



Contents

List of Symbols and Abbreviations.....	9
Abstract.....	13
Zusammenfassung.....	15
1 Introduction.....	17
2 Theoretical Background.....	23
2.1. Hydrodynamics at low Reynolds number.....	24
2.1.1 Colloidal solutions.....	24
2.1.2 Brownian motion.....	27
2.1.3 Self-diffusiophoresis.....	27
2.1.4 Self-electrophoresis.....	28
2.2 Solid state chemical process.....	29
2.2.1 Solid state surface diffusion.....	29
2.2.2 Kirkendall effect.....	30
2.2.3 Galvanic replacement mechanism.....	31
2.3 Biomaterials.....	31
2.3.1 Bacteriophages.....	31
2.3.2 Enzymes.....	33
2.4 Chemical reactions.....	35
2.4.1 Tollens reaction.....	35
2.4.2 Silver oxidation by H ₂ O ₂	35
2.4.3 Hydrogen peroxide disproportionation.....	36
2.4.4 Enzymatic activity assays.....	36
2.5 Background information of the general experimental methods.....	38
2.5.1 Glancing angle vapor deposition.....	38
2.5.2 Transmission Electron Microscopy.....	40
2.5.3 Dynamic light scattering.....	47
3 Dynamic Inclusion Complexes.....	51



3.1	Review on the fabrication methods of asymmetric hollow structures-Nanocups	55
3.1.1	On-surface nanocups	55
3.1.2	Nanocups in colloids	56
3.1.3	Inclusion Complexes	57
3.2	Fabrication and characterization of the dynamic inclusion complexes.....	58
3.2.1	Fabrication mechanism of Au@cups	58
3.2.2	Characterization of the inclusion complex	61
3.3	Proposed mechanism of inclusion complex formation	67
3.4	Other fabrication procedures	69
3.4.1	Fabrication of empty nanocups	69
3.4.2	Fabrication with other materials	71
4	Self-Propelling Nanomotors	73
4.1.1	Self-phoretic effects (Self-electrophoresis/Self-diffusiophoresis)	77
4.2	Review of Janus Nanoparticle Fabrication Methods	79
4.2.1	Self-assembly of block-copolymers	79
4.2.2	Reactions at a liquid interface	80
4.2.3	Growth on a solid surface	82
4.3	Fabrication of Janus nanomotors.....	84
4.3.1	Fabrication mechanism of Pt-Au Nanomotors	84
4.3.2	Characterization techniques	86
4.4	Characterization of the chemical nanoswimmers	88
4.4.1	30 nm Janus Nanoparticles	88
4.4.2	60 nm Janus Nanoparticles	92
4.4.3	Control Experiments	94
5	Biocompatible Nanomotors	99
5.1	Enzyme powered nanomotors.....	101
5.1.1	Enzyme powered nanoparticles	101
5.1.2	Enzyme powered micropumps	102
5.2	Fabrication and characterization	103
5.2.1	His-tag bacteriophages	103



5.2.2	Enzyme coupling to bacteriophages	108
5.2.3	Activity assays	110
5.3	EVP-constructs as nanoswimmers	111
5.3.1	GOX-Phages-Janus nanoparticles (GOx-VJP constructs)	114
5.3.2	Urease-Phages-Janus nanoparticles (EVJP constructs).....	115
5.4	EVP-constructs to build Micropumps.....	117
5.4.1	EVP constructs as a micropump.....	118
5.4.2	Negative controls for the EVP pumping activity.....	121
5.4.3	Enzyme recovery assay	123
6	Conclusions	125
7	References	129
	Acknowledgments.....	149