Control of Stability and Structure of Gel-phase Liposomes by Means of Nanoparticles.....	169
5.2	Internalization of Silica Nanoparticle within Fluid Liposomes	171
5.3	Conclusion.....	174
5.4	Outlook.....	174
	Appendix.....	177
	Appendix to chapter 3	177
	Appendix to chapter 4	179